Transcission Gully Project

Assessment of Water Quality Effects

Technical Report 15

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Contents

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1. Executive Summary

This report assesses the water quality impacts associated with the Transmission Gully Project ("the Project") construction and operation and the proposed actions to avoid, remedy or mitigate these impacts. The assessment addresses issues associated with the quality of water that is expected to run off the land and into the streams, estuaries and coastal areas. It addresses the impact of the road both during construction and in the long term defining:

- The stream baseline water quality for key parameters
- Erosion control measures and sizing and design of sediment treatment ponds for during construction
- The effect of sediment inputs into streams during construction
- The effect of sediment inputs to the harbour and coast during construction
- The operational stormwater treatment devices sizing and design along the alignment
- The effect of the constructed road on contaminant loads in streams
- The effect of the constructed road on contaminant loads discharged to the harbour and coast.

This report should be read in conjunction with following technical reports:

- Technical Report 14: *Assessment of Hydrology and Stormwater Effects* contains the hydrological and engineering analysis used for the sizing of stormwater treatment devices and assesses the effect of increased imperviousness on stream flow regimes
- Technical Report 11: *Ecological Impact Assessment* contains the assessment of the ecological effects (based on the water quality predictions in this report) for the discharge of stormwater during construction and operation of the Project.

1.1. Water Quality Characterisation

Water quality data collection was undertaken for the following purposes:

- To describe the existing water quality in the freshwater receiving environment to inform the assessment of environmental effects
- To provide data to calibrate and validate models used to compare scenarios with and without the Transmission Gully Project
- To inform the planning of future pre-construction baseline monitoring
- To inform the planning of construction and operational stormwater discharge performance and compliance monitoring.

Table 15.1 summarises the water quality at all the monitored sites. The following points can be drawn from the data:

- Water quality in the streams within Project catchments are impacted by nutrients, including both nitrogen and phosphorus constituents, with most sites exceeding ANZECC ecological trigger levels
- Some of the urbanised streams have levels of metals which exceed ecological trigger levels. The upper reaches of streams and the more rural streams tend to have levels of metals that are below the ANZECC ecological trigger levels

- Poly-aromatic hydrocarbons were not identified at any site at levels which exceed the ANZECC ecological trigger levels
- The streams generally meet the standard for stock drinking water purposes
- The Te Puka Stream meets the standard for fishery purposes.

Table 15.1 Summary of Water Quality for All Sites

Catchment	Sampling site	Location in relation to Project	Turbidity	Metals	Nutrients	Hydrocarbons
Whareroa	Whareroa 1	Upstream	✓	✓	x	✓
Te Puka	Te Puka 1	Upstream	✓	✓	✓	✓
	Te Puka 2	Downstream	✓	✓	x	✓
Horokiri	Horokiri 1	Upstream	✓	✓	✓	✓
	Horokiri 2	Downstream	✓	✓	x	✓
	Horokiri 3	Control site	✓	✓	x	✓
	Horokiri 5	Downstream	✓	✓	x	✓
Ration	Ration 1	Upstream	✓	✓	x	✓
	Ration 2	Downstream	✓	x	x	✓
Pauatahanui	Pauatahanui 1	Upstream	✓	✓	x	✓
	Pauatahanui 2	Downstream	x	x	x	✓
Duck	Duck 1	Upstream	✓	✓	x	✓
	Duck 2	Downstream	✓	✓	x	✓
	Duck 3	Downstream	✓	x	x	✓
Kenepuru	Kenepuru 1	Upstream	✓	✓	x	✓
	Kenepuru 2	Downstream	✓	✓	x	✓
	Kenepuru 3	Downstream	x	x	x	✓
Porirua	Porirua 1	Upstream	x	x	x	✓
	Porirua 2	Downstream	x	x	x	✓

Note: ✓ indicates that median values are all within guideline values, x indicates at least one median value in this group is outside guideline values.

1.2. Construction Stormwater Discharges

This report assesses the change in water quality associated with the Transmission Gully Project construction, by comparing the scenarios with and without the Project. It addresses the following aspects of stormwater management during construction:

- Erosion control measures
- The sizing and design of sediment control ponds
- The impact of the road construction on the sediment load delivered to streams
- The sediment transport and deposition of increased sediment loads in streams
- The impact of the road construction on the sediment load delivered to the coast
- The sediment transport and deposition of increased sediment loads in Porirua Harbour

- Mitigation through the performance monitoring and adaptive management of erosion and sediment control measures.

Erosion and Sediment Control

Erosion and sediment control measures will be employed for this project. These will be in accordance with Greater Wellington Regional Council's *Erosion and Sediment Control Guidelines* (2002) and will be specified in detailed erosion and sediment control plans (ESCP) along with site specific environmental management plans (SSEMP) for each worked catchment area during the project.

It is proposed to combine the following primary construction methodologies for mitigation against sediment release to the environment:

- Targeted erosion control
- Chemically treated ponds
- Performance monitoring.

Each of these tools has the ability to control different aspects of the project and deliver measurable results. At this stage, erosion and sediment control design is at a concept stage, but has been developed in more detail at chosen sites.

The following controls will mitigate and remedy the likely effects from the construction earthworks:

- Performance monitoring will be specified within each SSEMP. This would be developed following the detailed design once the likely construction programme and design are better identified. The intent of the monitoring would be to confirm that effects that are occurring are within the predicted range, and if unanticipated effects are occurring then management changes can be made to rectify the discharge issues. The monitoring will include an assessment of the downstream changes in environmental factors including water quality, sediment deposition and ecology (Note: any ecology performance measures would be advised as an output of Technical Report 11: *Ecological Impact Assessment*).
- Strict control of chemicals and other construction materials used on site will be outlined in the Project's Environmental Management Plan. This will specify factors surrounding their delivery, storage, use, and disposal and also outline methods in place and procedures to prepare for and respond to any accidental spills
- An erosion and sediment control plan (ESCP) will be developed for the Project. This will specify measures used to minimise erosion and control sedimentation in accordance with this report and appropriate guidelines. The ESCP will specifically document methods to operate and maintain the sediment devices (including chemical treatment); to install and maintain erosion control devices; and to minimise disturbance of stream bed and banks and erosion for all planned in river works, including any temporary stream crossings.

Stream Sediment Transport Assessment

The range of potential impacts, associated with the construction of the Transmission Gully Project, on suspended and deposited sediment entering the streams during rainfall has been assessed through the hydraulic modelling of eight major streams.

Modelling has shown that the road construction is likely to increase TSS in the streams during rainfall events. During these heavy rainfall events the visual clarity, even without the additional sediment associated with the

Project construction, will be above guidelines values in all streams. While the changes may be conspicuous, the effect of the increased TSS on visual clarity and colour is only expected to occur for the duration of storm events with no lasting effect. The visual effect is considered minor.

The increase in depth of sediment deposition in streams during construction has been modelled in the 1/3 of the Q2, 10, 20 and 50 year ARI rainfall events. In most scenarios the average change in bed deposition in the nine streams is less than 1mm (especially for more the frequent events). A maximum estimated 8mm increase was identified in a 50 year ARI event in the Whareroa catchment.

The effect of any additional deposition on ecological receptors is assessed in Technical Report 11: *Ecological Impact Assessment*.

Harbour Sediment Transport Assessment

Porirua Harbour is a complex environment with many factors influencing the patterns of sedimentation. This complexity has lead to the undertaking of detailed modelling to predict the fate of additional sediment entering the harbour associated with the construction of the highway. This includes developing an understanding of the quantity, location and duration of both suspended and deposited terrestrial sediments. An envelope of potential effects has been derived from the modelling of a range of rainfall and wind conditions. In addition a simplified version of the model was used to assess the long term cumulative impacts of the Project construction.

The hydrodynamic, wave and sediment transport models constructed as part of this study demonstrate acceptable calibration with the available data. The calibration results combined with the sensitivity analysis give confidence that the model provides an acceptable tool to use in the assessment of effects on terrestrial sediment entering the harbour.

It is likely that during the construction of the Transmission Gully Project there will be one or more 2 year ARI rainfall events that could contribute up to an additional 200 tonnes of sediment (5% of the total) as a result of the Project construction. The model results indicate that there will be little impact on sediment deposition patterns in a 2 year ARI rainfall event. Should this event occur during peak construction there is likely to be isolated pockets of increased sedimentation, typically less than 5mm deep, in locations already heavily impacted and largely in the sub tidal areas of the harbour. The quantified increases in suspended sediment in a 2 year ARI rainfall event are unlikely to be visually detectable for an extended period of time.

While it is unlikely that a 10 year ARI rainfall event will occur during the predicted peak construction period a rainfall of this magnitude should be anticipated during the full construction duration. Should this event occur during the peak construction period it is predicted that between 271 and 645 tonnes of additional sediment will enter the harbour. This is estimated to be an increase of between 4 and 9% of the total sediment entering the harbour in a 10 year ARI event. The model results determined that the effects of this additional sediment are dependent on where it enters the harbour and the coincident wind conditions. The model was used to test a range of rainfall and likely wind conditions. In most of the scenarios the 10 year ARI events indicated that much of the additional sediment would be deposited in the deeper central basins of the arms in areas already experiencing high levels of deposition. However three events were singled out as having a greater impact on the more vulnerable intertidal zones. These three events were:

- High sediment loads entering the harbour from the Horokiri catchment during a southerly wind event
- High sediment loads entering the harbour from the Duck and Pauatahanui catchments during a northerly wind event

- High sediment loads entering the harbour from the Kenepuru catchment during a southerly wind event.

The long term model results provide an indication of the cumulative effects of deposition in the harbour from the full construction period. In the long term simulation an additional 3000 tonnes of sediment is estimated to enter the harbour as a result of all the construction activities. This represents around 2% of the total terrestrial sediment load entering the harbour over a 10 year period. The long term model results indicated that there was little loss of terrestrial sediment from the harbour and that much of the sediment would be deposited over time in the deeper central basins. The results indicated that after 20 years from the start of construction of the Project there would be almost no detectable increase in sedimentation rates in the Onepoto arm of the harbour and only an average increase of between 0.1 and 0.2mm/yr in the Pauatahanui Arm.

