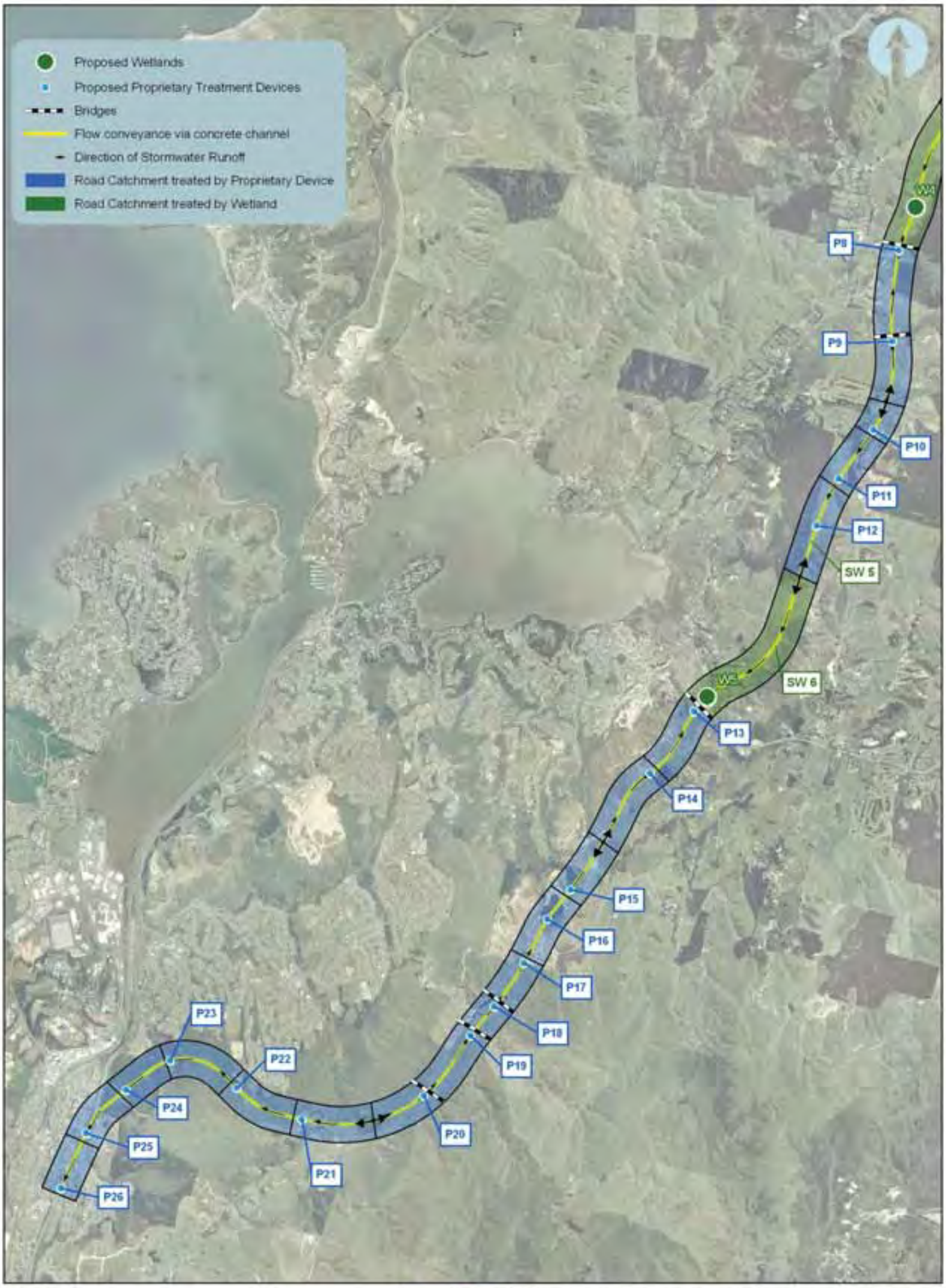
Appendix 15.U Location of Stormwater Treatment Devices



NEW ZEALAND TRANSPORT AGENCY

TRANSMISSION GULLY PROJECT
TECHNICAL REPORT 14

SJB | MAY 2011
CMM

Map 10B
Stormwater Runoff Treatment Catchments

38000 | AE03778

CLIENT NEW ZEALAND TRANSPORT AGENCY
PROJECT TRANSMISSION GULLY PROJECT TECHNICAL REPORT 15
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DATE MAY 2011
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TITLE Map 10A
Stormwater Runoff Treatment Catchments

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SKM PROJECT No. AE03778

Appendix 15.V Harbour Model Construction

V.1 Model Construction

To undertake the Event Based and Long Term Modelling assessments a coupled hydrodynamic, wave and sediment transport model was developed using the DHI MIKE21 HD (Hydrodynamic), MIKE21 SW (Spectral Wave) and MIKE21 MT (Sediment Transport) of Porirua Harbour. All models were built using Flexible Mesh (FM) and version 2009, service pack five. The following sections describe the construction, calibration and verification of the models.

V.1.1 Co-ordinate System and Vertical Datum

For the harbour modelling investigation, all data is presented using the New Zealand Transverse Mercator projection (NZTM) and the vertical datum is Mean Sea Level (MSL) relative to Mana Marina. An analysis of 2009 sea level data at Mana Marina by Land Information New Zealand (LINZ), showed that MSL at Mana Marina is 1.06m above Chart Datum (Glen Row, LINZ, *per comms*).

V.1.2 Hydrodynamic Model

The hydrodynamic model used was MIKE21 HD. MIKE21 HD simulates the water level variations and flows in response to a variety of forcing functions in oceans, estuaries, bays and coastal areas. MIKE 21 HD can be applied to a wide range of hydraulic and related phenomena such as tidal hydraulics, wind and wave generated currents, storm surges and flood waves.

The MIKE21 HD model is based on the numerical solution of the depth averaged two-dimensional incompressible Reynolds averaged Navier-Stokes equations, invoking the assumptions of Boussines and of hydrostatic pressure. Thus the model consists of continuity, momentum, temperature, salinity and density equations and it is closed by a turbulent closure scheme.

V.1.3 Wave Model

The wave model used was MIKE21 SW. This model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and nearshore areas. MIKE 21 SW includes two different formulations:

- Fully spectral formulation
- Directional decoupled parametric formulation.

The fully spectral formulation is based on the wave action conservation equation, as described in Komen *et. al.* (1994) and Young (1999). The directional decoupled parametric formulation is based on a parameterization of the wave action conservation equation following the Holthuijsen *et. al.* (1989) approach. The fully spectral model includes the following physical phenomena:

- Wave growth by action of wind
- Non-linear wave-wave interaction
- Dissipation due to white-capping
- Dissipation due to bottom friction

- Dissipation due to depth-induced wave breaking
- Refraction and shoaling due to depth variations
- Wave-current interaction
- Effect of time-varying water depth.

V.1.4 Sediment Transport Model

The sediment transport model used was MIKE21 MT (Mud Transport). This model was used since the land based sediment which enters the harbour is predominately cohesive mud.

MIKE 21 MT is a mud transport model that simulates the fate of suspended cohesive materials in marine, brackish and freshwater areas and can include the following physical phenomena:

- Flocculation due to concentration
- Flocculation due to salinity
- Density effects at high concentrations
- Hindered settling
- Consolidation
- Morphological bed changes

Non-cohesive sediments can be included as sand fractions, however only suspended transport and not bed load transport is predicted by the model. The model is not appropriate for predicting the fate of marine based sediments where bed load is a significant portion of the transport of sediment. This is considered appropriate for an assessment of effects associated with the Transmission Gully Project where the impacts being assessed will be almost exclusively on terrestrial rather than marine sediment and the rate of marine sediment movement in and out of the harbour will be unaffected by both the construction and operational phases of the project.

V.2 Data Collection

This chapter focuses on data made available for the study from existing sources and new data that was collected specifically for the study. Field surveys were carried out by Discovery Marine Ltd (DML) in 2009 and Cawthron Institute (Cawthron) January to March 2010 and July to October 2010.

The field campaigns carried out by Cawthron, were developed through joint discussions between DHI, Cawthron and SKM. For the first data collection campaign, the instrument/sample locations were selected to provide information on currents and water levels, wave heights and sediment size distribution throughout the whole study area, including:

- Approaches to the harbour
- Entrance to the harbour
- Within the harbour arms.

Total Suspended Sediments (TSS) information was only collected within the arms of the harbour as this study focuses on the fate of terrestrial based sediment within the harbour and has not included marine based sediment.

A second data collection campaign was carried out by Cawthron, for the period, July to October 2010, since there were only a few significant wind and rainfall events that occurred during the initial data collection campaign, January to March 2010. The data collected in the second campaign focused only on the arms of the harbour, since the data from the first campaign was considered sufficient for calibrating the hydrodynamic model. The data from the second campaign which recorded more significant storm events was used to calibrate the wave and sediment transport models.

V.2.1 Bathymetry Survey

Discovery Marine Ltd (DML) undertook a hydrographic survey of Porirua Harbour in March and April of 2009 as part of a wider harbour study for Porirua City Council. The area surveyed incorporated all parts of the harbour east of a curved line between Te Rewarewa Point on the northern headland at the entrance to Porirua Harbour, to the headland (Te Paokapo) north of Titahi Bay. The survey extent is shown in Figure V1. The channels at the entrance to each arm of the harbour, being considered more critical to future harbour modelling requirements, were surveyed at an approximate line spacing of 10 to 20 m whilst in the rest of the harbour arms surveying was undertaken at an approximate line spacing of 50 to 100 m.

The fieldwork undertaken used a combination of hydrographic and topographic survey techniques to collect elevation data up to the Mean Water High Springs (MWHS) level. It is noted that the survey included intertidal areas located below the MHWS. The bathymetric data was provided in Chart Datum (CD).

The data collected by DML in 2009 was supplemented in places by topographic information from Porirua City Council to accurately model the low lying land surrounding the harbour.

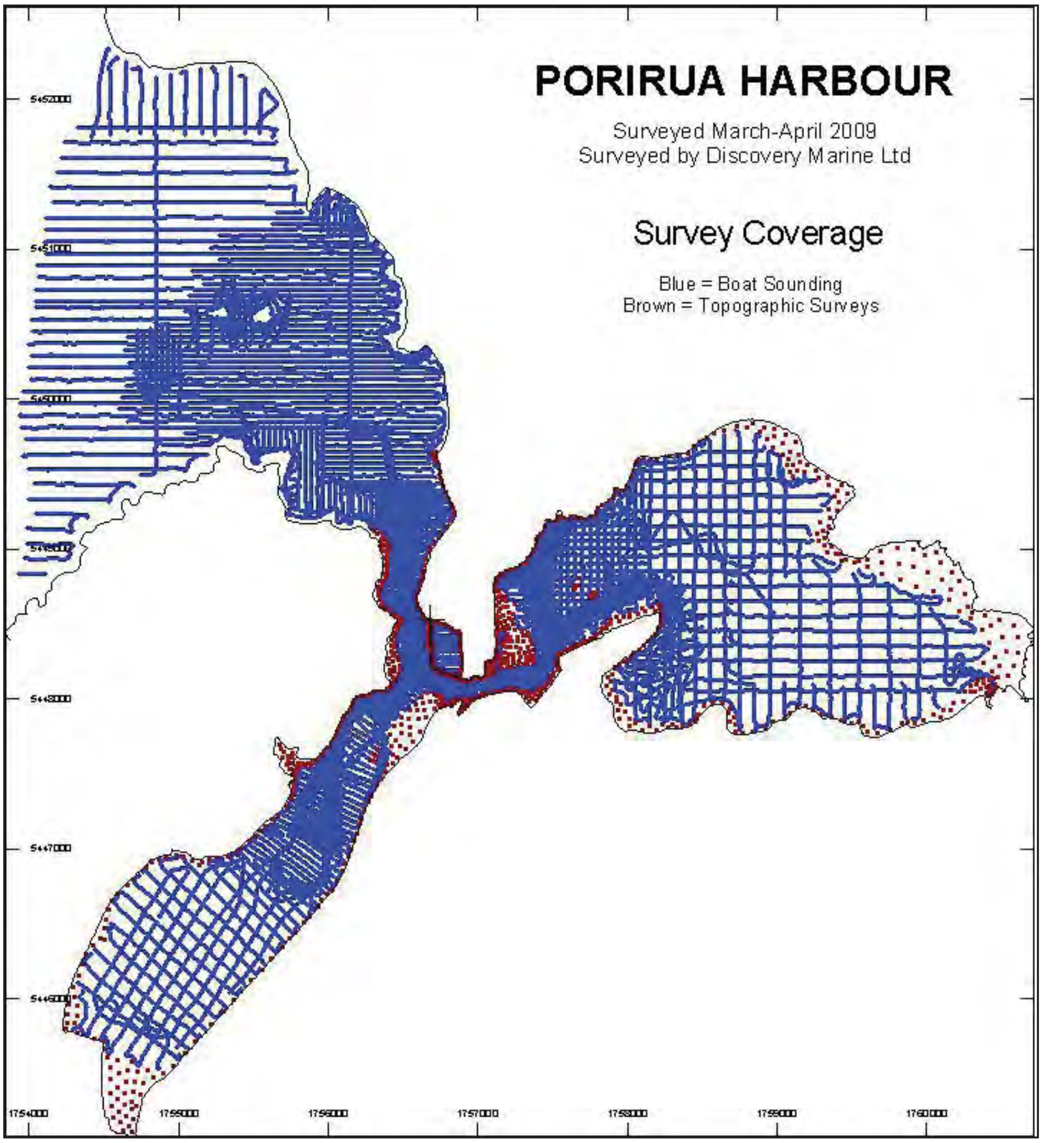


Figure V1 DML Bathymetric Survey Coverage (DML, 2009)

V.2.2 Weather Data

Climate data was obtained from a variety of locations and sources, including within the arms of the harbour. The locations where wind data was collected is shown in **Figure V2**.

Figure V2 Locator Map for Wind Data

Hourly wind data was obtained for Mana Island (approximately 100 m above MSL) from NIWA's climate database (CliFlo) for the period 13th September 2004 to 1st May 2010 as shown in **Figure V2**. Mana Island wind data was also obtained for a second period 1st July 2010 to 1st October 2010 (see **Figure V3**) to coincide with the period wind data was collected within the arms of the harbour. The predominant wind directions were north – north westerly and south – south easterly for this period.

Hourly wind and atmospheric pressure data was also obtained from Greater Wellington Regional Council (GWRC) from Tawa (6 m above MSL) for the period 1st January to 1st March 2010. The predominant wind directions were north easterly and south westerly. It is apparent that the Tawa wind data is very influenced by the surrounding topography at Tawa, since the predominant wind directions were so different when compared with Mana Island wind data. This suggests that the wind behaviour in the arms of the harbour will also be influenced by surrounding topography.

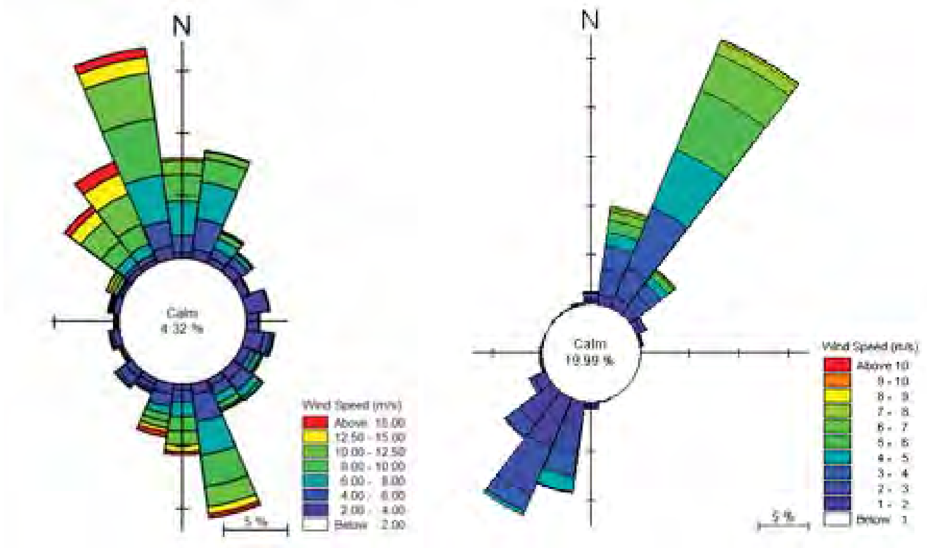


Figure V3 Wind Data From Mana Island (left) and Tawa (right)

Atmospheric pressure data from Wellington Airport was also obtained from CliFlo for the period 1st June 2010 to 4th October 2010 as shown in **Figure V5**. Atmospheric pressure will match closely with that of the Porirua area (**Figure V4**).

The atmospheric pressure data was obtained to adjust water levels measured by pressure sensors which cannot account for changes in water levels resulting from changes in atmospheric pressure. Atmospheric pressure changes can significantly increase or decrease levels. A change in barometric pressure of 1 hPa may cause approximately a 1 cm variation in sea level (Singh, 2005). An increase in atmospheric pressure will decrease the sea level and vice versa. In comparison with a mean atmospheric pressure of 1013 hPa, it is probable that water levels were increased by 30 cm on 17th September 2010.

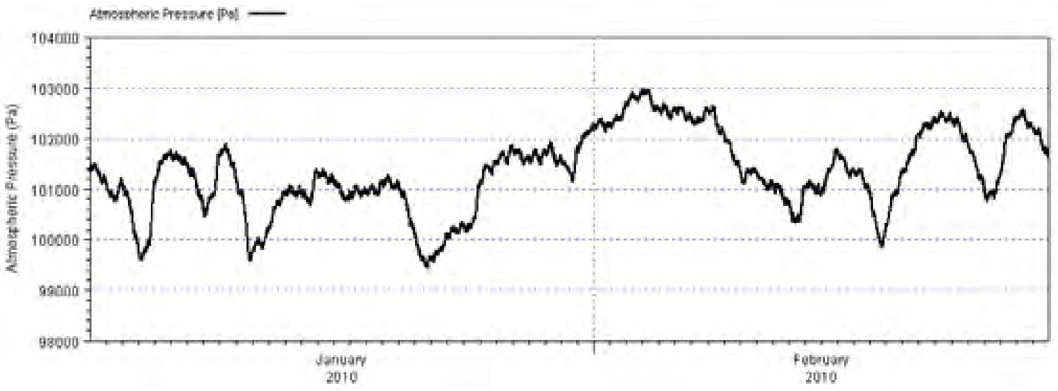


Figure V4 Atmospheric Pressure Data from Tawa

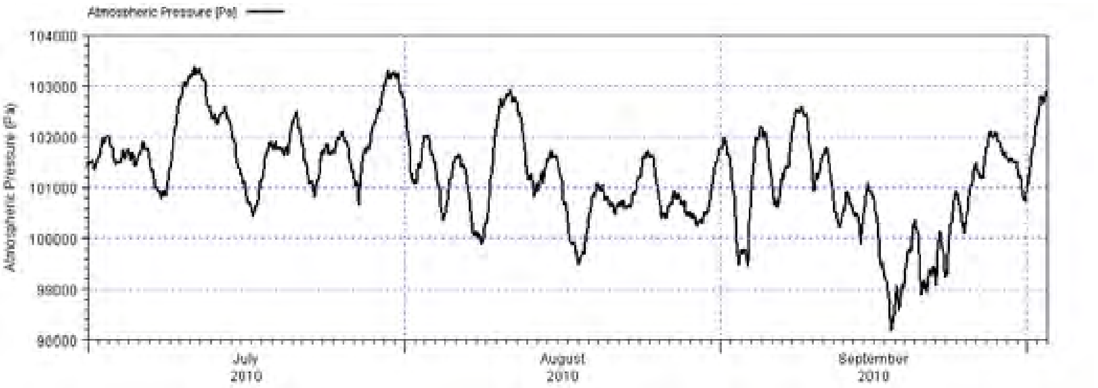


Figure V5 Atmospheric Pressure Data from Wellington Airport

(1) First Data Collection Period

Cawthron deployed an anemometer (approximately 2 m above MSL) in Pauatahanui Inlet (NZTM 1759050, 5448551) for the period 13th January to 27th February 2010 to measure wind speed and direction. A comparison of wind data from Pauatahanui Inlet and Mana Island for the same period is shown in Figure V6. The predominant wind directions were north – north westerly and south – south easterly for this period, which is similar to Mana Island.

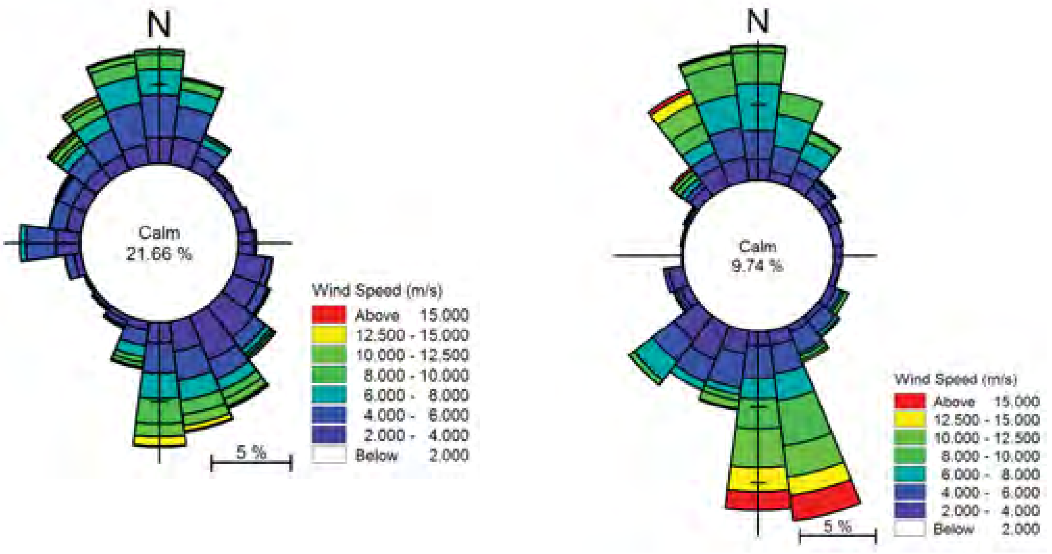


Figure V6 Wind Data from Pauatahanui Inlet (left) and Mana Island (right) for First Data Collection Period

(2) Second Data Collection Period

Cawthron also deployed anemometers (approximately 2 m above MSL) in Pauatahanui Inlet (NZTM 1759050, 5448551) and Onepoto Arm (NZTM 1755053, 5446327) for the period 1st July to 1st October 2010 to measure wind speed and direction. Unfortunately there was a technical malfunction with the Onepoto Arm instrument that meant data was only collected for the period, 9th September to 1st October 2010 for this location. During this period the majority of wind was from a northerly direction.

Also presented in Figure V7 is Mana Island wind data for the same period as the Pauatahanui Inlet data. It is interesting to note that the predominant wind directions for Mana Island were north westerly and southerly for this period, while for Pauatahanui Inlet the predominant wind directions were northerly and south – south easterly for this period. This provides an indication of the influence of the surrounding topography.

Figure V8 presents a comparison of wind speed and direction for the period 9th September to 1st October 2010 when data was collected in both arms of the harbour. This shows that there is very little difference in wind directions within the arms of the harbour for northerly winds. There appeared to be a difference in directions for southerly winds for period 9th September – 10th September 2010. Unfortunately there was no other period with southerly winds to investigate this further. It is possible that, due to the topography of the surrounding land, there could be a difference in southerly wind directions in both arms of the harbour.

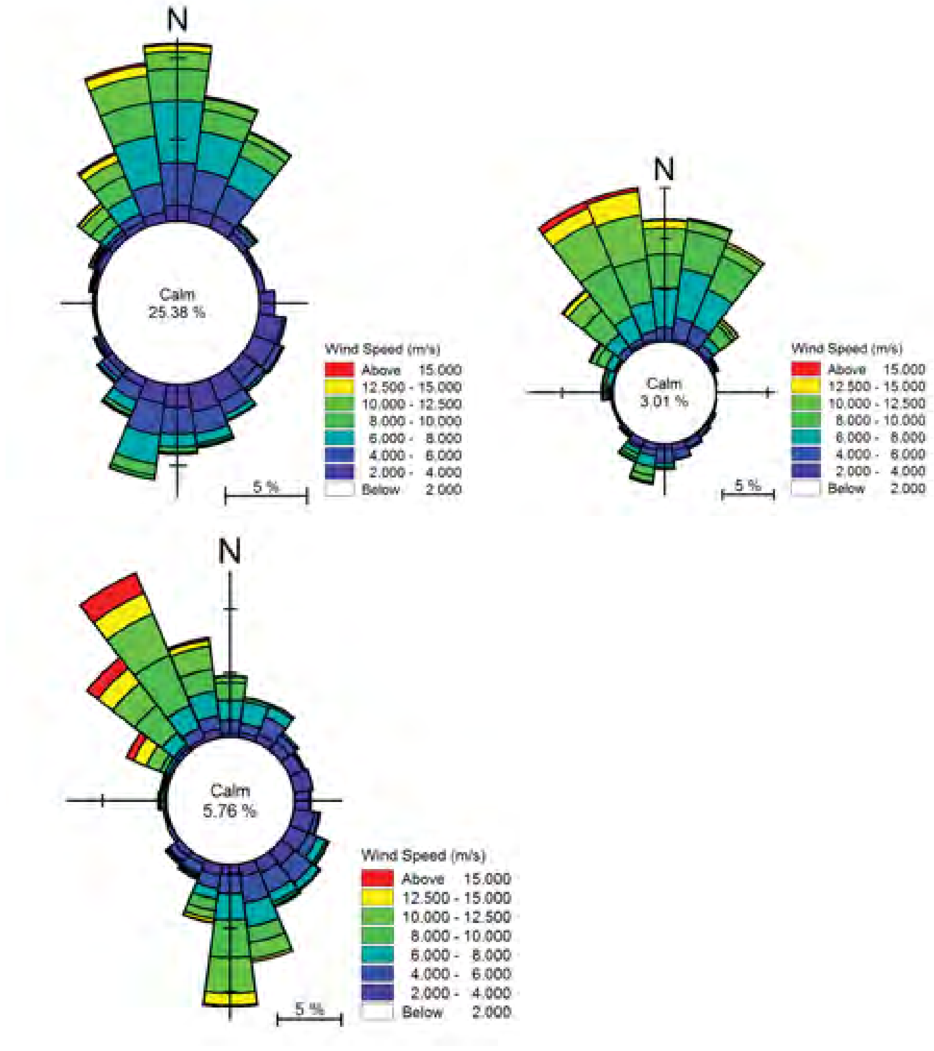


Figure V7 Wind Data from Pauatahanui Inlet (top left) and Onepoto Arm (top right) and Mana Island (bottom left) for Second Data Collection Period

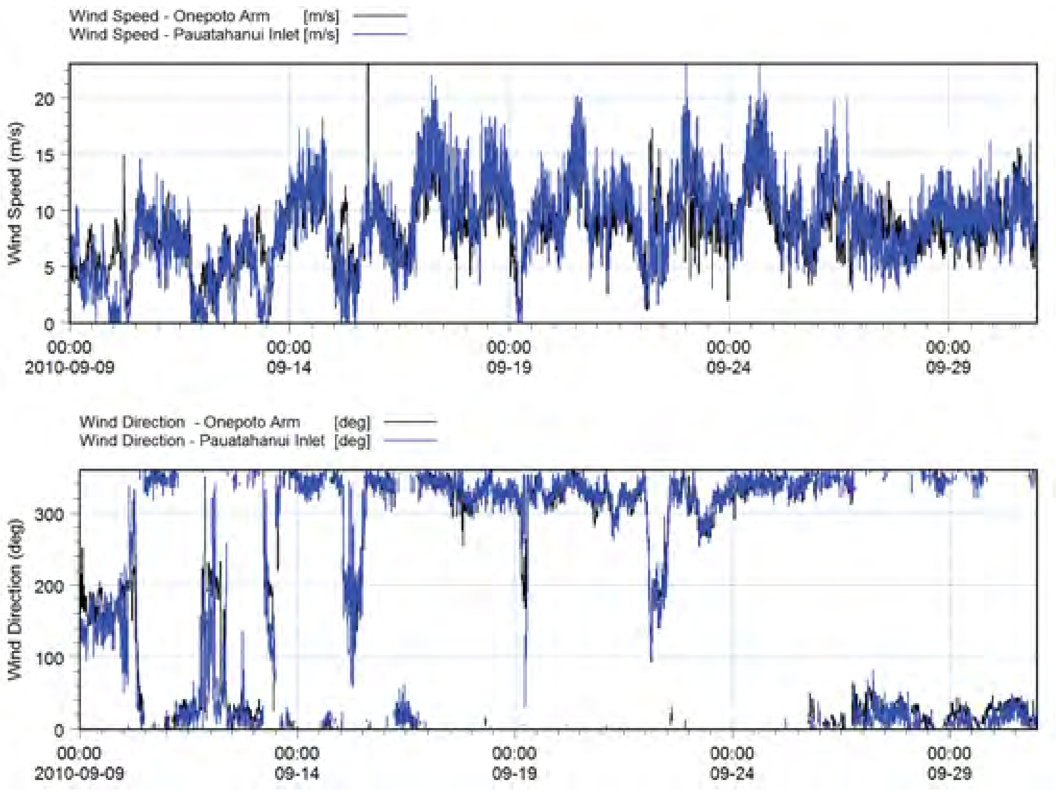


Figure V8 Wind Speed (top) and Wind Direction (bottom) from Pauatahanui Inlet and Onepoto Arm for Period 9h September – 1st October 2010

(3) Scaling Wind Data

All MIKE by DHI software assumes that all wind inputs are at 10 m above the sea surface, hence any data used in the model had to be scaled to 10 m above the sea surface using the following formula (Ahrens, 2003):

$$WS_2 = WS_1 \times \frac{ln\left(^{Z_2}/_{Z_o}\right)}{ln\left(^{Z_1}/_{Z_o}\right)}$$

Where WS_2 = wind speed at height Z_2 (m/s)

WS_1 = wind speed at height Z_1 (m/s)

Z_o = aerodynamic roughness length (m)

For the ocean Z_o = 0.0002 m, therefore to scale the Pauatahanui Inlet and Onepoto wind speeds from 2 m to 10 m the scaling factor is 1.15 and to scale the Mana Island wind speeds from 100 m to 10 m the scaling factor is 0.82.

It is interesting to note that a comparison of scaled wind speed data for Mana Island and Pauatahanui Inlet (Figure V9) for period 20th August to 1st October 2010, shows that wind speeds were similar. Herein, all wind data mentioned in the rest of this report has been scaled to 10 m.

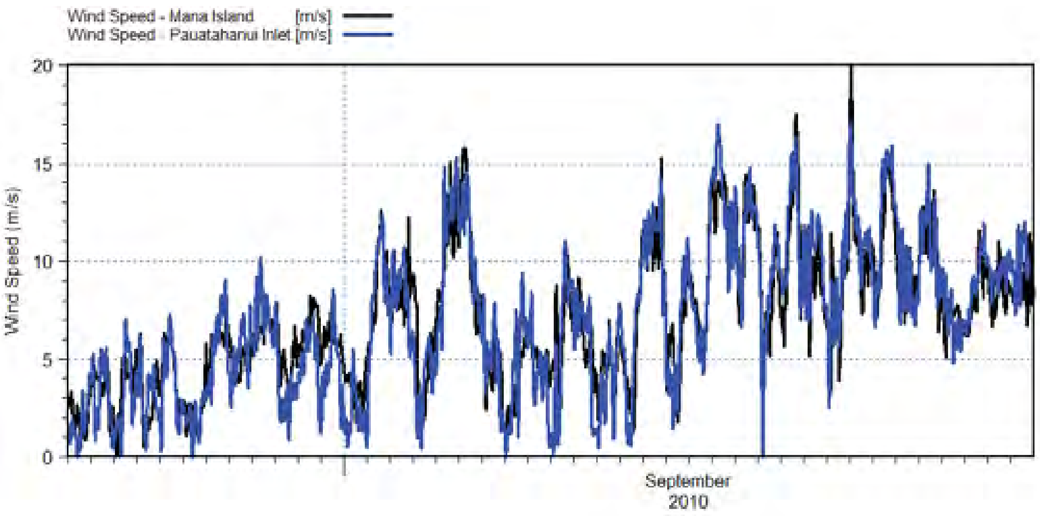


Figure V9 Comparison of Scaled Wind Speed Data for Mana Island and Pauatahanui Inlet

V.2.3 Metocean Data

Figure V10 presents an overview of the locations where met ocean data was collected by Cawthron. A summary of the data is presented in Table V1.

Table V1 Summary of Metocean Data Collected by Cawthron

Location	Data Collected	Data Collection Period
Tokaapapa Reef	Significant wave height, mean wave direction and water level	22/01/2010 – 1/03/2010
Pauatahanui Inlet Entrance (Bridges)	Water level, current speed and direction	21/01/2010 – 21/02/2010
Main Harbour Entrance	Water level, current speed and direction	13/01/2010 – 3/03/2010
Pauatahanui Inlet Entrance (Bridges) – Transect	Discharge	26/02/2010
Main Harbour Entrance - Transect	Discharge	26/02/2010
Pauatahanui Inlet	Significant wave height, water level, current speed and direction	13/01/2010 – 3/03/2010 1/07/2010 – 1/10/2010
Onepoto Arm	Significant wave height, water level, current speed and direction	13/01/2010 – 3/03/2010 1/07/2010 – 1/10/2010

Figure V10 Cawthron Data Collection Sites

(1) Water Levels, Current and Waves

Water level, current and wave data was collected during the first and second data collection periods. All water level data measured from pressure sensors was adjusted to account for changes in barometric pressure. The majority of instruments deployed contained an internal pressure sensor. All water level data is presented in MSL.

(2) First Data Collection Period

Two Acoustic Doppler Current Profilers (ADCP) were deployed in the main harbour entrance (NZTM 1756567, 5448506) for the period 20th January to 21st February 2010 and the entrance to Pauatahanui Inlet (NZTM 1756982, 5448067) in the vicinity of bridges for the period 20th January to 3rd March 2010. The ADCP in the main harbour entrance was located in a localised depression of approximately 19 m depth (MSL), while the ADCP in the entrance to Pauatahanui Inlet was located at 5 m depth (MSL). The instruments measured current speed and direction throughout the water column for discrete bun sizes and water levels. This data is presented in Figure V11 and Figure V12.

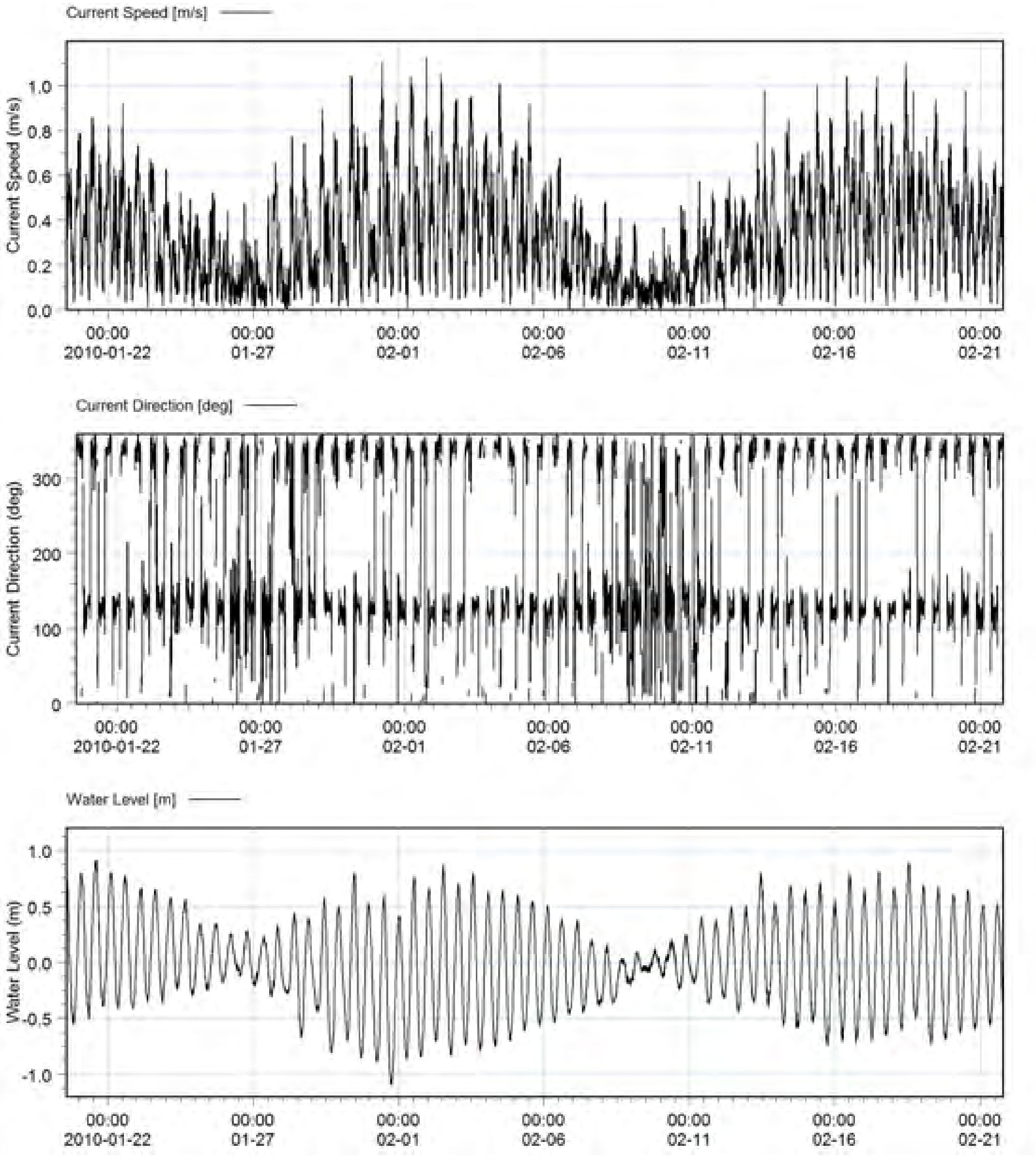


Figure V11 Main Harbour Entrance – Mid Water Column Current Speed (top), Current Direction (middle) and Water Level (bottom)

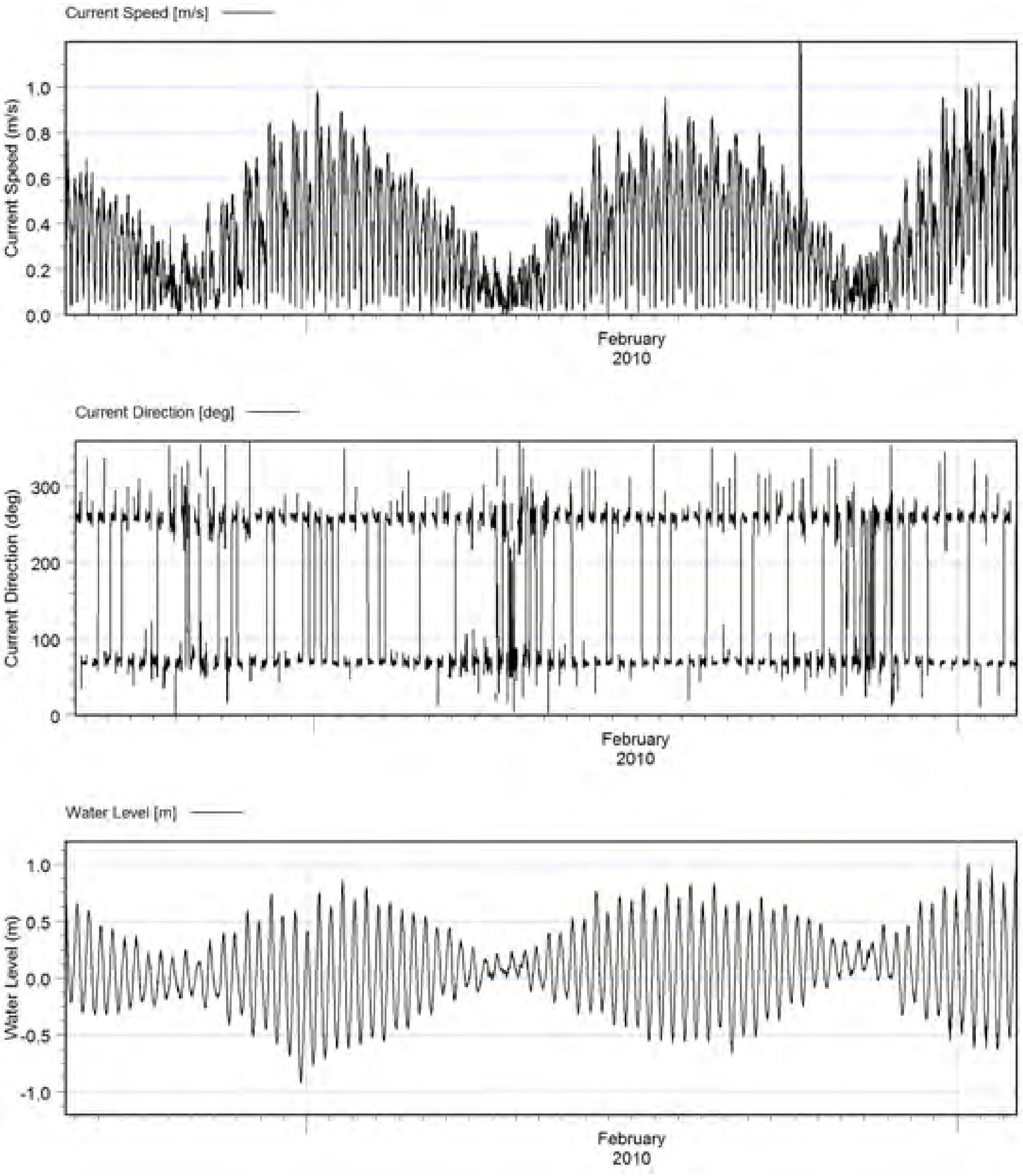


Figure V12 Pauatahanui Inlet Entrance – Mid Water Column Current Speed (top), Current Direction (middle) and Water Level (bottom)

The average speed profile for both ADCPs is presented in Figure V13 and Figure V14. In the entrance to the Pauatahanui Inlet, the velocity profile was reasonably constant throughout the water column with expected lower velocities closer to the bed due to bottom friction. The velocity profile for the main harbour entrance was more complex with a distinct three dimensional structure. There were much larger velocities in the upper water column, close to the surface.