The ecological assessment of the predicted increase in sediment loads during construction in the harbour is discussed in Technical Report 11: *Ecological Impact Assessment*. For the remaining water quality management objectives, the effects of the predicted increase in sediment loads during construction is managed by the proposed erosion and sediment control measures, with minor potential effects.

1.3. Operation Stormwater Discharges

This report assesses the change in water quality associated with the Transmission Gully Project operation, by comparing the scenarios with and without the Project. The report addresses the following aspects of operational stormwater management:

- The sizing and design of operational stormwater treatment devices along the alignment
- The impact of the road operation on the contaminant load in streams
- The impact of the road operation on contaminant deposition in the harbour
- Mitigation through the maintenance and performance monitoring of stormwater management devices.

By 2031 urbanisation is projected to increase slightly in all of the catchments affected by the Transmission Gully Project. The increase in imperviousness associated with the Transmission Gully Project is 1 - 2%.

All of the stormwater discharged from the Project will be treated to remove on average 77% of total suspended solids, and will provide treatments for metals and TPH. The treatment proposed will mitigate the effects of the ongoing operation of the Project on the water quality of the freshwater and coastal receiving waters.

Contaminant load models developed for the Project predict the change in contaminant load on a catchment basis for all streams that will receive stormwater discharges, and for the Porirua Harbour on a grouped catchment basis. This illustrates the relative change in contaminant load in the situation with and without the Project, and enables the cumulative effect of the Transmission Gully Project to be assessed in the context of the wider catchments.

In some stream catchments, the levels of TSS, metals and TPH in the treated stormwater discharges are predicted to increase. Even without the Project the stream catchments with sediment quality that exceeds the ISQG guidelines trigger levels for ecosystems are: the Porirua, Kenepuru and Collins for zinc and the Porirua for copper.

The contaminant load for the Porirua and the Collins is predicted to reduce in the scenario with the Transmission Gully Project. The increase in contaminant load in the Kenepuru is 2% for zinc. For all other streams the sediment quality is predicted be below the ISQG- Low ecological trigger values. There is no change predicted in the rate or location of sediment deposition in streams in operational phase of the Transmission Gully Project.

The small increase in imperviousness associated with the Project has only a slight effect on stream flows. Wetlands will be designed to include extended detention. This will mitigate the hydrological effects in those catchments that are suitable for wetland treatment. In addition, native planting is proposed as part of the ecological mitigation. This planting will in part compensate for increases in imperviousness in some catchments. In every case erosion protection measures will be used to protect streams from erosion at point source discharge locations.

In the Onepoto Arm Inlet of the Porirua Harbour, levels of TSS, metals and TPH in stormwater discharged to the arm as a whole are predicted to decrease. This is because the Transmission Gully Project will displace traffic off roads that also drain to Porirua Harbour and that do not provide stormwater treatment. The Project provides the opportunity to provide stormwater treatment as an integral part of the road design.

In the Pauatahanui inlet arm of the Porirua harbour, levels of TSS, metals and TPH in stormwater discharged to the inlet as a whole are predicted to increase. The reason the increase is small is because the Transmission Gully Project will displace traffic off roads that also drain to the Pauatahanui inlet and that do not provide stormwater treatment. The Transmission Gully project will result in a change in distribution of stormwater discharges, with decreased contaminant loads in the Browns, Collins and Kakaho and some small stormwater outfalls and increases in the Duck, Pauatahanui, Ration and Horokiri.

On the Kapiti Coast, levels of TSS, metals and TPH in stormwater discharged are predicted to decrease. Again, the reason for the decrease is because the Transmission Gully Project will displace traffic off roads that also drain to Kapiti Coast and that do not provide stormwater treatment.

2. Introduction

The Transmission Gully Project (the Project) consists of three components:

- The "Transmission Gully Main Alignment" (the Main Alignment) involves the construction and operation of a State Highway formed to expressway standard from Linden to MacKays Crossing. The NZ Transport Agency (NZTA) is responsible for the funding and delivery of the Main Alignment.
- The "Kenepuru Link Road" involves the construction and operation of a State Highway (limited access road) from the Kenepuru Interchange to Kenepuru Drive. The NZTA is responsible for the funding and delivery of the Kenepuru Link Road
- The "Porirua Link Roads" involves the construction and operation of two local roads connecting the Main Alignment to the existing eastern Porirua road network. The Porirua City Council (PCC) is responsible for the funding and delivery of the Porirua Link Roads.

2.1. The Transmission Gully Main Alignment

The Main Alignment will provide an inland State Highway between Wellington (Linden) and the Kapiti Coast (MacKays Crossing). Once completed, the Main Alignment will become part of State Highway 1 (SH1). The existing section of SH1 between Linden and MacKays Crossing will likely become a local road.

The Main Alignment is part of the Wellington Northern Corridor (Wellington to Levin) Road of National Significance (RoNS). The Wellington Northern Corridor is one of the seven RoNS that were announced as part of the Government Policy Statement on Land Transport Funding (GPS) in May 2009. The focus of the RoNS is on improved route security, freight movement and tourism routes.

The Main Alignment will be approximately 27km in length and will involve land under the administrative jurisdiction of four separate territorial authorities: Wellington City Council, Porirua City Council, Upper Hutt City Council, and Kapiti Coast District Council. The Main Alignment will be a motorway under Section 71 of the Government Roading Powers Act 1989 (GRPA).

The key design features of the Main Alignment are:

- Four lanes (two lanes in each direction with continuous median barrier separation)
- Rigid access control
- Grade separated interchanges
- Minimum horizontal and vertical design speeds of 100 km/h and 110km/hr respectively
- Maximum gradient of 8%
- Crawler lanes in some steep gradient sections to account for the significant speed differences between heavy and light vehicles.

2.1.1.The Kenepuru Link Road

The Kenepuru Link Road will connect the Main Alignment to western Porirua. The Kenepuru Link Road will provide access from Kenepuru Drive to the Kenepuru Interchange. This road will be a State highway (limited access road) designed to following standards:

- Two lanes (one in each direction)
- Design speeds of 50 km/h
- Maximum gradient of 10%
- Limited side access

2.1.2.Porirua Link Roads

The Porirua Link Roads will connect the Main Alignment to the eastern Porirua suburbs of Whitby (Whitby Link Road) and Waitangirua (Waitangirua Link Road). The Porirua Link Roads will be local roads designed to the following standards:

- Two lanes (one in each direction)
- Design speeds of 50 km/h
- Maximum gradient of 10%
- Some side access will be permitted

2.2. Background to the Transmission Gully Project

The concept of an inland, alternative route to bypass the existing SH1 coastal route and communities north of Wellington was first raised in the early 1940s and has been under consideration by various parties ever since.

The key events in the development of the Transmission Gully Project are:

- In the early 1940s, there was first talk of an alternative inland route for SH1 north of Wellington.
- In 1981, the National Roads Board embarked on an assessment of the Western Corridor (undertaken by the Ministry of Works and Development and the Ministry of Transport) looking at options for an inland route (now known as Transmission Gully) in comparison to an upgrade of the coastal route.
- In 1986, the findings of the National Roads Board's Western Corridor Report were released with the report rejecting an inland route and supporting major improvements along the existing coastal route.
- In 1987, the Greater Wellington Area Land Use and Transportation Strategic Review (GATS) was jointly funded by the National Roads Board, Wellington Regional Council and the Urban Transport Council. The Western Corridor section was separated out for early consideration. The GATS considered a large number of options including routes through Porirua East/Whitby, Takapu Valley, Belmont deviation through Belmont Regional Park to SH2, as well as upgrades to the coastal route.
- In 1989, an environmental impact report (EIR) was produced to compare the impacts of options proposed in GATS including public transport and roading upgrades. The EIR considered both coastal and inland options. The EIR concluded that in addition to public transport upgrades, roading improvements were required to address the growing congestion on SH1. The EIR found the inland route was more environmentally and socially acceptable. The favoured route was an inland alignment from MacKays Crossing to Takapu, continuing through the Takapu Valley with an interchange on SH1 at Tawa.

- In 1990, the Parliamentary Commissioner for the Environment (PCE) conducted an audit of the EIR. The PCE agreed in principle with the findings of the EIR with some reservations and recommendations. The audit found that Takapu Valley was not necessarily the best alignment at the southern end and that further investigation of the links to the Hutt Valley and Porirua was required. The PCE's principal recommendations were to finalise and designate the inland route and to consult with the public to reduce uncertainty for both the coastal and inland route communities.
- In 1991, the Wellington Regional Council conducted further investigations into possible alignments at the southern end. A number of alignments were examined and the conclusion was for a connection to SH1 at Linden as well as connection to western Porirua via a Kenepuru link. Justification for this was clear benefits to the management of Porirua traffic and relief to SH58 around Pauatahanui Inlet. This would also reduce environmental and social impacts associated with the Takapu Valley option.
- In 1996, a preliminary design was produced for the Linden to MacKays Crossing alignment and the notices of requirement were lodged.
- In 1997, the hearing takes place for the notices of requirement for the Linden to MacKays Crossing alignment.
- In 2003, all the appeals on the notices were finally resolved and the designations for the Linden to MacKays Crossing alignment were included in the relevant district plans.
- In 2004, an existing local road designation was altered to provide local road access to the Linden to MacKays Crossing alignment from eastern Porirua.
- In 2004, the Western Corridor Transportation Study (jointly commissioned by Greater Wellington Regional Council and Transit New Zealand) commenced to provide the basis for an integrated transportation strategy to manage travel demands in the Western Corridor. The resulting Western Corridor Plan (WCP) included consideration of major public transport and roading options and travel demand management (TDM) initiatives. Consultation on the WCP indicated that affected communities did not support the coastal route and expressed a strong preference for the Transmission Gully Project.
- In 2006, the WCP was endorsed by the Transit NZ Board and adopted by the Greater Wellington Regional Council and included the Transmission Gully Project in the Regional Land Transport Strategy (2007 to 2016) for construction within 10 years as part of a balanced multi-modal approach to addressing transport needs within the Western Corridor.
- In 2008, a draft scheme assessment report (SAR) was undertaken which involved the assessment of numerous options for a Transmission Gully Project alignment both within and outside the confines of the existing designation. Together with a detailed consultation process, preferred alignment for Transmission Gully Project was produced.
- In 2009, detailed environmental and engineering investigation work commenced for the Project.
- In May 2009 the GPS is released which included the RoNS programme. The Wellington Northern Corridor is one of the RoNS.
- In December 2009, NZTA's Board announces that the Transmission Gully Project is the preferred route to improve access through the southern end of the Western Corridor. The NZTA press release stated; "our task was to choose the route which would deliver the best result for the region and New Zealand [as part of the Roads of National Significance], while also bearing in mind the potential impact on the environment and surrounding communities. In the end it was clear that Transmission Gully was the better choice. It is

less expensive, it will provide a safer four-lane route, it's better for local communities and better for the environment, and it will reduce travel times between Kapiti and Wellington".

- In 2010, detailed environmental and engineering investigation work is progressed and the preferred alignment is optimised to accommodate road design, ecological, water quality and other considerations. In March, the NZTA signals its intention to lodge the statutory RMA documentation with the EPA using the new "national consenting process".

2.3. Project Description

2.3.1. Transmission Gully Main Alignment

The Main Alignment is a proposed 27km expressway from Linden in Wellington City to MacKays Crossing on the Kapiti Coast.

The Main Alignment consists of nine sections:

Section number	Section name	Station value (m)	Length (km)
1	MacKays Crossing	00000 – 03500	3.5
2	Wainui Saddle	03500 – 06500	3.0
3	Horokiri Stream	06500 – 09500	3.0
4	Battle Hill	09500 – 12500	3.0
5	Golf Course	12500 – 15500	3.0
6	State Highway 58	15500 – 18500	3.0
7	James Cook	18500 – 21500	3.0
8	Cannons Creek	21500 – 24900	3.4
9	Linden	24900 – 27700	2.8

Section 1: MacKays Crossing

This section is approximately 3.5km long, and extends from the tie-in at the existing MacKays Crossing Interchange on SH1 to the lower part of the Te Puka Stream valley. The Main Alignment will connect to the existing SH1 at approximately 00700m. The first 700m is the existing State Highway 1 alignment which is a grade separated interchange providing access across the North Island Main Trunk rail line (NIMT). Any alteration to the MacKays Crossing Interchange will be minimal.

This section of the Main Alignment will provide for three lanes in the northbound carriageway from 00700m and from 02100m in the southbound carriageway. Southbound traffic will be able to exit the Main Alignment at approximately 01250m. This exit will pass under the Main Alignment at approximately 01800m and will connect to the existing SH1 heading south towards Paekakariki. Traffic heading northbound from Paekakariki will be able to join the Main Alignment from a connection at approximately 01200m.

A subway at 01990m will provide vehicular access across the state highway to three properties. This subway will also provide access across the Main Alignment for pedestrians, cyclists and stock. For the rest of this section heading south, the carriageway will be three lanes in both directions and rises up the Te Puka Stream valley. At approximately 02900m there will be an arrestor bed adjacent to the northbound carriageway for any out of control vehicles heading downhill. The section finishes at 03500m.

Section 2: Wainui Saddle

Section 2 starts at approximately 03500m and will continue climbing for about 2km to the top of the Wainui Saddle at approximately 262m above sea level (at about 05500m). This will be the highest point of the Main Alignment. Just south of the Wainui Saddle peak at about 05600m there will be a brake check area for both northbound and southbound carriageways. Slightly further south, at approximately 06000m, three lanes in each direction will be reduced to two lanes in each direction. Section 2 finishes at 06500m.

Section 3: Horokiri Stream

This section is approximately 3km long and extends from the southern end of the Wainui Saddle to the northern end of Battle Hill Farm Forest Park. For the entire length of this section, the Main Alignment will run generally parallel to the Horokiri Stream. From 06500m to approximately 08550m the Main Alignment will be to the west of the Horokiri Stream, while from 08550m to 09500m it will be to the east of the stream. As the Main Alignment runs parallel to the stream it will cross a number its minor tributaries which generally run perpendicular to the Horokiri Stream and the Main Alignment.

Over this section, the Main Alignment will cross the Horokiri Stream once with a bridge at 08540m. The section finishes towards to northern boundary of the Battle Hill Farm Forest Park (BHFFP) at approximately 09500m.

Section 4: Battle Hill

This section is approximately 3km long and extends from the northern boundary of the BHFFP to the Pauatahanui Golf Course. Shortly after the Main Alignment enters the BHFFP from the north it crosses over the Horokiri Stream with a bridge at approximately 09720m. Over the remainder of this section heading south the Main Alignment will follow the Horokiri Valley floor which widens from north to south through the BHFFP.

Access across the Main Alignment for park users will be provided by a subway located at approximately 10500m. This will provide a connection between the eastern and western part of the park for pedestrians, cyclists and stock. The Main Alignment will continue south from the BHFFP boundary towards the Pauatahanui Golf Course. At about 11750m it will crosses an unnamed stream with a bridge. Access across the Main Alignment will be available underneath this bridge. The section finishes at 12500m where there will be a subway providing pedestrian and stock access across the Main Alignment.

Section 5: Golf Course

This section is approximately 3km long, and extends from north to south through rural land adjacent to the Pauatahanui Golf Course and Flighty's Road. The Main Alignment will cross a number of small tributaries along this section but there will be no major stream crossings requiring bridges.

Section 6: State Highway 58

This section is approximately 3km long and starts at 15500m. The SH58 / Pauatahanui Interchange will be located at approximately 17500m. At this interchange the Main Alignment will be elevated above a roundabout which will provide access to and from the Main Alignment for traffic travelling in both directions on existing SH58. Immediately south of this interchange, at approximately 17660m, there will be a bridge across the Pauatahanui Stream.

At approximately 18250m the Main Alignment will widen to provide three lanes in each direction. This section finishes at approximately 18500m.

Section 7: James Cook

This section starts just south of the State Highway 58 / Pauatahanui Interchange, at approximately 18500m. Three lanes will be provided for both the northbound and southbound carriageways. The James Cook Interchange will be located at approximately 19500m. This will be a dumbbell interchange with the Main Alignment being elevated above the local road connections. These roads will provide access to the Main Alignment in both directions to and from the Porirua Link Roads. In the vicinity of this interchange, the number of lanes in each direction will be reduced from three to two. This will occur at approximately 18900m in the northbound carriageway and at 19500m in the southbound carriageway. From the James Cook Interchange, the Main Alignment will continue southwards for a further 2km. This section finishes at approximately 21500m.

Section 8: Cannons Creek

This section begins at 21500m and is approximately 3.4 km long. Throughout this section the Main Alignment will run along the eastern side of Duck Creek valley, and across an undulating, weathered greywacke plateau between Duck and Cannons Creeks.

There will be four bridges in this section:

- A 140m long bridge starting at 21555m, crossing a tributary of Duck Creek
- A 150m long bridge starting at 21845m, crossing a tributary of Duck Creek
- A 160m long bridge starting at 22780m, crossing a tributary of Duck Creek
- A 260m long bridge starting at 23550m, crossing Cannons Creek.

These bridges will follow the horizontal alignment of the Main Alignment. This section finishes at 24900m.

Section 9: Linden

This southernmost section is approximately 2.8km long. From the start of the section at approximately 24900m, a third lane will be provided in the northbound carriageway heading uphill.

There will be two bridges:

- A 50m long bridge starting at 25790m, crossing an unnamed stream that flows into the Onepoto arm of the Porirua Harbour
- A 90m long bridge starting at 26010m, crossing an unnamed stream that flows into the Onepoto arm of the Porirua Harbour.

The Kenepuru Interchange will be located at approximately 26700m. This interchange will involve the Main Alignment being elevated above a roundabout which will connect to the Kenepuru Link Road.

South of the Kenepuru Interchange, the Main Alignment will continue downhill to where it will tie into the existing SH1 along the Tawa straight. For traffic joining the Main Alignment in a northbound direction, the carriageway will be elevated and will pass over the existing southbound SH1 carriageway. Traffic continuing to Porirua will be able to do so by taking the left lane exit from the existing SH1.

2.3.2.The Kenepuru Link Road

The Kenepuru Link Road will provide a connection from the Main Alignment to western Porirua. This link road will provide a connection from the Kenepuru Interchange to the existing Kenepuru Drive and will be approximately 600m long. There will be a roundabout at the intersection with Kenepuru Drive. The Kenepuru Link Road will be a State Highway (limited access road) designed to the following standards:

- Two lanes (one in each direction)
- Design speeds of 50 km/h
- Maximum gradient of 8%
- Limited access only.

The Kenepuru Link Road will contain a curved 240m long bridge over the existing SH1 and the NIMT.

2.3.3.Porirua Link Roads

The Porirua Link Roads will connect the Main Alignment to the eastern Porirua suburbs of Whitby and Waitangirua. The Porirua Link Roads will be local roads designed to the following standards:

- Two lanes (one in each direction)
- Design speeds of 50 km/h
- Maximum gradient of 10%
- Some side access will be permitted.

The Waitangirua Link Road will be approximately 2.5km long will run from the James Cook Interchange to the existing intersection of Niagara Street and Warspite Avenue. This will be a signalised intersection. The Waitangirua Link Road will cross five waterways. The most significant of these will be a crossing of Duck Creek requiring a culvert. The Waitangirua Link Road will link into the western side of the James Cook Interchange.