Bin	Height
19	19.25 - 20.25m
18	18.25 - 19.25m
17	17.25 - 18.25m
16	16.25 - 17.25m
15	15.25 - 16.25m
14	14.25 - 15.25m
13	13.25 - 14.25m
12	12.25 - 13.25m
11	11.25 - 12.25m
10	10.25 - 11.25m
9	9.25 - 10.25m
8	8.25 - 9.25m
7	7.25 - 8.25m
6	6.25 - 7.25m
5	5.25 - 6.25m
4	4.25 - 5.25m
3	3.25 - 4.25m
2	2.25 - 3.25m
1	1.25 - 2.25m

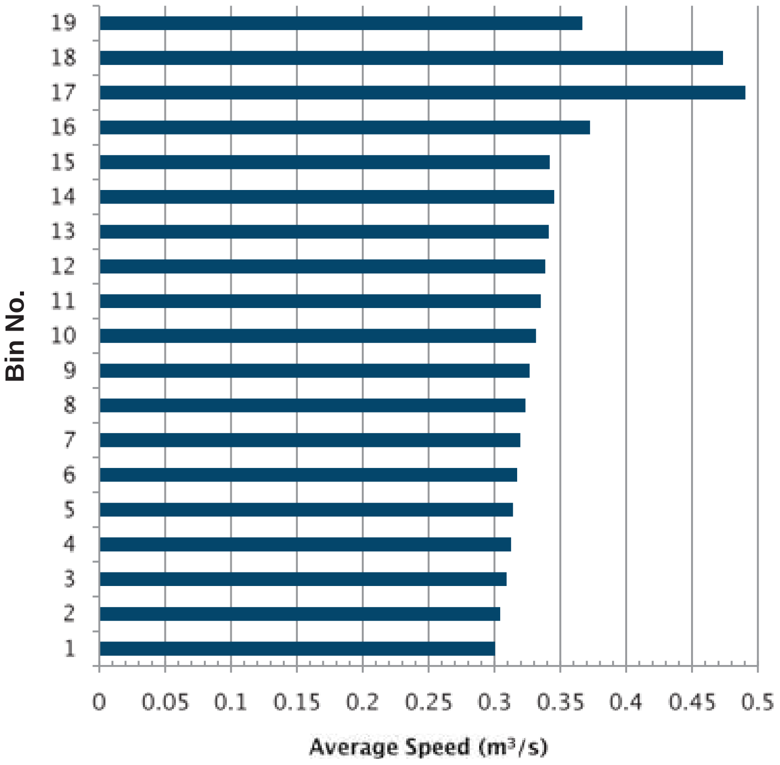


Figure V13 Main Harbour Entrance – Average Speed Profile

Bin No#	Height Above Bed
10	Floating bin (i.e. 5.1m to top of water surface)
9	4.6 – 5.1m above the bed
8	4.1 – 4.6m above the bed
7	3.6 – 4.1m above the bed
6	3.1 – 3.6m above the bed
5	2.6 – 3.1m above the bed
4	2.1 – 2.6m above the bed
3	1.6 – 2.1m above the bed
2	1.1 – 1.6m above the bed
1	0.6 – 1.1m above the bed

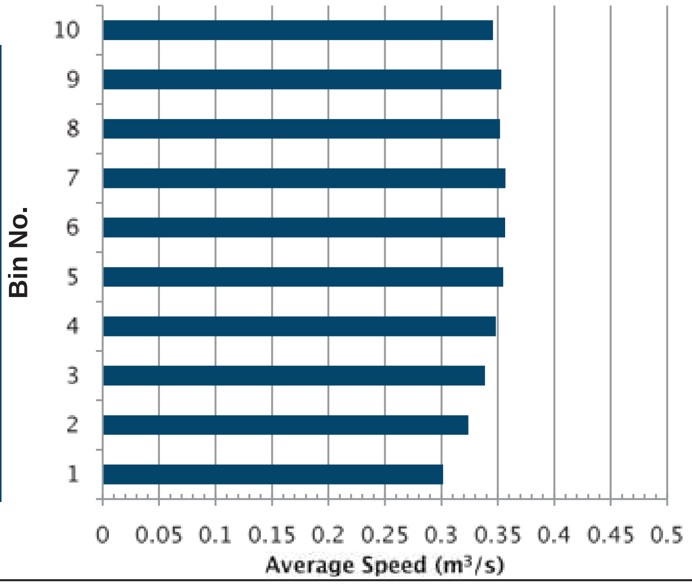


Figure V14 Pauatahanui Inlet Entrance – Average Speed Profile

FSI current meters were deployed for the period, 13th January to 3rd March 2010, in both the Pauatahanui Inlet (NZTM 1759050, 5448551) and the Onepoto Arm (NZTM 1755053, 5446327) to measure current speed, current direction and water depth. This data is presented in Figure V15 and Figure V16. Unlike the main harbour entrance and Pauatahanui Inlet entrance, for both arms of the harbour there did not appear to be a distinct pattern that corresponded with the tide for the current speed and direction. Instead it appeared that the main driver for currents in the middle of the arms of the harbour was wind. This is especially evident in Figure which illustrates that there were comparatively large currents when the tidal range was actually at its smallest.

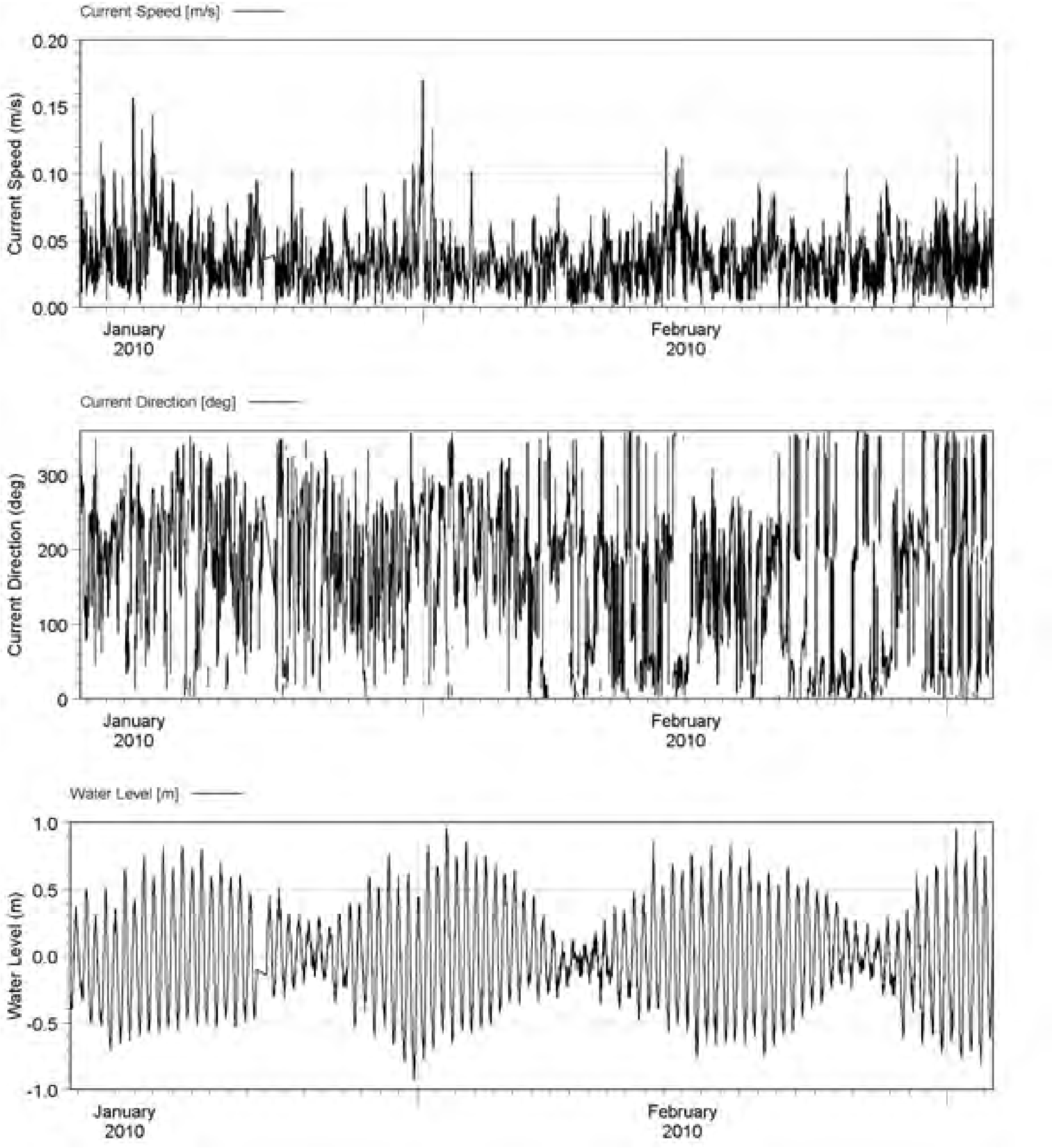


Figure V15 Onepoto Arm – Current Speed (top), Current Direction (middle) and Water Level (bottom)

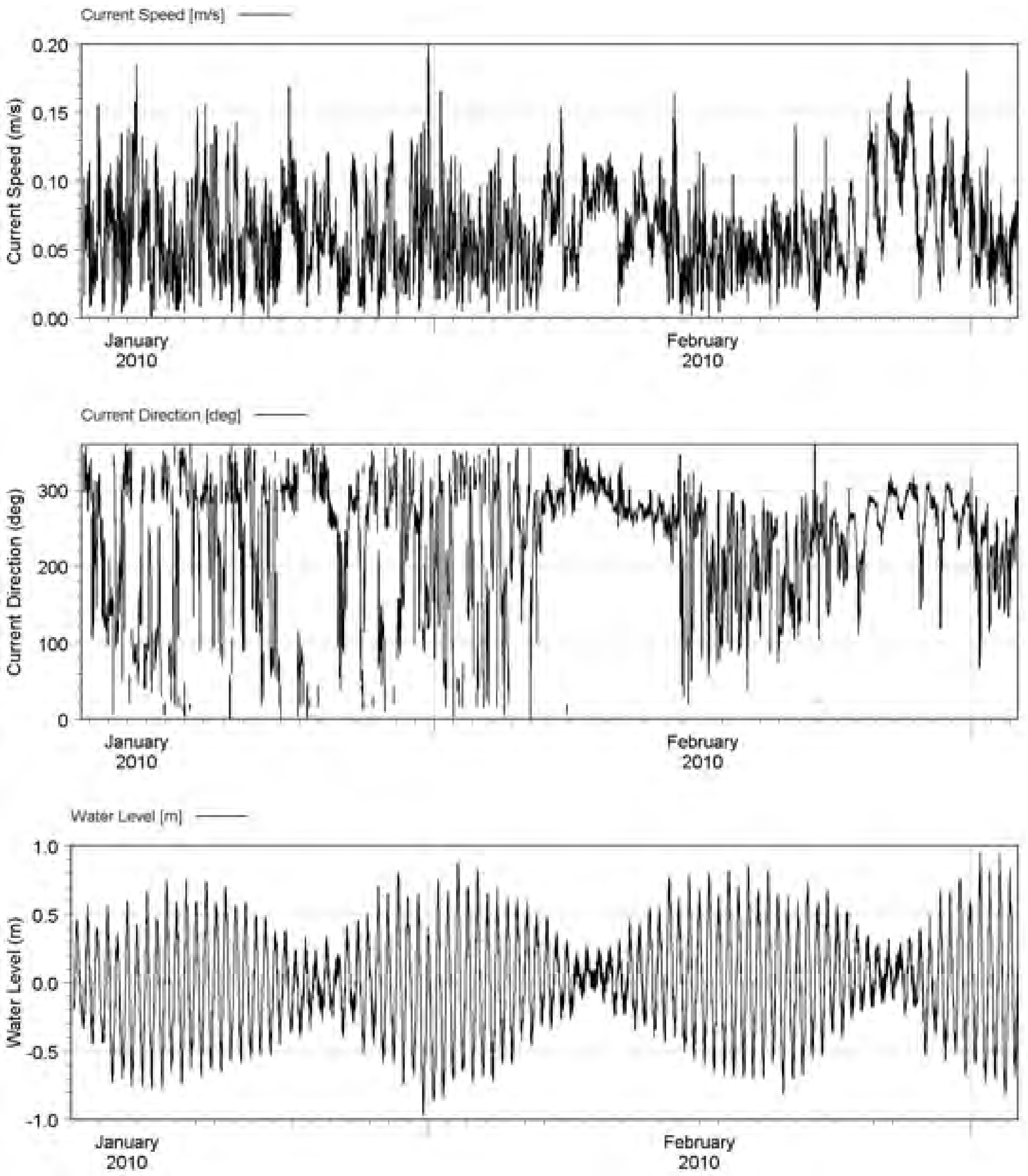


Figure V16 Pauatahanui Inlet – Current Speed (top), Current Direction (middle) and Water Level (bottom)

A DOBIE wave gauge was also deployed with the FSI meters to measure significant wave height and its deployment period was split between the two arms. The wave gauge was deployed in the Onepoto Arm for the period 13th January to 5th February 2010 and the Pauatahanui Inlet for the period 5th February to 3rd March 2010. The DOBIE wave gauge was unable to resolve wave heights smaller than 4 cm. Significant wave height data for both arms is shown in Figure V17.

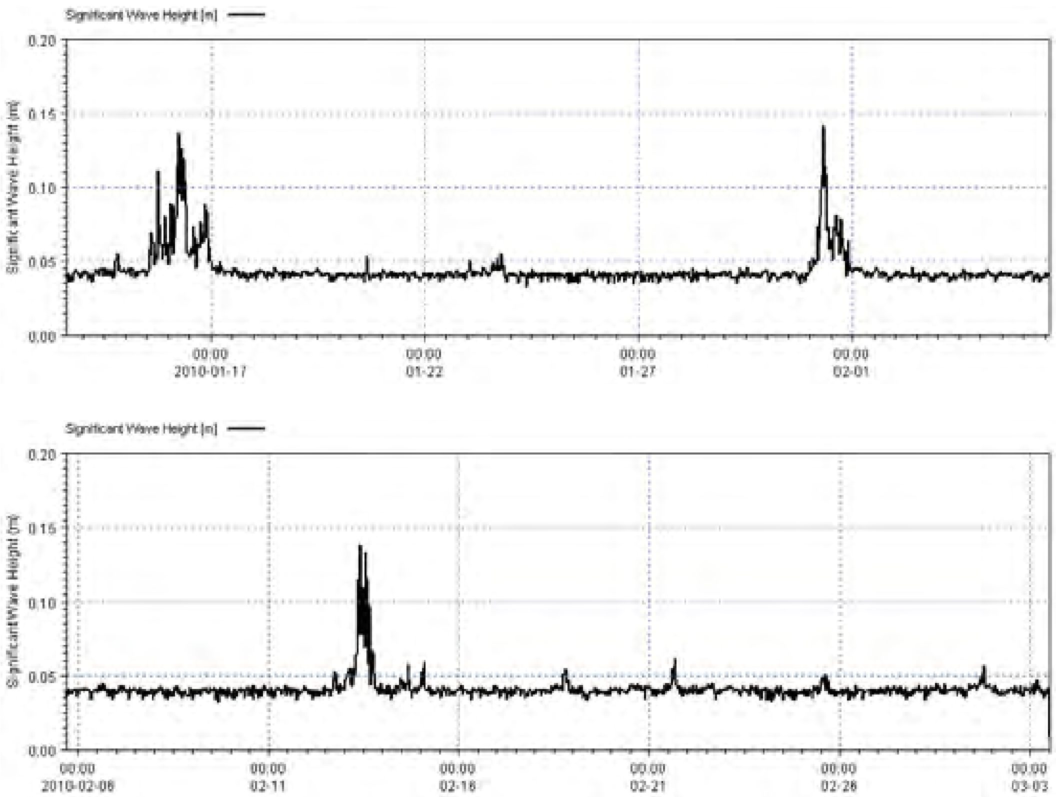


Figure V17 Significant Wave Height in Onepoto Arm (top) and Pauatahanui Inlet (bottom)

The waves measured in the harbour are quite small (of order 0.04 m to 0.15 m), however they are consistent with fetch and depth limited wave heights calculated using equations 3-39 and 3-40 from the Shore Protection Manual (Coastal Engineering Research Center, 1984). For example, for a 10 m/s wind event in Pauatahanui Inlet and assuming a fetch ≈ 0.5 km and a depth ≈ 1.5 m, a significant wave height of 0.13 m is calculated, which is consistent with the significant wave heights observed in Pauatahanui Inlet.

An ACM (acoustic current meter) and wave gauge was deployed in the approaches to the Porirua Harbour entrance (NZTM 1754728, 5450909) close to Tokaapapa Reef for the period 22nd January to 1st March 2010, to measure significant wave height, mean wave direction and water levels. The wave data and water level data is presented in **Figure V18**.

It was relatively calm for first half of data collection period. There is a significant event with a significant wave height of approximately 2.5 m on 13th February 2010 and several smaller events after this time. Although the event on 13th February 2010 coincides with an event in Pauatahanui Inlet (see **Figure V19**), wind data suggests that the waves in Pauatahanui Inlet were generated by local wind and not wave penetration into the harbour.

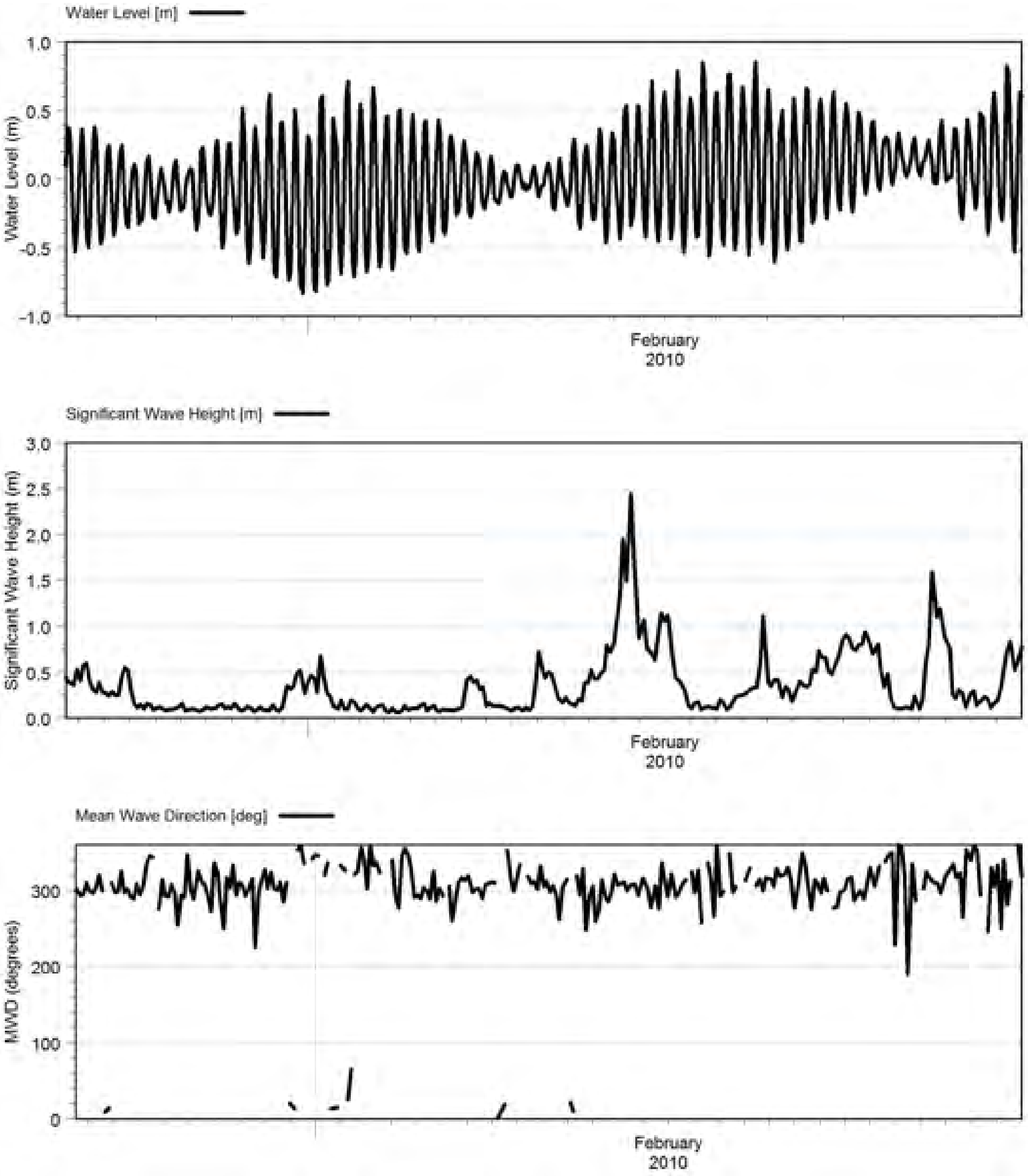


Figure V18 Water Level (top) from Approaches to Porirua Harbour, Significant Wave Height (top) and Mean Wave Direction (bottom) from Approaches to Porirua Harbour

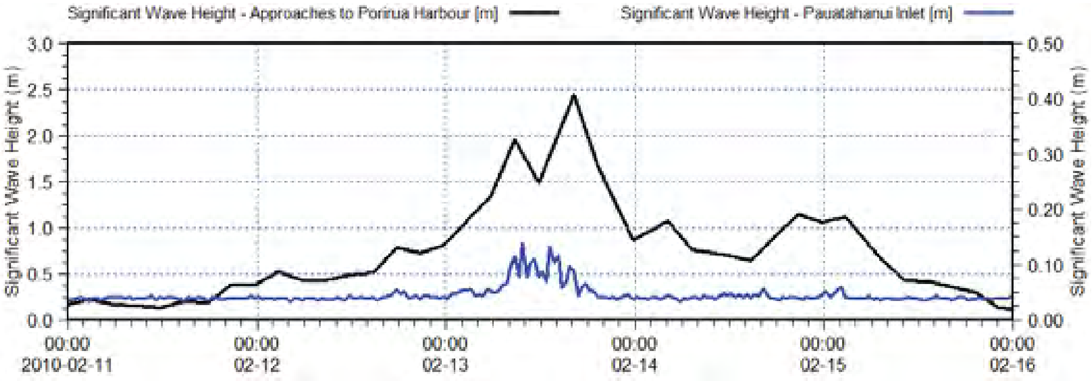


Figure V19 Comparison of Significant Wave Height for Approaches to Porirua Harbour (black) and Pauatahanui Inlet (blue)

(3) Second Data Collection Period

FSI current meters were deployed for the period, 1st July to 1st October 2010, in both the Pauatahanui Inlet (NZTM 1759050, 5448551) and the Onepoto Arm (NZTM 1755053, 5446327) to measure current speed, current direction and water depth, see **Figure V20** and **Figure V21**.

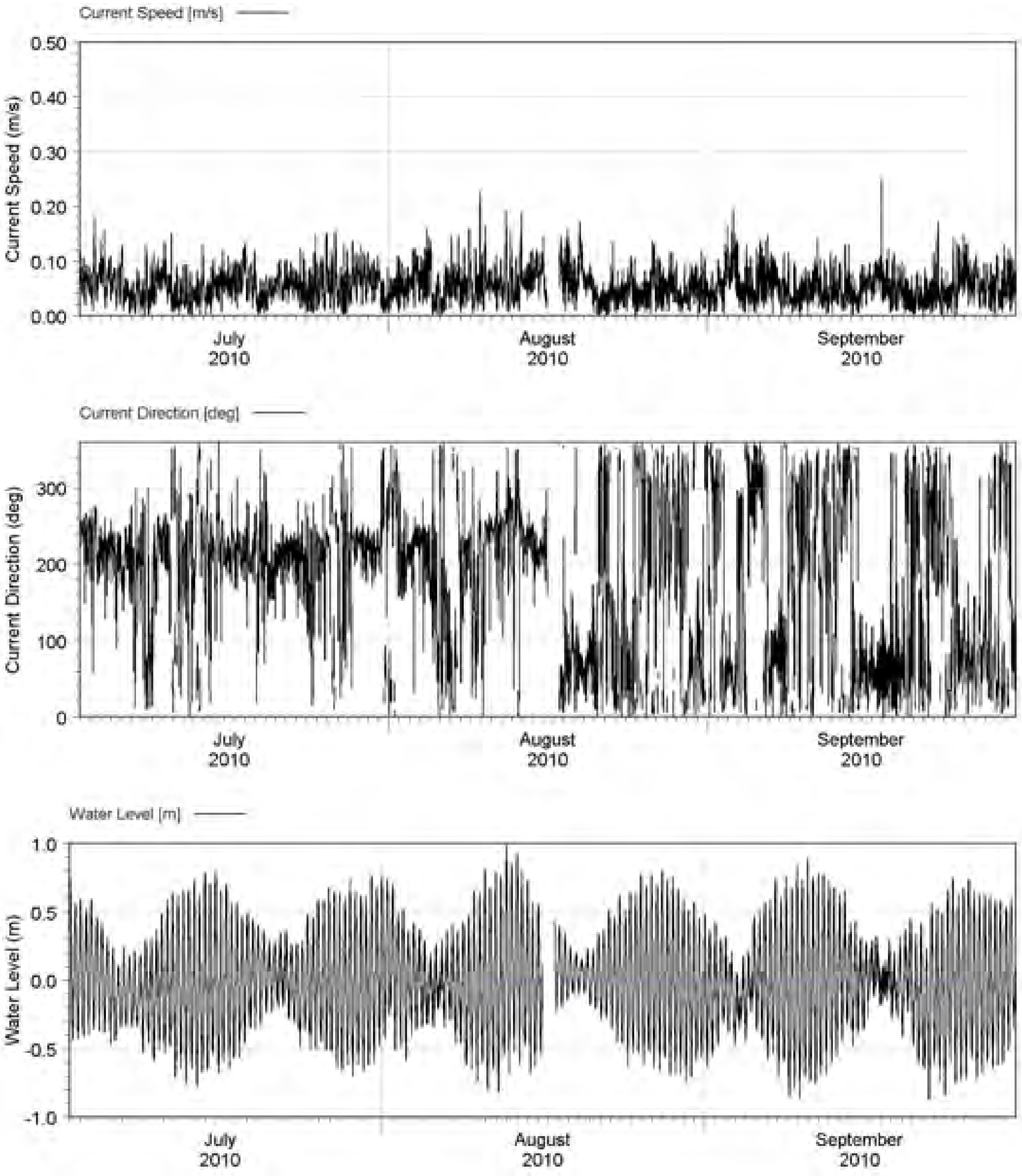


Figure V20 Onepoto Arm – Current Speed (top), Current Direction (middle) and Water Level (bottom)

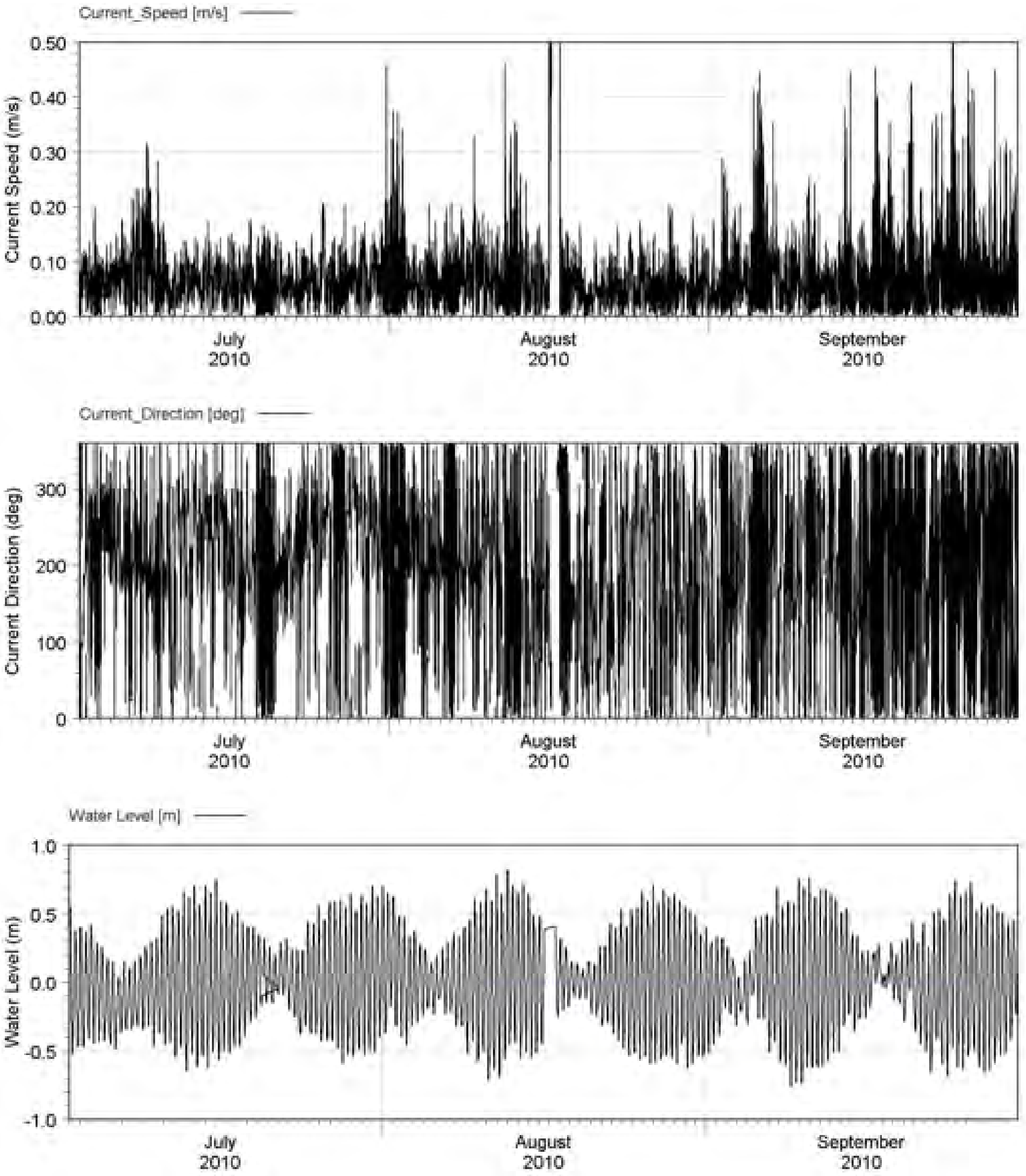


Figure V21 Pauatahanui Inlet – Current Speed (top), Current Direction (middle) and Water Level (bottom)

A DOBIE wave gauge was also deployed with the FSI meter in Pauatahanui Inlet to measure significant wave height, as shown in **Figure V22**. A wave gauge was also deployed with the FSI current meter in Onepoto Arm, however this data appears to be erroneous and therefore is not presented here. Within Pauatahanui Inlet there were numerous significant wind events, especially during September, with significant wave heights greater than 10 cm.

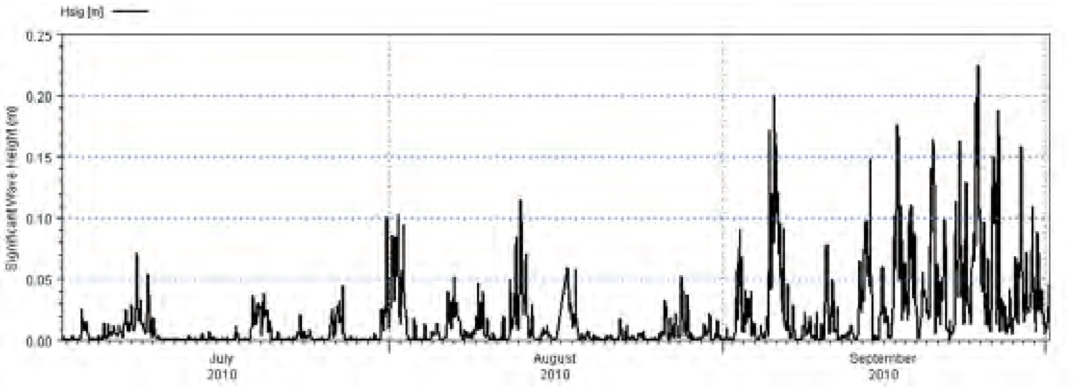


Figure V22 Significant Wave Height in Pauatahanui Inlet

V.2.4 Entrance Flow Measurements

Flow measurements for two transects in the harbour were collected (see **Figure V23**), in the main harbour entrance and the entrance to Pauatahanui Inlet at the bridges. The measurements comprise cross-section transects, measuring water speed and direction (at 0.25 m intervals over the water depth) as well as local water depth using a boat mounted ADCP. The transects were carried out on 26th February 2010, when the tidal range was approximately 0.7 m. The calculated flow through the transects is shown in Figure V23. A positive discharge corresponds to a flood tide while a negative discharge corresponds to an ebb tide. The flow measurements suggest that 60% of the volume of water flowing into main harbour entrance flows into Pauatahanui Inlet. This is consistent with previous observations (Wynne, 1981).

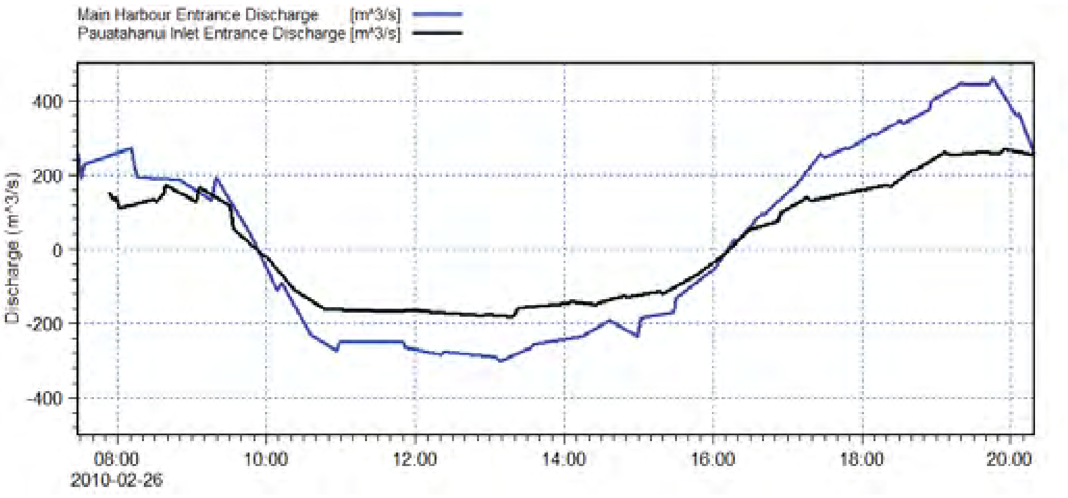


Figure V23 Measured Discharge Through the Main Harbour and Pauatahanui Inlet Entrances

V.2.5 Tide Gauge

In support of the survey carried out by DML, GWRC installed a permanent gauge at Mana Marina. GWRC provided data in Chart Datum from this gauge, for two periods, 9th February 2009 – 29th March 2010 and 15th June – 6th October 2010, as shown in **Figure V24**. The average tidal range for spring tide was approximately 1.5 m, while for neap tides there was very little tidal variation.

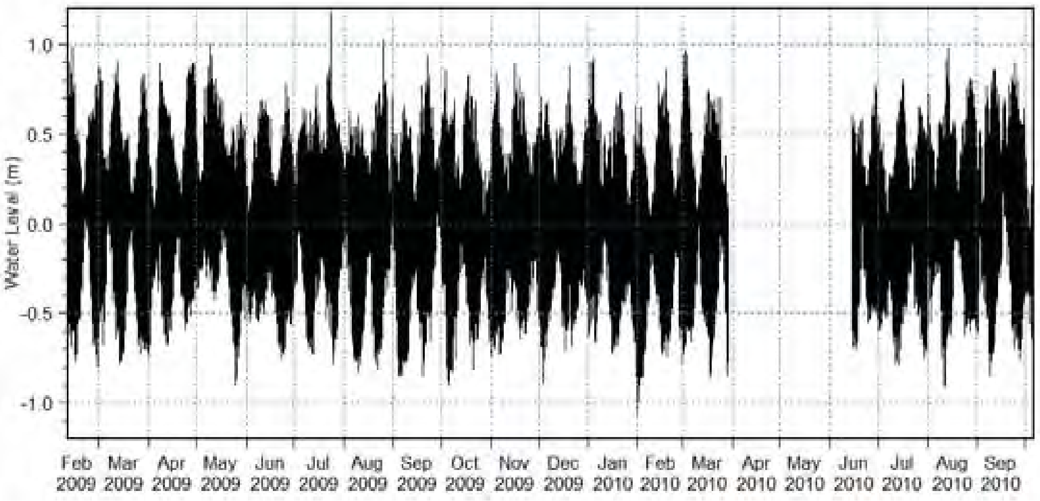


Figure V24 Water Level Data from Mana Marina

V.2.6 Sediment Data

For this study, an extensive grab sampling exercise was undertaken by Cawthron. Twenty sample locations were selected and are shown in Figure V25. The samples were analysed for grain size distribution into the class sizes in Table V2, while Table V3 presents the grain size distribution for the grab samples.

The data suggest that there is a high re-suspension rate of fines around the edges of both the Onepoto and Pauatahanui Arms resulting in high concentrations of fines depositing in the middle of the arms and low concentrations around the edges. This is consistent with a previous study (Green *et. al*., 1997), which showed dramatic changes in turbidity accompanying development of waves in intertidal regions. Similar behaviour was observed in intertidal regions by Green and Coco (2007).

The data agrees with a previous study that suggests there are two dominant sources of sediment to the harbour (Gibb *et. al.,* 2009):

- Marine based sediment which supplies sand to both the ebb-tide and flood-tide deltas
- Terrestrial based sediment which supplies mud to the central basins and sand and gravel to the beaches surrounding the harbour.

Table V2 Sediment Grain Size Classes

Sediment Class	Sediment Diameter (d)
Gravel	d >2 mm
V. Coarse Sand	2 mm > d > 1 mm
Coarse Sand	1 mm > d > 500 µm
Medium sand	500 µm > d > 250µm
Fine Sand	250 µm > d >125 µm
V. Fine Sand	125 µm > d > 63 µm

Silt & clay	d < 63 μm

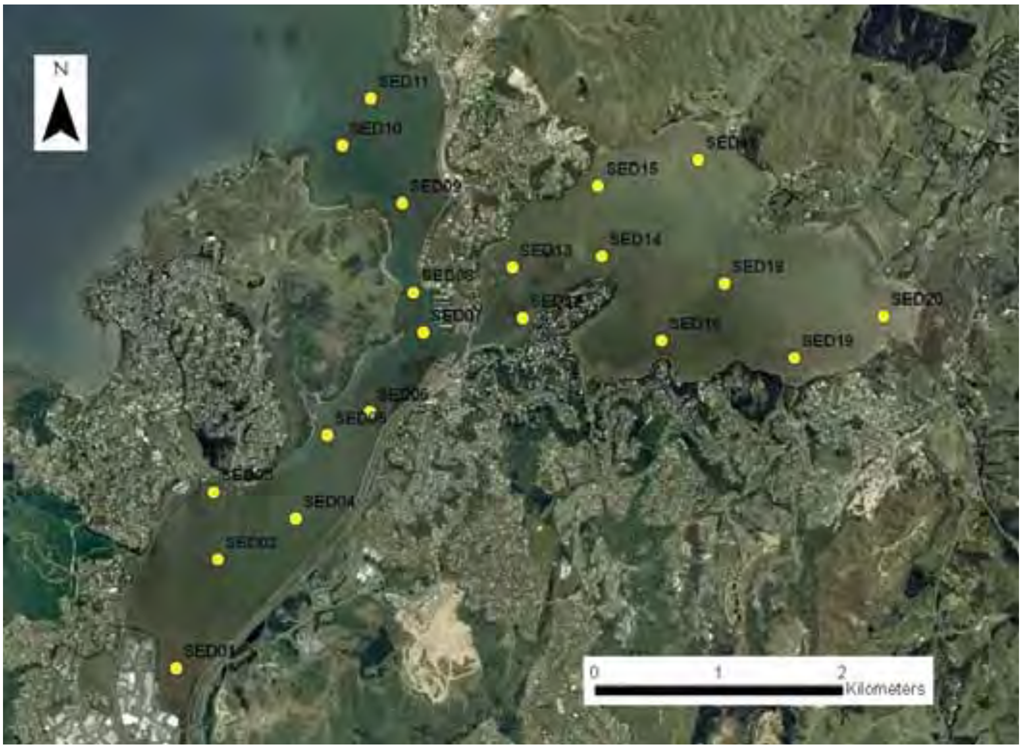


Figure V25 Sediment Bed Grab Sample Locations

Table V3 Grain Size Distribution for Grab Samples

Location	Sediment grain size (%w/w)						
	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt & Clay
SED-01	14.4	9.9	6.8	12.5	20.8	17.2	18.4
SED-02	<0.1	<0.1	0.1	0.1	0.4	1.4	98.0
SED-03	4.5	0.4	0.8	10.8	70.2	5.8	7.5
SED-04	0.6	0.1	0.2	0.4	3.7	19.4	75.7
SED-05	<0.1	0.1	0.1	3.5	36.4	57.8	2.2
SED-06	4.5	0.3	0.3	1.7	24.6	65.3	3.2
SED-07	6.2	0.8	2.2	21.8	47.8	19.0	2.3
SED-08	1.2	1.6	7.2	23.7	47.4	15.6	3.4
SED-09	0.4	0.1	3.0	18.6	67.5	9.5	0.8
SED-10	<0.1	0.2	0.3	2.3	12.1	84.2	0.9
SED-11	<0.1	<0.1	<0.1	0.7	18.2	79.8	1.2

SED-12	2.8	0.6	1.5	6.0	56.4	29.4	3.4
SED-13	<0.1	0.2	0.4	0.9	35.1	55.8	7.6
SED-14	17.6	10.1	8.4	7.1	30.9	21.1	4.9
SED-15	0.6	0.2	0.8	1.1	20.2	60.7	16.5
SED-16	<0.1	<0.1	0.2	0.8	4.5	21.2	73.2
SED-17	0.5	0.2	2.7	9.6	53.4	23.6	10.0
SED-18	0.2	0.1	0.1	0.2	1.3	3.1	95.0
SED-19	0.6	<0.1	0.2	0.8	1.4	30.6	66.4
SED-20	0.5	0.3	1.8	17.5	60.7	14.7	4.4

V.2.7 Suspended Sediment Data

Turbidity data was collected using turbidity meters (or nephelometers) in the Pauatahanui and Onepoto Arms at the same location as the deployed current meters during both the first and second data collection periods.

Turbidity data is most commonly measured in Nephelometric Turbidity Units (NTU). The correlation between NTU and Total Suspended Sediments (TSS) is unique for every location and situation. Cawthron calibrated the turbidity meters to determine the relationship between NTU and TSS before deploying the instruments, from which a formula was derived for each instrument. These formulae have been used to generate TSS data from the NTU data.

(1) First Data Collection Period

During the first data collection period, turbidity data was collected 13th January to 3rd March 2010. The generated TSS data is presented in Figure V26. It should be noted that the turbidity meters could not collect data above approximately 100 NTU or 0.2 kg/m^3 of TSS. The Pauatahanui Inlet data was erroneous after approximately 6th February 2010 and is not presented here. The erroneous data was most likely as a result of fouling of the instrument, a common occurrence in coastal waters.

All periods of elevated TSS corresponded with significant wind and therefore comparatively significant wave events within the harbour.

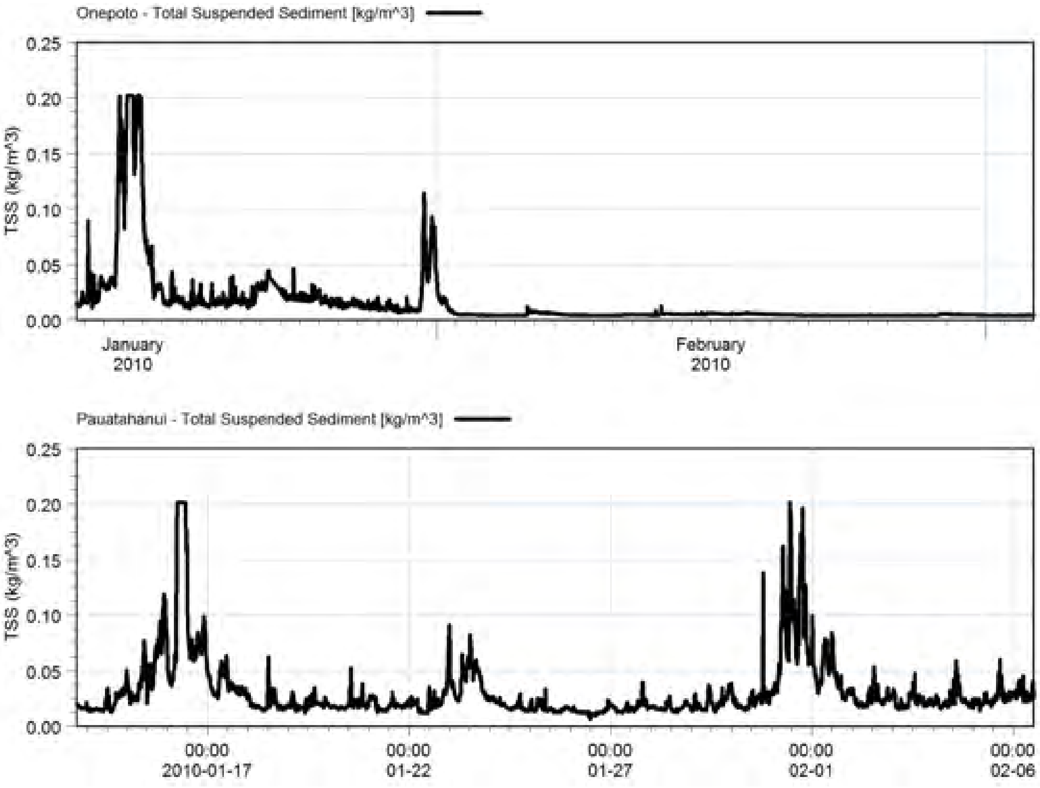


Figure V26 TSS Data From Onepoto (top) and Pauatahanui Inlet (bottom)

(2) Second Data Collection Period

During the second data collection period, turbidity data was collected 13th January to 3rd March 2010. Although turbidity data was collected within Onepoto Arm, the data appears to be erroneous due to an issue with the instrument and is not presented here. The generated TSS data from Pauatahanui is presented in **Figure V27**.

Similar to the first data collection period, the majority of periods of elevated TSS corresponded with significant wave events. On the 30th September there was one event where there were no significant waves with wind speeds of approximately 10 m/s, but there was a spike in TSS in Pauatahanui Inlet. This corresponds to a rainfall event that resulted in a ten year ARI event in the Horokiri catchment. The spike in TSS was due to the sediment plumes that develop as a result of freshwater inflows to the harbour and their associated sediment load.

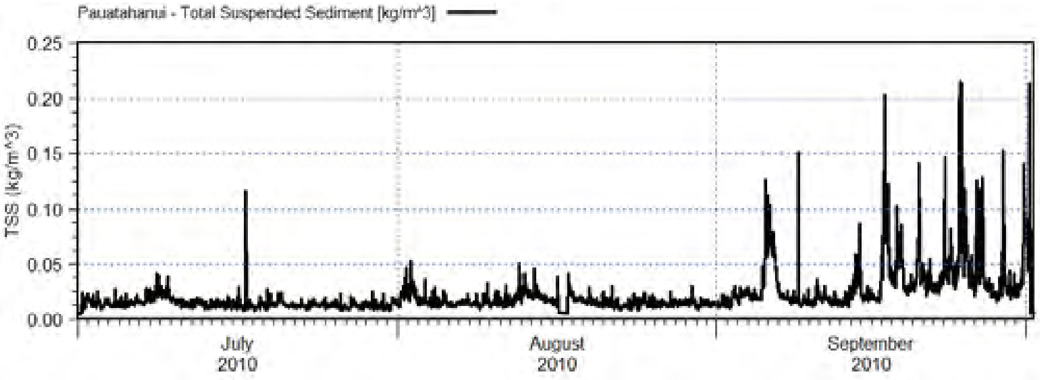


Figure V27 TSS Data From Pauatahanui Inlet

V.3 Model Set Up, Calibration and Validation

This chapter outlines the hydrodynamic, wave and sediment transport model development, calibration and where necessary validation. A two dimensional model of Porirua Harbour was developed, extending out to approximately 1km from the entrance. The model was created to predict the fate of land based sediment entering the harbour from the surrounding catchment. A two dimensional approach was chosen, since due to the relatively shallow depth of the harbour, it is reasonable that a two dimensional model will approximate physics and processes that occur within the arms of the harbour.

V.3.1 Bathymetry

Two model domains for Porirua Harbour were developed using the available bathymetric data:

- High resolution mesh for event-based scenarios
- Coarse resolution mesh for long-term scenarios.

A coarse resolution model was required for the long term simulations, since the run times required for the high resolution model were unfeasible.

A flexible mesh was built which allows the computational domain to be discretized into a mixture of tessellating triangular and quadrilateral elements of various sizes. This allows flexibility in defining and resolving the model domain, and features within the domain such as river channels. This enabled hi-resolution definition where necessary, but reduced computational requirements in other areas. Quadrilateral elements can be utilised for areas where flow is constrained along a stream-wise direction, such as channels, offering a more efficient mesh than with triangles.

The model bathymetries were constructed using the bathymetric survey data from DML and topographic data. The model bathymetry and extent is shown in **Figure V28**, while **Figure V29** shows the high resolution mesh for the harbour and arm entrances. Triangular elements have been used for the whole mesh. A number of meshes were tested during the calibration phase with the final resolution a combination of an acceptable calibration and realistic run times. The coarse resolution mesh is shown in **Figure V30** and included a combination of triangular and quadrilateral elements.

The main factors that should be taken into account when developing a model mesh are:

- Resolving the required physical processes
- Achieving a satisfactory calibration
- Achieving run times that are realistic for the timeframes of the study (often a compromise has to be made with mesh resolution).

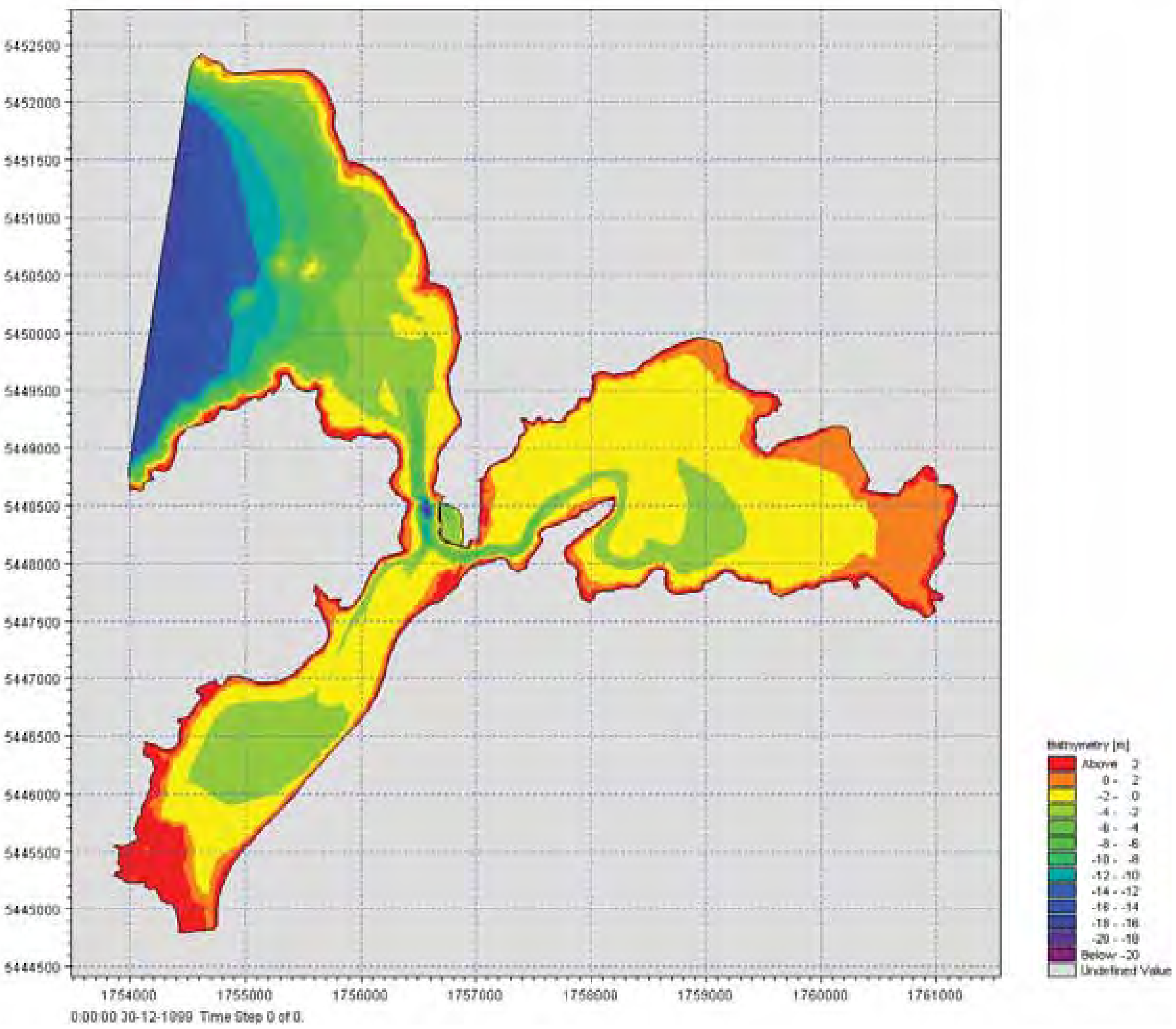


Figure V28 Model Extent, Bathymetry and Mesh (MSL)

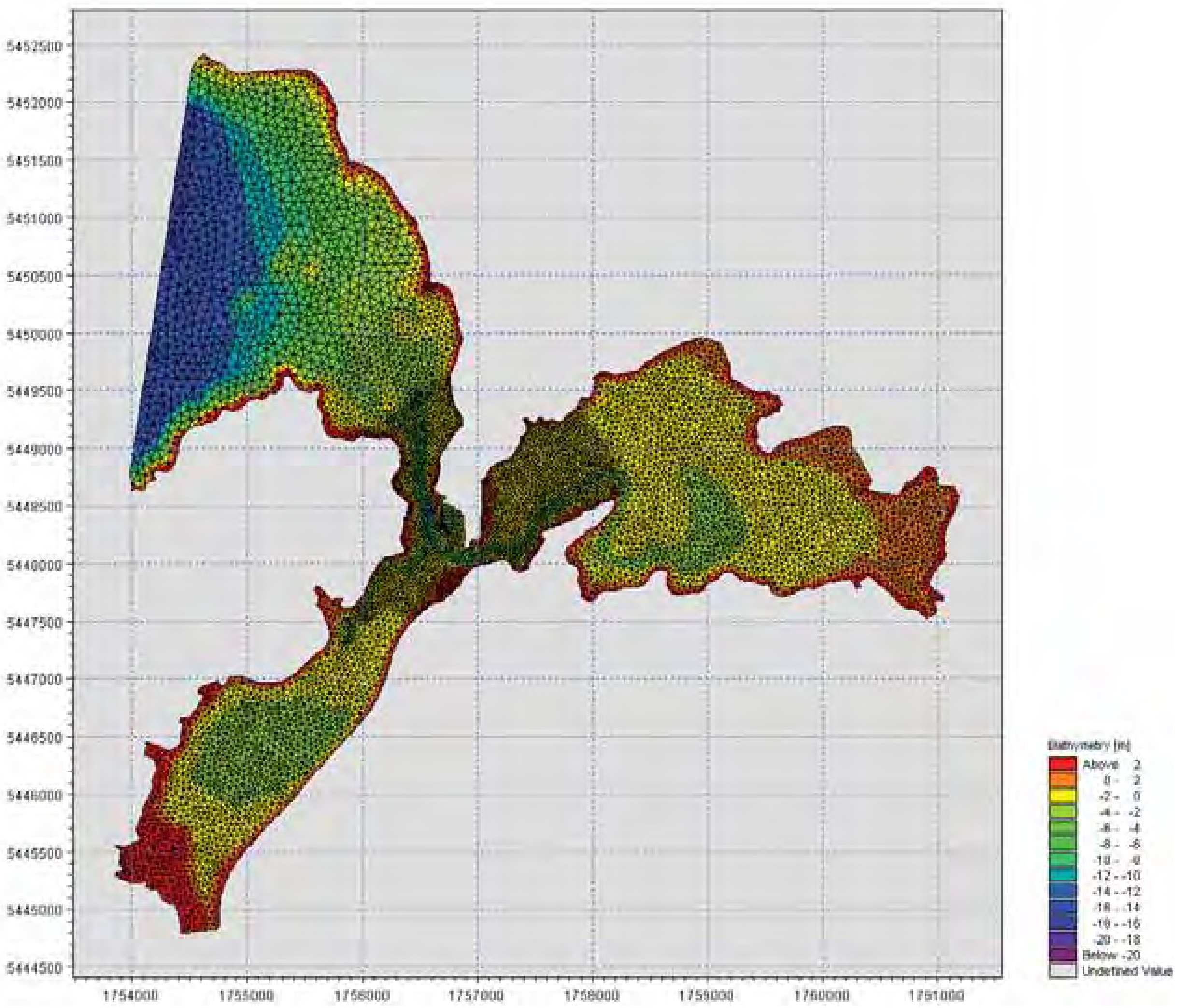


Figure V29 High Resolution Model Mesh (MSL)

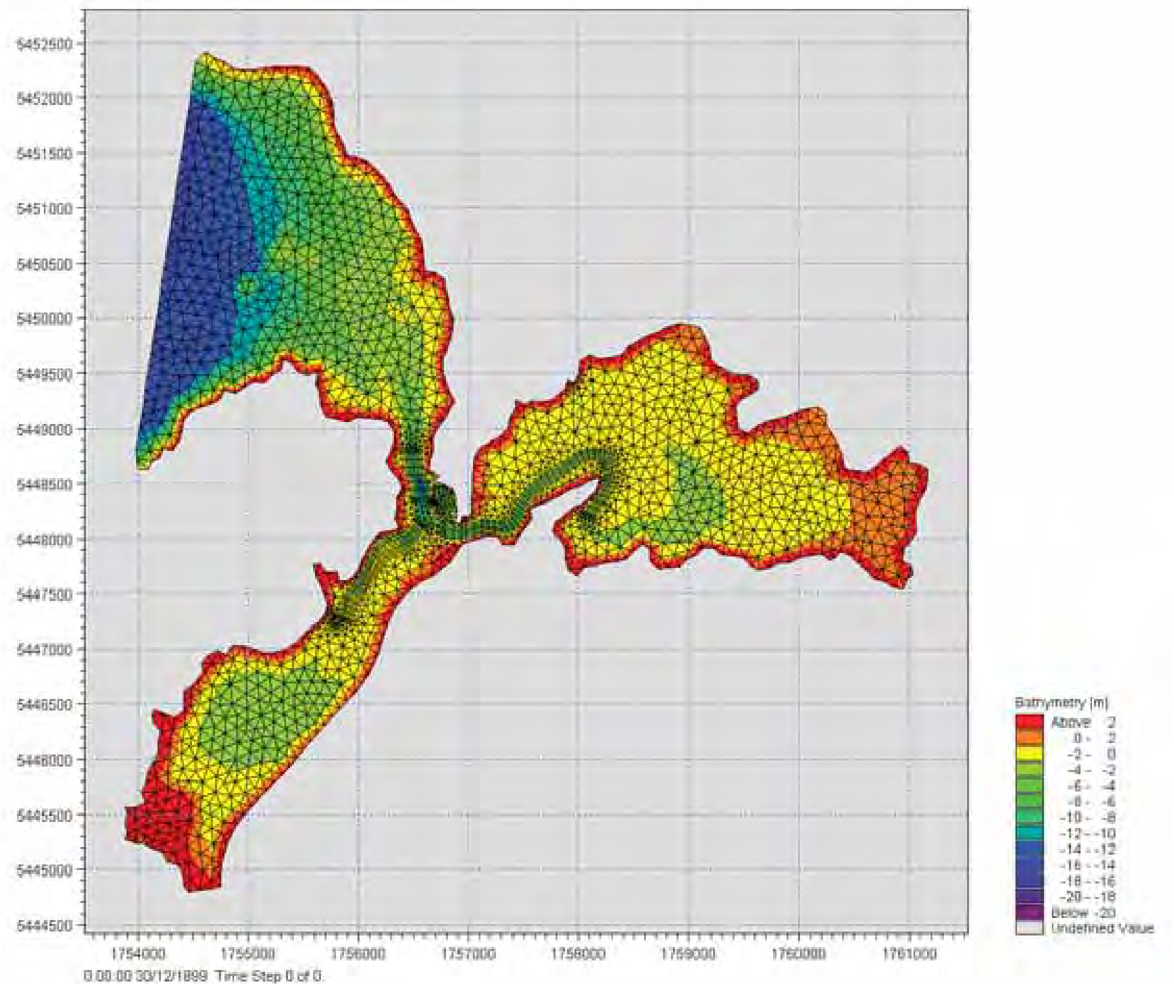


Figure V30 Coarse Resolution Model Mesh (MSL)

V.3.2 Open Ocean Boundary

One open ocean boundary is specified for the mesh. It was originally thought that the most logical data to use for the open ocean boundary was the water level data from the approaches to the harbour at Tokaapapa Reef, since this is closest to the open ocean boundary. However the frequency that the instrument in this location recorded water levels was not frequent enough to capture the highest and lowest water levels during a tidal cycle. Instead water level data from Mana Marina was used for the open ocean boundary. The Mana Marina data also has the advantage that it is measured from a referenced tidal gauge hence it is able to record variations in water level due to processes such as storm surge and changes in atmospheric pressure.

The data collected by Cawthron indicates that there is minimal propagation of offshore waves into the harbour arms (see Section 4.3) hence no open ocean wave boundary condition was included in the model set up.

V.3.3 Wind Forcing

For the model calibration, wind data collected from Pauatahanui Inlet has been used as wind boundary data. As mentioned in Section 12, for southerly wind directions there is possibly variations in wind directions in both arms, however due to data constraints, we were unable to investigate this further. It was therefore deemed appropriate to use wind data from Pauatahanui Inlet for both Pauatahanui Inlet and Onepoto Arm.

V.3.4 Freshwater and Sediment Inflows

Freshwater and sediment inflows have been included in the model for the 23 major catchments which surround Porirua Harbour as shown in Figure V31. For each of these catchments flow and associated sediment inflow time series were developed for inputs into the harbour. The methodology used to develop the sediment inputs is described in detail in Section 10.

Figure V31 Location of Freshwater and Sediment Inflows with Associated Catchments

There do not appear to be any major channels that form as a result of the freshwater inflows and any small channels that exist are complex bird foot deltas and were not resolved by the bathymetry survey. Since the small tidal channels are not resolved in the model, the freshwater inflows and the associated sediment inflows have been located below Mean Low Water Springs (MLWS) in the model. To account for the momentum that any freshwater inflows would have when entering into the harbour, all inflows have an associate velocity (specified as x- and y- direction components). The velocity components were calculated assuming a 5 m wide and 1 m deep channel and the likely direction of flow into the harbour. For smaller catchments where it was obvious that the inflow enters into catchment via a culvert (i.e. catchments a, b, c, d and e), the velocity components were calculated assuming a 0.25 diameter culvert.

V.3.5 Terrestrial Particle Size Distribution

Three terrestrial sediment fractions were included in the sediment transport model to account for clay/silt (<63 µm), fine sand (63 µm – 125 µm) and sand (125 µm – 250 µm). The clay/silt fraction was included as a cohesive sediment with a settling velocity coefficient consistent with the calibration model. It is most likely that the TSS data which was used to calibrate the sediment transport model mostly consisted of clay/silt due to the small magnitude of the waves for these events.

Fine sand and sand were included as non-cohesive sand fractions with settling velocities calculated using Stokes law assuming a diameter of 100 µm for fine sand and 200 µm for sand.

A particle size distribution for sediment loads to the estuary has been calculated based on samples taken from the surrounding catchments. Table V4 presents the particle size distribution calculated for each catchment.

Table V4 Particle Size Distribution for Catchments

Catchment	Sediment Type		
	Clay/Silt (%)	Fine Sand (%)	Sand (%)
Browns Catchment	60.00	20.00	20.00
Collins Stream Catchment	62.84	18.58	18.58
Duck	65.18	17.41	17.41
Horokiri	77.47	11.26	11.26
Kakaho Catchment	80.43	9.79	9.79
Kenepuru	63.75	18.13	18.13
Pauatahanui	68.90	15.55	15.55
Porirua	66.92	16.54	16.54
Ration	77.66	11.17	11.17
Takapuwahia Catchment	63.32	18.34	18.34
a	60.00	20.00	20.00
b	60.00	20.00	20.00
c	60.00	20.00	20.00
d	60.00	20.00	20.00
e	60.00	20.00	20.00
f	70.47	14.76	14.76
g	60.40	19.80	19.80
h	60.00	20.00	20.00
i	63.70	18.15	18.15
j	72.00	14.00	14.00

Catchment	Sediment Type		
	Clay/Silt (%)	Fine Sand (%)	Sand (%)
k	67.84	16.08	16.08
l	60.00	20.00	20.00
m	60.00	20.00	20.00

V.3.6 Model Calibration

The main aim for the Porirua Harbour model in the context of this study, was to represent three significant, complex interrelated processes: hydrodynamics, waves and sediment transport.

The calibration of the model comprised quantitative plots of observed against predicted data with qualitative comments of the agreement between the two sets of data.

Considering the number of events and range of processes that the model is representing, we consider the model to be fit for purpose. It should be noted that all model calibrations were carried out using the high resolution mesh.

(1) Hydrodynamic Model Calibration

The hydrodynamic model calibration involved the refinement of bathymetry and hydraulic parameters to provide an acceptable match between measured and predicted data.

The hydrodynamic model was calibrated using currents and tidal levels collected within Porirua Harbour for four, seven day periods. Two were taken from the first data collection period and two were taken from the second data collection period. The calibration periods are summarised in **Table V4**.

For the current calibration, in locations where current data was collected using an ADCP (main harbour entrance and Pauatahanui Inlet entrance), the predicted depth averaged current speed and direction were compared with the observed current speed and direction from mid water column. Observed depth averaged current speeds and directions were not used due to time constraints for processing. The average current speed profiles substantiates that the mid column current speeds and directions are mostly representative of the vertical characteristics of the water column.

Table V4 Calibration Periods for Hydrodynamic Model

Calibration Period	Period	Data Available
1	28th January – 5th February 2010	Harbour Entrance, Pauatahanui Entrance, Pauatahanui Inlet and Onepoto Arm.
2	15th February – 22nd February 2010	Harbour Entrance, Pauatahanui Entrance, Pauatahanui Inlet and Onepoto Arm.
3	7th September – 14th September 2010	Pauatahanui Inlet and Onepoto Arm.
4	15th September – 22nd September 2010	Pauatahanui Inlet and Onepoto Arm.

The specifications for the calibrated hydrodynamic model are summarised in **Table V5.** Further explanation of these parameters can be found in the MIKE 21 HD FM User Manual (DHI, 2009). Although a Manning number = 60 $m^{1/3}/s$ is reasonably high when compared to ‘typical’ experience, the MIKE 21 FM HD model requires a slightly higher value to account for diffusive effects of the numerical scheme.

Table V5 Specifications for Calibrated Hydrodynamic Model

Parameter	Value
Solution Technique	Low order, fast algorithm Minimum time step: 0.01 s Maximum time step: 30 s Critical CFL number: 0.8
Enable Flood and Dry	Drying depth: 0.01 m Flooding depth: 0.05 m Wetting depth: 0.1 m
Wind	Varying in time, constant in domain (wind data from Pauatahanui Inlet)
Wind Friction	Linear variation 0.001255 at 7 m/s and 0.002425 at 25 m/s
Eddy Viscosity	Horizontal: Smagoringsky formulation, constant 0.28
Resistance	Manning number = 60 $m^{1/3}/s$

(2) First Hydrodynamic Model Calibration Period

The tidal and wind forcing for the first calibration period are shown in **Figure V32**. A significant southerly wind event occurred on the 31st January, 2010.

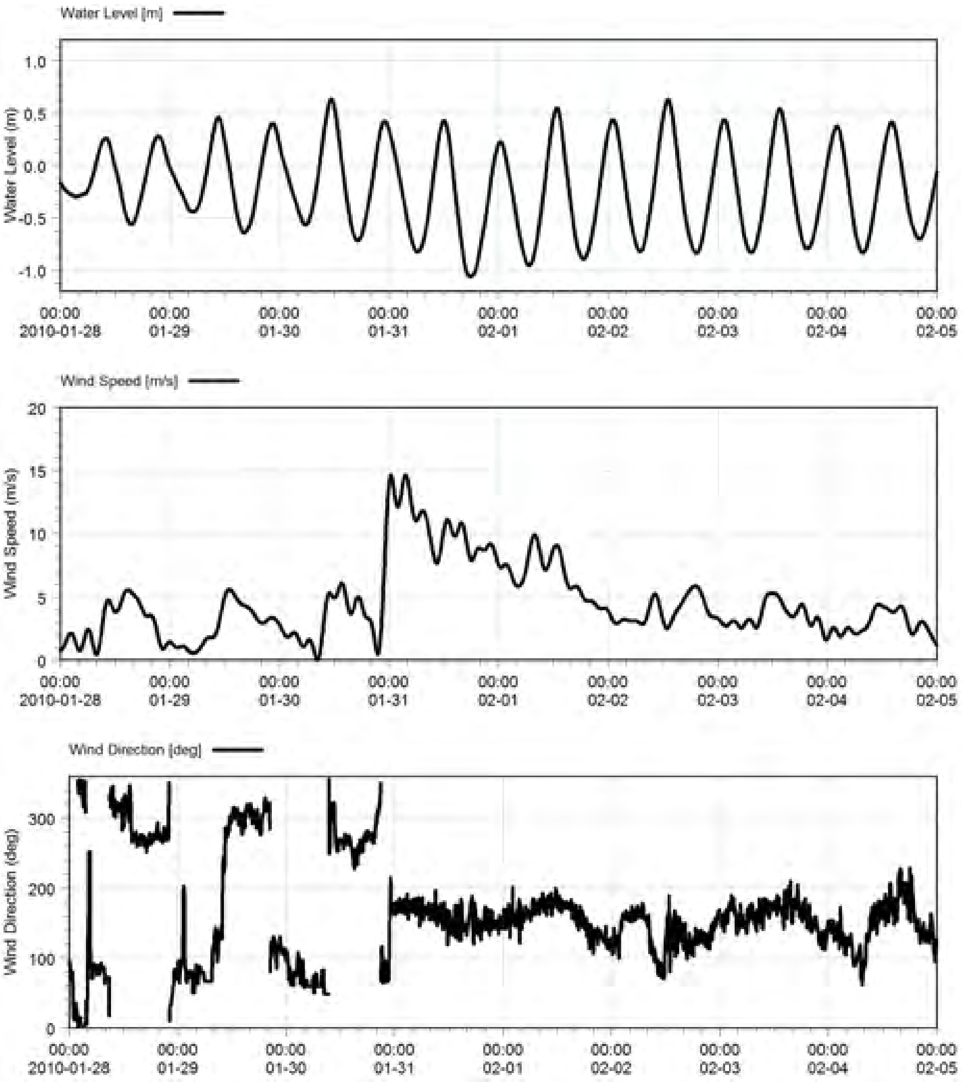


Figure V32 Water Level from Mana Marina (top) and Wind Speed (middle) and Wind Direction (bottom) Observed in Pauatahanui Inlet for First Hydrodynamic Model Calibration Period

For the first calibration period the model was able to satisfactorily predict water levels for all locations as shown in **Figure V32**. The model appeared to slightly under predict the peak levels at the entrance to Porirua Harbour.

There was a very good match between observed and predicted current speed and direction in the entrance to Pauatahanui Inlet, however current speeds were under predicted in the entrance to Porirua Harbour, as shown in **Figure V33**. It appears that the reason for this is that the 2D model was not able to effectively reproduce the hydrodynamics of the localised hollow, where the ADCP was located in the main harbour entrance. Also shown in the same figure are the predicted current speeds just north of the localised depression. These compared well with the observed current speeds. The fact that the model could not replicate the hydrodynamics of the hole was not deemed to be critical by the project team, since the model was shown to satisfactorily predict the volume of water which flows in and out of Porirua Harbour. For the main entrance channel there is a difference of 40 degrees between observed and predicted current direction for the flood tide. This was not considered to significantly affect the predictive capabilities of the model. For the arms of the harbour it was much more difficult to obtain a close match as in the main harbour entrance and Pauatahanui Inlet entrance. The reason was that the harbour arms are shallow, typically 1.5 m and therefore very influenced by wind forcing. There was also the possibility that the bathymetry had changed since the bathymetry survey was carried out, which would have an impact on currents. Considering these limitations there was a reasonable agreement between observed and predicted current speed and directions in the arms of the harbour as shown in **Figure V34**. Current speeds were typically of the right magnitude, especially for the southerly wind event that occurred on the 31st January, 2010.

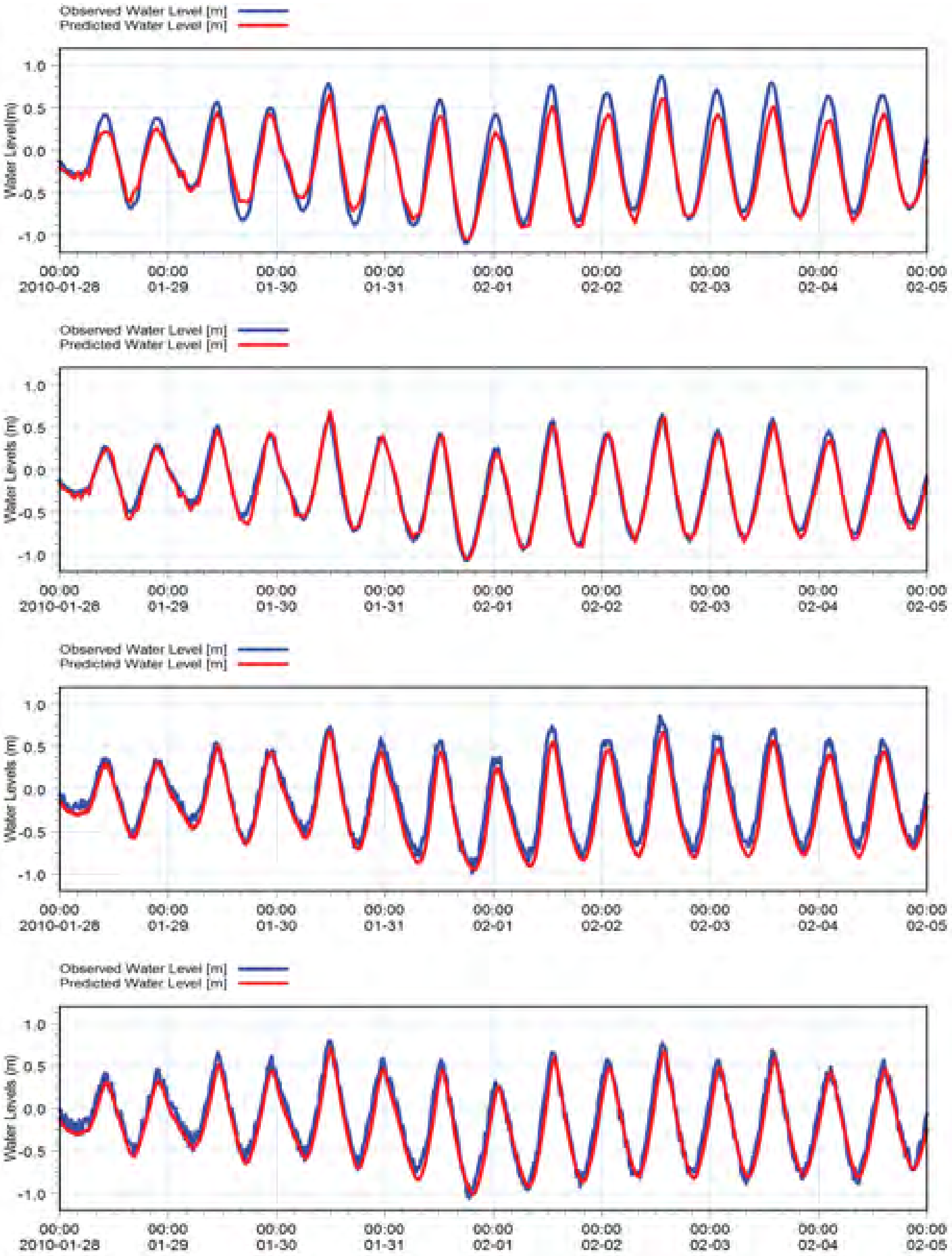


Figure V32 Comparison of Observed and Predicted Water Levels for Porirua Harbour Entrance (top), Pauatahanui Inlet Entrance (top-middle), Onepoto Arm (bottom-middle) and Pauatahanui Inlet (bottom) for First Hydrodynamic Model Calibration Period

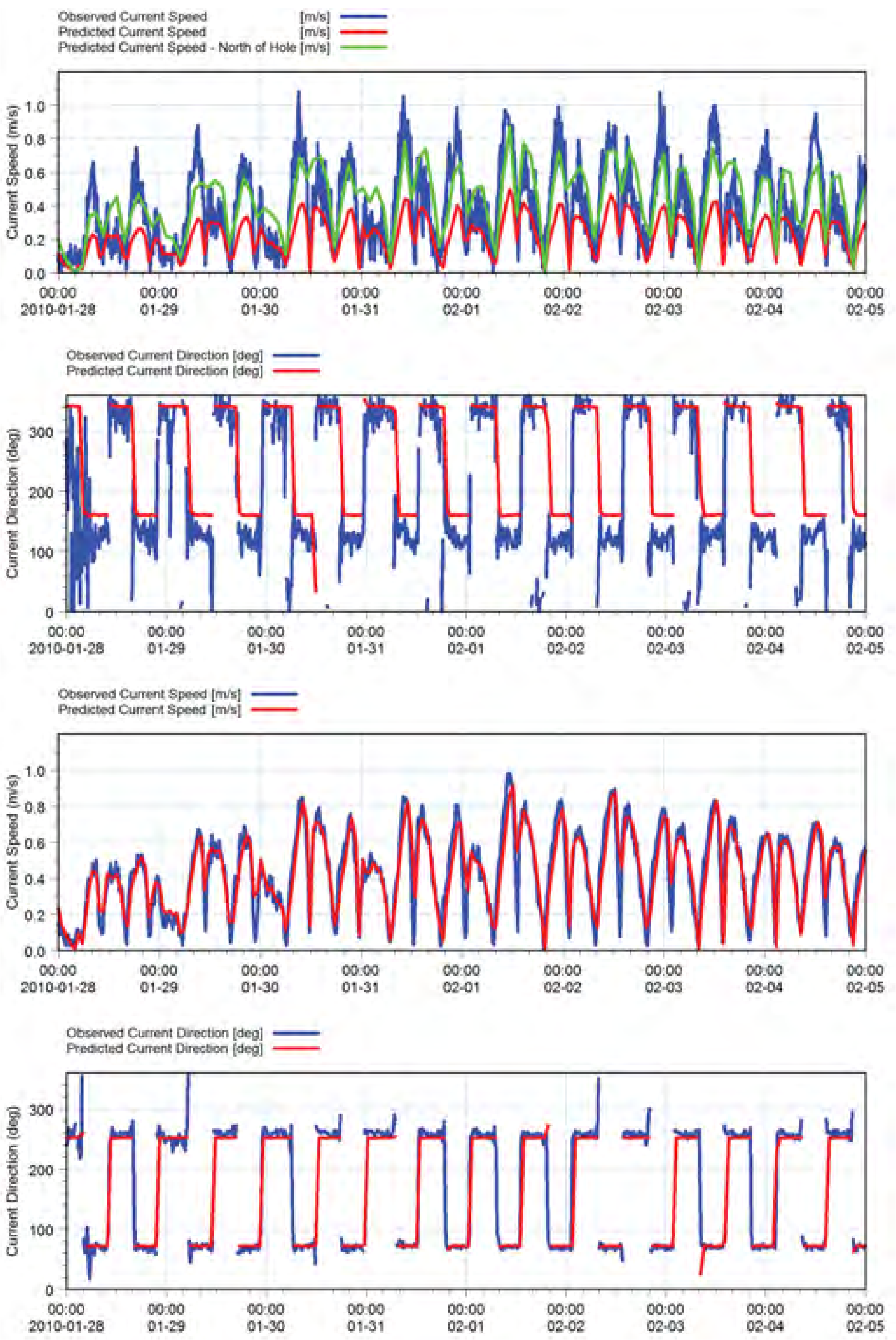


Figure V33 Comparison of Observed and Predicted Current Speed and Direction for Porirua Harbour Entrance (top) and Pauatahanui Inlet Entrance (bottom) for First Hydrodynamic Model Calibration Period

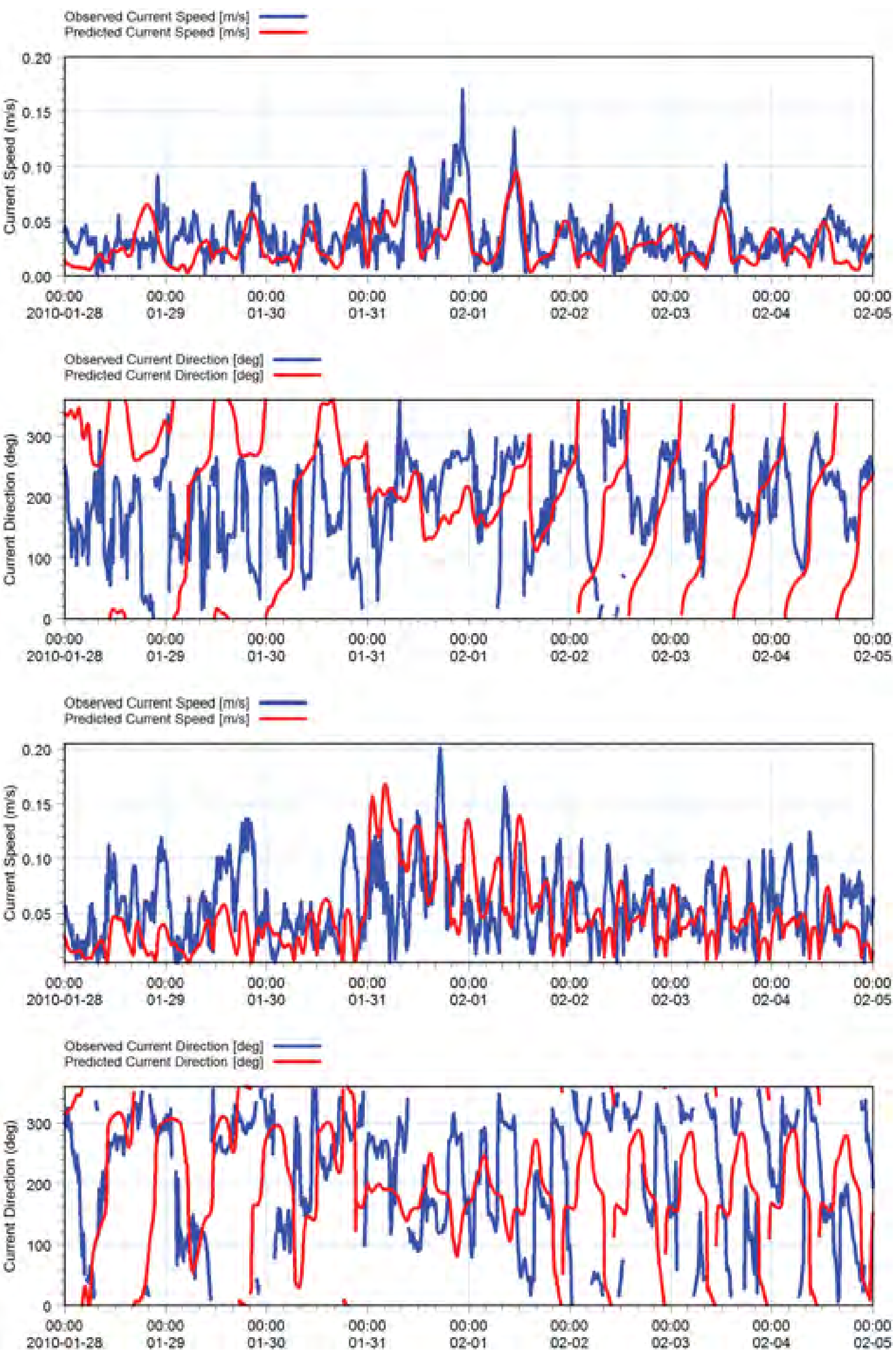


Figure V34 Comparison of Observed and Predicted Current Speed and Direction for Onepoto Arm (top) and Pauatahanui Inlet (bottom) for First Hydrodynamic Model Calibration Period

(3) Second Hydrodynamic Model Calibration Period

The tidal and wind forcing for the second calibration period are shown in **Figure V35**. No significant wind events occurred during this period.