The Whitby Link Road will be 0.9km long and will run from the existing roundabout at the intersection of James Cook Drive and Navigation Drive to the Waitangirua Link Road. The new intersection of the proposed Waitangirua and Whitby link roads will be an unsignalised T-intersection with traffic from the Whitby Link Road giving way to Waitangirua Link Road traffic.

2.4. Development of the Current Design

The scheme assessment report (SAR) was undertaken between 2006 and 2008. The key objective for this phase was to identify the most advantageous route alignment which could then be further refined and used for assessment and consenting.

The SAR is referred to as Phase I and the investigations and assessments (the current phase) are referred to as Phase II. Phase III refers to the consenting of the Project.

Work undertaken on the route since 2006 provided the first real opportunity to conduct on-site, in-depth investigations into the impact of the proposed alignment from an engineering and environmental perspective.

The key aspects that were considered during the SAR phase were:

- Geotechnical constraints
- Physical environmental impacts
- Social impacts
- Cost
- Timeliness
- Network flexibility
- Route performance and safety.

The associated findings from these investigations indicated that the proposed route provides several significant benefits over the existing designated alignment and the coastal route.

The key benefits include:

Improving Route Security

While both the existing coastal route and the Transmission Gully Project route traverse fault lines, the Transmission Gully Project's proposed design offers greatly improved route security for the existing State Highway 1 and the region's road network over the existing coastal route.

Where the route is vulnerable to damage from major seismic events, engineered earth embankments have been used rather than bridge structures, which will provide greater resilience and allow easier and quicker reinstatement in order to restore road access to the region.

Improving Highway Safety and Function

The alignment will be constructed for open road speed limits (100km/h) and a median barrier will be provided along the entire route. Crawler lanes and an arrester bed as well as 'run-off areas' for out of control vehicles) on the steepest sections, along with grade separated interchanges to remove conflicts associated with vehicle turning movements provide additional safety improvements over the coastal route.

Managing Environmental Impacts

Generally, the proposed route provides greater opportunities to manage environmental impacts as compared to the previously designated alignment or the coastal route. The mitigation measures required by conditions on the existing designation (such as the planting of approximately 150,000 native trees and shrubs) will still be able to be utilised in the proposed alignment.

Improving Connections to Local Roads

An eastern Porirua interchange known as the James Cook Interchange will connect to both James Cook Drive in Whitby and Warspite Avenue in Waitangirua, providing improved connections with the wider Porirua area.

The Kenepuru Link Road will also connect the Main Alignment to western Porirua.

3. Road Design

The design used for this assessment is described in Technical Report 1: *Design Philosophy Statement: Roading Design*.

3.1. Construction Staging

The staging assumptions are based on work undertaken by MacDonald International for NZTA. The staging scenario that has been used for the assessment of effects for the construction and operational stormwater discharges is considered to be realistic representation of a likely construction programme for the proposed design.

The construction scenario assumes the Transmission Gully Project is constructed on three fronts simultaneously (based on catchments):

- Front 1 – State Highway 58 to Cannons Creek (Ch. 16830 – Ch. 23600)
- Front 2 – MacKays Crossing to State Highway 58 (Ch.00 – Ch. 16830)
- Front 3 – Cannons Creek to Linden (Ch. 23600 – Ch. 27700).

Other key construction assumptions relevant to calculating potential sediment loads are as follows:

- The current highway alignment will be used as the haul road for the majority of the work
- The constructed road will be sealed progressively as work progresses
- The total area of open road will be minimised with the maximum length of road being opened up, within any one catchment, limited to 3km.
- With consideration of the topography and likely road construction techniques the average width of open earthworks is predicted to be approximately 100m with approximately 25% of this area likely to be stabilised to at least pre construction levels.

3.1.1. Streams

A six year programme was considered which allowed for simultaneous construction on three fronts. For the steams assessment the year with the maximum active earthworks was considered for each catchment.

- **Table 15.2 Maximum Active Earthworks Area in Each Individual Stream Catchment**

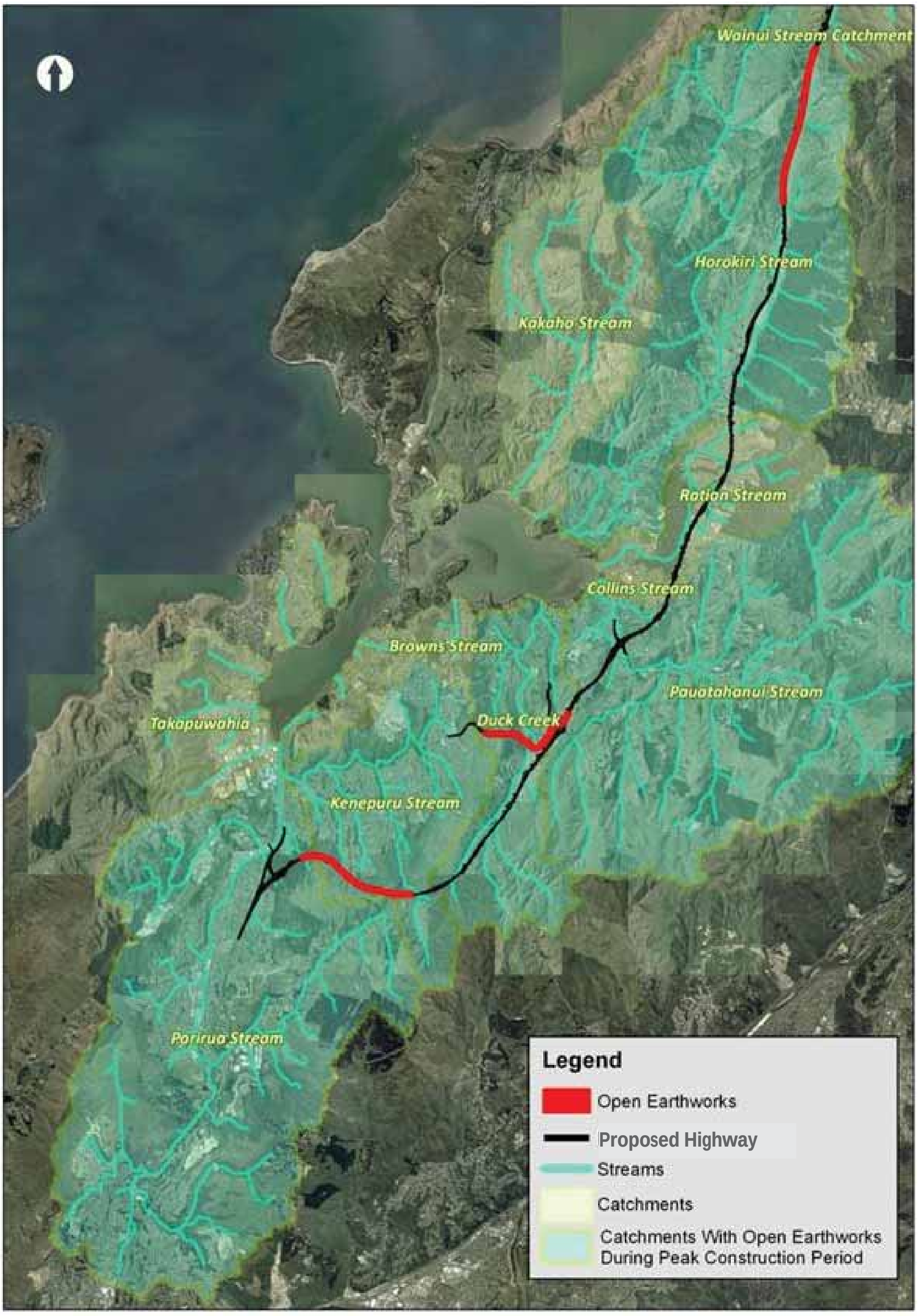
Catchment	Active length (km)	Active area (Ha)
Whareroa	0.6	4.5
Te Puka	2	15
Horokiri	2.8	21
Ration	3.2	24
Collins	0.4	3
Pauatahanui	1.8	13.5
Duck	1.8	13.5
Kenepuru	1.1	8.25
Porirua	1.8	13.5

3.1.2.Harbour

Again a six year programme was considered which allowed for simultaneous construction on three fronts. The Macdonald International estimation of the likely staging programme was assessed and the period in which the maximum cumulative active earthworks in the Pauatahanui Inlet catchment was used for the modelling effects in the Porirua harbour described in **Section 11**. At the peak of construction there is a total of approximately 5km of highway earthworks open in the Pauatahanui Inlet catchment and 2.3km open in the Onepoto Catchment. The earthworks areas that were assumed to be open in this scenario are recorded below and illustrated in **Figure 15.1**.

Pauatahanui Inlet	**Length**	**Area**[1]
▪ Horokiri	3.0km	(22.5Ha)
▪ Duck	1.9km	(14.25Ha)
▪ Pauatahanui	0.1km	(0.75Ha)
Onepoto Arm	**Length**	**Area**[1]
▪ Kenepuru	2.1km	(15.75Ha)
▪ Porirua	0.2km	(1.5Ha)

[1] Assuming an average 75m width of un-stabilised earthworks



- **Figure 15.1 Areas of Open Earth Works Used in the Event-Based Simulations**

3.2. Erosion and Sediment Control Devices

Erosion and sediment control measures are an integral part of the proposed road construction methodology. The erosion and sediment control philosophy is described in **Section 9**.

Erosion and sediment control treatment standards require that sediment control devices are sized on contributing catchment area. The required volume has been calculated to provide 300m^3 of storage capacity for each hectare of contributing catchment. Calculated pond volumes for catchments requiring treatment by retention ponds are summarised in **Appendix 15.M**. Note that this list excludes catchments in which decanting bunds, super silt fences, etc have been the recommended sediment treatment device. Where devices other than ponds are used, these will be designed to have the same volume.

3.3. Stormwater Management Devices

Stormwater management devices are an integral part of the proposed road design. The stormwater treatment philosophy is described in **Section 15**. The design and location of assessed devices is described in **Section 16**.