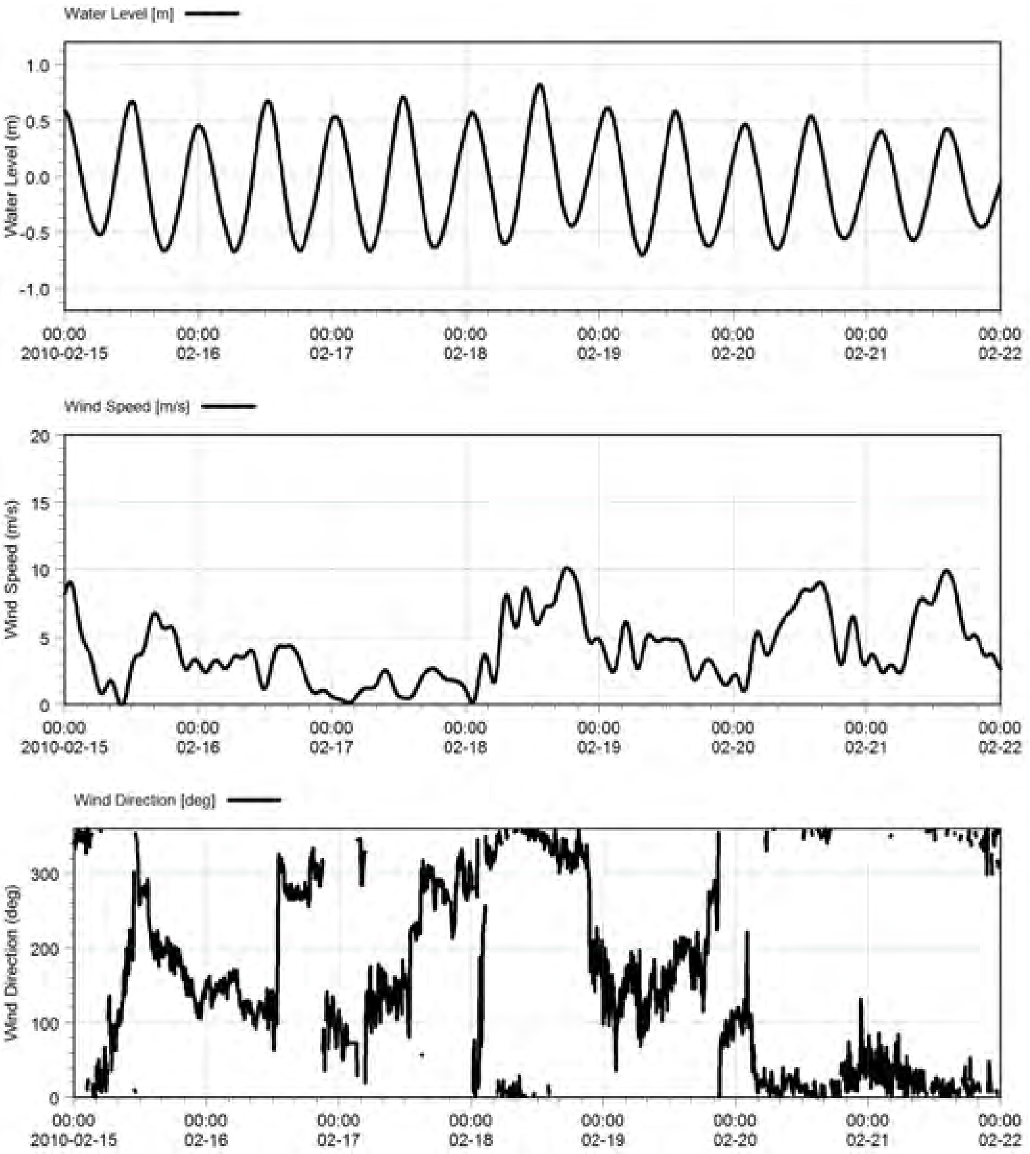


Figure V35 Water Level from Mana Marina (top) and Wind Speed (middle) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Second Hydrodynamic Model Calibration Period

There was a similar agreement between the observed and predicted water levels and currents compared with the first calibration period as shown in **Figure V36**, **Figure V37** and **Figure V38**. The predicted current speeds north of the localised depression have also been included for comparison. There was a reasonable agreement between observed and predicted current speeds in the arms of the harbour, while for current directions there was a better agreement for Pauatahanui Inlet compared with Onepoto Arm.

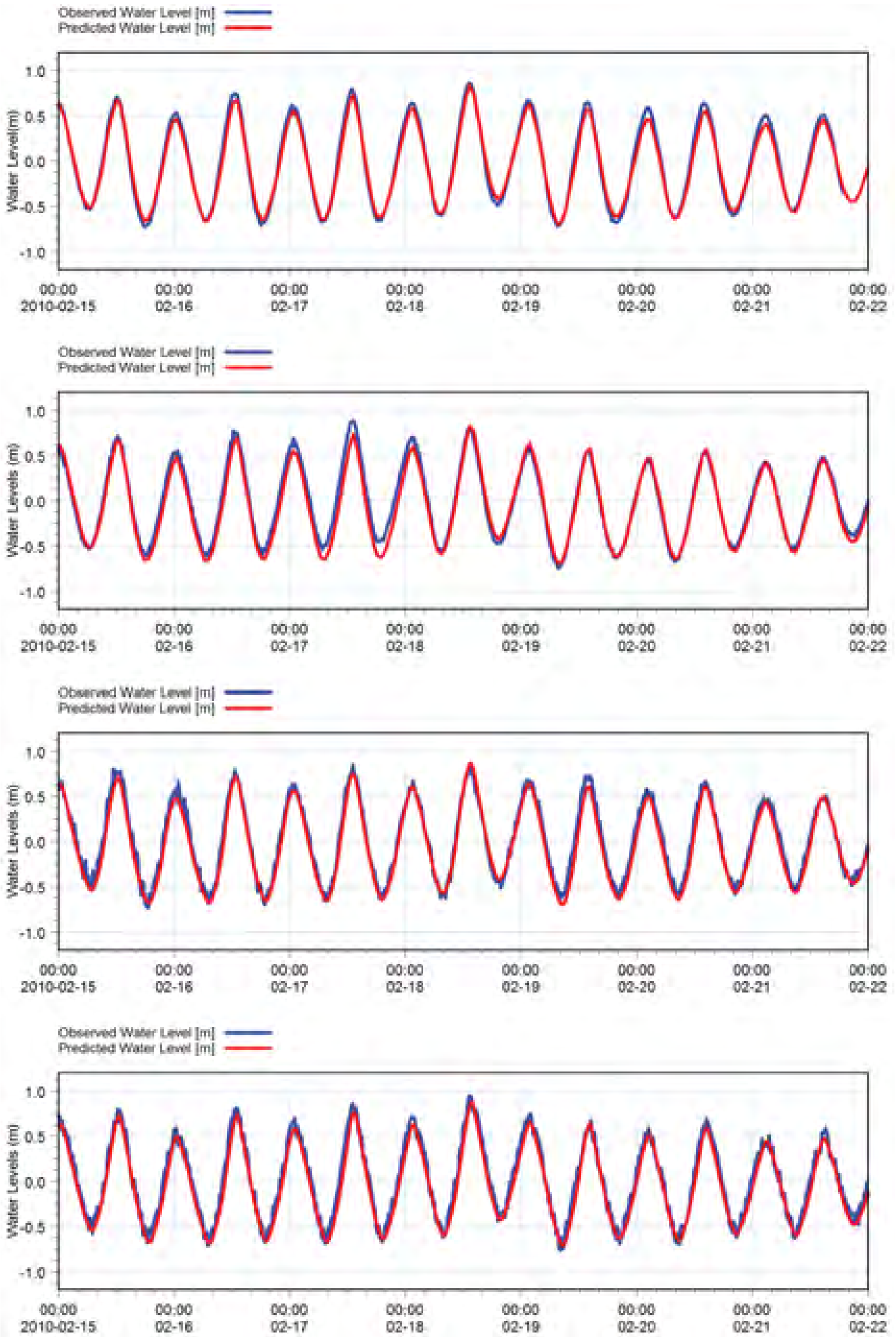


Figure V36 Comparison of Observed and Predicted Water Levels for Porirua Harbour Entrance (top), Pauatahanui Inlet Entrance (top-middle), Onepoto Arm (bottom middle) and Pauatahanui Inlet (bottom) for Second Hydrodynamic Model Calibration Period

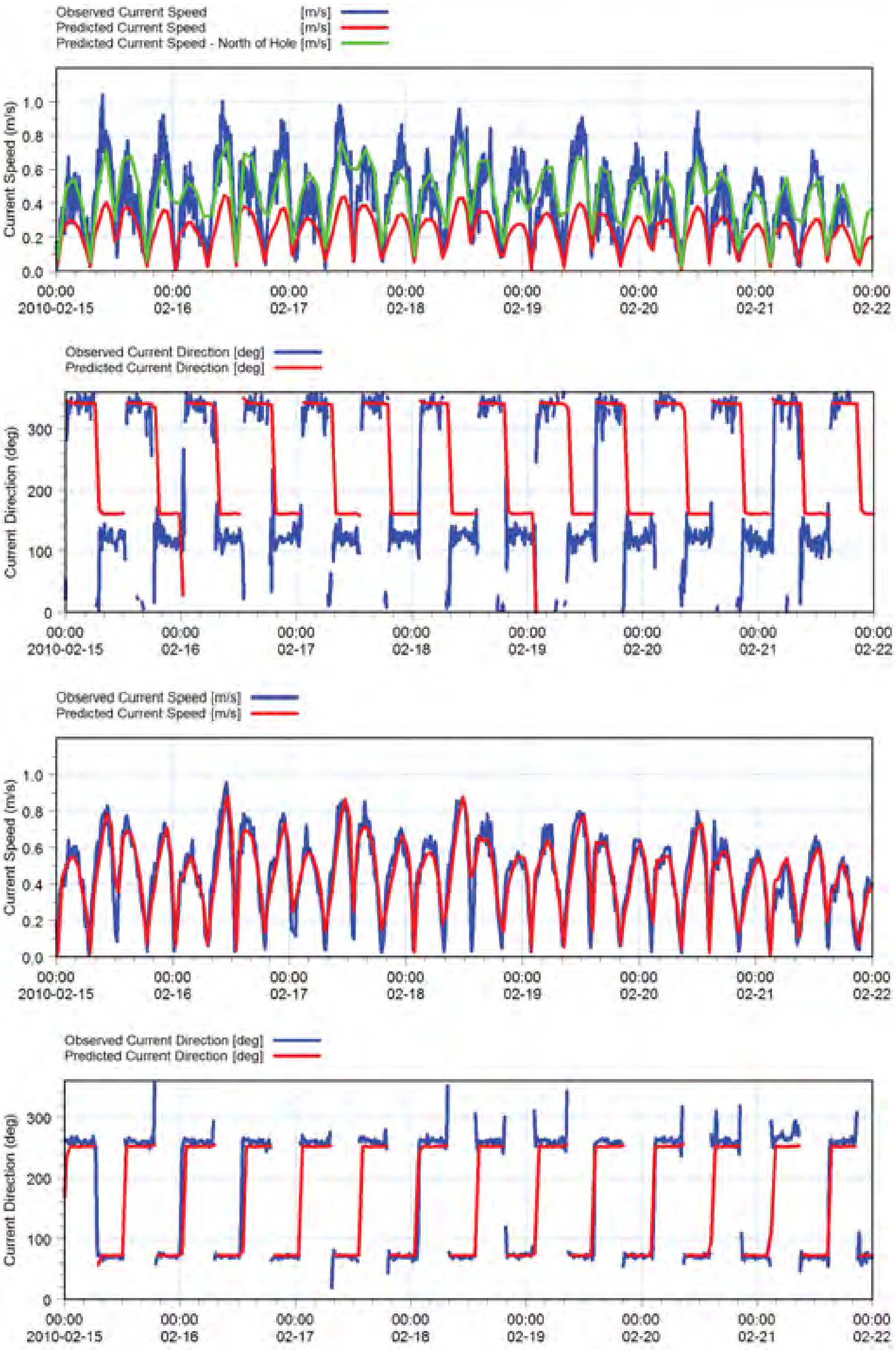


Figure V37 Comparison of Observed and Predicted Current Speed and Direction for Porirua Harbour Entrance (top) and Pauatahanui Inlet Entrance (bottom) for Second Hydrodynamic Model Calibration Period

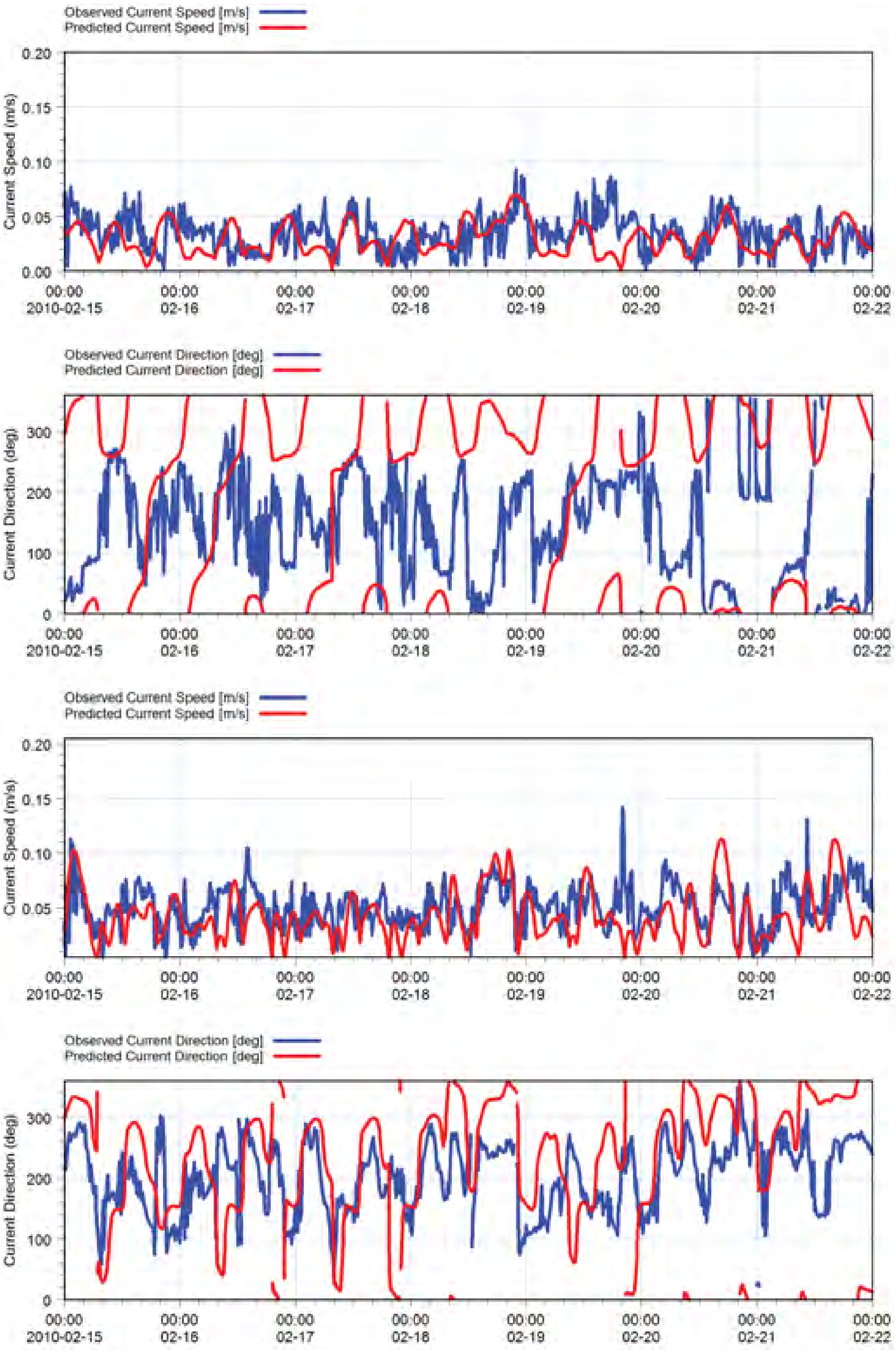


Figure V38 Comparison of Observed and Predicted Current Speed and Direction for Onepoto Arm (top) and Pauatahanui Inlet (bottom) for Second Hydrodynamic Model Calibration Period

(4) Third Hydrodynamic Model Calibration Period

The tidal and wind forcing for the third calibration period are shown in **Figure V39**. No significant wind events occurred during this period.

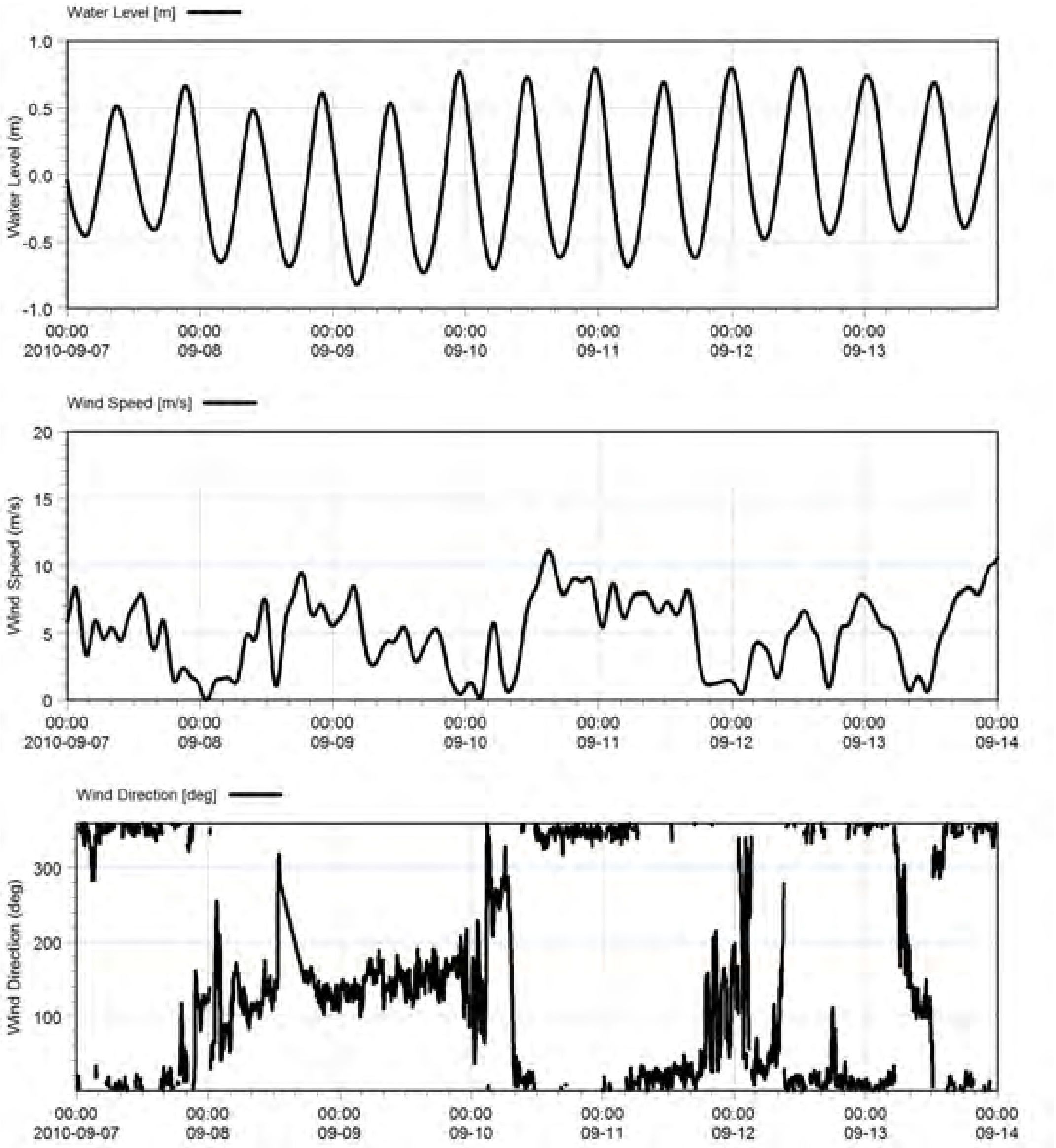


Figure V39 Water Level from Mana Marina (top) and Wind Speed (middle) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Third Hydrodynamic Calibration Period

For the third calibration period there was a reasonable comparison between observed and predicted water levels for both locations as shown in **Figure V39**. Water levels were slightly over predicted for the peak water levels in Pauatahanui Inlet. The comparison between observed and predicted current speed and direction in the arms of the harbour is presented in **Figure V40**. In general predicted current speeds were of the right magnitude and predicted current directions displayed a similar behaviour.

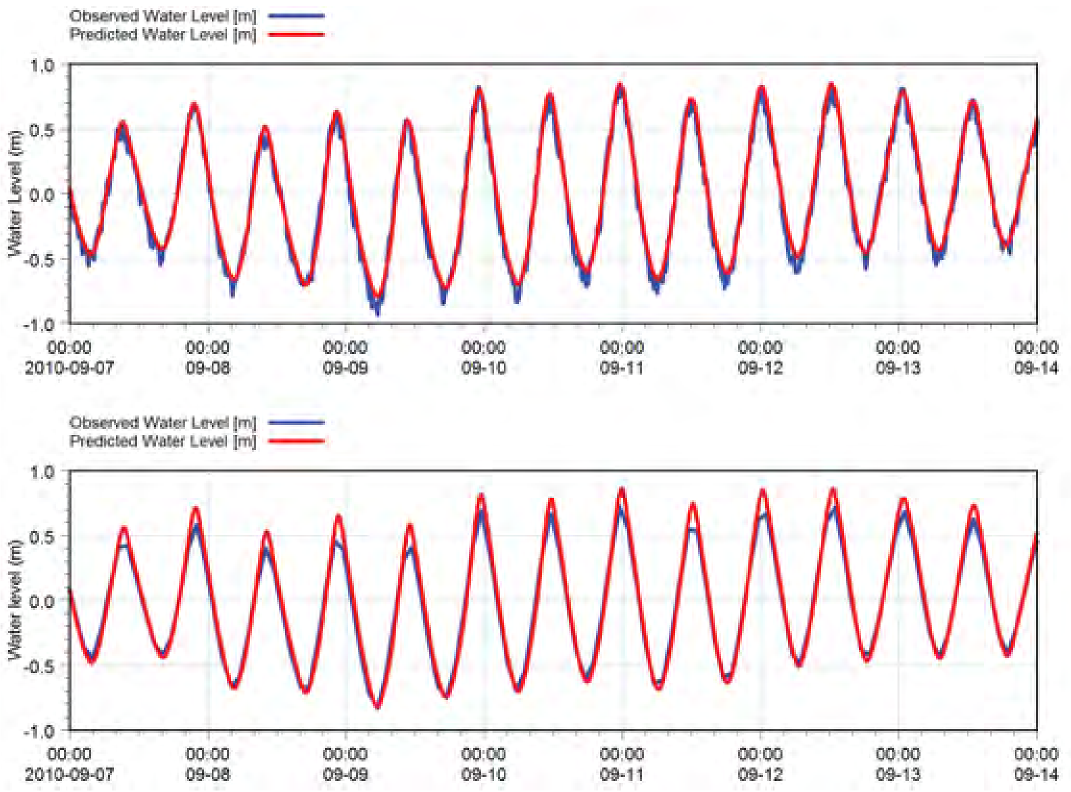


Figure V39 Comparison of Observed and Predicted Water Levels for Onepoto Arm (top) and Pauatahanui Inlet (bottom) for Third Hydrodynamic Calibration Period

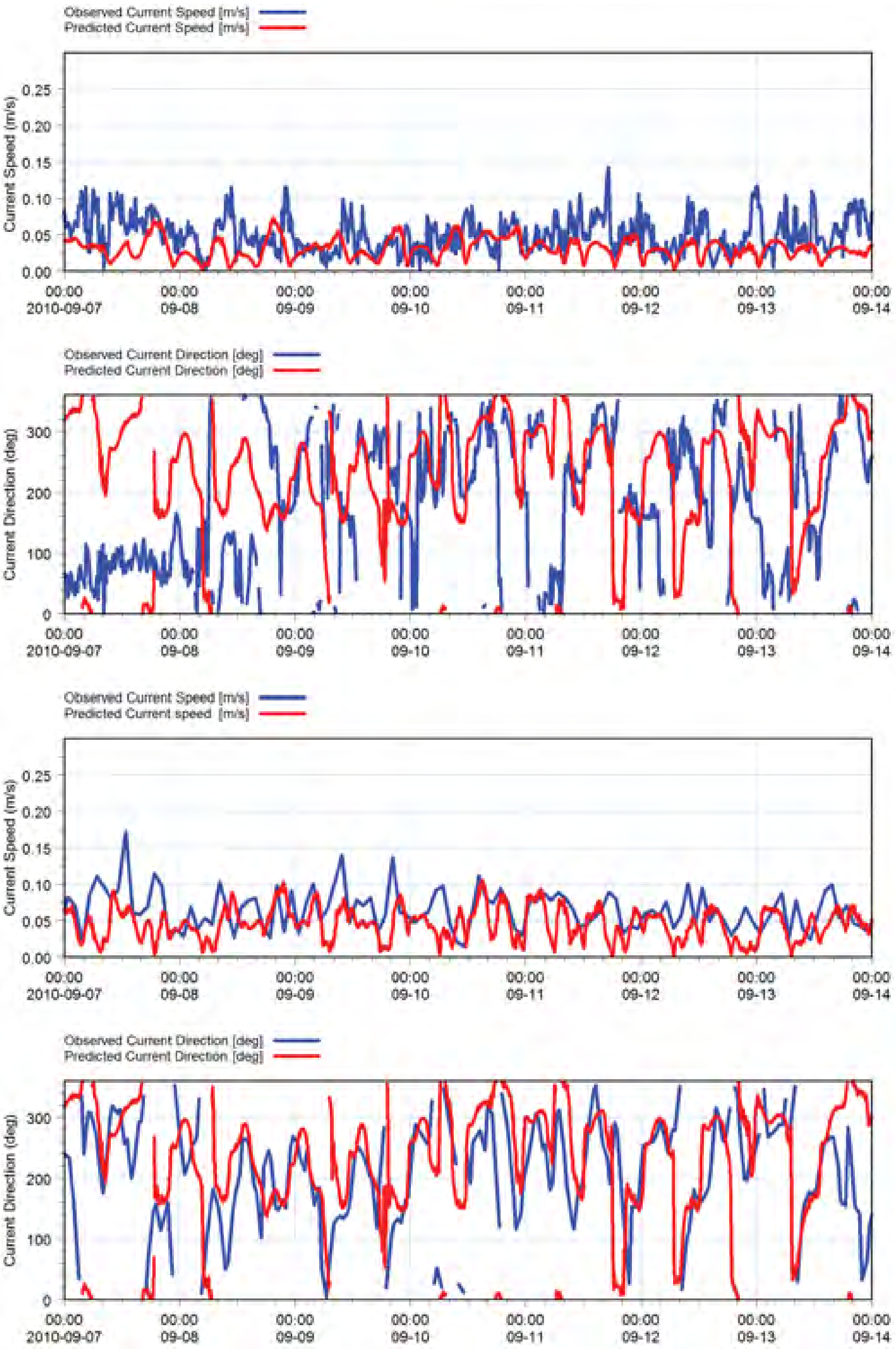


Figure V40 Comparison of Observed and Predicted Current Speed and Direction for Onepoto Arm (top) and Pauatahanui Inlet (bottom) for Third Hydrodynamic Calibration Period

(5) Fourth Hydrodynamic Model Calibration Period

The tidal and wind forcing for the fourth calibration period are shown in **Figure V41**. Unlike the other calibration periods, this period included a neap tide. There were several significant northerly wind events throughout the calibration period.

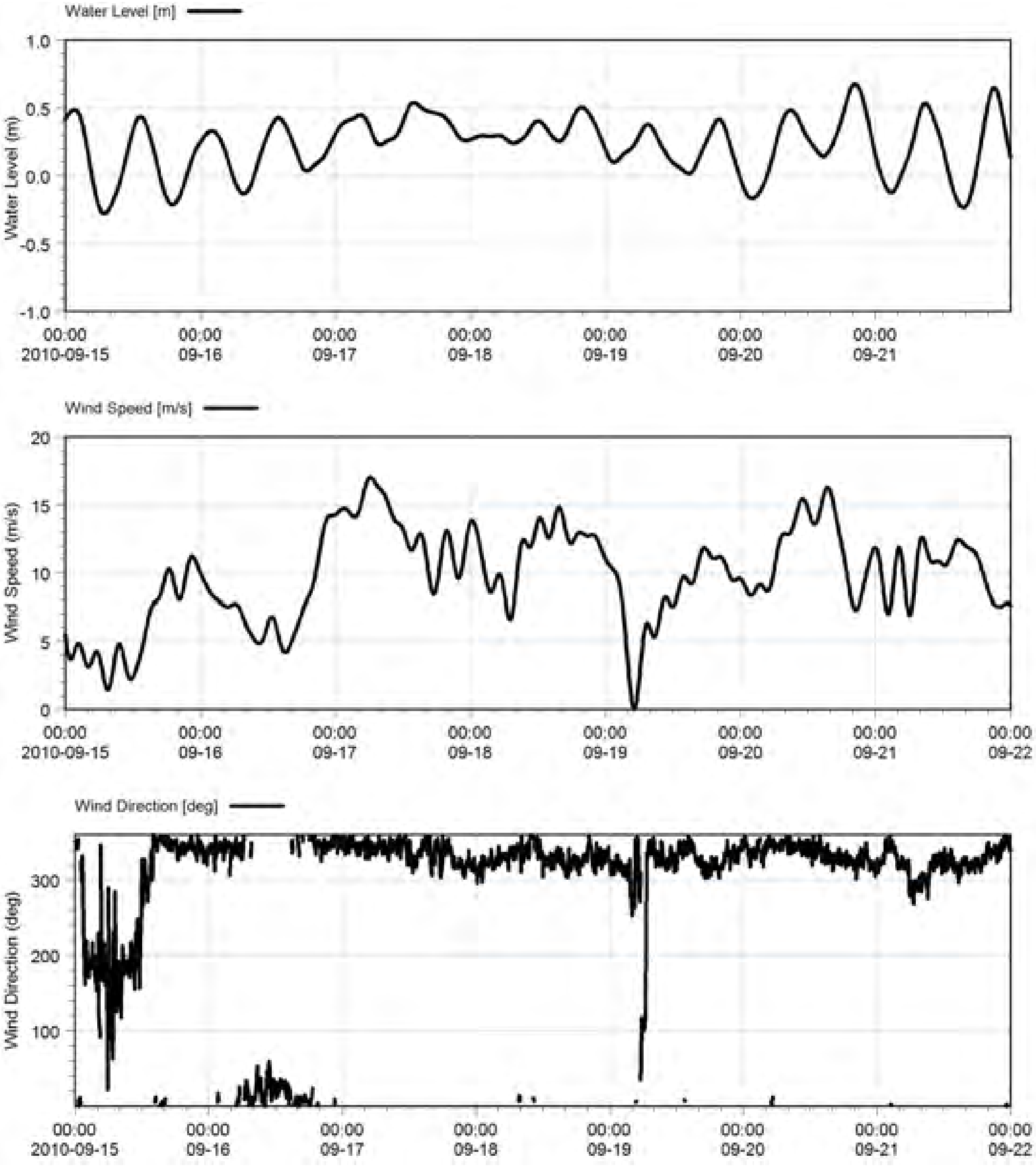


Figure V41 Water Level from Mana Marina (top) and Wind Speed (middle) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Fourth Hydrodynamic Model Calibration Period

There was a good match between observed and predicted water levels in the arms of the harbour as shown in **Figure V42**.There was a reasonable agreement between observed and predicted current speeds and directions in the arms of the harbour as shown in **Figure V43**. The elevated current speeds which appeared to be a result of the northerly wind events were reproduced by the model. There was approximately a 70 – 90 degree difference in observed and predicted current directions in Onepoto Arm for the period 16th September to 20th September 2010, however there was a better agreement for Pauatahanui Inlet.

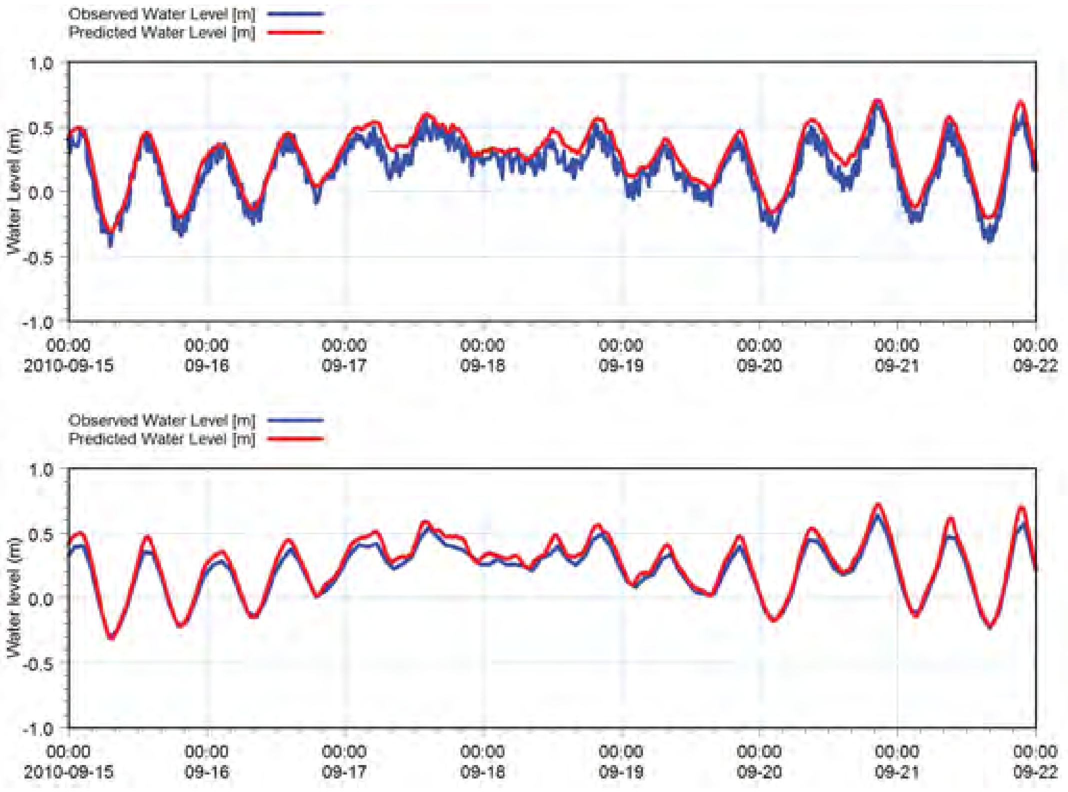


Figure V42 Comparison of Observed and Predicted Water Levels for Onepoto Arm (top) and Pauatahanui Inlet (bottom) for Fourth Hydrodynamic Model Calibration Period

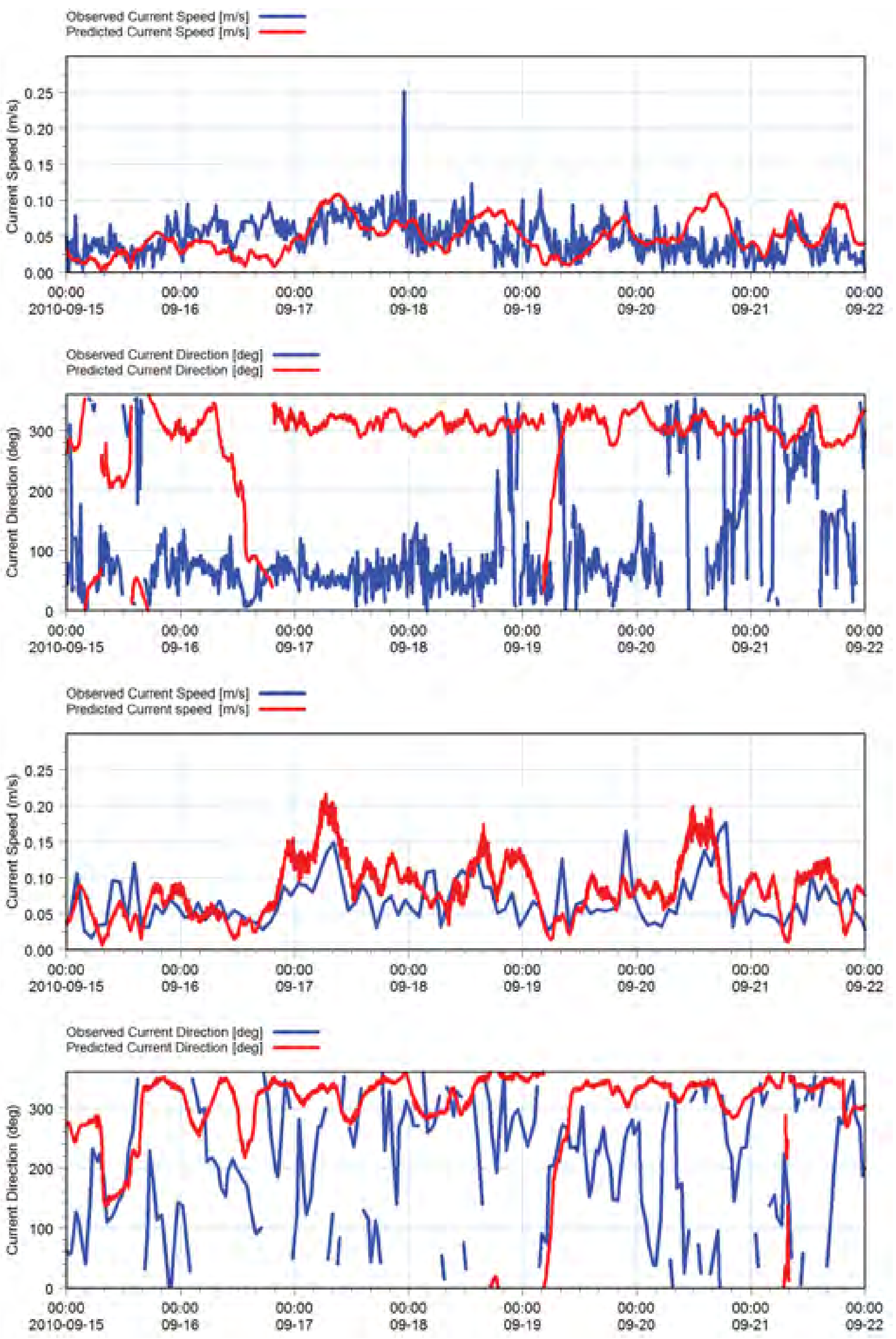


Figure V43 Comparison of Observed and Predicted Current Speed and Direction for Onepoto Arm (top) and Pauatahanui Inlet (bottom) for Fourth Hydrodynamic Model Calibration Period

(6) Hydrodynamic Model Validation

To validate that the model was able to correctly reproduce the tidal prism for Porirua Harbour, the predicted discharge through the main harbour entrance and Pauatahanui Inlet entrance was compared against discharges that were measured through both entrances 26th February 2010. There was a very good agreement between observed and predicted flow, which provides confidence that the model was able to correctly reproduce the volume of water entering and exiting the harbour on flood and ebb tides, see **Figure V44**.

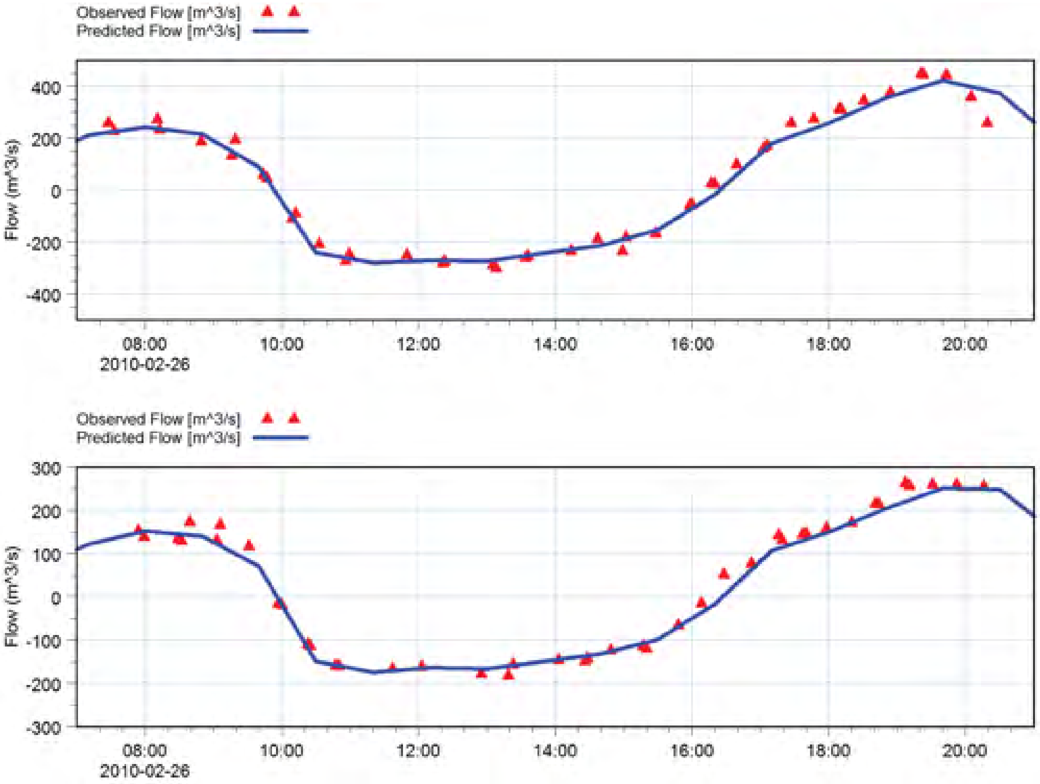


Figure V44 Comparison of Observed and Predicted Flow Through Main Harbour Entrance (top) and Pauatahanui Inlet Entrance (bottom)

(7) Wave Model Set–up and Calibration

A wave model of Porirua Harbour was calibrated using the significant wave height data collected within the arms of the harbour. The wave model was coupled with the calibrated hydrodynamic model since water levels can impact on the growth and breaking of waves.

Four, six day calibration periods were selected where there was significant wind to generate waves larger than 10 cm in the harbour arms. Three periods were taken from the second data collection period and one period was taken from the first data collection period. The calibration periods are presented in **Table V5**.

Table V5 Calibration Periods for Wave Model

Calibration Period	Period	Locations with Wave Data Available
1	3rd September – 9th September 2010	Pauatahanui Inlet
2	16th September – 22nd September 2010	Pauatahanui Inlet

3	22nd September – 28th September 2010	Pauatahanui Inlet
4	14th January – 20th January 2010	Onepoto Arm.

The parameters that were used for the calibrated model are shown in **Table V6**. Further explanation of these parameters can be found in the MIKE 21 SW User Manual (DHI, 2009). The model was able replicate significant wave heights for wave events larger than 10 cm; however the model consistently overestimated significant wave heights less than this. This was deemed acceptable by the project team, since it was more important that the model was able to match significant wave heights for the larger wave events which have the most significant impact on sediment transport.

Table V6 Specifications for Calibrated Wave Model

Parameter	Value
Spectral Formulation	Fully spectral formulation
Time Formulation	Instationary formulation
Frequency discretisation	Logarithmic Number of frequencies = 25 Minimum frequency = 0.005 Hz Frequency factor = 1.15
Direction discretisation	22.5 degrees
Bottom Friction	kn = 0.01m
Wind Forcing	Uncoupled air-sea interaction (type of drag = version 2)
Energy Transfer	Triad wave interaction (coefficient = 0.25)
Wave Breaking Formulation	Ruessink et. al. (2003)
White Capping	Dissipation coefficient, Cdis = 2 and DELTA dis = 0.5

(8) First Wave Model Calibration Period

The wind forcing for the first calibration period is shown in **Figure V45**. A significant northerly wind event and associated wave event commenced on 5th September 2010. It should be noted that the high winds were sustained for almost two days.

The comparison between observed and predicted significant wave heights in Pauatahanui Inlet for the first calibration period is presented in **Figure V46**. The calibration was satisfactory for this wave event.

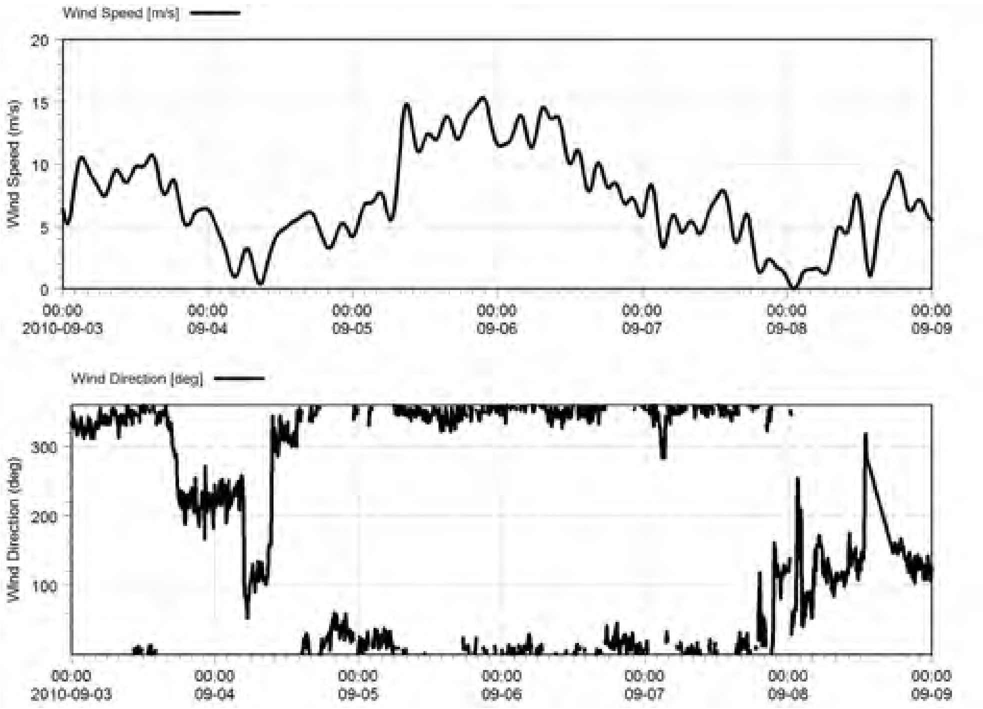


Figure V45 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for First Wave Model Calibration Period

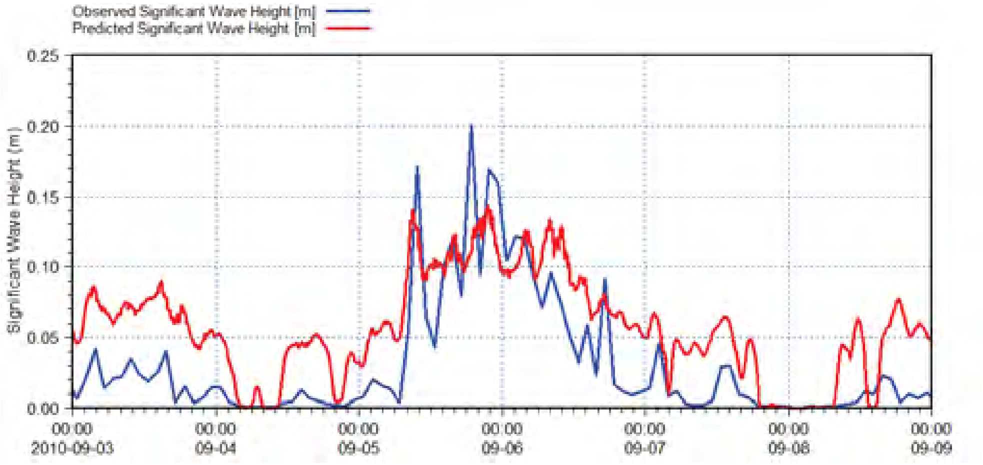


Figure V46 Comparison of Observed and Predicted Significant Wave Height for Pauatahanui Inlet for First Wave Model Calibration Period

(9) Second Wave Model Calibration Period

The wind forcing for the second calibration period is shown in **Figure V47**. Three significant northerly wind events and associated wave events occurred during this period.

The comparison between observed and predicted significant wave heights in Pauatahanui Inlet for the second calibration period is presented in **Figure V48**. There was a good match between observed and predicted peak significant wave heights for these wave events.

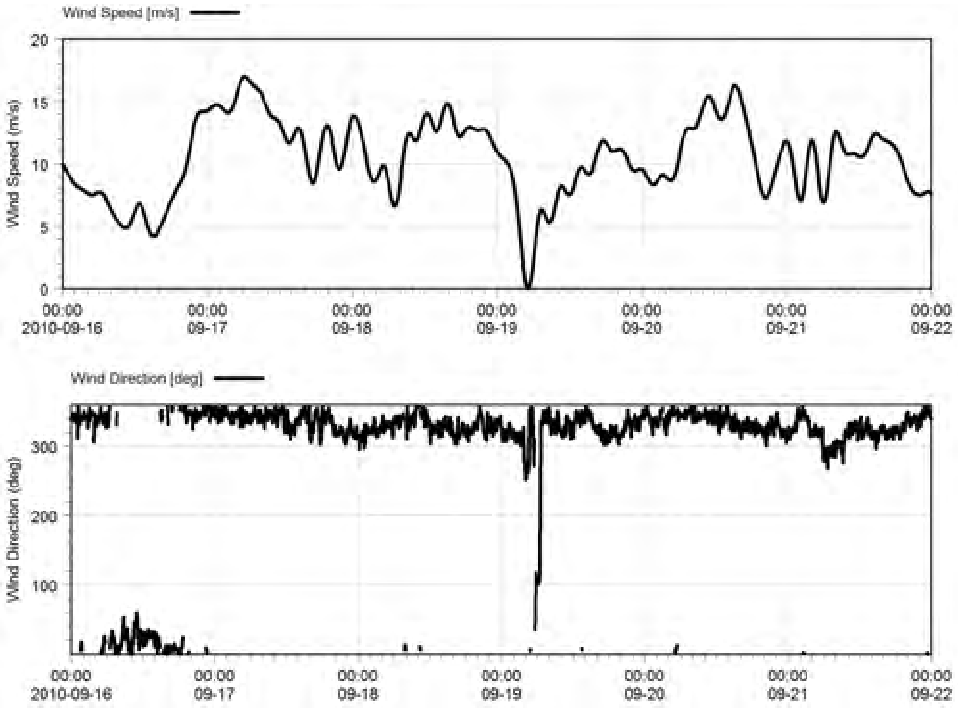


Figure V47 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Second Wave Model Calibration Period

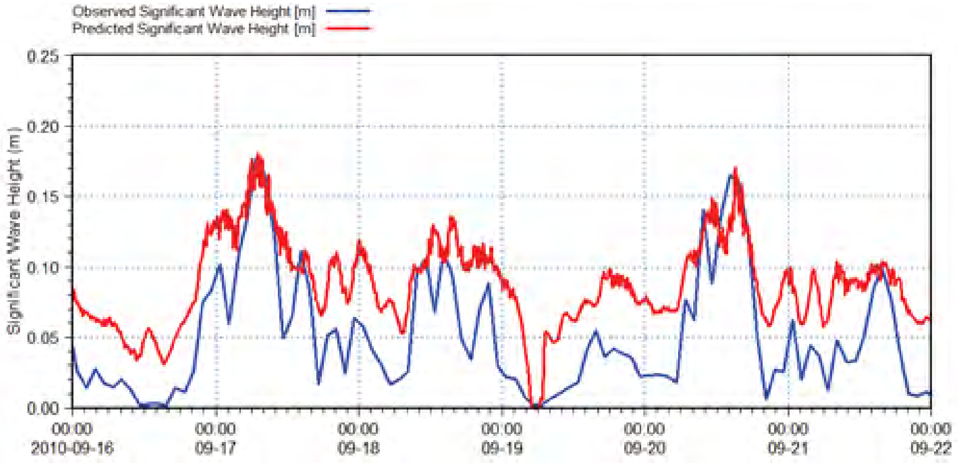


Figure V48 Comparison of Observed and Predicted Significant Wave Height for Pauatahanui Inlet for Second Wave Model Calibration Period

(10) Third Wave Model Calibration Period

The wind forcing for the fourth calibration period is shown in **Figure V49**. Three significant northerly wind events and associated wave events occurred during this period. It is worth noting that for over four days there was a northerly wind sustained at around 10m/s.

The comparison between observed and predicted significant wave heights in Pauatahanui Inlet for the first calibration period is presented in **Figure V50**. The calibration was satisfactory for this wave event, with the significant wave height slightly under predicted for the wave event on 24th September 2010.

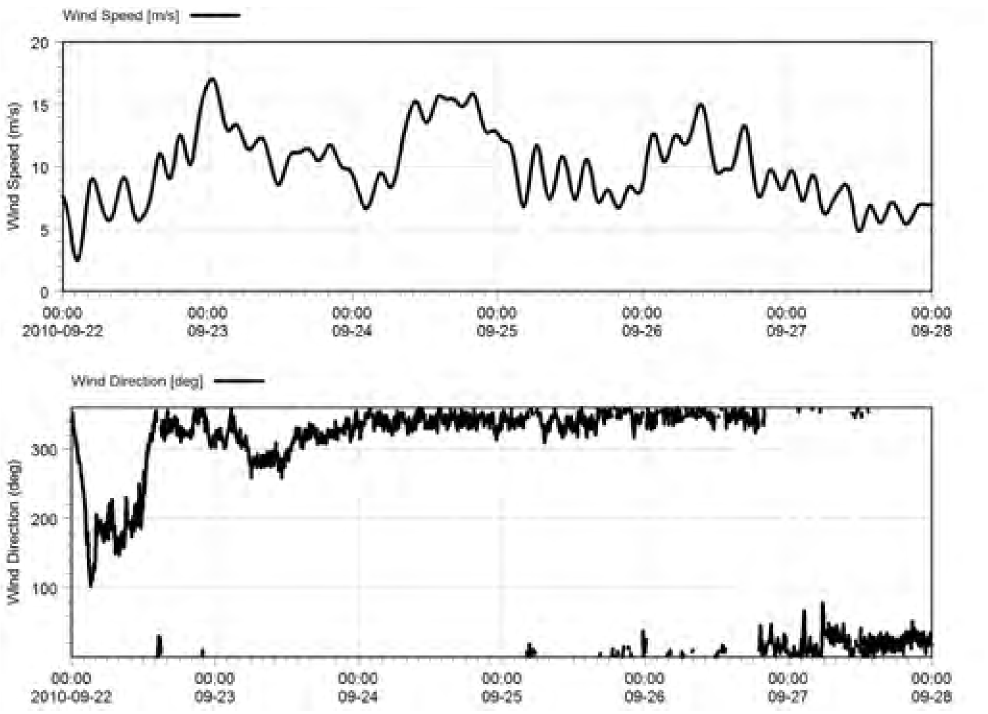


Figure V49 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Third Calibration Period

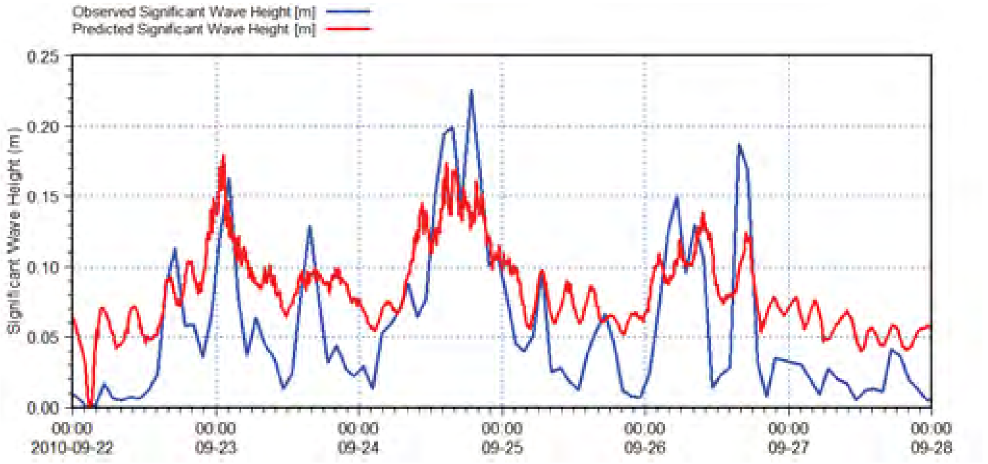


Figure V50 Comparison of Observed and Predicted Significant Wave Height for Pauatahanui Inlet for Third Wave Model Calibration Period

(11) Fourth Wave Model Calibration Period

The wind forcing for the fourth calibration period is shown in Figure . This event was included so that it could be illustrated that the model could reproduce wave behaviour within Onepoto Arm to a satisfactory level. The wind event was not as significant as events from other calibration periods. However this wind event was a southerly event unlike the other events.

The comparison between observed and predicted significant wave heights in Onepoto Arm for the fourth calibration period is presented in **Figure V51**. There was a reasonable match between observed and predicted significant wave height when considering it was not certain whether there is a difference in direction of southerly wind events in Onepoto Arm compared with Pauatahanui Inlet.

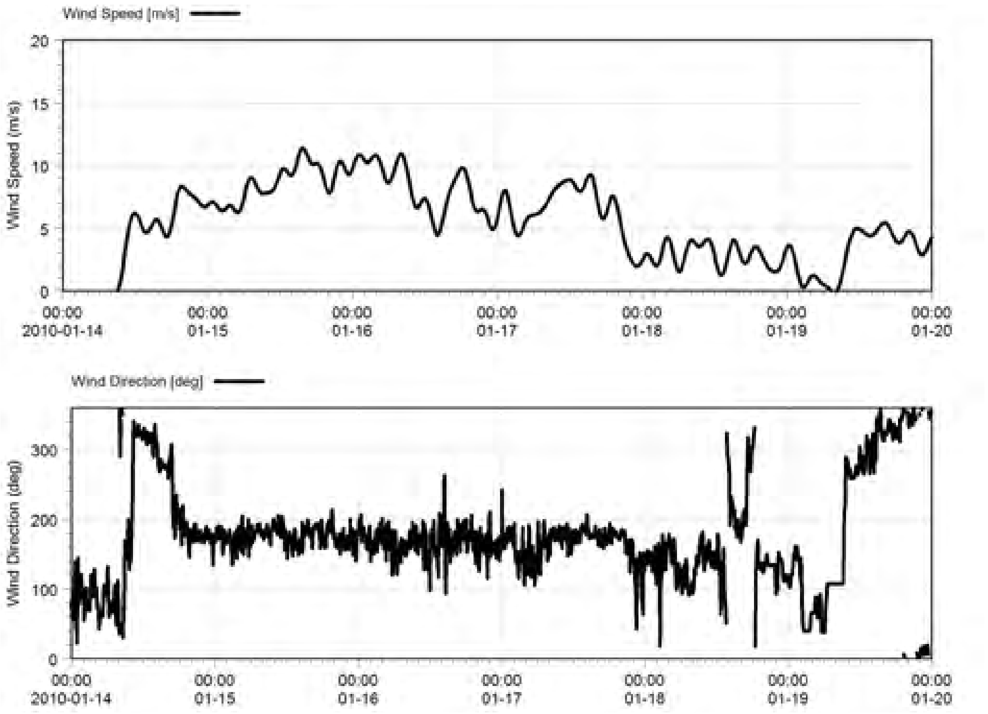


Figure V51 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Fourth Wave Model Calibration Period

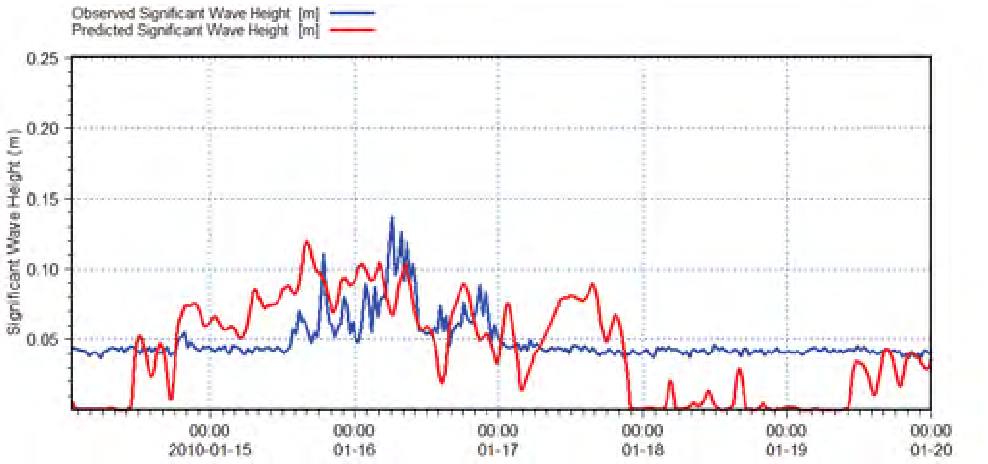


Figure V52 Comparison of Observed and Predicted Significant Wave Height for Onepoto Arm for Fourth Wave Model Calibration Period

V.3.7 Sediment Transport Model Set-up and Calibration

A sediment transport model of Porirua Harbour was calibrated using the available TSS data collected within Onepoto Arm and Pauatahanui Inlet. The sediment transport model was coupled with the calibrated hydrodynamic and wave models. Sources for suspended sediment in this harbour model are from freshwater inflows or re-suspension of sediment from the bed. The data provided four events where there was sufficient TSS data for calibrating the sediment transport model.

Four, six day calibration periods have been selected as shown in **Table V6**. Calibration periods One, Three and Four are a result of re-suspension of sediment resulting from wave events, with no significant inflows into the harbour. Calibration period Two is unique since for this period there were no significant waves, with wind speeds of approximately 10 m/s, but there was a spike in TSS in Pauatahanui Inlet. This corresponded to a 10 year ARI rainfall event in the Horokiri catchment. Hence the elevation in TSS was most likely from the suspended sediment plume entering into the harbour. The model was able to be calibrated for both sources of suspended sediment in the harbour, freshwater inflows and re-suspension of sediment from the bed.

Table V6 Calibration Periods for Sediment Transport Model

Calibration Period	Period	Locations with TSS Data Available
1	22nd September – 28th September 2010	Pauatahanui Inlet
2	28th September – 12pm 1st October 2010	Pauatahanui Inlet
3	29th January – 4th February 2010	Pauatahanui Inlet, Onepoto Arm
4	14th February – 20th February 2010	Pauatahanui Inlet

The parameters that were used for the calibrated model are shown in **Table V7**. Further explanation of these parameters can be found in the MIKE 21 MT FM User Manual (DHI, 2009).

Table V7 Specifications for Calibrated Sediment Transport Model

Parameter	Value
Solution Technique	Higher Order
Water Column Parameters	Flocculation calculations included. Deposition critical shear stress = 0.07 N/m^2 Settling velocity co-efficient = 5 m/s
Bed Parameters	Bed critical shear stress = 0.3 N/m^2 Bed density = 400 kg/m^3
Forcings	Mean Soulsby shear stress formulation (Soulsby *et. al.*, 1993)
Dispersion	Scaled eddy viscosity formulation (scaling factor = 1)

It should be noted that the settling velocity co-efficient is a function of flocculation. The settling velocity is calculated based from the concentration of TSS using the equation below:

$$W_s = W_o \left[\frac{c}{\rho_{sediment}}\right]^{\gamma}$$

Where W_s = settling velocity (m/s);

W_o = settling velocity coefficient (m/s);

c = concentration of TSS (kg/m^3);

$\rho_{sediment}$ = density of sediment (kg/m^3) and

γ = power constant.

An initial bed layer thickness map was developed to represent the muddy basins that occur in the middle of both arms. The initial bed layer thickness map is shown in **Figure V53**. Due to time constraints it was not possible to run the model for a long enough warm up period, to allow a natural muddy bed layer to evolve, where mud will erode in locations with higher current speeds and deposit in areas with lower current speeds. The initial bed layer thickness map was developed by carrying out a simulation for a 15 day period with tidal forcing only, with an initial bed thickness of 10 mm for all areas below MLWS within the arms of the harbour. The final bed thickness from this simulation was then used as the initial bed layer thickness map.

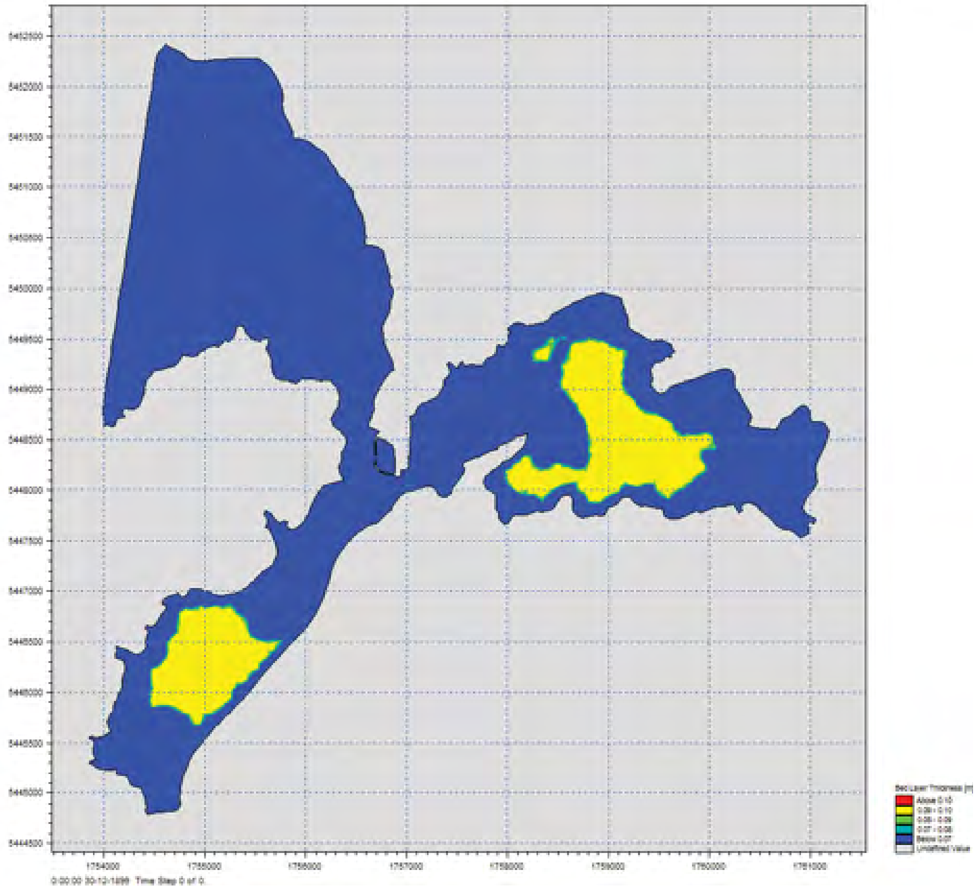


Figure V53 Initial Bed Layer Thickness

The main difficulty for calibrating the sediment transport model was that it was not possible to know the initial state of the bed at the commencement of each simulation. A wind event may re-suspend an area of deposited mud that is not included in the initial bed thickness map.

The main aim of the sediment transport model calibration is to obtain a good match for the overall behaviour of TSS, by determining model parameter values and a shear stress formulation that appears to represent the overall characteristics of the sediment entering into and already deposited within the harbour. Using different bed thickness maps for different calibration periods did yield better agreement between observed and predicted TSS; however the aim of model calibration is to produce one set of model parameters and initial conditions that provides a satisfactory calibration for a number of different periods containing various ocean and weather conditions.

(1) First Sediment Transport Model Calibration Period

The wind forcing for the first calibration period is shown in **Figure V54**. Three significant northerly wind events and associated wave events occurred during this period. The wind event on the 24th September 2010 produced the most re-suspension of sediment.

The comparison between observed and predicted TSS in Pauatahanui Inlet for the first calibration period is presented in **Figure V55**. There was a good match for the concentration of TSS and also the timing of re-suspension and transport of resulting sediment plume to the location of the TSS measurements.

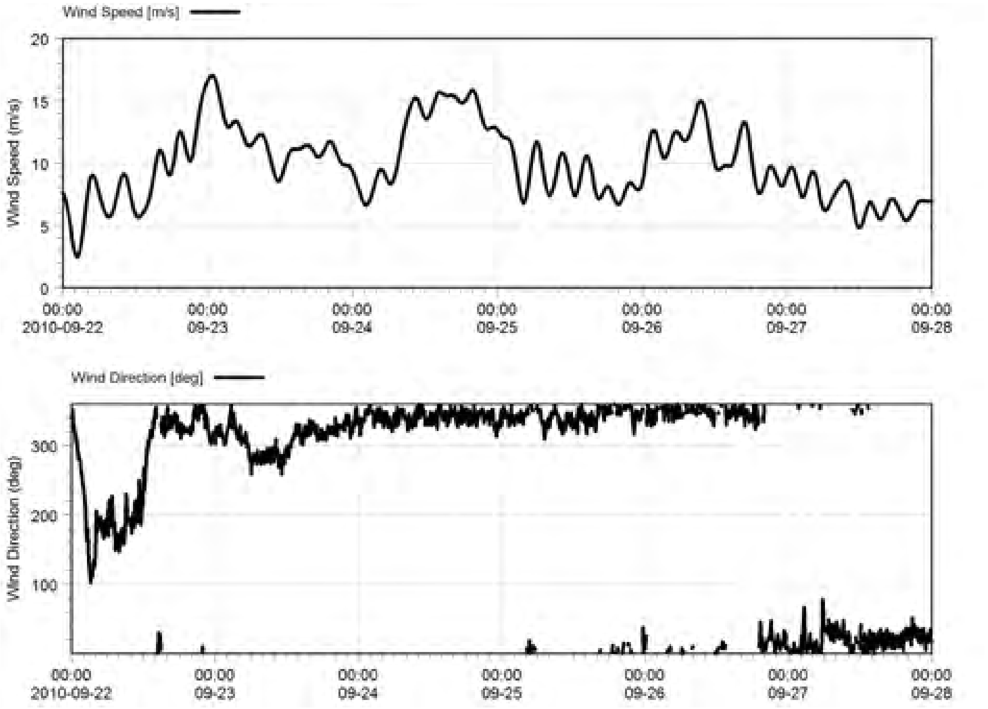


Figure V54 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for First Sediment Transport Calibration Period

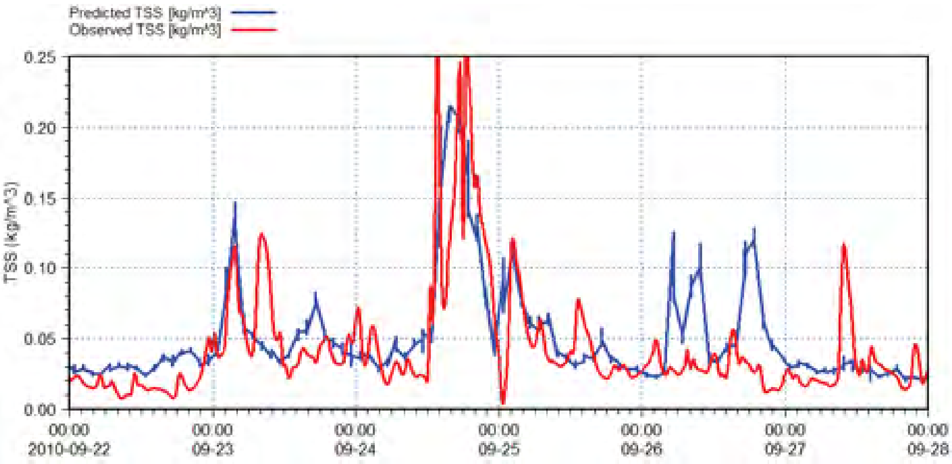


Figure V55 Comparison of Observed and Predicted TSS for Pauatahanui Inlet for First Sediment Transport Calibration Period

(2) Second Sediment Transport Model Calibration Period

The wind forcing for the second calibration period is shown in **Figure V56**. There is a 5 - 10 m/s northerly wind during this period. For this calibration simulation, derived inflows and associated sediment loads were also included in the model, the sediment inputs from the major catchments are shown in **Figure V57**.

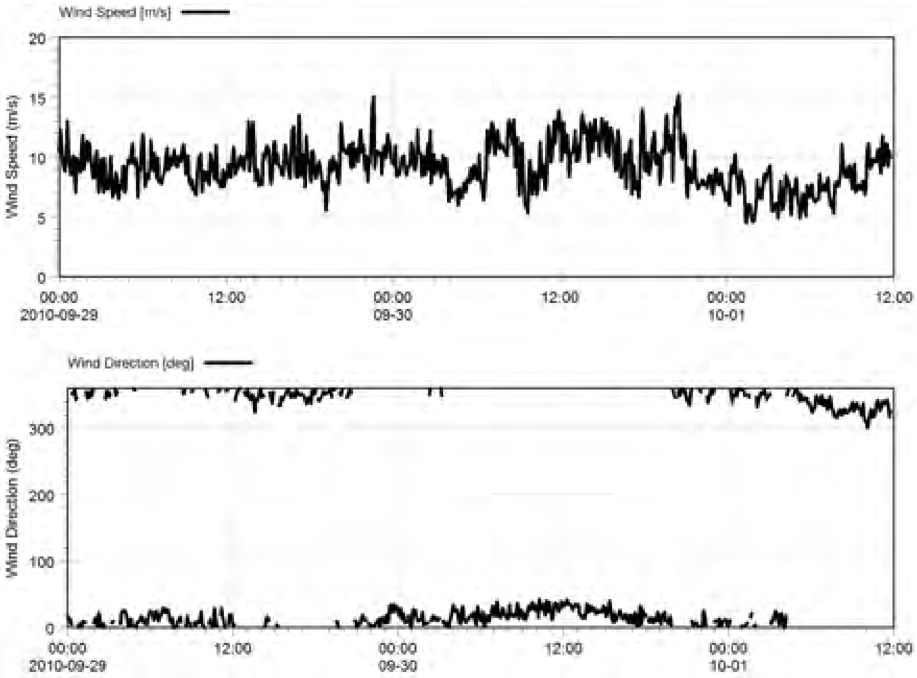


Figure V56 Wind Speed (top) and Wind Direction (top middle) Observed in Pauatahanui Inlet

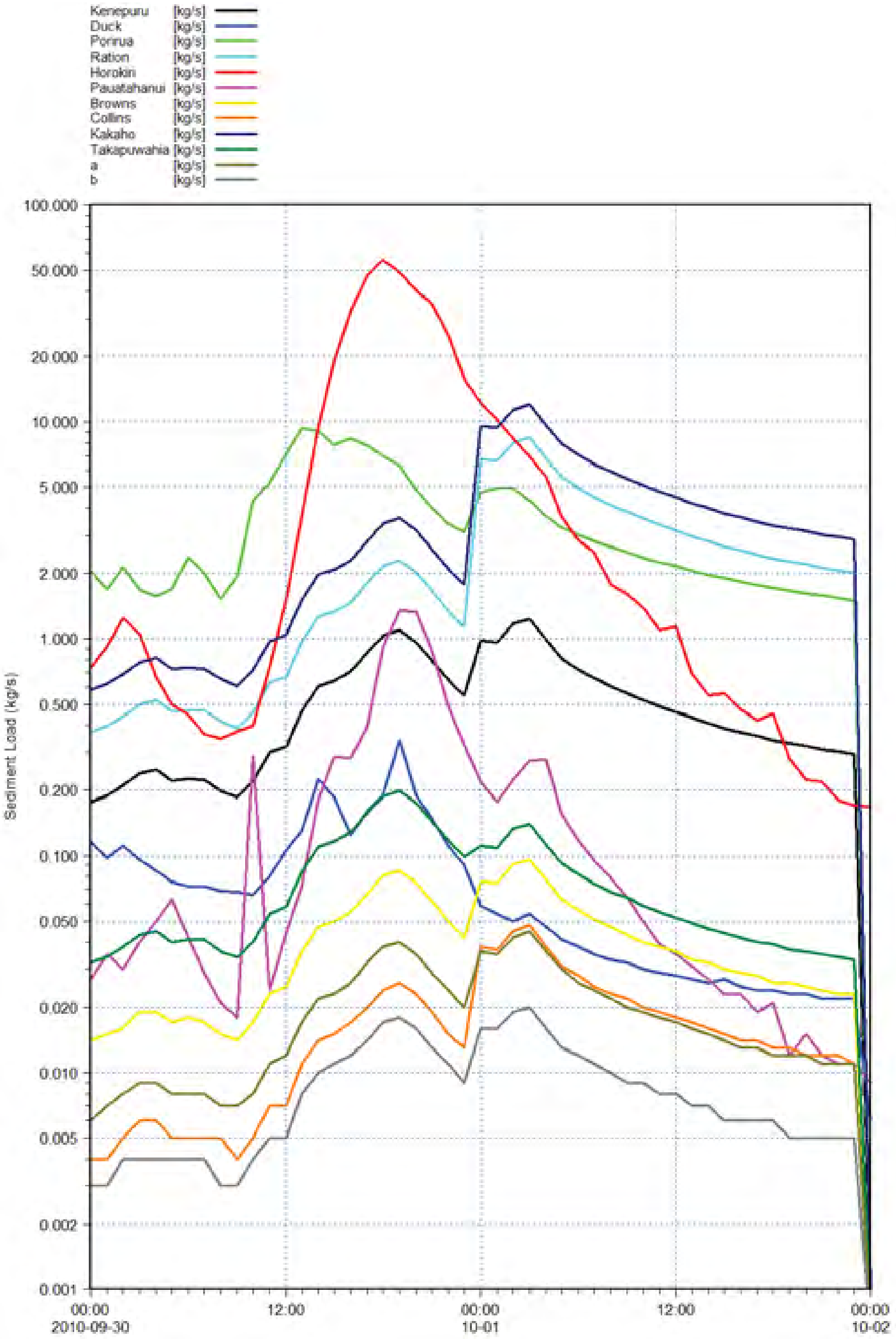


Figure V57 Sediment Loads from the Major Catchments used as Inputs into the Second Sediment Transport Model Calibration Period. Where Available, Observed Data was Used

The comparison between observed and predicted TSS in Pauatahanui Inlet for the second calibration period is presented in **Figure V58**. There was a good agreement for the initial peak in TSS with regard to concentration and timing. There is not such a close agreement for the second peak in TSS that occurs.

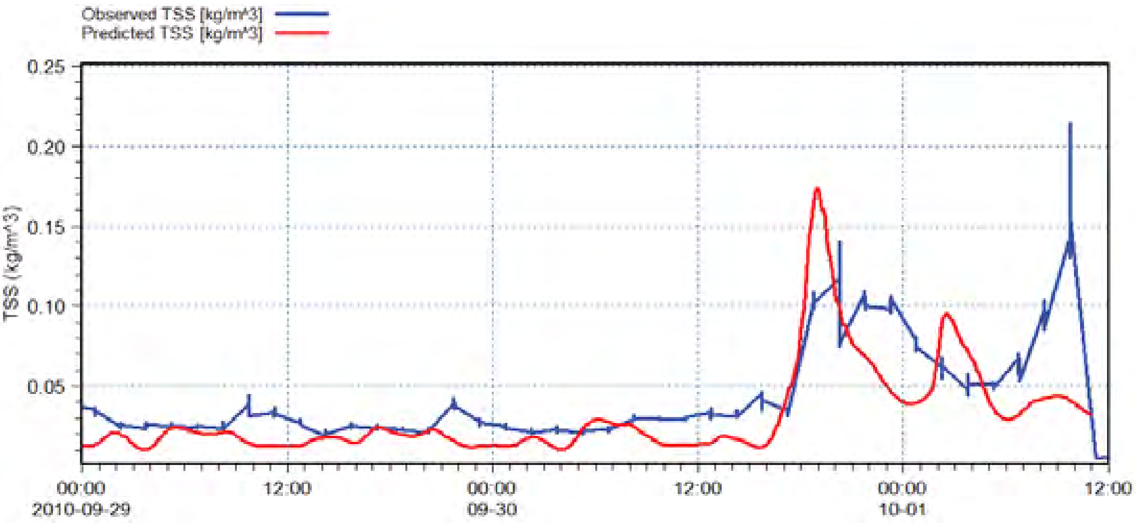


Figure V58 Comparison of Observed and Predicted TSS for Pauatahanui Inlet for Fourth Sediment Transport Model Calibration Period

(3) Third Calibration Period

A significant southerly wind event occurred on the 31st January, 2010.The wind forcing for the third calibration period is shown in **Figure V59**.