4. Purpose and Scope

This report presents the findings of water quality measurements, modelling, and assessment and mitigation design conducted as part of the environmental assessment of the Transmission Gully Project. It addresses issues associated with the discharge of stormwater that during construction and operation.

This report should be read in conjunction with a number of other technical reports:

- Technical Report 14: *Assessment of hydrology and stormwater effects*, which contains the hydrological and engineering analysis used for the sizing of stormwater treatment devices and assesses the effect of increased imperviousness on stream flow regimes.
- Technical Report11: *Ecological impact assessment*, which contains the assessment of the ecological effects of the construction and operational stormwater discharges, which are predicted in this report.

4.1. Water Quality Characterisation

The water quality characterisation data collection was undertaken for the following purposes:

- To describe the existing water quality in the freshwater receiving environments to inform the assessment of environmental effects
- To provide data to calibrate and validate models used to compare the scenarios with and without the Transmission Gully Project
- To inform the design of future pre-construction baseline monitoring
- To inform the design of construction stormwater discharge performance and compliance monitoring
- To inform the design of operational stormwater discharges performance and compliance monitoring.

4.2. Construction Stormwater Discharges

This report assesses the change in water quality associated with the Transmission Gully Project construction, by comparing the scenarios with and without the Project at 2021. The report addresses the following aspects of stormwater management during construction:

- The erosion control measures
- The sizing and design of sediment control ponds
- The impact of the road construction on the sediment load delivered to streams
- The sediment transport and deposition of increased sediment loads in streams
- The impact of the road construction on the sediment load delivered to the coast
- The sediment transport and deposition of increased sediment loads in Porirua Harbour
- Mitigation through the performance monitoring and adaptive management of erosion and sediment control measures.

4.3. Operational Stormwater Discharges

This report assesses the change in water quality associated with the Transmission Gully Project operation, by comparing the scenarios with and without the Project at 2031. The report addresses the following aspects of operational stormwater management:

- The sizing and design of operational stormwater treatment devices along the alignment
- The impact of the road operation on contaminant load in streams
- The impact of the road operation on contaminant load discharged to the coast
- The impact of the increase in imperviousness associated with the road on stream flow regimes.

5. Description of Receiving Environments

The following describes the receiving environment in relation to water quality.

5.1. Streams

There are nine stream catchments that will receive operational stormwater discharges from the Transmission Gully Project.

- Porirua
- Kenepuru
- Duck
- Pauatahanui
- Ration
- Collins
- Horokiri
- Wainui/Te Puka
- Whareroa.

The Regional Freshwater Plan (GWRC, 1999) identifies that the streams in the study area are required to be managed for a number of purposes including:

- Aquatic ecosystems (Horokiri Stream, Ration Stream)
- Fishery and fish spawning (Wainui Stream)
- Nationally threatened indigenous fish and aquatic plants (Whareroa Stream, Wainui Stream, Horokiri Stream, Ration Stream, Pauatahanui Stream, Duck Creek)
- High degree of natural character (Pauatahanui and Horokiri)
- Standard water quality standards (Kenepuru Stream, Porirua Stream)

The Porirua, Kenepuru and Duck catchments are impacted by urban development. The Porirua Stream in its upper reaches is largely natural though in some areas the aquatic macroinvertebrate habitat is poor. Flow through the urban areas is through controlled channels. The Kenepuru Stream and a major tributary Cannons Creek channel flows through largely unnatural stream beds. Through the urban area the channel is concrete lined and at points along the stream there are perched culverts and concrete steps obstructing fish passage. The water quality and the ecology of these streams are degraded.

The upper reaches of the Duck catchment is largely pasture, flowing into plantation forest through the middle reach, and urbanisation at the lower end. It is a steep catchment thereby restricting fish passage to climbing species only. Even with development in the lower reaches, on the whole the water quality and ecology in this stream is good.

The remaining streams are largely rural in nature, many with steep upper reaches and flat lower reaches whereby sediment deposition can occur on the plains. They are impacted by nutrients, but have low levels of metals and TPH. They are briefly described below.

Pauatahanui Stream flows through bush and shrubland in the upper catchments, exotic shelter belts and pasture through the middle reach and transforms to a relatively wide lowland stream draining through a wetland into the Pauatahanui Inlet. The stream is in a reasonably natural condition with good riparian cover.

The Ration and Collins catchments are similar. They are relatively flat catchments draining plantation forest (Ration) and pasture. In the upper reaches water is not necessarily flowing, and where it is, velocities can be slow. The water is often cloudy and nutrient and sediment levels can be high. Both catchments drain to the Pauatahanui Inlet.

Horokiri and Wainui/Te Puka catchments both have steep headwaters and middle reaches. In the Horokiri the river becomes a large slow lowland river running through an alluvial plain. The stream is relatively unmodified and in good condition with clear water, even though exotic pasture in the upper reaches is unprotected from stock. The Wainui/Te Puka Stream has good aquatic habitat in the upper reaches, before flowing through forest forming a semi-braided stream with simple uniform habitat. As the gradient falls in the lower reach the stream is impacted by farming.

The upper reaches of the Whareroa catchment are very steep, draining mainly pasture with some areas of scrub and plantation forest. The lower reaches below SH1 are very flat, with many pastoral drain tributaries unprotected from stock. Velocities are slow and water quality is poor through these lower reaches.

Further information on these catchments is available in the following places:

- The water quality characterisation of each stream is described in **Section 6** of this report
- The sediment transport characteristics of the streams are described in **Section 11** of this report
- The physical characteristics and ecology of the stream is described in Technical Report 9: *Freshwater Habitats and Species: Descriptions and Values*.

5.2. Porirua Harbour

The Porirua Harbour is low energy estuarine receiving environment, which receives and accumulates sediment discharged from the streams receiving runoff from the Transmission Gully Project.

Further information on the Porirua Harbour is available in the following places:

- The physical characteristics and ecology of the harbour is described in Technical Report 10: *Estuarine Habitat and Species: Description and Values*
- The sediment transport characteristics of the harbour are described in **Section 11** of this report.

Several studies have assessed surface sediment quality in the Porirua Harbour, including both the Onepoto Arm and Pauatahanui Inlet. Investigations have been carried out determining levels of various heavy metals, nutrients and organic compounds such as DDT and polyaromatic hydrocarbons (PAHs), including Glasby *et al*. (1990), Botherway & Gardner (2002), Stevenson & Mills (2006), Milne & Watts (2008), Robertson & Stevens (2008) and Sorenson & Milne (2009). In general, results of these studies indicate that the concentrations of several contaminants are elevated at sites throughout the harbour. Contaminant concentrations are typically higher in the Onepoto Arm, around the Porirua Stream mouth and other nearby stormwater outfalls.

Most recently, a Greater Wellington Regional Council (GWRC) study conducted by Sorenson & Milne (2009) collected data at seventeen intertidal sites and adjacent to stream mouths in both arms of the Harbour. Surface sediments were collected at ten sites at the southern end of the harbour adjacent to the Porirua Stream mouth and other stormwater outfalls. Samples were also collected in the Pauatahanui Inlet near the mouths of Browns Stream and Duck Creek. Sediments were tested for a range of heavy metals, nutrients, PAHs and organic compounds such as DDT and dieldrin.

Concentrations were compared to the Australian and New Zealand Environment and Conservation Council Guidelines (ANZECC) (2000) for both the ISQC 'Low' trigger values (where the onset of biological effects could occur) and the ISQC 'High' trigger values (where significant biological effects are expected). Where available, concentrations were also compared to the Auckland Regional Council's (ARC) amber and red Environmental Response Criteria (ERC) (ARC, 2004) which provides a trigger for investigative action to address pollution causes to begin. The ARC ERC guidelines are all lower than the ANZECC guidelines.

In summary, the following observations were made:

- Zinc concentrations in surface sediment are elevated in some areas of the harbour especially in the Onepoto Arm where the ANZECC ISQG 'Low' trigger was exceeded at seven sites and a further three sites exceeded the ARC ERC amber threshold. Zinc concentrations were also above the ARC ERC amber threshold adjacent to the Onepoto Stream mouth
- In the Onepoto Arm, several sites exceeded the ARC ERC amber threshold for copper and lead
- One site exceeded the ANZECC ISQG 'Low' trigger for mercury
- DDT concentrations are elevated at several sites in both arms of the harbour. Eight of the ten sites in the Onepoto Arm and sites adjacent to the Onepoto Stream, Duck Creek and Browns Stream mouths all exceeded the ARC ERC amber and ANZECC ISQG-'Low' trigger
- Some tested PAHs were also elevated above ARC ERC amber and ANZECC ISQC 'Low' guidelines at several sites in both arms of the harbour.

5.3. Kapiti Coast

The Kapiti Coast is a high energy coastal environment, where sediment discharged with stormwater is not expected to accumulate.

5.4. Geology, Topography and Soil Loss

Table 15.3 summaries the geology and topography along the route of Transmission Gully Project.