The comparison between the observed and predicted TSS in the Onepoto Arm and Pauatahanui Inlet for the third calibration period are presented in **Figure V60** and **Figure V61**. For the Onepoto Arm, there was a reasonable match for the concentration of TSS and also the timing of re-suspension and transport of resulting sediment plume into location of TSS measurements. For Pauatahanui Inlet, the model over predicted TSS, however there was a reasonable match for the timing of the sediment plume.

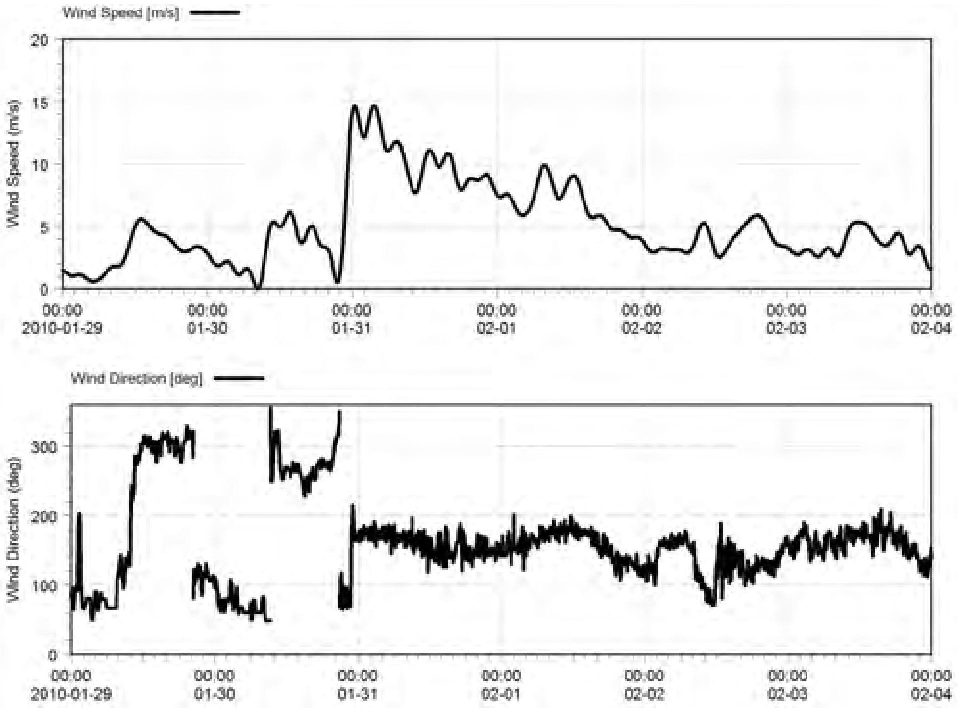


Figure V59 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Third Sediment Transport Model Calibration Period

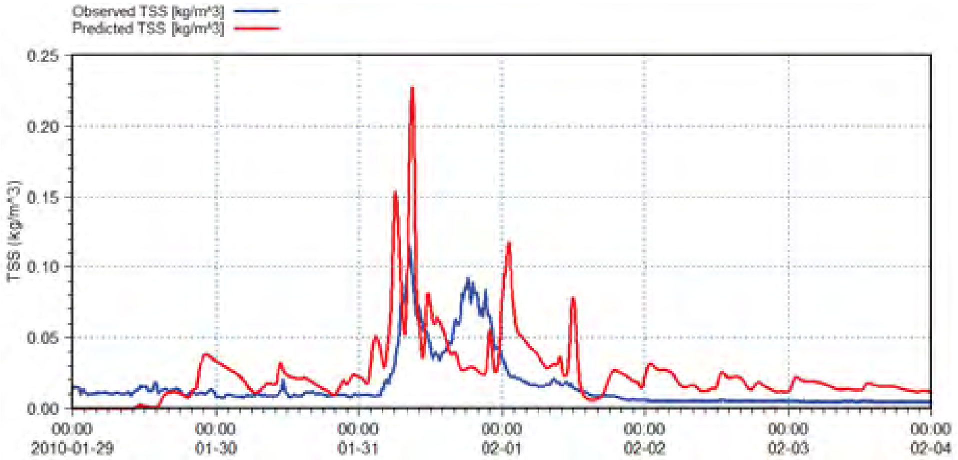


Figure V60 Comparison of Observed and Predicted TSS in the Onepoto Arm for the Third Sediment Transport Model Calibration Period

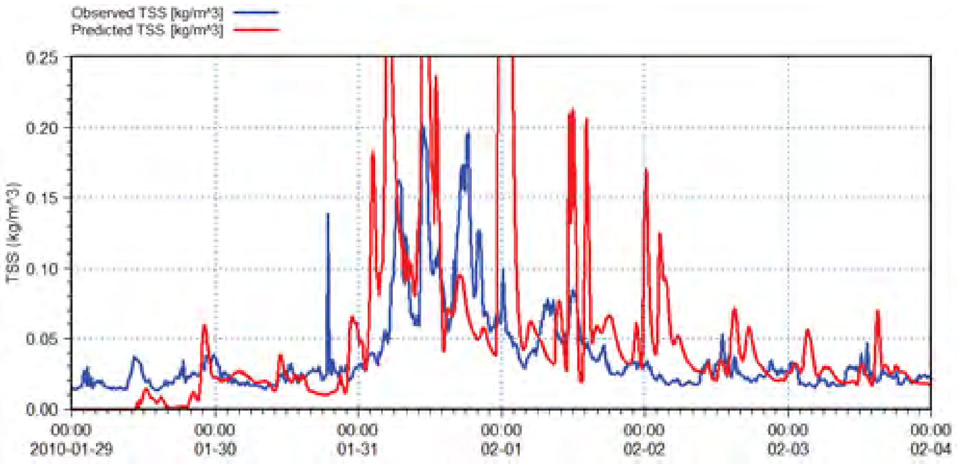


Figure V61 Comparison of Observed and Predicted TSS in the Pauatahanui Inlet for the Third Sediment Transport Model Calibration Period

(4) Fourth Sediment Transport Model Calibration Period

The wind forcing for the fourth calibration period is presented in **Figure V62**. A southerly wind event occurred on the 15th January, 2010.

The comparison between observed and predicted TSS in Pauatahanui Inlet for the fourth calibration period is presented in **Figure V63**. TSS concentration greater than 0.2 kg/m^3 were measured on 16th January 2010. The model was able to replicate the overall timing of the sediment plume, however the data indicates that there was a sediment plume of high TSS, located within the middle of Pauatahanui Inlet for a significant period during 16th January 2010, which the model was not quite able to replicate. An explanation for this is that the model might have underestimated the amount of sediment re-suspended from the bed.

V.4 Sensitivity Tests

To assess the sensitivity in the predicted deposition patterns to variations of the parameters selected for the calibrated sediment transport model, a series of sensitivity tests have been carried out on the critical parameters (or equivalent). A 10 year flood event in the Horokiri catchment with a northerly wind (E15) was been selected as an appropriate simulation to test the sensitivity of the parameters. A simulation with wind was selected, since it is important to test the parameters influence on keeping sediment in suspension and re-suspension. The sensitivity of depositional patterns on state of tide (neap or spring) has also been assessed.

A summary of the sensitivity test simulations is included in **Table V8**.

Table V8 Summary of Sensitivity Test Simulations

Scenario	Parameter	Original Value	Sensitivity Test Value
E15_S1	State of Tide	Spring to Neap	Neap to Spring
E15_S2H	Critical Shear Stress for Erosion	0.3 N/m²	0.4 N/m²

E15_S2L	Critical Shear Stress for Erosion	0.3 N/m²	0.2 N/m²
E15_S3H	Critical Shear Stress for Deposition	0.07 N/m²	0.1 N/m²
E15_S3L	Critical Shear Stress for Deposition	0.07 N/m²	0.05 N/m²
E15_S4H	Density of Bed Layer	400 kg/m³	550 kg/m³
E15_S4L	Density of Bed Layer	400 kg/m³	250 kg/m³
E15_S5H	Settling Velocity Coefficient (cohesive) / Mean Settling Velocity (sand fractions)	5 m/s for clay/silt 0.006 m/s for fine sand 0.023 m/s for sand	10 m/s for clay/silt 0.012 m/s for fine sand 0.046 m/s for sand
E15_S5L	Settling Velocity Coefficient (cohesive) / Mean Settling Velocity (sand fractions)	5 m/s for clay/silt 0.006 m/s for fine sand 0.023 m/s for sand	2.5 m/s for clay/silt 0.003 m/s for fine sand 0.012 m/s for sand

For each of the sensitivity scenarios the bed deposition 3 days after the peak of the storm event has been extracted. A comparison of these results has been carried out to identify the variation in sediment patterns. The results and comparisons are shown in Figure S-1 to S-15 in Appendix15.CC.

To identify the impact of the state of the tide during the storm event the model was run with the storm event coinciding with a neap and spring tide. The comparison of the bed deposition 3 days after the storm event for these scenarios is shown in Figure S-3. These results indicate that the state of the tide at the time of the sediment inputs does not have a significant impact on deposition patterns. There is some increased deposition in the southern part Onepoto Arm and south eastern part of Pauatahanui Inlet and decreased deposition for a small area in the north of Pauatahanui Inlet. This shows that wave and wind driven currents dominate tidal currents within the harbour arms during wind events.

The results for the sensitivity scenarios for the sediment behaviour parameters for critical shear stress for erosion and critical shear stress for deposition are shown in Figure S-4 to Figure S-9. There were only minimal differences in deposition that occurred.

Varying the factors for bed layer density and the settling velocity/particle sizes had greater effects on sediment deposition in the harbour as shown in Figure S-10 to Figure S-15, however the comparison of the high and low range selected showed that these effects on bed deposition were not wide spread.

The sensitivity tests illustrate that, given the range of factors likely in the Porirua Harbour catchment, predicting areas where deposition will occur is only partially associated with the sediment characteristics. The hydrodynamics within the harbour are the most important characteristics that determine where sediment is predicted to deposit.

These sensitivity runs increased the confidence in the range of results that the model produces. Furthermore the sensitivity results help confirm the appropriateness of the methodology selected for undertaking the analysis, including the use of three wind conditions and rainfall events which are an important driver of the harbour hydrodynamics.

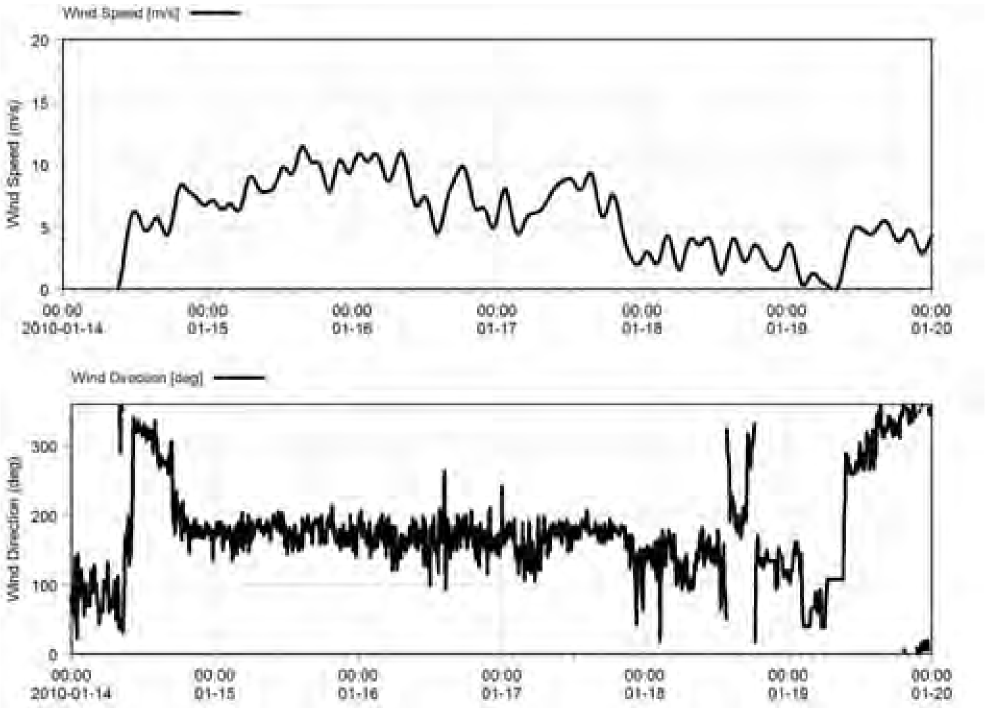


Figure V62 Wind Speed (top) and Wind Direction (bottom) Observed in Pauatahanui Inlet for Fourth Sediment Transport Model Calibration Period

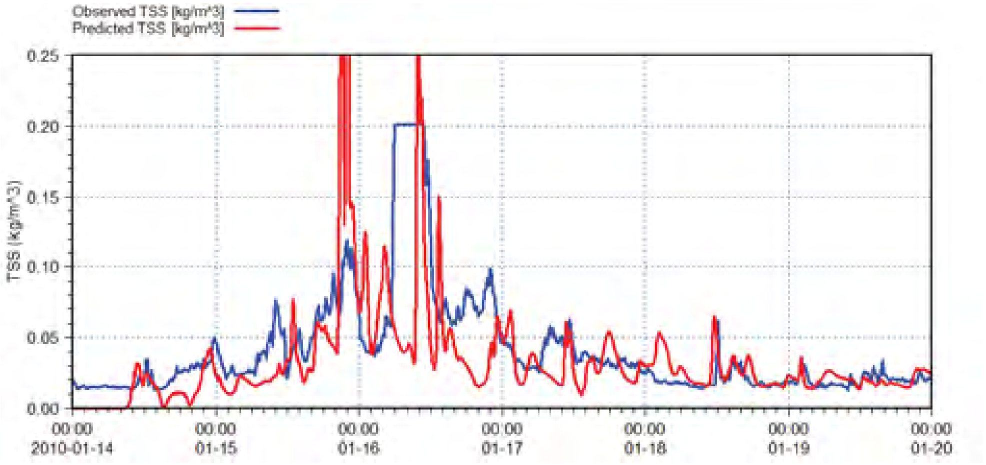


Figure V63 Comparison of Observed and Predicted TSS for Pauatahanui Inlet for Fourth Sediment Transport Model Calibration Period

V.4.1 Coarse Resolution Model Verification

To verify that the coarse resolution model, for long term simulations, would still sufficiently resolve the important hydrodynamic, wave and sediment transport processes within the harbour, a simulation was carried out using the hydrodynamic, wave and sediment transport models for the period 28th January to 28th February 2010. All parameter values for the coarse model were taken from the high resolution model.

(1) Hydrodynamic Model

The coarse model was still able to satisfactorily predict water levels and currents within the model domain compared with observed data as shown in **Figure V64** and **Figure V65**. For the verification it was deemed only necessary to compare the observed and predicted current speed and direction for the entrance to Pauatahanui Inlet and the middle of Pauatahanui Inlet.

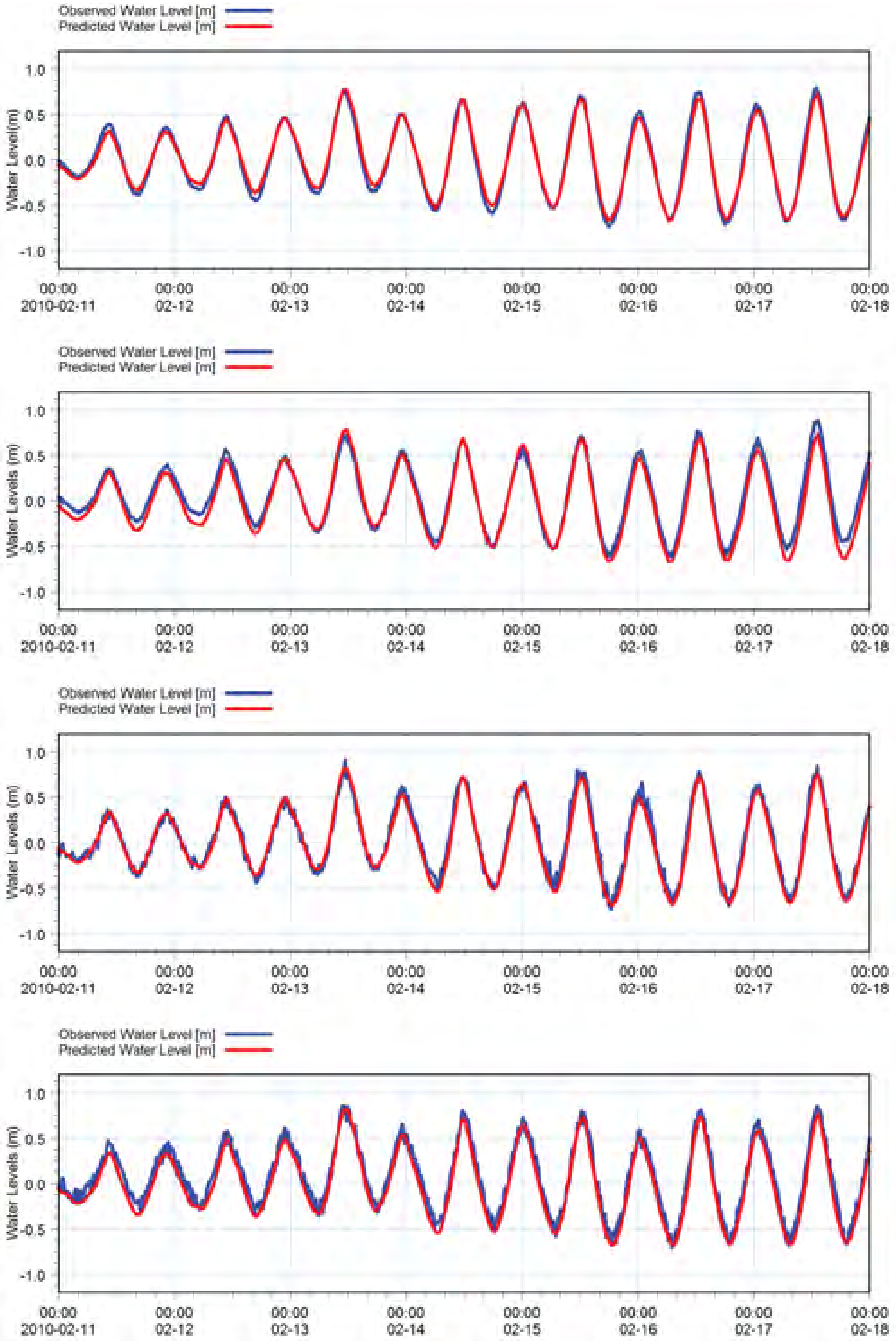


Figure V64 Predicted (blue) and Observed (red) Water Levels (MSL) in Porirua Harbour Entrance (top), Pauatahanui Inlet Entrance (middle-top), Onepoto Arm (middle-bottom) and Pauatahanui Inlet (bottom) for Period 11th February to 18th February 2010

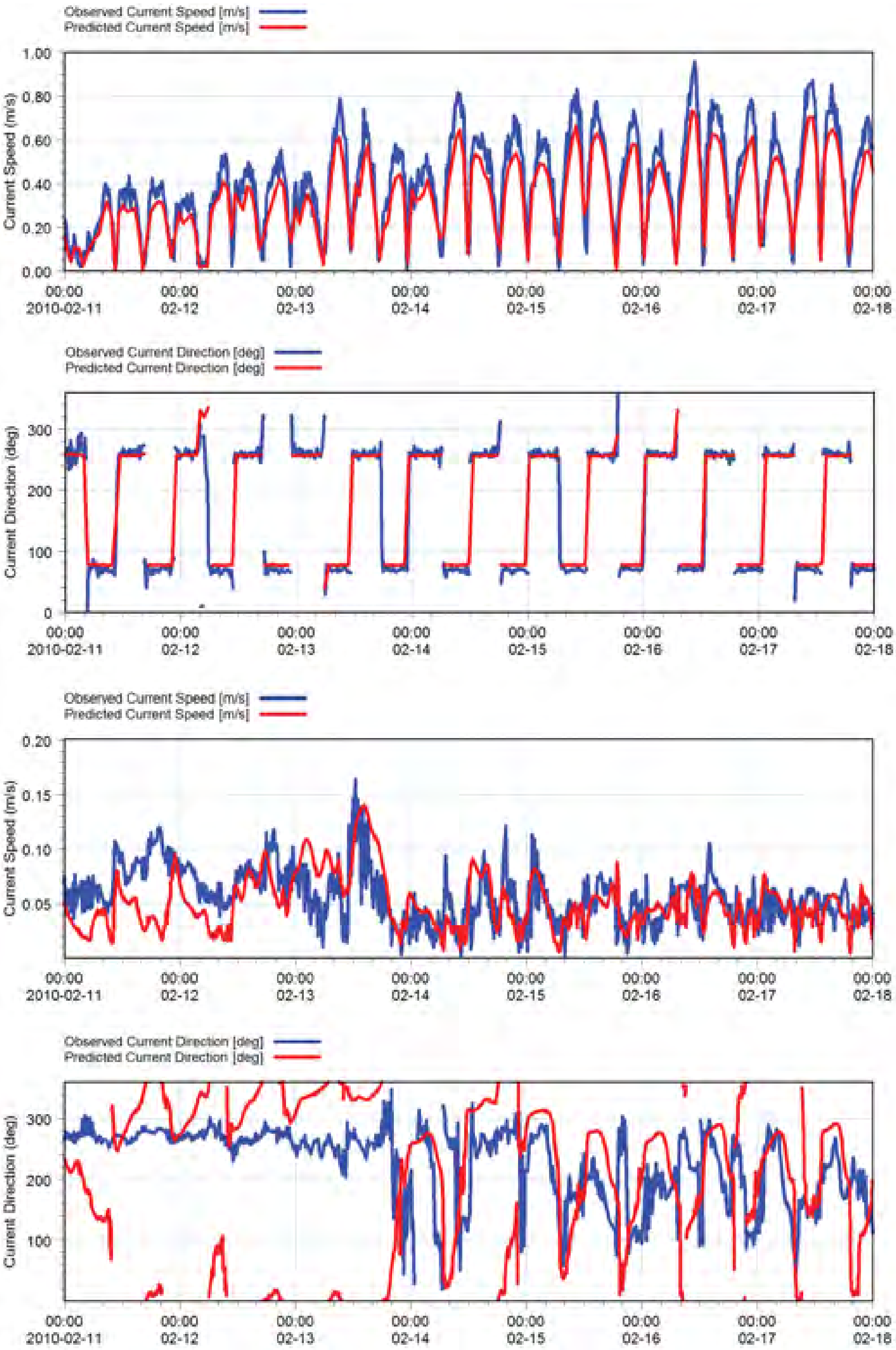


Figure V65 Predicted (blue) and Observed (red) Current Speed and Direction in Porirua Harbour Entrance (top) and Pauatahanui Inlet (bottom) for Period 11th February to 18th February 2010

(2) Wave Model

The coarse model was still able to satisfactorily predict significant wave heights within Onepoto Arm and Pauatahanui Inlet compared with observed data as shown in **Figure V66** and **Figure V67**.

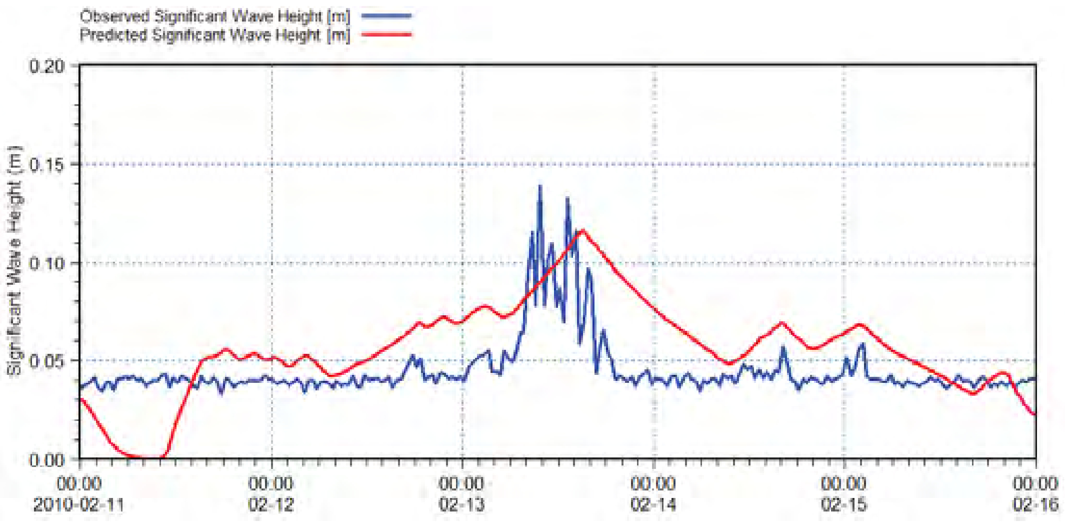


Figure V66 Predicted (blue) and Observed (red) Significant Wave Height in Pauatahanui Inlet for Period 11th February to 16th February 2010

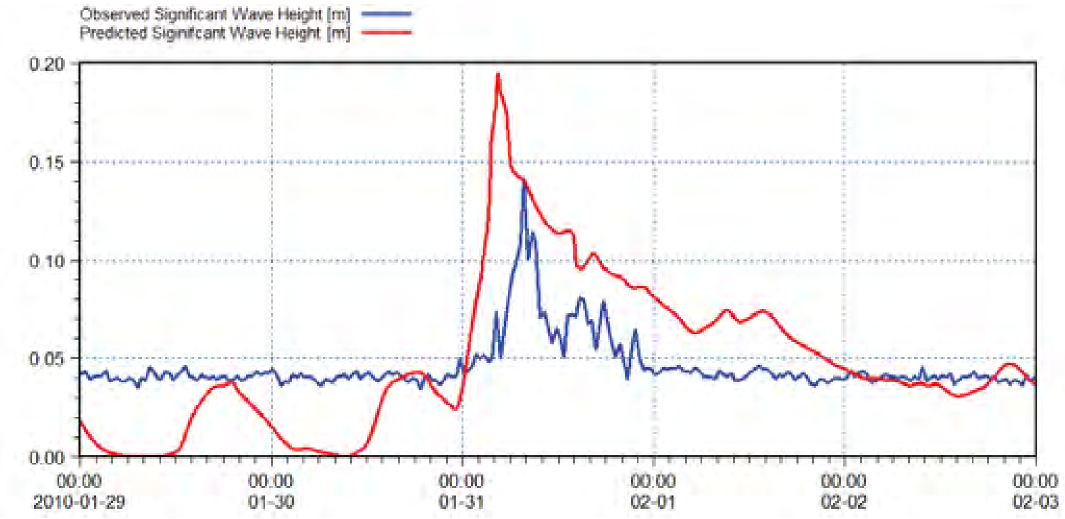


Figure V67 Predicted (blue) and Observed (red) Significant Wave Height in Onepoto Arm for Period 29th January to 3rd February 2010

(3) Sediment Transport Model

The coarse model was still able to satisfactorily predict TSS within Onepoto Arm and Pauatahanui Inlet compared with observed data as shown in **Figure V68**.

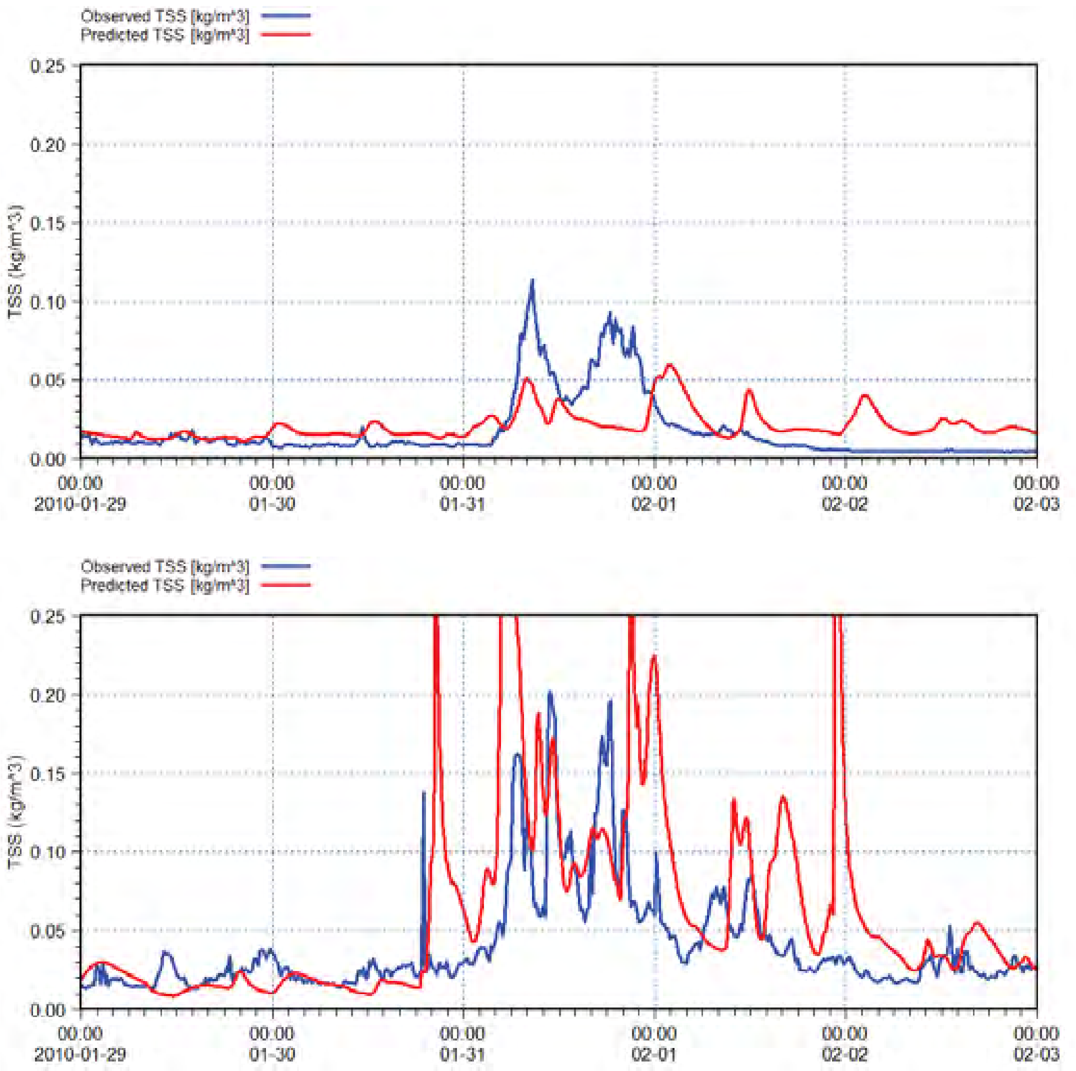


Figure V68 Predicted (blue) and Observed (red) TSS in Onepoto Arm (top) and Pauatahanui Inlet (bottom) for Period 29th January to 3rd February 2010

V.4.2 Sensitivity Tests

To assess the sensitivity in the predicted deposition patterns to variations of the parameters selected for the calibrated sediment transport model, a series of sensitivity tests have been carried out on the critical parameters (or equivalent). An early version of the 10 year flood event in the Horokiri catchment with a northerly wind was selected as an appropriate simulation to test the sensitivity of the parameters. A simulation with wind was selected, since it is important to test the parameters influence on keeping sediment in suspension and re-suspension. The sensitivity of depositional patterns on state of tide (neap or spring) has also been assessed.

A summary of the sensitivity test simulations is included in **Table V10**.

Table V10 Summary of Sensitivity Test Simulations

Parameter	Low Sensitivity Test Value	Original Value	High Sensitivity Test Value
State of Tide	Neap to Spring	Spring to Neap	Spring to Neap
Critical Shear Stress for Erosion	0.2 N/m^2	0.3 N/m^2	0.4 N/m^2
Critical Shear Stress for Deposition	0.05 N/m^2	0.07 N/m^2	0.1 N/m^2
Density of Bed Layer	250 kg/m^3	400 kg/m^3	550 kg/m^3
Settling Velocity Coefficient (cohesive) / Mean Settling Velocity (sand fractions)	2.5 m/s for clay/silt 0.003 m/s for fine sand 0.012 m/s for sand	5 m/s for clay/silt 0.006 m/s for fine sand 0.023 m/s for sand	10 m/s for clay/silt 0.012 m/s for fine sand 0.046 m/s for sand

For each of the sensitivity scenarios the bed deposition 3 days after the peak of the storm event was extracted and the Low and High sensitivity values were compared to identify the variation in sediment patterns. The comparisons are shown in **Figure V69**, **Figure V70**, **Figure V71**, **Figure V72** and **Figure V73**.

In **Figure V69** indicates that the state of the tide at the time of the sediment inputs does not have a significant impact on deposition patterns with only minor changes observed. This shows that wave and wind driven currents dominate the tidal currents within the harbour arms during wind events.

The results for the sensitivity scenarios for the sediment behaviour parameters for critical shear stress for erosion and critical shear stress for deposition are shown in **Figure V70** and **Figure V71**. There were only minimal differences in deposition that occurred.

Varying the factors for bed layer density and the settling velocity/particle sizes, as shown in **Figure V72** and **Figure V73**, demonstrated that the effects were generally localised to the areas around the stream mouths.

Figure V69 Sensitivity Check: State of Tide

Figure V70 Sensitivity Check: Critical Shear Stress for Erosion

Figure V71 Sensitivity Check: Critical Shear Stress for Deposition

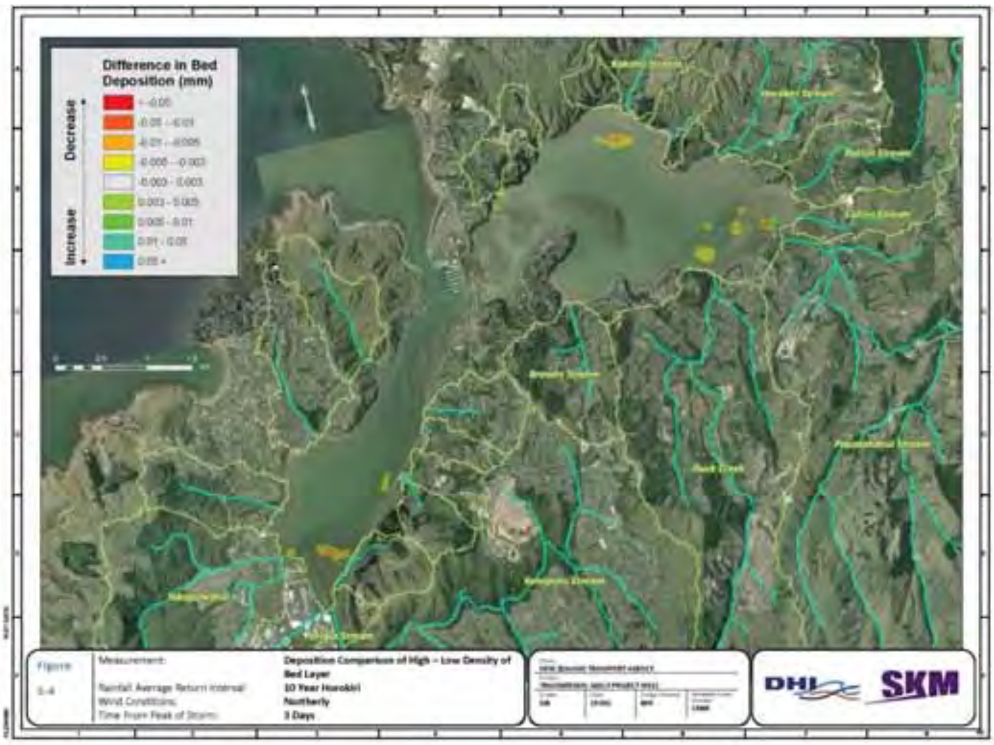


Figure V72 Sensitivity Check: Density of Bed Layer

Figure V73 Sensitivity Check: Settling Velocity/Particle Size

The sensitivity tests suggest that, given the range of factors likely in the Porirua Harbour catchment, predicting areas where deposition will occur is only partially associated with the modelled sediment characteristics. The hydrodynamics within the harbour are the most important characteristics that determine where sediment is predicted to deposit.

These sensitivity runs increased the confidence in the range of results that the model produces. Furthermore the sensitivity results help confirm the appropriateness of the methodology selected for undertaking the analysis, including the use of three wind conditions which are an important driver of the harbour hydrodynamics.

Appendix 15.W Operational Performance Monitoring Plan Example

W.1 Compliance Monitoring Plan Structure

This document is structured as follows:

- Section W1 of this Draft Compliance Monitoring Plan provides an introduction to the Compliance Monitoring Plan including who has responsibility for its control and ownership and the status of the document.
- Section W2 covers the roles of the people who have actions to implement this plan and their responsibilities.
- Section W3 provides an overview of the proposed operational stormwater treatment measures for the road alignment. Section W4 outlines the compliance monitoring required to ensure that the proposed measures are operating as designed.
- Section W8 outlines the monitoring that is proposed to confirm that the impacts of the stormwater discharges from the road on catchment water quality is as anticipated.

W.1.1 Interaction with other Compliance Monitoring Documents

To cover in this section is how it interacts with any proposed/required monitoring of ecological impact in the streams/estuary. This document establishes measures to ensure the performance of the devices proposed, plus measurement of the overall impacts on the streams water quality.

W.1.2 Document Control and Ownership

This draft document has been produced to support resource consent applications. Post consenting and pre commissioning of the road this document will need to be updated. It is anticipated that ownership of the document will continue to be held by the NZTA throughout the lifespan of the stormwater discharge consents.

W.1.3 Version

This document is Draft A. It is intended to provide an overview of the compliance monitoring of stormwater treatment devices and the resulting impacts on water quality. This draft provides information for consenting purposes. It is anticipated that ownership of the document will pass to the construction contractors following consents being granted.

W.2 Roles and Responsibilities

W.2.1 Key Contacts

This section will outline who the key contacts and their responsibilities. This section is to include contact details for the following key roles - site management, training, inspection, sampling, communication, reporting and emergency response roles. It will be completed prior to road commissioning.

W.2.2 Emergency Contacts

This section will outline key NZTA, Regional Council and Emergency Services contact details.

W.3 Overview of Stormwater Treatment Approach and Devices

Operational stormwater treatment methods vary along the length of the alignment. The devices selected reflect the catchment constraints and environmental risks. Devices include proprietary devices (Stormwater 360 StormFilter with ZPG media), swales and wetlands. All stormwater from the road will pass through one of these devices or through a treatment train approach utilising more than one of these devices (e.g. swales then a wetland) prior to discharge.

The proposed location of stormwater treatment devices is described and detailed in Section 3.

The performance of these devices has been established from available literature and manufacturers specifications. This has been used in understanding and predicting the potential adverse effects from the discharges. The intention is that device selection is such that it leads to a discharge suitable for the receiving environment. Resource consents will be sought to permit the discharges and their resulting predicted effects on water quality.

W.4 Compliance Monitoring Activities

W.4.1 Overview

During operation of the road the stormwater treatment devices proposed will require inspection and maintenance to ensure they are operating as intended. Device performance (in terms of contaminant removal) has been assessed and is described in Section 3. This performance will be assumed for the Assessment of Effects on the Environment (AEE). It is not proposed to monitor the individual performance of each treatment device. This is partly due to the cost and complexity of that approach but also as understanding exactly whether an individual device performs as designed does not inform about the bigger picture impact on the catchment and state of the stream receiving multiple discharges. The intention within this compliance monitoring plan is therefore to specify compliance activities to ensure that devices are kept operational and compliance monitoring to confirm that the actual effects on the environment relate to those predicted in the AEE.

To maintain the operation of the proposed devices it will be necessary to have a regime of inspection and maintenance works with associated management actions and reporting.

Monitoring of the environmental condition of the receiving environments is outlined in section 6. Where possible this will utilise sample points used in the AEE and for the long term catchment control monitoring of the construction phase. Monitoring will be required pre construction to establish a baseline and then during operation. It is proposed that the monitoring frequency and parameters change over time in relation to results to ensure that the monitoring stays relevant and cost effective.

W.5 Inspection and Maintenance of Stormwater Treatment Devices

Table W1 sets out the inspection and maintenance requirements for the three stormwater devices proposed for the road alignment. Undertaking of these should ensure that the device performance is maintained over the lifespan of the consent. These requirements have been identified with consideration of the manufacturers recommended maintenance specifications, the Auckland Regional Council’s TP10 (ARC, 2003) document and the NZTA Stormwater Standards (NZTA, 2009). **Table W1** sets out the following:

- Routine Inspection – Documents the inspection frequency that is required to ensure the devices are operative, performing as designed and ready for future rain events.
- Inspect for – Notes specific factors to be considered and noted during the inspection.
- Compare limits - Outlines what performance or specification the inspection of the measures should be compared against
- Maintenance / management action – Outlines what to do should an issue be found during inspection
- Reporting – Notes what should be reported and where

Table W1 Inspection and Maintenance of Stormwater Treatment Devices

Treatment device	Routine Inspection	Inspect For	Compliance Limits	Maintenance / Management Action	Reporting
StormFilters	Annual	Sediment build-up and media function	Treatment capacity to retain treatment performance	Remove sediment / replace media as required1	Report inspections undertaken and any actions required in annual report
		Damage to device, blockages of inlet/outlet, erosion at outlet	Design Specifications	Rectify any damage / erosion or blockages	
Wetland / wet ponds	Inspection and maintenance as per the NZTA Stormwater Maintenance Inspection Form – Stormwater Pond / Wetland Maintenance Inspection Checklist (**Appendix 15.W**)				No reporting of routine maintenance activities Report annually any non-routine maintenance activities

Notes: It is not possible to specify exact maintenance / management actions or frequencies. The manufacturer notes that “Annual inspections of all our products is recommended. Based on results of the annual inspection, maintenance actions will be suggested. The typical maintenance interval is 12 to 36 months. Ultimately, the maintenance frequency will depend on site conditions, regulatory requirements and site-specific pollutant loading.”
http://www.stormwater360.co.nz/index.asp?s1=products&s2=StormFilter

W.6 Monitoring of Effects on Water Quality

Compliance monitoring of the proposed stormwater treatment devices is intended to ensure that they operate as designed and that their performance is maintained over the lifespan of their use on the project. The discharges from the proposed treatment devices will enter watercourses throughout the catchments. The following monitoring of the receiving environment is proposed to check whether the effects of the discharges are as anticipated.