- **Table 15.3 Summary of the Common Geomorphology & Geology on Transmission Gully**

Location	Geology	Topography	Soil Loss (t/yr/ha)
McKay's Crossing – Te Puka Terrace (SH1)	Sand dunes and inter-dunal peat outwash gravels	Flat terrain with low sand dunes and inter-dunal soft ground, with outwash alluvial fan deposits at the northern entrance to the Transmission gully	1.2
Te Puka Terrace	Gravel alluvial terrace (with landslide material as top soil)	Flat terrace elevated well above the Te Puka stream, with pine forested hillside to the east	1.1
Te Puka Terrace to Wainui Saddle	Greywacke (fault disturbed rock, with landslide materials top soil)	Steeply incised valley with steep hillsides to the east and west, which straddles the Ohariu fault along this sector	0.8

Location	Geology	Topography	Soil Loss (t/yr/ha)
Wainui Saddle to Kennings Stockyard	Greywacke	Narrow valley with steep hillsides with Horokiri stream on valley floor	2.0
Kennings Stockyards to south of Battle Hill farm where Horokiri Valley swings to the west	Greywacke, Old terrace	Broader valley with steep hillsides to the east with terrace remnants of older gravel deposits	2.3
Horokiri Valley south to terrace immediately north of SH58	Old terrace (with loess/gravel materials as top soil	Rolling subdued terrain with a number of older terrace gravel deposits overlying bedrock	0.8
SH58 crossing at Pauatahanui estuarine plains	Low lying ground (with marine silt/clay, swampy material as top soil	Estuarine flats associated with the Pauatahanui inlet, with swampy ground	2.1 (high due to current development within the local catchment)
SH58 crossing at Pauatahanui to Duck Creek crossing	Weathered Greywacke (with some loess material as top soil)	Moderately steep weathered greywacke terrain dominated by Duck Creek which straddles the moonshine fault.	1.6

6. Water Quality Characterisation

This section describes:

- Methodologies for water quality monitoring
- Water quality results for each of the eight streams monitored.

6.1. Freshwater Management Purposes and Water Quality Guidelines

In determining the design of the water quality data collection that was undertaken for the Water quality Characterisation, consideration was given to the Regional Freshwater Plan (RFP).

The GWRC classifies freshwater bodies in the RFP for the Wellington Region (GWRC, 1999) according to their purpose. These cover a range of aquatic ecological and human use values and are summarised in Table 15.4.

The Council's approach has the following objectives for water quality and discharges to fresh water:

- The quality of freshwater meets the range of uses and values for which it is required while the life supporting capacity of water and aquatic ecosystems is safeguarded
- The quality of freshwater has the potential to meet the reasonably foreseeable needs of future generations
- The quality of water is, as far as practicable, consistent with the values of the tangata whenua.

The RFP also references a number of other guideline documents that should be used to guide numerical criteria for receiving waters, which are:

- The ANZECC water quality guidelines (ANZECC, 1992)
- The Ministry for the Environment water quality guidelines (Ministry for the Environment, 1992 & 1994)
- The Department of Health guidelines for recreation and shellfish gathering (McBride et al., 1992)
- The Ministry of Agriculture and Fisheries technical paper on the influence of agriculture (Smith et al. 1993).

The ANZECC guidelines take the approach of providing 'trigger values'. These are not absolute limits to water quality, where adverse effects on aquatic ecology will occur, but instead are intended to identify that there is a risk that adverse ecological effects could occur and the intent in general is to 'trigger' further investigation.

Triggers are provided for a number of chemical parameters and also for different effects. Consideration has been given to the following:

- Trigger levels for toxicants, which identify where toxic effects on aquatic ecology resulting from the concentration of chemical parameters may be experienced
- Trigger values for physical and chemical stressors in New Zealand for slightly disturbed ecosystems. These trigger values are used to assess the risk of adverse effects, such as undesirable biological growth due to nutrients, biodegradable organic matter and pH.

It needs to be recognised that these trigger levels are for chronic exposure (as below), and are a conservative as measure for 'pulse' exposures. First flush concentrations during wet weather are an example of a 'pulse' exposure.

> "*For non-biological indicators in sections 3.3 to 3.5 the guideline trigger values represent the best currently available estimates of what are thought to be ecologically low risk levels of these indicators for chronic*

> *(sustained) exposures................Users should also be aware that short term intermittent (or pulse) exposures to very high contaminant or stressor values may also need to be managed in certain situations."* (ANZECC, 2000)

Other Relevant Guidelines

For the purpose of this report it is intended to provide water quality characterisation. As such, given that the identified values of the water bodies are predominantly managed for aquatic ecosystems, comparison to guidelines intended to protect these ecosystems has been undertaken. It is considered that the appropriate guidelines are the *Aquatic Ecosystems Section of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality Guidelines* published by ANZECC in 2000. Note these are an update of the 1992 guidelines referred to in the GWRC plan.

Where these guidelines do not provide information to assist the assessment of the water quality then comparison has been made to relevant parameters in the GWRC's *Water Quality Guidelines. The Canadian Environmental Quality Guidelines* (CCME 2002) for the protection of freshwater ecosystems have also been used. These guidelines are internationally recognised risk-based standards which have been identified using the Ministry for the Environment: Environmental Guideline Value Database. Where no relevant guidelines exist, a general description of the data is provided.

■ **Table 15.4 Regional Freshwater Plan Management Values and Water Quality Guidelines**

Catchment	Sub-catchment	Management Objectives and Water Quality Guidelines					
		8.1	8.2	8.5	8.6		
		Minimum water quality standards`	Water managed for aquatic ecosystem purposes	Water managed for aquatic ecosystem and fish spawning purposes	Water managed for aquatic ecosystem and water supply purposes	Wetlands, Lakes and Rivers and their Margins, with a High Degree of Natural Character, Part B: Surface Water to be Managed for Aquatic Ecosystem Purposes	Water Bodies with Nationally Threatened Indigenous Fish Recorded in the Catchment and Nationally Threatened Indigenous Aquatic Plants
Whareroa							✓
Wainui	Te Puka			✓	✓		✓
Horokiri			✓			✓	✓
Ration			✓				✓
Collins		✓					
Pauatahanui						✓	✓
Duck							✓
Kenepuru	Cannons Creek	✓					
Porirua		✓					

6.2. Overall Methodology and Approach to Monitoring

This section of the report describes the overall methodology and approach to the freshwater water quality characterisation monitoring. **Appendix 15.C (C1)** provides an overview map of the Project catchments in which monitoring was undertaken.

Table 15.5 identifies the environmental data collected and the purpose of this data in investigating water quality for the project.

Table 15.5 Summary of Data Collection

Purpose	Method	Parameters	Comments
Water quality characterisation	Wet and dry weather grab samples (4 rounds)	Field parameters, visual observations, heavy metals, nutrients, hydrocarbons (refer to Table 3 Transmission Gully Scoping Study)	To provide an overall picture of water quality for the different streams to be used for assessing effects and verification of the contaminant load model.
Fine sediment deposition in streambeds	Quorer sampling (3 rounds) and visual assessment of fine sediment (1 round)	Suspended inorganic and organic sediment	Assess current fine sediment quantities in stream substrate
Turbidity	Continuous turbidity sampling	Turbidity	Continuous logging of turbidity to input to the calibration of sediment yield estimations
Water quality during storm events	Automatic samplers	Total suspended sediment, turbidity, selected heavy metals	To determine water quality of selected streams during storm events – to distinguish differences between concentrations at the beginning of storms and throughout the rest of the storm
Sediment quantity during storm events	Event sampling	Total suspended sediment, turbidity	Results to be used for calibration of sediment yield estimations

6.2.1.Sampling Methodology

6.2.1.1. Wet and Dry Weather Grab Samples

The water quality characterisation monitoring programme consisted of four rounds of sampling that was conducted quarterly.

‘Dry’ samples were collected where less than 2.5mm of rainfall had fallen in the last 72 hours before sample collection. Conversely, ‘wet’ samples were collected when at least 2.5mm of rainfall had fallen in the previous 72 hours. This was measured at the nearest rainfall gauge to each sampling location. The first round of sampling was done primarily in ‘dry’ flow events and the remaining three rounds were all in ‘wet’ flow events.

The following sample rounds were undertaken:

- Round 1 – dry/wet weather ‘winter’ sampling round
- Round 2 – wet weather ‘spring’ sampling round
- Round 3 – wet weather ‘summer’ sampling round

- Round 4 – wet weather 'autumn' sampling round

Grab samples were collected from each of the grab sampling locations shown in **Appendix 15.C (C1)**. Field observations and tests as detailed were carried out at each sampling location. Water samples were collected using standard sampling practices and transported to Hills Laboratory for analysis for a range of parameters as shown in **Appendix 15.A**.

6.2.1.2. Quorer Sampling

Currently there is debate in New Zealand about appropriate methods to use for determining in-stream fine sediment quantities. The Cawthron Institute in Nelson is currently running a national programme trialling six methods for assessing fine sediment content. This is being undertaken by Regional Councils across New Zealand and is not complete. At present there is no established single protocol for this work and as the methods depend on substrate type, it would appear that a single method recommendation is unlikely to be an outcome. A suite of options and protocols for different substrates is more likely to be developed.

For this Project, NIWA's quorer methodology (NIWA, 2008) for estimating the quantity of deposited fine sediment in streams was used for three rounds of quorer sampling. These were undertaken during 'dry' flow events (as defined above in Section 6.2.1.1) at six stream locations (**Appendix 15.C (C1)**). Seven samples were collected and transported to Hills Laboratories for analysis for volatile suspended solids and total suspended solids. This data was used to calculate areal and volumetric suspendable organic sediment and suspendable inorganic sediment for each sample. The geometric mean was then calculated for each site. The purpose of this data was to provide an indication of the amount of sediment currently deposited in the substrate of freshwater bodies in the study area.

During the last quorer sample round, another method for estimating stream sediment was also utilised at the same sites: 'in-stream visual assessment of fines' (Cawthron, 2009). This was undertaken in order to trial a different methodology that may be more useful for future monitoring of sediment. This visual assessment method gave an indication of the percentage of fine sediment visible on the top of the stream substrate at each site.

6.2.1.3. Event Sampling

Eight grab samples were collected at the mouths of five of the streams that drain into the Porirua Harbour (**Appendix 15.C (C1)**). Event based sampling was carried out during or immediately following high rainfall events, where flow was expected to be high at these locations. Samples were collected and transported to Hills Laboratories for analysis for total suspended solids and turbidity. Data from these grab samples has been used to establish relationships between turbidity and total suspended solids concentrations. This information has been used in calibrating sediment yield estimations for modelling of sediment deposition in streams and to the harbour as detailed Section10.

6.2.1.4. Continuous Turbidity Logging

Continuous turbidity loggers were installed at four stream locations as detailed in **Appendix 15.C (C1)**. These loggers were in place from October 2009 to October 2010 and logged turbidity every 15 minutes. The relationships between total suspended solids and turbidity from both event and grab sample results were used to estimate sediment concentrations during different flow events. This data was also used to verify the sediment load modelling and sediment yield estimations for the modelling of sediment deposition in streams and the Porirua Harbour. In this report, turbidity data has also been compared to gauged stream flow data (where available).

6.2.1.5. Automatic Water Sampling

Automatic water samplers were installed at three locations for a period of three months as shown in **Appendix 15.C (C1)**. Samples were taken when the rate of rise in the stream reached the figure in **Table 15.6**. After the first sample 24 consecutive samples were taken every 10 minutes. The first two samples collected were combined and represented the beginning of the storm event. The remaining 22 bottles were combined into a composite sample representing water collected throughout the rest of the storm event.

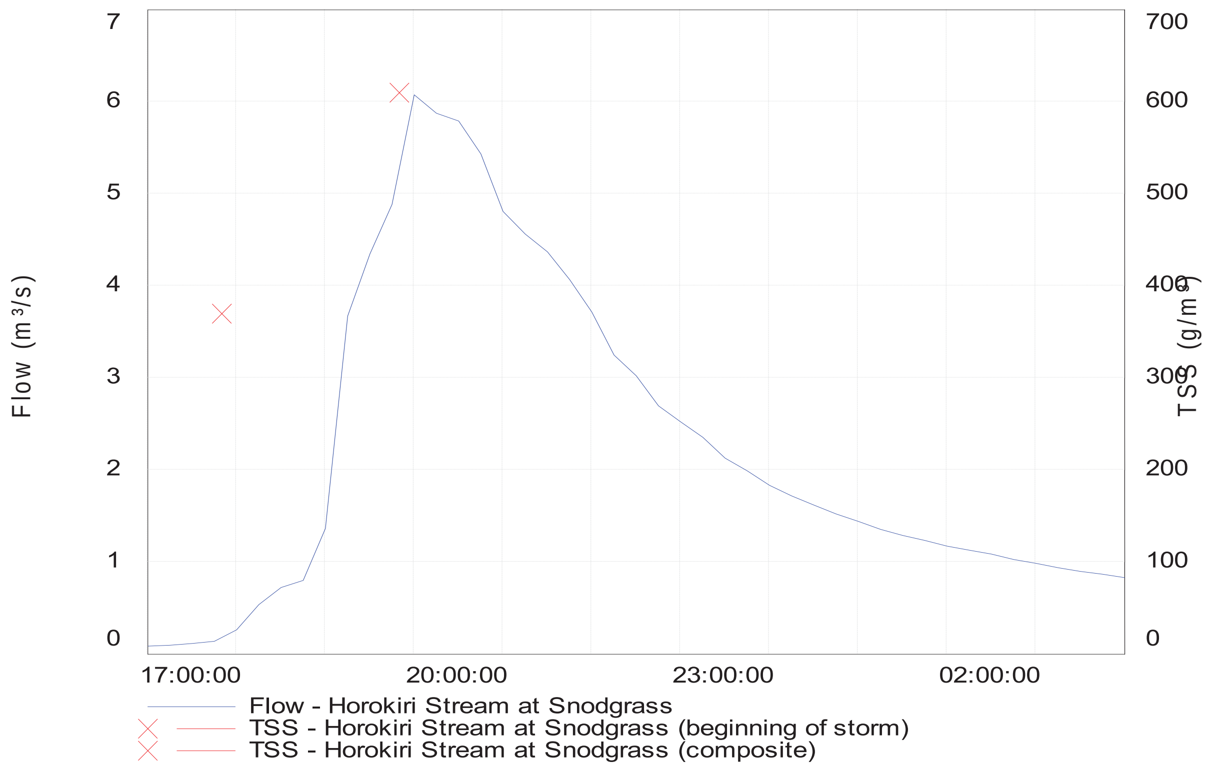
Figure 15.2 shows a storm on the Horokiri Stream on 27-28th April 2010. In this instance, flow started increasing at about 17:00. The automatic sampler triggered at 17:45, with samples collected at 17:45 and 17:55. The remaining samples, collected every 10 minutes between 18:05 and 21:35, were combined to form the composite sample. Note that sample points on the graph for beginning of storm and composite samples represent mid points of these time intervals.

Samples were collected by field staff, transported to Hills Laboratories and analysed for total suspended solids (TSS), turbidity and total and dissolved zinc and copper. The results were used for two purposes:

- To determine TSS and turbidity concentrations throughout storm events (to be used to verify the sediment yield estimations for the modelling of sediment deposition in both the streams and the estuary)
- To provide water quality characterisation for selected parameters at both the beginning of the storm and throughout the storm events under a range of different sized storm events.

Table 15.6 Rate of Rise Triggers for Automatic Samplers

Sample Location	Rate of Rise (mm per 15 min)
Porirua at Town Centre	15
Horokiri at Snodgrass	10
Pauatahanui at Gorge	10



- **Figure 15.2 Total Suspended Sediment Concentrations for Beginning of Storm and Composite Samples Collect for Storm Event on 27 and 28 April 2010 with Flow at Horokiri Stream at Snodgrass**

6.2.2.Sampling Locations By Catchment

The following section describes each of the grab sample sites that were monitored. Photos were been taken by SKM personnel while sampling was being undertaken. Landuse for each catchment utilising data from Ministry for the Environment's Land Cover Database from 2001/2002 is shown in Section 10. Maps of grab sample locations for each individual catchment are displayed in **Appendix 15.C**.

6.2.2.1. Whareroa Stream Catchment

The Whareroa Stream catchment is the northern most catchment in the Main Alignment, and is one of the smaller streams in the study area.

Whareroa 1

Whareroa 1 is the only sample site in this catchment and is located upstream of the proposed road alignment. Landuse upstream of the sample location is predominantly prime pastoral and scrub. At this location, the stream is approximately 1.4 metres wide. The stream is generally open with little overhanging vegetation. A photograph of the sample location is shown in **Figure 15.3**.

▪ **Figure 15.3 Whareroa 1 Sample Location**

6.2.2.2. Wainui and Te Puka Stream Catchment

The Wainui and Te Puka Stream catchment is one of the smaller catchments in the study area. It contains the Wainui Stream to the north and the Te Puka Stream further south. Both these streams cross the Main Alignment. They converge downstream of the alignment and flow into the township of Paekakariki as the Wainui Stream.

Samples are collected at two sites on the Te Puka branch of the Wainui Stream – Te Puka 1 and Te Puka 2.

Te Puka 1

Te Puka 1 is upstream of the proposed road. The site is located in steep hill country with upstream landuse being mostly scrub and some indigenous forest. At the sample location the stream is approximately 1.2 metres wide and contains many large boulders. There is a lot of overhanging vegetation and the stream is shaded most of the time. **Figure 15.4** shows the sampling location at Te Puka 1.

▪ **Figure 15.4 Te Puka Sampling Location Looking Upstream**

Te Puka 2

Te Puka 2 is located downstream of the proposed road alignment. Landuse upstream of this site is predominantly scrub and planted forest. The stream channel at the sampling location is approximately 2 metres wide and is upstream of a culvert. There is little overhanging vegetation and the substrate is composed of medium sized cobbles. Surrounding landuse is grazing, with stock allowed access to the stream. There are also some farm tracks used by farm vehicles. **Figure 15.5** shows upstream and downstream views at the site.

■ **Figure 15.5 Te Puka 2 Sampling Site – Looking Upstream (a) and Downstream (b)**

6.2.2.3. Horokiri Stream Catchment

The Horokiri Stream catchment is one of the larger catchments within the Project area. The stream has two main tributaries, one of which crosses the proposed road alignment. Landuse within this catchment is mostly prime pastoral with scrub and planted forest. Samples were collected at four locations in the Horokiri Stream catchment.

Horokiri 1

Horokiri 1 is upstream of the Main Alignment. At this site upstream landuse is mostly scrub, with some indigenous forest. The width of the stream at this site is approximately 2 metres wide. The channel is surrounded by scrub and farmland and stock are able to access the stream. **Figure 15.6** shows the sampling location at Horokiri 1.

▪ Figure 15.6 Horokiri 1 Sampling Location Looking Across the Stream

Horokiri 2

This site is downstream of the Main Alignment. It is also downstream of the western Horokiri Stream tributary which does not cross the proposed road. Landuse upstream is a mixture of scrub, prime pastoral and planted forest. The stream channel is approximately 5 metres wide at this location. There is no overhanging vegetation and the site is surrounded by farmland.

Horokiri 3

This site is on the western tributary of the Horokiri Stream. It joins the main branch of the Horokiri downstream of the road. Therefore this site represents a catchment that is unlikely to be affected by any changes resulting from runoff from the Project. Upstream landuse is prime pastoral and scrub. The site is located in prime pastoral farmland with stock having access to the stream. The stream width at this site is approximately 4.3 metres. **Figure 15.7** show a photograph of the sampling location.

▪ Figure 15.7 Horokiri 3 Sampling Location – Looking Upstream

Horokiri 5

This site is the most downstream site on the Horokiri Stream. Landuse is a mixture of prime pastoral, scrub and planted forest. The stream width here is wider than upstream at approximately 6.5 metres. The site is surrounded by farmland, where both stock and people have ready access to the stream. Samples are taken upstream from a small bridge. Photographs shown in **Figure 15.8** are taken from this bridge.

▪ **Figure 15.8 Horokiri 5 Sampling Location – Upstream View (a) and Downstream View (b)**

6.2.2.4. Ration Stream Catchment

The Ration Stream catchment is 680 hectares in area and is one of the small catchments in the study area. The stream has two tributaries, both of which cross the Main Alignment. Samples were collected at two locations; both are downstream of the alignment and downstream of the confluence of these tributaries. Catchment landuse is mostly prime pastoral, scrub and planted forest with an area of coastal wetlands at the stream mouth. There is also a golf course upstream of the sampling sites.