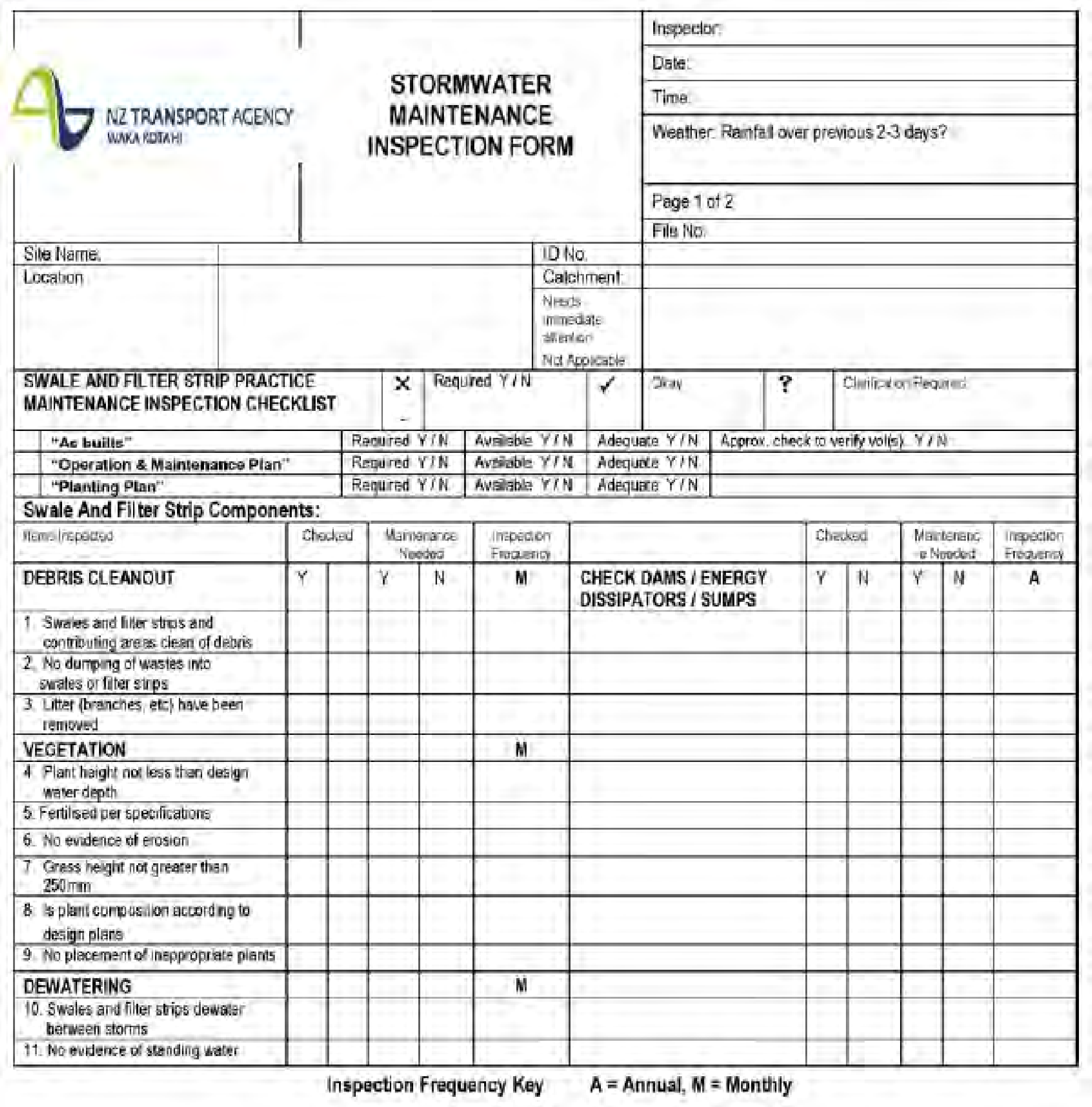
W.7 Monitoring Philosophy

Within the road alignment are a number of catchments. There will be many discharge points from stormwater treatment devices, including swales, wetland and StormFilters within each catchment. Detailed design for a number of locations (i.e. 'Hotspots') along the alignment will be undertaken as part of a separate package of work. This detailed design will include specific details of discharge points for stormwater.

It is not intended to monitor impacts upstream and downstream of each device throughout the entire consent period. Instead an approach of setting up long term **catchment control** monitoring sites is proposed. The intent is that the catchment control sites create a long term dataset of upstream and downstream water quality as it relates to the impact the road may have on the entire catchment. These locations will in general be the same as those proposed for the catchment control sites used for monitoring the impact of the construction phase discharges. These are intended to understand the overall change in water quality and impact of the road in each catchment as a result of the Motorway.

The catchment control monitoring will give an understanding of overall changes in long term water quality in the wider catchment. It is also considered necessary to understand the smaller scale impacts that representative road discharges are having on small reaches of streams. To that regard, where the downstream catchment control is located below a number of tributaries and can be potentially affected by other landuses an additional **direct impact** sample site will be identified for each catchment. This will be downstream of a section of road immediately below the upstream catchment control monitoring point. From this, a view of immediate impacts and changes can be gathered. This sampling will have to be undertaken during rain events. An indication of the monitoring locations required is presented in **Figure W1**.

NZTA Stormwater Maintenance Inspection Forms



NZ TRANSPORT AGENCY
WAKA KOTAHI

STORMWATER MAINTENANCE INSPECTION FORM

Inspector:

Date:

Time:

Weather: Rainfall over previous 2-3 days?

Page 1 of 2

File No:

Site Name:		ID No.	
Location		Catchment:	
		Needs immediate attention Not Applicable	

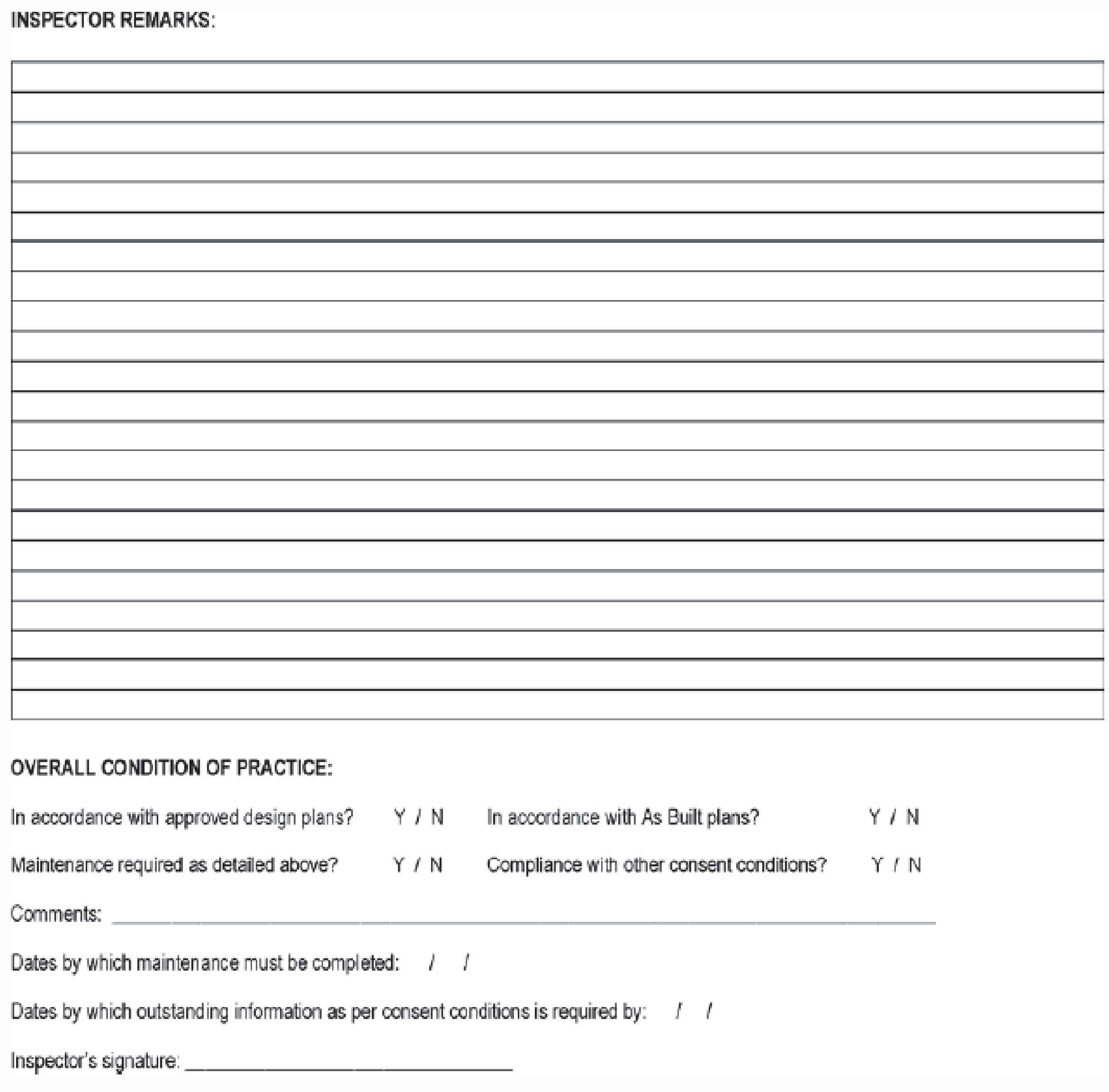
SWALE AND FILTER STRIP PRACTICE MAINTENANCE INSPECTION CHECKLIST	✕	Required Y / N	✓	Okay	?	Clarification Required

	"As builts"	Required Y / N	Available Y / N	Adequate Y / N	Approx. check to verify vol(s). Y / N
	"Operation & Maintenance Plan"	Required Y / N	Available Y / N	Adequate Y / N	
	"Planting Plan"	Required Y / N	Available Y / N	Adequate Y / N	

Swale And Filter Strip Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
DEBRIS CLEANOUT	Y		Y	N	**M**	**CHECK DAMS / ENERGY DISSIPATORS / SUMPS**	Y	N	Y	N	**A**
1. Swales and filter strips and contributing areas clean of debris											
2. No dumping of wastes into swales or filter strips											
3. Litter (branches, etc) have been removed											
VEGETATION					**M**						
4. Plant height not less than design water depth											
5. Fertilised per specifications											
6. No evidence of erosion											
7. Grass height not greater than 250mm											
8. Is plant composition according to design plans											
9. No placement of inappropriate plants											
DEWATERING					**M**						
10. Swales and filter strips dewater between storms											
11. No evidence of standing water											

Inspection Frequency Key A = Annual, M = Monthly



INSPECTOR REMARKS:

OVERALL CONDITION OF PRACTICE:

In accordance with approved design plans? Y / N In accordance with As Built plans? Y / N

Maintenance required as detailed above? Y / N Compliance with other consent conditions? Y / N

Comments: ____

Dates by which maintenance must be completed: / /

Dates by which outstanding information as per consent conditions is required by: / /

Inspector's signature: ______________________________

NZ TRANSPORT AGENCY
WAKA KOTAHI

STORMWATER MAINTENANCE INSPECTION FORM

Inspector:
Date:
Time:
Weather: Rainfall over previous 2-3 days?

Page 1 of 2

Site Name:
Location:
File No:
Consent No:
Catchment:

STORMWATER POND/WETLAND MAINTENANCE INSPECTION CHECKLIST

✗	Needs immediate attention	✓	Okay
-	Not Applicable	?	Clarification Required

"As builts"	Required Y / N	Available Y / N	Adequate Y / N	Approx. check to verify vol(s) Y / N
"Operation & Maintenance Plan"	Required Y / N	Available Y / N	Adequate Y / N	
"Planting Plan"	Required Y / N	Available Y / N	Adequate Y / N	

Pond/Wetland Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
EMBANKMENT & EMERGENCY SPILLWAY	Y	N	Y	N	**A,S**		Y	N	Y	N	
1. Is the spillway level?						20. Concrete/Masonry condition Riser and barrels					
2. Adequate vegetation & ground cover?											
3. Appropriate plants / weeds?						a) Cracks or displacement?					
4. Adequate freeboard?						b) Minor spalling (0.25mm)?					
5. Embankment erosion evident?						c) Major spalling (rebars exposed)?					
6. Cracking, bulging or sliding of dam						d) Joint failures?					
a) Upstream embankment						e) Water tightness adequate?					
b) Downstream embankment						21. Pond drain valve:					
c) At or beyond toe upstream						a) Operational / exercised?					
d) At or beyond toe downstream						b) Chained and locked?					
e) Emergency spillway						22. Slope protection or rip-rap failures?					
7. Pond & toe drains clear & functioning?						23. Other?					
8. Evidence of animal burrows?						**PERMANENT POOL (WET POND)**					**3M**
9. Seeps/leaks on downstream face?						24. Undesirable vegetative growth?					
10. Vertical & horizontal alignment of top of dam as per As Built plans?						25. Removal of floating debris required?					
						26. Visible pollution?					
11. Emergency spillway clear of obstructions & debris						27. Evidence of edge erosion?					
						28. Other?					
12. Provision of access for maintenance?						**DRY POND**					**3M**
a) By hand?						29. Adequate vegetation cover?					
b) For machinery?						30. Presence of undesirable vegetation / woody growth?					
13. Other?											
RISER & SERVICE SPILLWAY					**A**	31. Standing water or wet spots?					
Type: Reinforced concrete						32. Sediment and/or trash accumulation?					
Metal pipe						33. Low flow channels unobstructed?					
Masonry						34. Other?					
14. Low flow orifice obstructed?						**SEDIMENT FOREBAYS**					
15. Low flow trash rack						35. Is sediment accumulation > 50% (maintenance req'd immed. if Yes)					
a) Is debris removal necessary?											
b) Is corrosion evident?						36. Provision of access for maintenance					
16. Weir trash rack maintenance						a) By hand?					
a) Is debris removal required?						b) For machinery?					
b) Is corrosion evident?						**OUTFALLS INTO PONDS**					**A,S**
17. Is there excessive sediment accumulation inside the riser?						37. Riprap failures?					
						38. Condition of endwalls / headwalls	Good		Fair		Poor
18. Metal pipe condition	Good		Fair		Poor	39. Evidence of slope erosion?					
19. Outfall channels functioning?						40. Condition of any inflow pipes	Good		Fair		Poor
						41. Other?					

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
OTHER	Y	N	Y	N	**6M**	**CONSTRUCTED WETLAND AREAS**	Y	N	Y	N	**A**
41. Encroachments on pond or easement area?						45. Vegetation healthy and growing?					
42. Complaints from residents?						46. Evidence of invasive species?					
43. Aesthetics						47. Excessive sedimentation in wetland area?					
a) grass mowing required?											
b) graffiti removal needed?											
c) other (specify)?											
44. Any public hazards (specify)?											

Inspection Frequency Key **A = Annual, M = Monthly, S = after monthly storm**

INSPECTOR REMARKS:

OVERALL CONDITION OF PRACTICE:

In accordance with approved design plans? Y / N In accordance with As Built plans? Y / N

Maintenance required as detailed above? Y / N Compliance with other consent conditions? Y / N

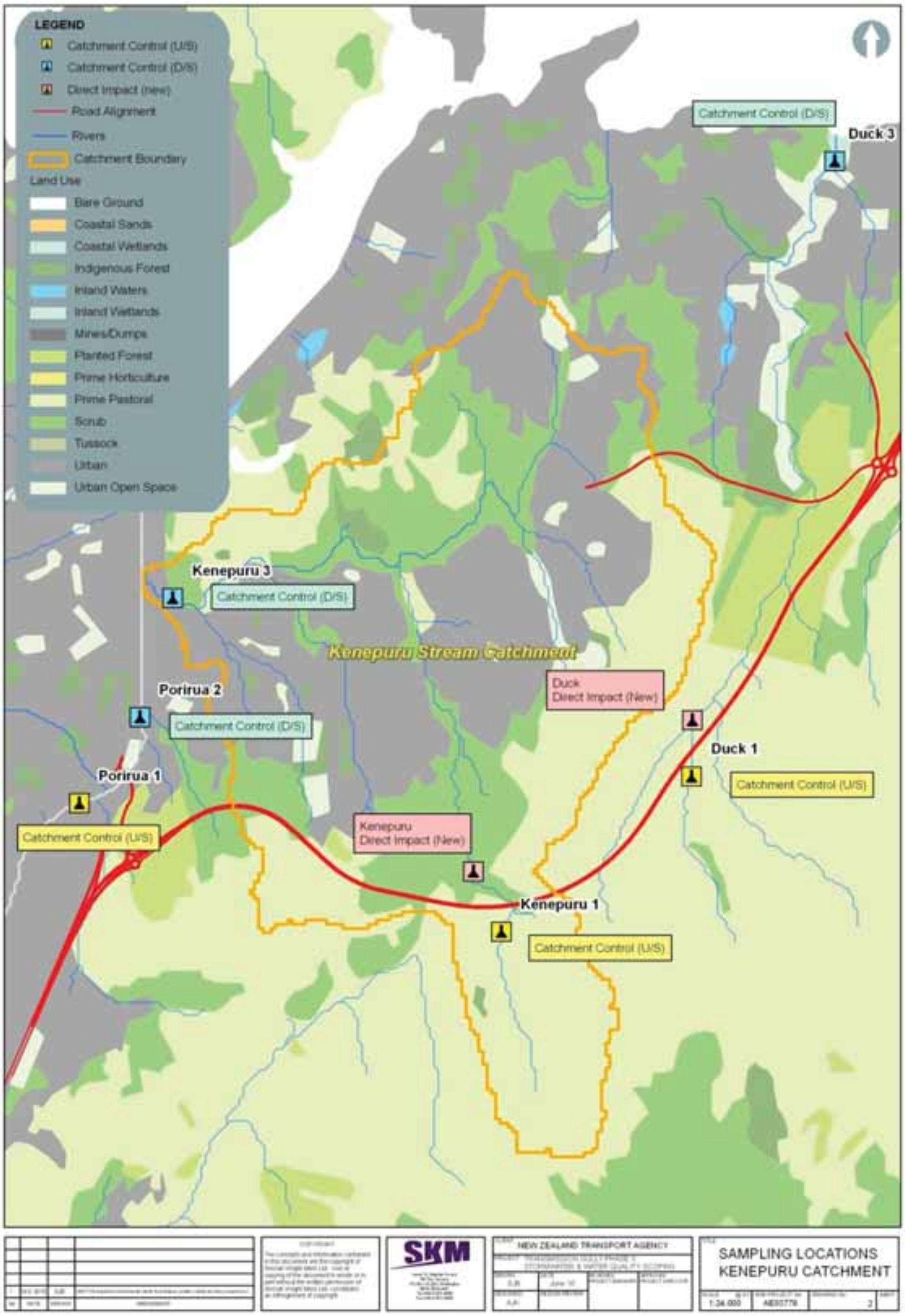
Comments: ____

Dates by which maintenance must be completed: / /

Dates by which outstanding information as per consent conditions is required by: / /

Inspector's signature: ______________________________

Figure W1 Indicative Monitoring Locations



W.8 Proposed Monitoring and Reporting

The requirements for the catchment control and direct impact monitoring are shown in **Table W2**. This table outlines the following details:

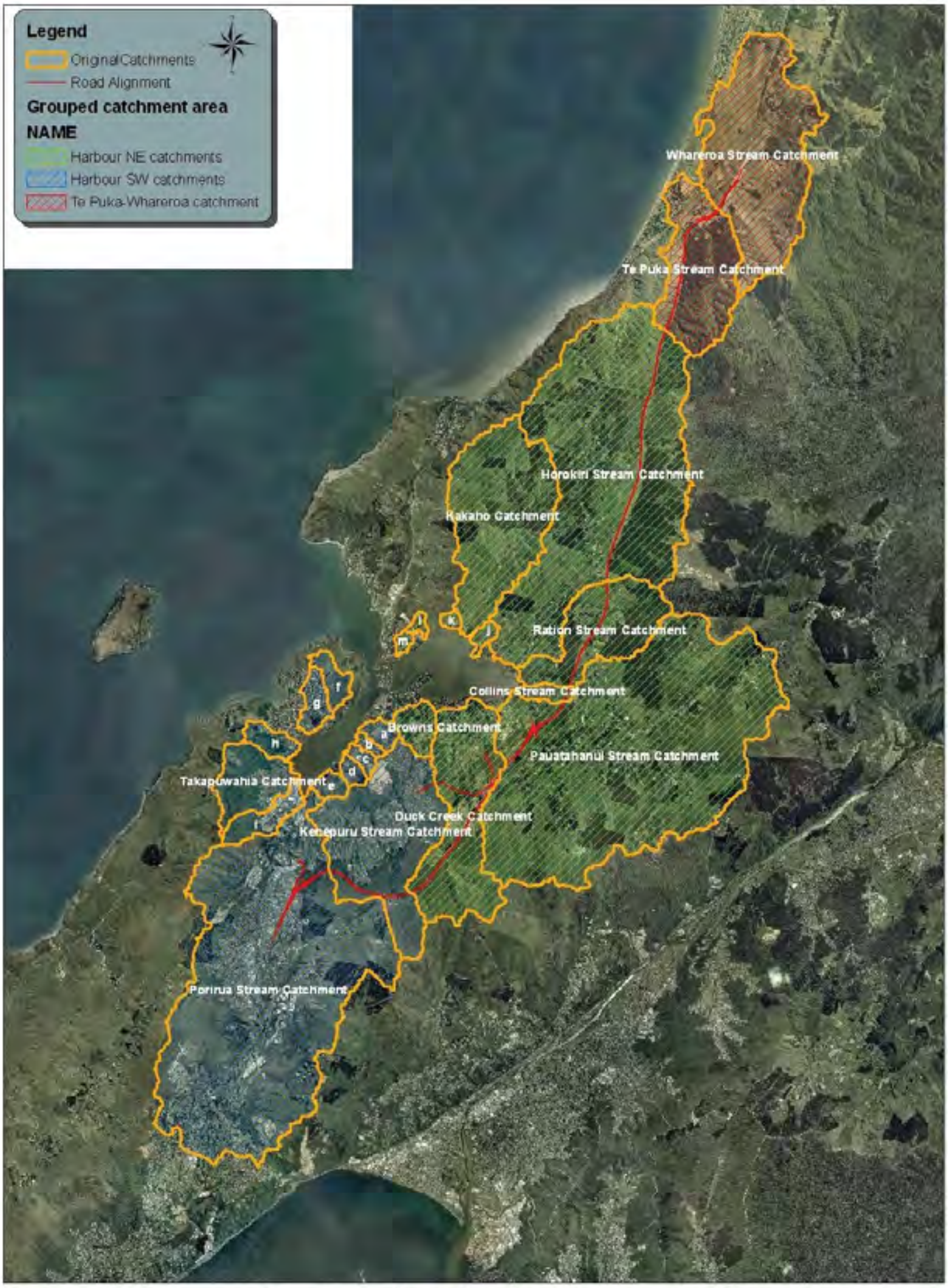
- Sample Point – The locations at which monitoring is to be undertaken. These are where possible sites used in the scoping studies and construction compliance monitoring.
  - Frequency - Required frequency of monitoring, this generally varies prior to road construction and during operation. The intention is to continue to sample pre construction to develop a robust baseline of data. Sampling will not be required during construction as the requirements of the Erosion and Sediment Control compliance monitoring plan cover this time period. Sampling will then be required once the road is operational.
  - Parameters – Recommended parameters to sample. These will be finalised after the AEE when the key concerns are identified based on the outputs of all Transmission Gully Work Packages. These are a subset of the monitoring undertaken for the baseline monitoring. For both the catchment control and direct impact monitoring sites key parameters include visual assessment of percentage fine sediment, turbidity, total suspended solids, nutrients (total nitrogen, ammoniacal nitrogen and nitrate nitrogen, total phosphorous and dissolved reactive phosphorous), metals (total and dissolved copper, zinc and lead) and hydrocarbons (benzene, toluene, ethylbenzene, and xylenes and TPH's c6-c36) as these relate to the primary operational stormwater discharge risks. In addition field parameters including temp, DO, conductivity and pH will be recorded.
  - Compliance Limits – Proposed limits for certain monitored parameters. These are only proposed for the key parameters of visual assessment of percentage fine sediment, turbidity and total suspended solids. The remaining parameters are intended to give a picture of longer term changes in the catchments and would be analysed over the lifespan of the project. As such no compliance limits are considered to be required. These will be finalised after the AEE when the key concerns are identified based on the outputs of all Transmission Gully Work Packages.
  - Reporting – An indication of how and when results should be reported. It is intended that all parameters are reported with analysis in an annual report. Exceedances of compliance limits should be reported to GWRC within 5 working days of receipt of the results.

Table W2 Monitoring Requirement for Catchment Control and Direct Impact Monitoring Sites

Sample point	Frequency	Parameters	Compliance limits – direct impact sites only	Reporting
All catchment control and direct impact monitoring sites noted in **Figure W.1**.	Pre construction for all sites: Monthly starting at least 12 months prior to works starting in the catchment. During operation for catchment control sites: Monthly for first two years after road is opened to traffic. Six monthly from	Fine sediment percentage by visual assessment method (%)	Change by X% at D/S site compared to U/S	To GWRC within 5 working days of non compliance In annual report
		Visual impact of discharge, oil, grease, suspended material, change in colour/clarity (direct impact sampling events only)	Non proposed	In annual report

	that time. During operation for direct impact monitoring sites: Sample during two storms that cause discharges from the treatment devices for three years (Note: Monitoring can start, and be at different sampling phases in each catchment. This will depend on the start date for works in each catchment.)	Temp (˚C)	Non proposed	In annual report
		pH	Non proposed	
		Conductivity (µS/m)	Non proposed	
		Dissolved Oxygen (mg/L and %sat)	Non proposed	
		Turbidity (NTU)	Change by XNTU's at D/S site compared to U/S	To GWRC within 5 working days of receipt of results In annual report
		Total Suspended Solids (g/m^3)	Change by X% at D/S site compared to U/S	
		Copper (Total and dissolved g/m^3)	TBC	
		Zinc (Total and dissolved g/m^3)	TBC	
		Lead (Total and dissolved g/m^3)	TBC	
		Total nitrogen (g/m^3)	TBC	
		Total ammoniacal Nitrogen (g/m^3)	TBC	
		Nitrate nitrogen (g/m^3)	TBC	
		Total phosphorous (g/m^3)	TBC	
		Dissolved reactive phosphorous (g/m^3)	TBC	
		TPH/BTEX (c6-c36) g/m^3)	Non proposed	In annual report

Appendix 15.X Contaminant Load Model Grouped Catchments



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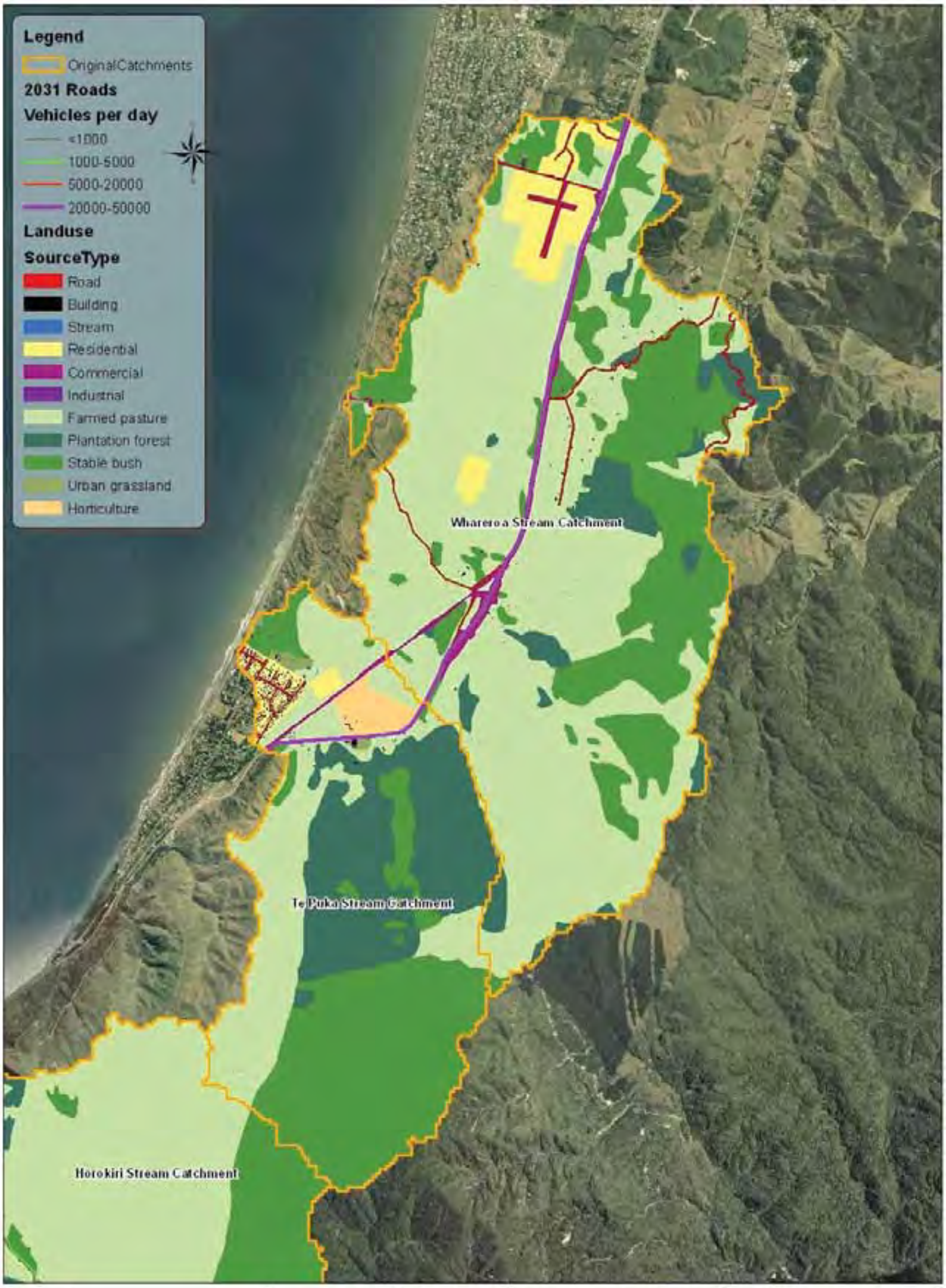
TRANSMISSION GULLY PHASE II
STORMWATER & WATER QUALITY
SJB
July 2010
AJH

GROUPED CATCHMENTS FOR CONTAMINANT LOAD MODEL
1:100,000
AE03770

Appendix 15.Y Contaminant Load Model Landuse Maps



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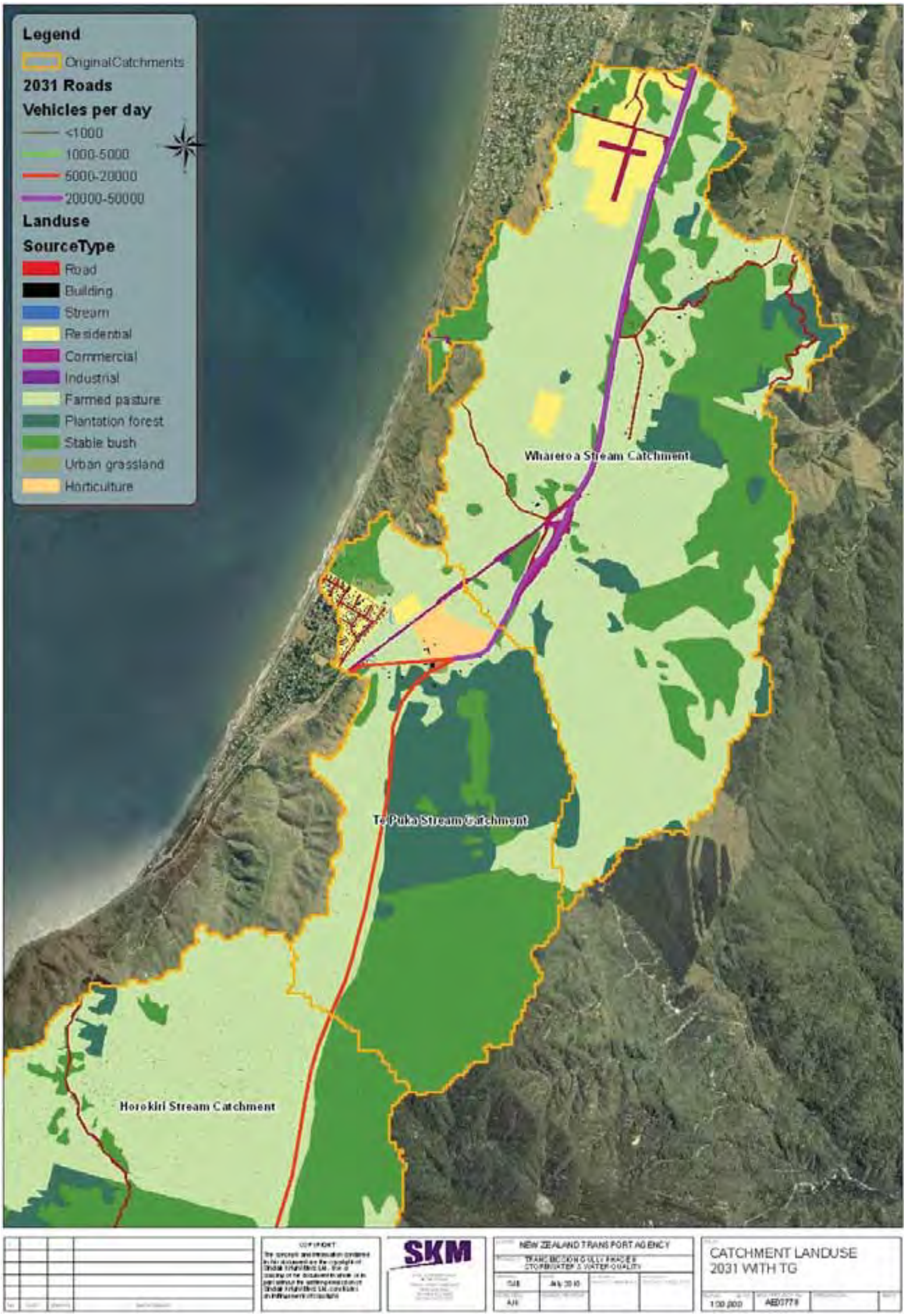
TRANSMISSION GULLY PHASE B
STORMWATER & WATER QUALITY
SJB
July 2010
A3

CATCHMENT LANDUSE
2031 WITHOUT TG

1:30 000
AE03778


Legend
OriginalCatchments
2031 Roads
Vehicles per day
<1000
1000-5000
5000-20000
20000-50000
Landuse
SourceType
Road
Building
Stream
Residential
Commercial
Industrial
Farmed pasture
Plantation forest
Stable bush
Urban grassland
Horticulture
Whareroa Stream Catchment
Te Puka Stream Catchment
Horokiri Stream Catchment
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July 2010
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2031 WITH TG
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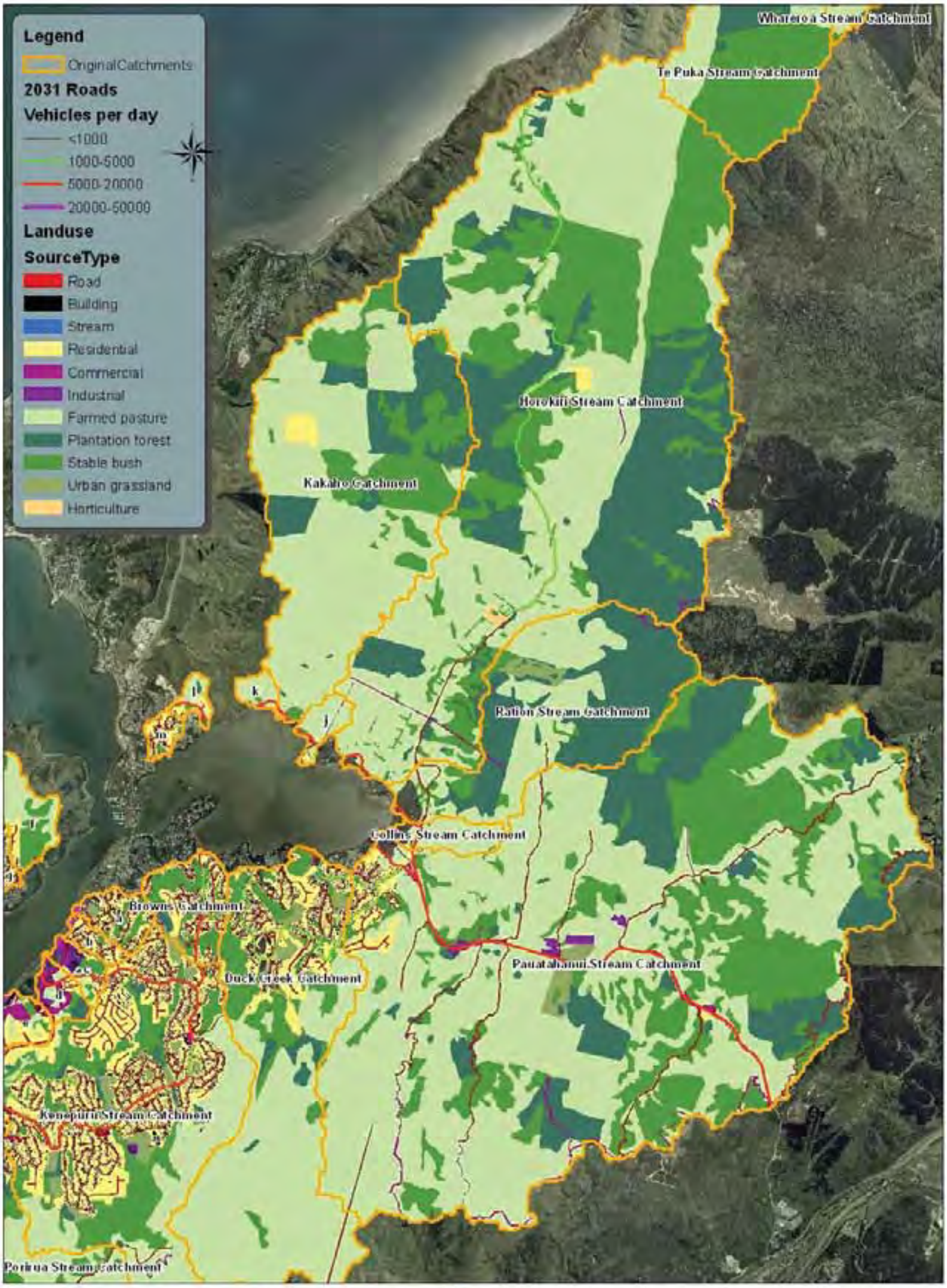

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CATCHMENT LANDUSE
2031 WITHOUT TG

1:50 000

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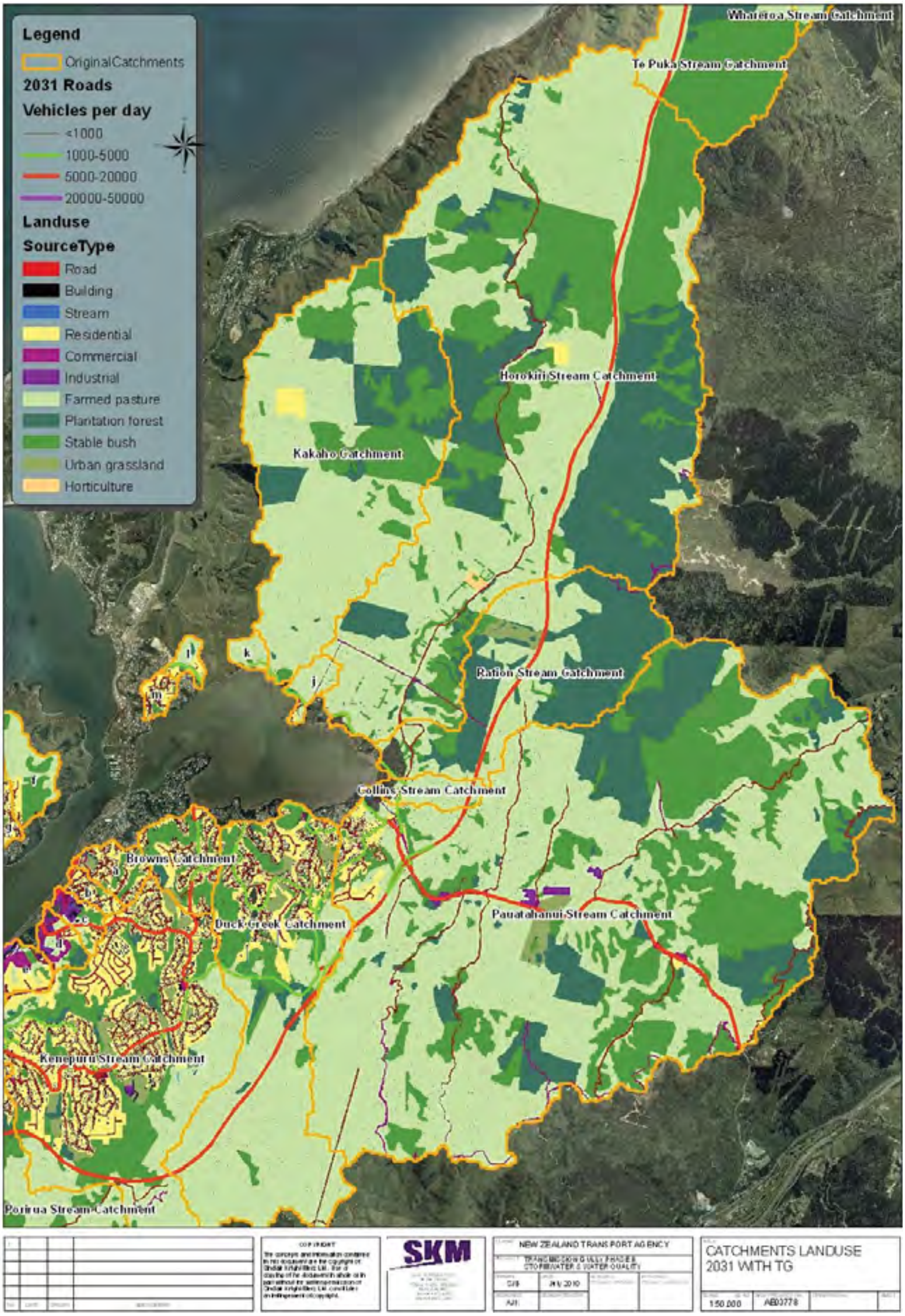
Legend
OriginalCatchments
2031 Roads
Vehicles per day
<1000
1000-5000
5000-20000
20000-50000
Landuse
SourceType
Road
Building
Stream
Residential
Commercial
Industrial
Farmed pasture
Plantation forest
Stable bush
Urban grassland
Horticulture
Whareroa Stream Catchment
Te Puka Stream Catchment
Horokiri Stream Catchment
Kakaho Catchment
Ration Stream Catchment
Collins Stream Catchment
Browns Catchment
Duck Creek Catchment
Pauatahanui Stream Catchment
Kenepuru Stream Catchment
Porirua Stream Catchment
a
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COPYRIGHT
SKM
NEW ZEALAND TRANSPORT AGENCY
TRANSMISSION GULLY PHASE 2 STORMWATER & WATER QUALITY
July 2010
A3
CATCHMENTS LANDUSE 2031 WITH TG
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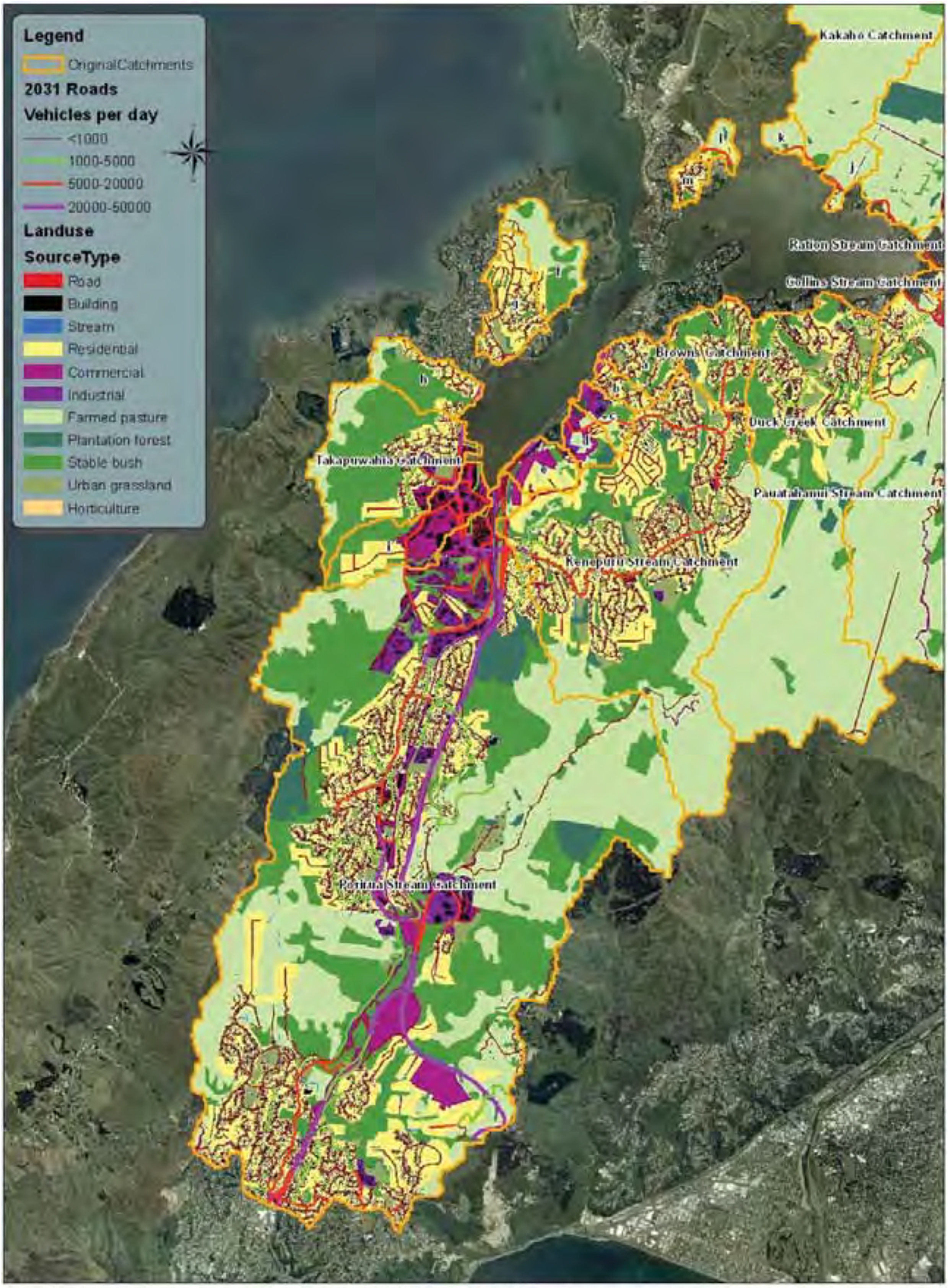
AE03778



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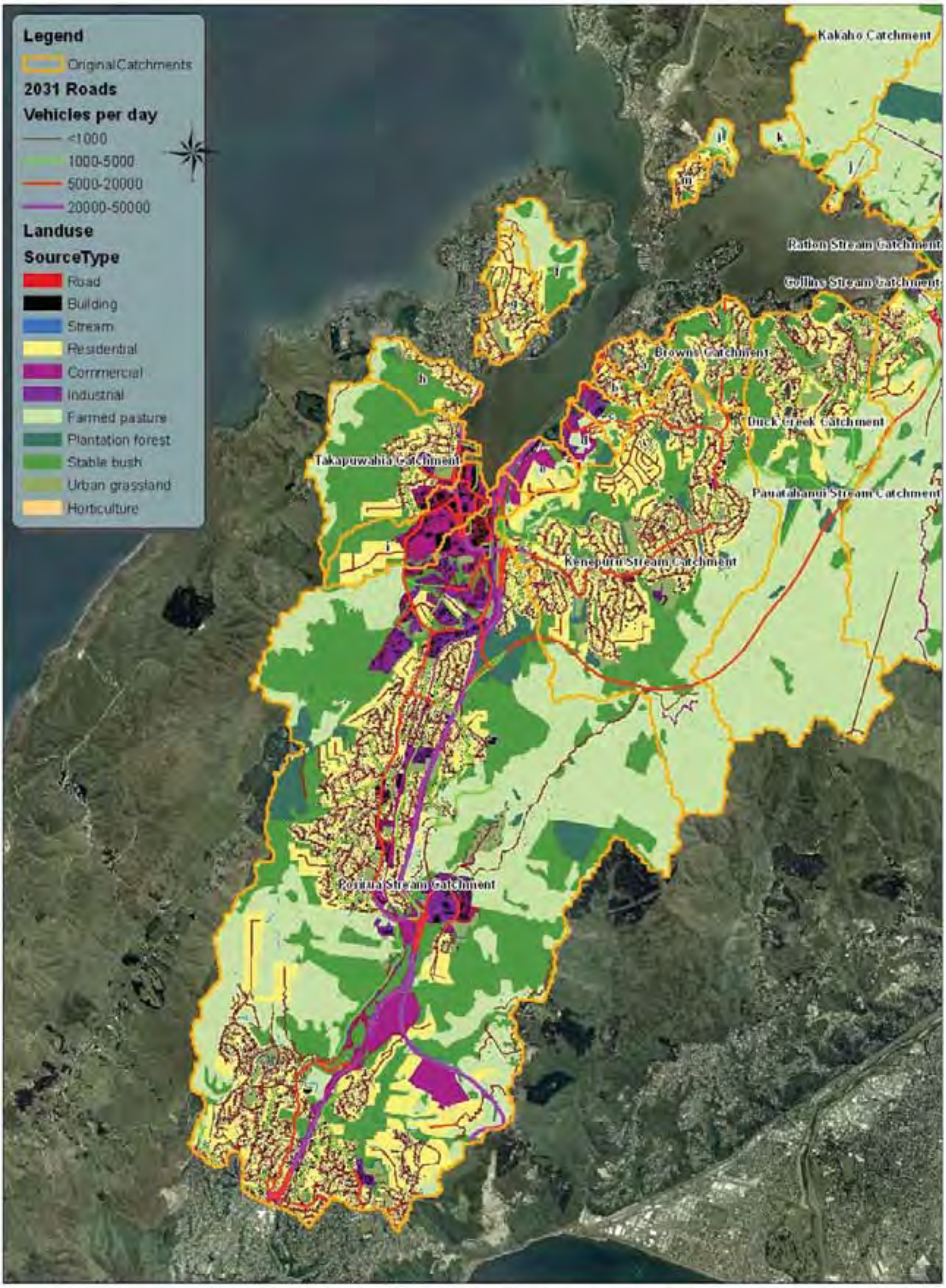

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TRANSMISSION GULLY PHASE 2 STORMWATER & WATER QUALITY

SJB

July 2010

AJK

CATCHMENT LANDUSE 2031 WITH TG

1:50 000

AE03778

Appendix 15.Z Contaminant Load Model Results – Stream Catchments

Z.1 2010 Scenario

Catchment	Catchment stream mouth load (kg/year)				Average yield				Average concentration (mg/kg)		
	TSS	Zn	Cu	TPH	TSS	Zn	Cu	TPH	Zn	Cu	TPH
					Kg/ha/year	g/ha/year	g/ha/year	g/ha/year			
A	26772	105	7	23	417	1635	107	361	3919	256	865
B	8951	54	4	23	307	1837	139	792	5981	451	2579
Browns	71111	164	10	56	525	1210	75	413	2306	142	787
C	36280	48	15	46	931	1236	382	1193	1327	410	1281
Collins	63384	13	2	24	1144	242	43	424	212	38	371
D	44786	22	12	31	1016	507	281	695	499	276	684
Duck	2880357	437	41	100	2809	426	40	98	152	14	35
E	77211	22	8	68	1374	400	134	1208	291	98	879
F	4415215	158	32	14	3543	127	26	11	36	7	3
G	35509	127	11	56	317	1138	96	498	3589	304	1571
H	71043	64	6	44	699	629	60	430	901	85	615
Horokiri	9319271	359	79	113	2822	109	24	34	38	8	12
I	152331	225	40	177	952	1408	250	1106	1480	263	1162
J	92852	14	4	35	2289	344	104	858	150	46	375
K	89799	7	2	17	3677	281	81	695	77	22	189
Kakaho	4415215	158	32	14	3543	127	26	11	36	7	3
Kenepuru	1830888	1245	83	422	1443	981	65	333	680	45	230
L	35922	11	3	29	1453	451	120	1175	311	83	809
M	6954	35	2	5	273	1362	74	197	4980	271	720
Pauatahanui	8428469	598	130	441	2025	144	31	106	71	15	52
Porirua	6779012	3204	480	2526	1647	779	117	614	473	71	373
Ration	907075	38	9	20	1364	57	14	30	42	10	22
Takapuwahia	283637	189	26	126	818	544	76	364	665	93	445
Te Puka	2524681	182	32	169	3039	219	39	203	72	13	67
Whareroa	3851495	288	81	606	2452	183	51	386	75	21	157

Z.2 2031 Without Road Scenario

Catchment	Catchment stream mouth load (kg/year)				Average yield				Average concentration (mg/kg)		
					TSS	Zn	Cu	TPH			
	TSS	Zn	Cu	TPH	Kg/ha/year	g/ha/year	g/ha/year	g/ha/year	Zn	Cu	TPH
A	28106	104	5	23	437	1614	83	360	3696	191	824
B	8864	54	4	23	303	1832	139	789	6045	460	2604
Browns	71453	168	11	68	527	1241	84	503	2357	160	956
C	36015	48	15	46	923	1237	382	1191	1341	414	1290
Collins	66214	14	2	24	1194	244	44	424	205	37	355
D	36611	34	13	34	798	744	291	738	933	365	925
Duck	2895401	451	42	86	2820	439	41	84	156	14	30
E	41034	63	13	107	610	944	189	1586	1547	310	2599
F	86113	16	1	3	876	162	14	27	185	16	31
G	32066	122	9	19	286	1087	76	173	3799	267	605
H	73946	65	6	44	727	642	61	430	884	83	591
Horokiri	9293835	361	79	113	2814	109	24	34	39	9	12
I	117751	254	41	180	736	1586	257	1122	2155	350	1525
J	91865	10	3	17	2264	259	76	429	114	34	190
K	89799	7	2	17	3677	281	81	695	77	22	189
Kakaho	4343136	172	34	14	3452	137	27	11	40	8	3
Kenepuru	1842069	1280	87	444	1452	1009	68	350	695	47	241
L	25723	11	3	27	1047	465	117	1114	444	112	1065
M	5390	35	2	5	213	1402	77	198	6581	364	929
Pauatahanui	8414398	611	132	447	2021	147	32	107	73	16	53
Porirua	6693828	3555	540	3204	1626	864	131	778	531	81	479
Ration	907063	38	9	20	1364	57	14	30	42	10	22
Takapuwahia	283844	206	27	119	817	593	77	343	725	94	419
Te Puka	2522493	184	32	169	3036	221	39	203	73	13	67
Whareroa	3527326	298	80	600	2248	190	51	382	84	23	170

Z.3 2031 With Road (No Treatment) Scenario

Catchment	Catchment stream mouth load (kg/year)				Average yield				Average concentration (mg/kg)		
					TSS	Zn	Cu	TPH			
	TSS	Zn	Cu	TPH	Kg/ha/year	g/ha/year	g/ha/year	g/ha/year	Zn	Cu	TPH
A	27703	104	5	23	432	1618	83	361	3747	193	836
B	8807	54	4	23	302	1837	139	792	6078	460	2621
Browns	70911	167	11	60	523	1230	80	441	2350	153	843
C	35303	46	14	34	908	1178	363	880	1297	400	969
Collins	65637	14	2	24	1169	244	44	434	209	38	371
D	36444	34	13	31	795	732	287	676	920	362	850
Duck	2878837	497	57	321	2784	481	55	311	173	20	112
E	41092	64	13	107	609	946	189	1580	1555	310	2596
F	85956	16	1	3	887	161	14	27	182	16	31
G	32051	122	9	19	286	1088	77	173	3799	267	606
H	73935	65	6	44	727	642	61	430	883	83	591
Horokiri	9270434	413	96	378	2796	124	29	114	45	10	41
I	118377	256	42	191	740	1600	262	1192	2161	354	1611
J	91150	8	2	5	2247	196	56	114	87	25	51
K	89038	4	1	3	3646	170	44	139	47	12	38
Kakaho	4342529	170	33	3	3452	135	26	2	39	8	1
Kenepuru	1836287	1305	95	572	1443	1026	75	449	711	52	311
L	24509	7	1	6	999	289	60	235	289	60	236
M	5387	35	2	5	213	1403	77	198	6583	364	930
Pauatahanui	8407454	633	139	559	2018	152	33	134	75	17	66
Porirua	6685103	3565	543	3255	1623	866	132	790	533	81	487
Ration	907519	66	18	159	1351	98	27	236	72	20	175
Takapuwahia	283872	206	27	120	818	593	77	346	725	94	423
Te Puka	2495175	203	38	272	2983	242	46	326	81	15	109
Whareroa	3521079	296	77	607	2244	189	49	387	84	22	172

Z.4 2031 With Road and Treatment Devices

Catchment	Catchment stream mouth load (kg/year)				Average yield				Average concentration (mg/kg)		
					TSS	Zn	Cu	TPH			
	TSS	Zn	Cu	TPH	Kg/ha/year	g/ha/year	g/ha/year	g/ha/year	Zn	Cu	TPH
A	27703	104	5	23	432	1618	83	361	3747	193	836
B	8807	54	4	23	302	1837	139	792	6078	460	2621
Browns	70911	167	11	60	523	1230	80	441	2350	153	843
C	35303	46	14	34	908	1178	363	880	1297	400	969
Collins	64828	12	2	22	1154	208	29	400	180	25	347
D	36444	34	13	31	795	732	287	676	920	362	850
Duck	2870315	475	48	169	2775	459	47	164	165	17	59
E	41092	64	13	107	609	946	189	1580	1555	310	2596
F	85956	16	1	3	887	161	14	27	182	16	31
G	32051	122	9	19	286	1088	77	173	3799	267	606
H	73935	65	6	44	727	642	61	430	883	83	591
Horokiri	9256008	376	81	274	2792	113	25	83	41	9	30
I	118377	256	42	191	740	1600	262	1192	2161	354	1611
J	91150	8	2	5	2247	196	56	114	87	25	51
K	89038	4	1	3	3646	170	44	139	47	12	38
Kakaho	4342529	170	33	3	3452	135	26	2	39	8	1
Kenepuru	1831454	1292	90	485	1440	1016	71	382	706	49	265
L	24509	7	1	6	999	289	60	235	289	60	236
M	5387	35	2	5	213	1403	77	198	6583	364	930
Pauatahanui	8402802	621	134	515	2017	149	32	124	74	16	61
Porirua	6677036	3544	535	3111	1621	860	130	755	531	80	466
Ration	901394	50	12	50	1342	74	18	74	55	13	55
Takapuwahia	283872	206	27	120	818	593	77	346	725	94	423
Te Puka	2486193	180	29	157	2972	215	35	188	72	12	63
Whareroa	3496034	233	51	549	2228	149	33	350	67	15	157

Note – removal efficiency for wetland + swales treatment = 88%, for filter devices = 75%

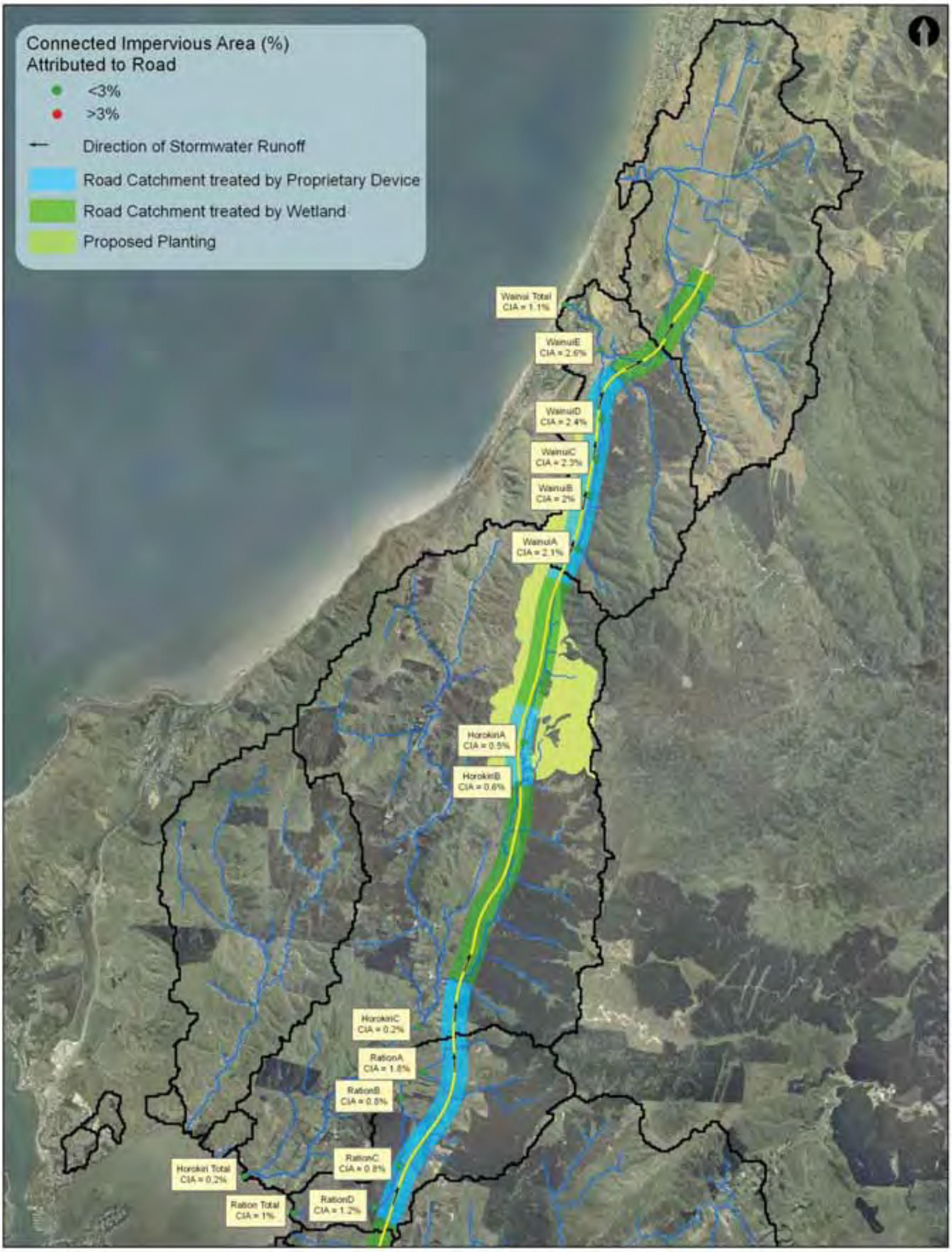
Z.5 Concentrations for Selected Catchments

Catchment (taken at mouth)	2010 Baseline				2031	2031 without road			Transmission Gully 2031 - No treatment			Transmission Gully 2031 (with treatment) Median Levels		
	Flow (m^3/s)	TSS (g/m^3)	Total Zinc (g/m^3)	Total Copper (g/m^3)	Flow (m^3/s)	TSS (g/m^3)	Total Zinc (g/m^3)	Total Copper (g/m^3)	TSS (g/m^3)	Total Zinc (g/m^3)	Total Copper (g/m^3)	TSS (g/m^3)	Total Zinc (g/m^3)	Total Copper (g/m^3)
Horokiri	1.33	222	0.009	0.002	1.33	156	0.009	0.002	156	0.010	0.002	156	0.009	0.002
Pauatahanui	1.56	171	0.012	0.003	1.56	121	0.012	0.003	121	0.013	0.003	121	0.013	0.003
Porirua	1.60	134	0.063	0.009	1.64	92	0.069	0.010	91	0.069	0.011	91	0.069	0.010
Duck	0.37	245	0.037	0.003	0.37	173	0.038	0.004	172	0.042	0.005	171	0.040	0.004
Ration	0.27	108	0.005	0.001	0.27	76	0.005	0.001	76	0.008	0.002	75	0.006	0.001
Kenepuru	0.47	123	0.083	0.006	0.48	86	0.084	0.006	85	0.086	0.006	85	0.085	0.006
Te Puka	1.32	61	0.004	0.001	1.32	43	0.004	0.001	42	0.005	0.001	42	0.004	0.001
Whareroa	2.47	49	0.001	0.001	2.47	32	0.004	0.001	32	0.004	0.001	32	0.003	0.001

Flows for 2010 and 2031 for the Horokiri, Pauatahanui, Porirua, Duck, Ration and Kenepuru streams were estimated using average wet day flows from the SWMB model

For the Te Puka and Whareroa streams 1/3 of the Q2 event flows were used.

Appendix 15.AA Catchment Imperviousness



NEW ZEALAND TRANSPORT AGENCY

WORKSTREAM 4

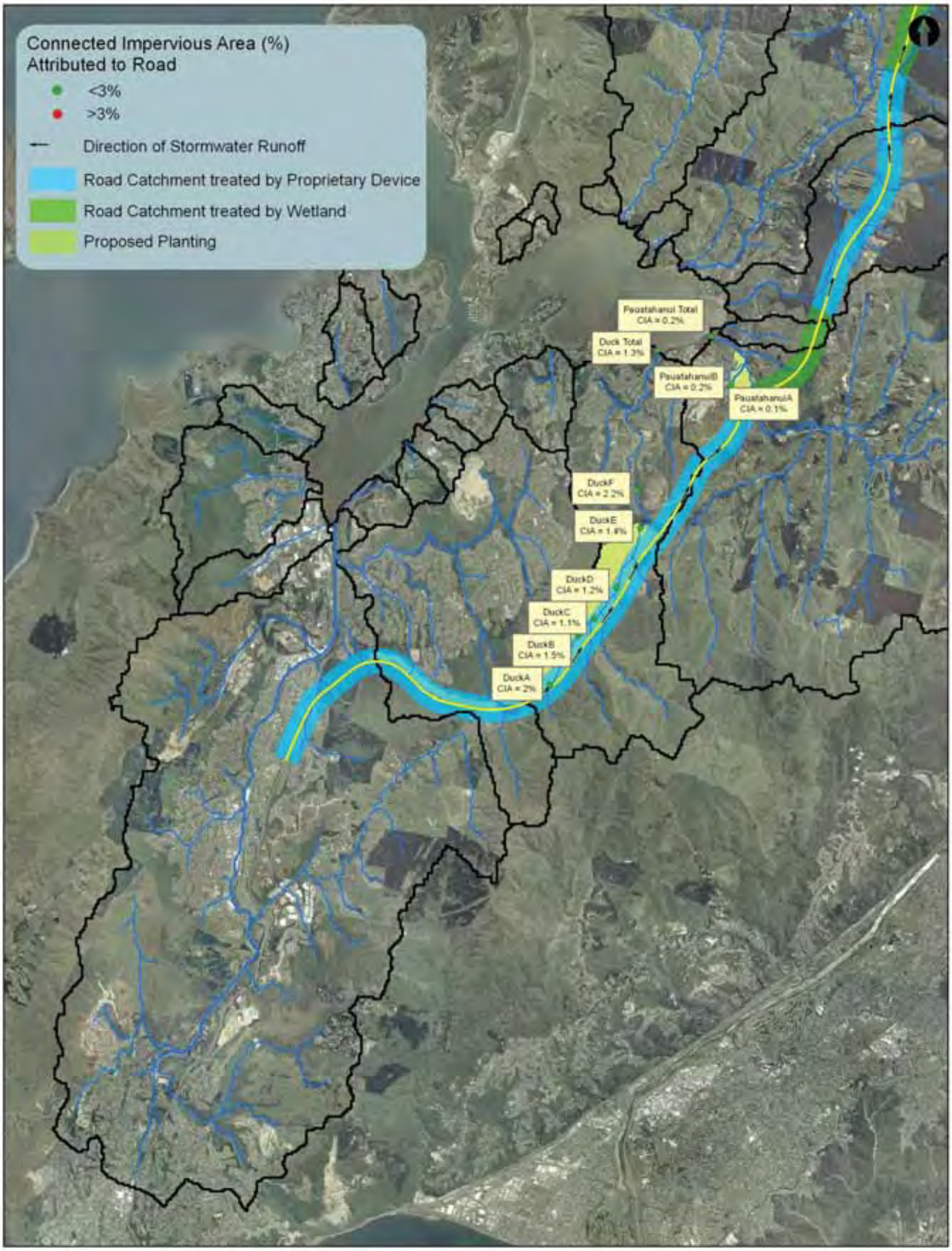
CAW

MAY 2011

Map
Catchment Connected Impervious
Area Attributed to Transmission Gully
in Rural Catchments

1:50,000

AE03778



NEW ZEALAND TRANSPORT AGENCY

Map
Catchment Connected Impervious Area Attributed to Transmission Gully in Rural Catchments

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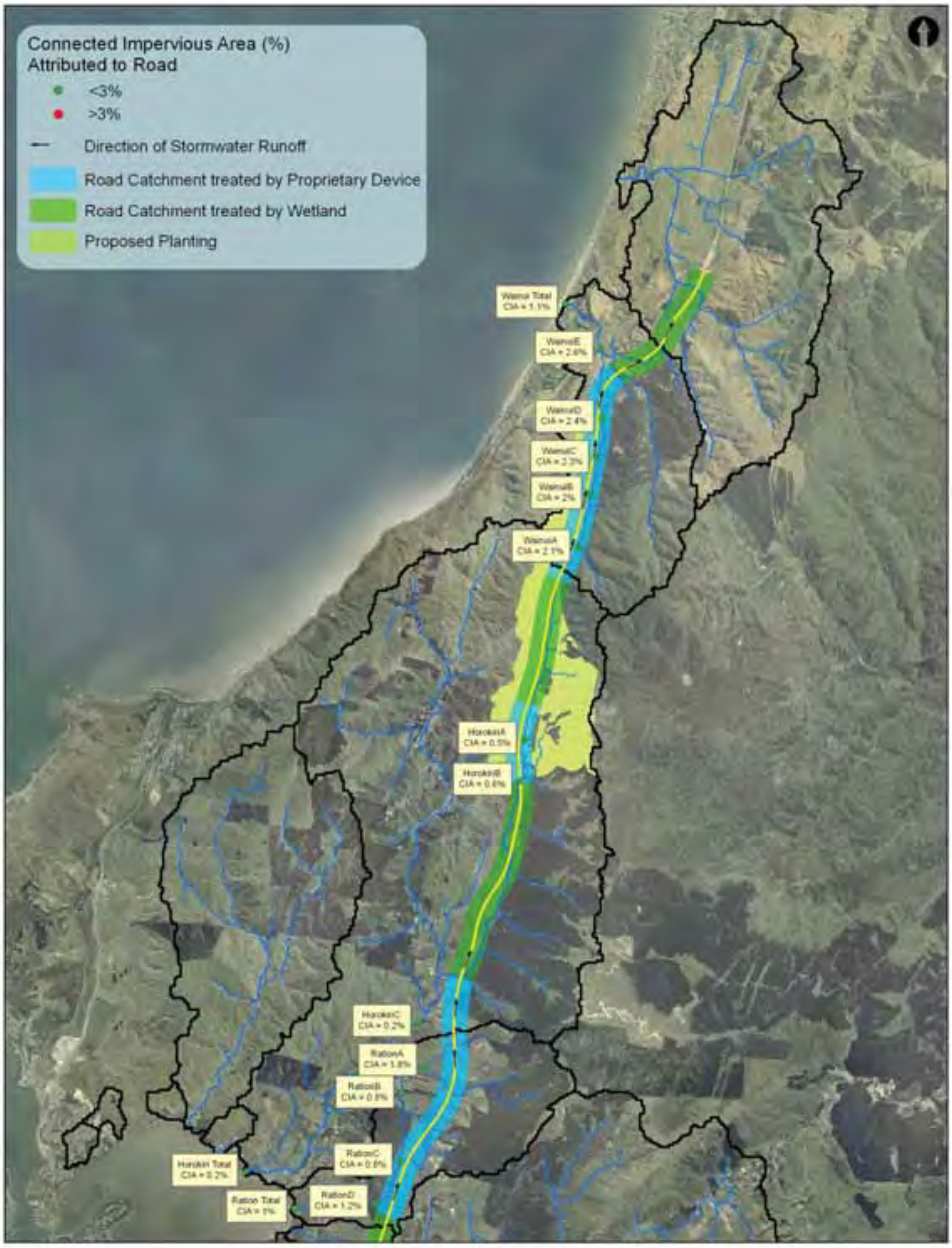

NEW ZEALAND TRANSPORT AGENCY

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Map
Catchment Connected Impervious Area Attributed to Transmission Gully in Rural Catchments

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AE03778

Appendix 15.BB Contaminant Load Model Results – Coastal Areas

Catchment	Catchment stream mouth load (kg/year)				Average yield				Average concentration (mg/kg)		
					TSS	Zn	Cu	TPH			
	TSS	Zn	Cu	TPH	Kg/ha/year	g/ha/year	g/ha/year	g/ha/year	Zn	Cu	TPH
2031 without road											
Kapiti (Te Puka - Whareroa)	6049819	482	113	768	2521	201	47	320	80	19	127
Pauatahanui (NE catchments)	26201885	1870	319	838	2447	175	30	78	71	12	32
Onepoto (SW catchments)	9266588	5745	754	4170	1440	893	117	648	620	81	450
2031 with road (no treatment)											
Kapiti (Te Puka - Whareroa)	6016286	499	116	879	2501	207	48	366	83	19	146
Pauatahanui (NE catchments)	26151136	2003	362	1523	2435	187	34	142	77	14	58
Onepoto (SW catchments)	9153502	5409	645	2493	1429	845	101	389	591	70	272
2031 with road and treatment devices											
Kapiti (Te Puka - Whareroa)	6002821	464	102	661	2495	193	43	275	77	17	110
Pauatahanui (NE catchments)	26111743	1901	322	1003	2431	177	30	93	73	12	38
Onepoto (SW catchments)	9145120	5387	636	2343	1428	841	99	366	589	70	256

Appendix 15.CC Harbour Modelling Results

CD available on request - approx. 150 maps.

Appendix 15.DD Motorway and Catchment Data

DD.1 Site Specific Data Used in Motorway Data Analysis

Catchment	Discharge analysis site	Catchment area to sampling site	Road area in catchment	Transmission Gully Traffic load (AADT)	Stormwater treatment devices (%)		Subcatchment total removal (%)			Subcatchment dissolved removal (%)	
					Wetland	Storm Filter	TSS	Zn	Cu	Zn	Cu
Pauatahanui	Pauatahanui 2	39295934	123059	28760	16	84	75	55	66	25	23
Porirua	Porirua 2	39847921	89593	31270	0	100	75	55	65	20	20
Te Puka	Te Puka 2	3653924	119885	22300	20	80	75	55	65	20	20
Whareroa	Whareroa 1	5335138	39300	26200	100	0	77	54	69	50	40
Horokiri	Horokiri 2	26263822	114342	22300	69	31	76	54	68	41	34
Duck	Duck 2	6311143	126038	22230	0	100	75	55	65	20	20
Ration	Ration 1	5324773	39083	22300	5	95	75	55	65	20	20
Kenepuru	Kenepuru 2	2043136	73950	18920	0	100	75	55	65	20	20
Te Puka	Te Puka 1	213661	5865	22300	0	100	75	55	65	20	20
Horokiri	Upper Horokiri 1	2501588	35190	22300	100	0	77	54	69	50	40
Duck	Duck 1	1093336	14450	22230	0	100	75	55	65	20	20
Kenepuru	Kenepuru 1	1592541	73950	18920	0	100	75	55	65	20	20
Duck	Duck 3	10178663	126038	22230	0	100	75	55	65	20	20
Horokiri	Horokiri 5	30549551	114342	22300	69	31	76	54	68	41	34
Kenepuru	Kenepuru 3	12513140	73950	18920	5	95	75	55	65	20	20
Ration	Ration 2	6346824	39083	22300	0	100	75	55	65	20	20
Ration	Upper Ration 1	1001145	25650	22300	0	100	75	55	65	20	20

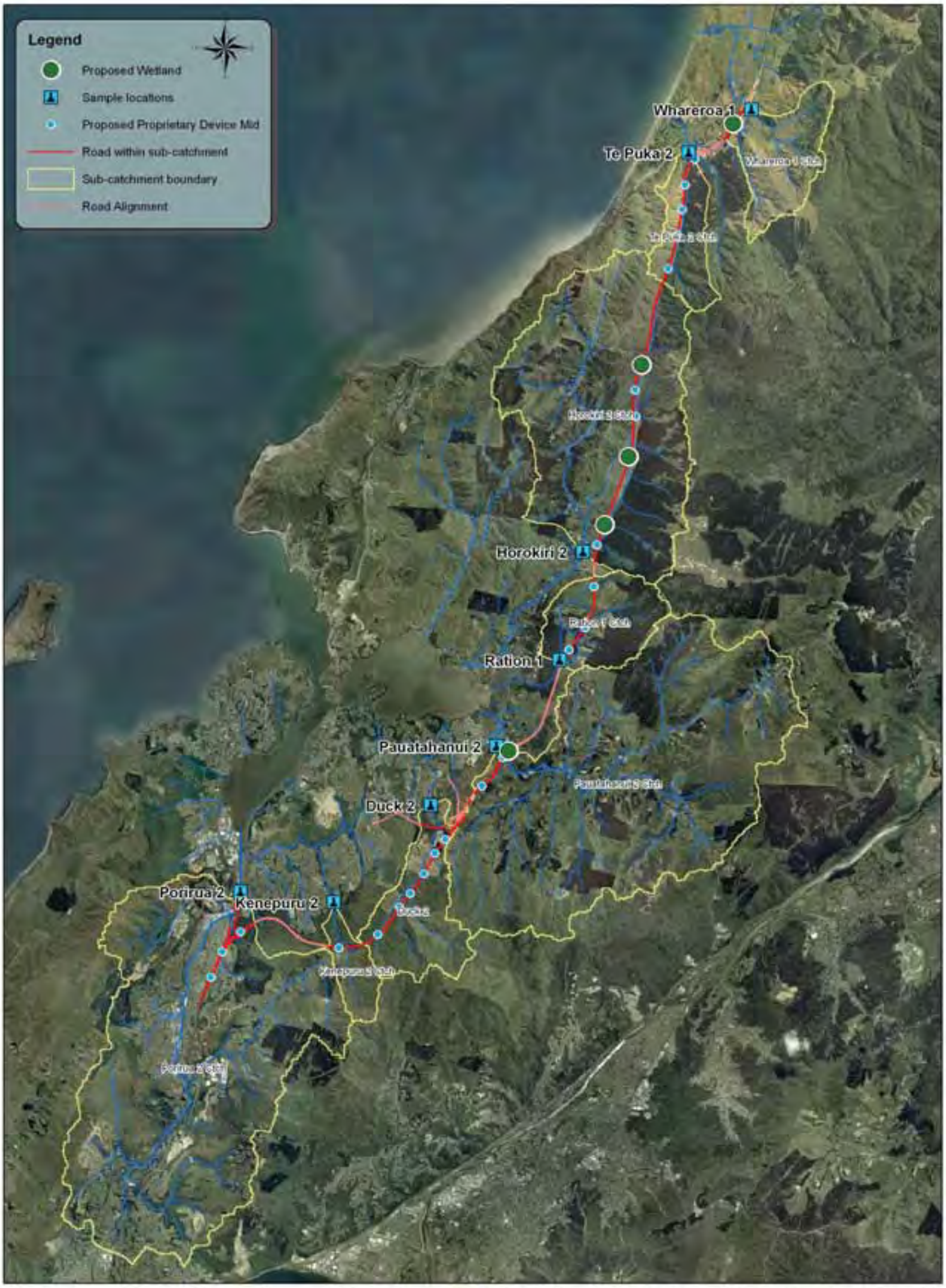
DD.2 Treatment Efficiencies for Proposed Treatment Devices

Contaminant	Total (%)		Dissolved (%)	
	Wetland	StormFilter	Wetland	StormFilter
TSS	77	75	-	-
Zinc	54	55	50	20
Copper	69	65	40	20

DD.3 Stormwater Quality Data from Auckland and Wellington Motorway Studies

Motorway Study	Vehicles per day	Median Concentration (g/m³)				
		TSS	Total Zn	Dissolved Zn	Total Cu	Dissolved Cu
Huapai	13866	107.1	0.08	0.05	0.02	0.01
Northcote	50849	8.8	0.03	0.02	0.02	0.01
Westgate	36088	76.3	0.13	0.08	0.03	0.02
Redvale	41541	47.4	0.06	0.04	0.01	0.01
All Auckland data combined	-	49.8	0.07	0.04	0.02	0.01
Wellington SH1 Tawa	36800	25.4	0.02	0.01	0.06	0.04
All Auckland and Wellington data combined	-	33.8	0.07	0.04	0.02	0.01

DD.4 Motorway Data Analysis Maps



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SKM

CLIENT NEW ZEALAND TRANSPORT AGENCY

PROJECT TRANSMISSION GULLY PHASE II STORMWATER & WATER QUALITY SCOPING

DRAWN SJB DATE JUN 24

DESIGNED AJK DESIGN REVIEW

TITLE MOTORWAY ANALYSIS IMMEDIATELY DOWNSTREAM OF ROAD

SCALE 1:85,000 SKM PROJECT No AE03778

No	DATE	DRAWN	AMENDMENT

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CLIENT NEW ZEALAND TRANSPORT AGENCY
PROJECT TRANSMISSION GULLY PHASE II STORMWATER & WATER QUALITY SCOPING
DRAWN SJE DATE JUN 24
DESIGNED SJE

TITLE
MOTORWAY ANALYSIS
MOST DOWNSTREAM
SAMPLING LOCATION
SCALE 1:85,000
SKM PROJECT No. AE03778