Ration 1

Ration 1 is downstream of the proposed road alignment. Upstream landuse is a mixture of prime pastoral, scrub and planted forest. The stream channel is narrow at 2 metres wide and confined by banks approximately 1 metre high. There is dense vegetation around the stream channel at this site. The stream is fenced and stock is prevented from entering the stream area. **Figure 15.9** shows upstream and downstream views at the site.

▪ **Figure 15.9 Ration 1 Sampling Location – View Upstream (a) and Downstream (b)**

Ration 2

Ration 2 is further downstream than Ration 1. It is at the upper most limit of tidal influence from the Pauatahanui Inlet. Upstream landuse is a combination of prime pastoral, scrub and planted forest. The sampling location is adjacent to an orchard and is fenced. There is some overhanging vegetation around the stream, particularly upstream of the sampling location. The stream width varies here depending on flow conditions. Our measurements indicate the stream channel fluctuates between approximately 3 and 4 metres width. There is a small footbridge at the site, where samples are usually taken from. **Figure 15.10** shows upstream and downstream views from this bridge.

- **Figure 15.10 Upstream (b) and Downstream (a) Views at Ration 2 Sampling Location**

6.2.2.5. Pauatahanui Stream Catchment

The Pauatahanui Stream catchment is the largest of the catchments in the study area at approximately 4200 hectares. The stream has several tributaries, which all converge upstream of our sampling locations. Landuse is a mixture of prime pastoral and scrub, with pockets of urban development in the lower reaches of the catchment. Samples were collected at two sites on the Pauatahanui Stream.

Pauatahanui 1

Pauatahanui 1 is upstream of the proposed road alignment. Landuse upstream of this site is primarily prime pastoral and scrub. There are also small areas of urban landuse adjacent to the stream. At this site the stream is bounded on southern side by high banks. On the northern side of the stream there are large areas of scrub. This area tends to flood during high flow conditions. The width of the stream varies greatly at this site, depending on flow conditions. At low flow conditions it is approximately 4.5 metres wide. We have been unable to accurately measure the width during high flow conditions. **Figure 15.11** shows upstream and downstream views at the sampling location.

- **Figure 15.11 Upstream (a) and Downstream (b) Views from Pauatahanui 1 Sampling Location**

Pauatahanui 2

Pauatahanui 2 is immediately downstream of the proposed road alignment. Upstream landuse is similar to Pauatahanui 1. There is some urban landuse between Pauatahanui 1 and Pauatahanui 2. This includes a garden supplies centre immediately upstream of Pauatahanui 2. There is farmland surrounding this site and stock has ready access to the stream. This site tends to flood during annual high flow conditions to the surrounding low lying paddocks (**Figure 15.13**). Generally during low flow conditions the stream is approximately 7 metres wide. There is some overhanging vegetation around the stream banks at this site. **Figure 15.12** shows the sampling location at this site.

- **Figure 15.12 Pauatahanui 2 Sampling Location, Looking Upstream**

- **Figure 15.13 Flooding Adjacent to Pauatahanui 2 on 16 October 2009**

6.2.2.6. Duck Stream Catchment

The Duck Creek catchment is 1030 hectares and has a mixture of landuse. In the upper reaches of the catchment landuse is primarily prime pastoral. Further downstream the catchment is mostly urbanised with patches of scrub. The stream has three tributaries which cross the Main Alignment. These converge downstream of the road and also pass the Whitby Link Road. Samples were collected from three locations on Duck Creek to gauge current water quality in the different environments throughout the catchment.

Duck 1

Duck 1 is upstream of the Main Alignment and is located in prime pastoral farmland. Stock has regular access to the stream. The stream channel is typically small at approximately 1 metre wide. The substrate is composed of a range of small to medium sized cobbles. Vegetation around the stream channel varies seasonally, with little overhanging vegetation in winter and overgrown stream weed during summer (**Figure 14.14**).

- **Figure 14.14 Photo of Duck 1 Sampling Location During Winter (a) and Summer (b)**

Duck 2

Duck 2 is downstream of Duck 1, the Main Alignment and the Whitby Link Road. Landuse upstream of this site is mostly prime pastoral and planted forest, with some indigenous forest. This site is wider and flatter than further upstream, with the stream channel varying between 2 and 3 metres in width. The site is surrounded by grass and some overhanging vegetation, particularly upstream. Downstream and adjacent to this site, an old golf course is being developed for residential use. **Figure 15.15** shows the sampling location at this site.

- **Figure 15.15 Duck 2 – Upstream (a) and Downstream (b) of Sampling Location**

Duck 3

Duck 3 is downstream of the other two sampling sites, and is located just upstream of the creek mouth. This site is downstream of residential urban landuse in the suburbs of Whitby. Upstream of the urban area there is indigenous and planted forest, scrub and prime pastoral land. The stream channel here is wider and flatter than upstream locations and is about 7 metres wide. It is surrounded by wetlands and scrub which are part of Department of Conservation (DOC) land. **Figure 15.16** shows views looking upstream and downstream of this site.

- **Figure 15.16 Duck 3 Sampling Location – Looking Upstream (a) and Downstream (b)**

6.2.2.7. Kenepuru Stream Catchment

The Kenepuru Stream catchment is located adjacent to the Duck Creek and Porirua Stream catchments. The stream has several tributaries – one of which crosses the proposed road alignment. At the lower end of the Kenepuru Stream it flows into the Porirua Stream. The catchment is mostly urbanised, with some prime pastoral and scrub areas in the upper reaches of the catchment. Samples were collected at three locations on the Kenepuru Stream catchment – upstream and downstream of the road; and at the lower reaches of the catchment, downstream of the main urban area in the catchment.

Kenepuru 1

Kenepuru 1 is upstream of the proposed road alignment. Upstream landuse is prime pastoral. At this site, the stream channel is narrow (about 1.5 metres wide) and is located in farmland, where stock has access to the stream. There is a culvert under a farm road upstream of the sampling site. **Figure 15.17** shows the sampling location at Kenepuru 1.

- **Figure 15.17 Kenepuru 1 Sampling Location – Looking Upstream (a) and Downstream (b)**

Kenepuru 2

Kenepuru 2 is downstream of the proposed road alignment. Landuse upstream is both prime pastoral and scrub. The channel here is similarly narrow to Kenepuru 1 at approximately 1.4 metres wide. The site is located within the Belmont Regional Park and the public have ready access to it. Native vegetation and grass surround the stream at this portion of the channel (**Figure 15.18**).

- **Figure 15.18 Kenepuru 2 Sampling Location**

Kenepuru 3

Kenepuru 3 is the furthermost downstream sampling location and is upstream of where the Kenepuru Stream joins the Porirua Stream. The channel is wider than the other two sampling sites at approximately 4 metres wide. Adjacent to the site is urban landuse, and with prime pastoral and scrub land upstream. Immediately surrounding the sampling site there is grass adjacent to a road. There is also a ford which is used to access farmland on the northern side of the stream. Samples are collected downstream of the ford. **Figure 15.19** shows a photo of this sampling site.

- **Figure 15.19 Kenepuru 3 Sampling Location**

6.2.2.8. Porirua Stream Catchment

The Porirua Stream catchment is of comparable size to the Pauatahanui catchment at around 4100 hectares in area. A large proportion of the area adjacent to the stream channel is urban landuse and 27% of the total catchment area is urbanised. SH1 passes through this catchment, and is in close proximity to the stream channel in places. In 2009, the Annual Average Daily Traffic (AADT) was 41,885 taken at Tawa College (upstream of both sampling sites) (NZTA, 2009). Upstream areas are mostly prime pastoral and scrub. There are several tributaries to the main channel, which drain the surrounding hill catchments. We collected samples from two sampling locations on the Porirua Stream. They are situated downstream and upstream of Waitangirua Link Road.

Porirua 1

Porirua 1 is upstream of the Waitangirua Link Road. This site is in the downstream reaches of the large Porirua Stream catchment. Landuse immediately upstream is urban, although in the upper reaches of the stream there is mostly prime pastoral and scrub. This part of the Porirua Stream is a manmade concrete channel, with steep artificially shaped grassed banks (**Figure 15.20**). The public have direct access to the stream in this area. The width of the stream fluctuates during different flow conditions, but is typically between 4 and 5 metres wide.

- **Figure 15.20 Porirua 1 Sampling Location – Looking Downstream**

Porirua 2

Porirua 2 is downstream of Porirua 1 and the Waitangirua Link Road. Landuse is similar to Porirua 1. The channel here is more in its natural state, but trees and some vegetation sporadically along the stream banks.

The width of the stream is generally around 4.5 metres wide. **Figure 15.21** shows the sampling site at Porirua 2.

- **Figure 15.21 Porirua 2 Sample Location, Looking Downstream**

6.2.3.Quorer Sampling Locations

Quorer samples were collected at one site downstream of the Main Alignment on each of six streams that drain into the Porirua Harbour:

- Horokiri Stream
- Pauatahanui Stream
- Duck Creek
- Kenepuru Stream
- Porirua Stream
- Ration Stream.

Sampling locations are at or adjacent to freshwater grab sampling sites and are displayed in **Appendix 15.C**.

6.2.4.Event Sampling Locations

Event sampling was conducted at the following stream mouths draining into the Porirua Harbour:

- Porirua Stream mouth
- Duck Creek mouth
- Horokiri Stream mouth
- Ration Stream mouth.

Appendix 15.C shows the location of these sampling sites.

6.2.5.Turbidity Logger Locations

Turbidity loggers were installed at two sites on the Horokiri Stream, one site on the Pauatahanui Stream and one site on Duck Creek as follows:

- Horokiri 3 – downstream of the road alignment, adjacent to our freshwater sampling site

- Horokiri 4 – a control site upstream of the road alignment
- Pauatahanui 2 – downstream of the road alignment, approximately 100m upstream of our freshwater sampling site
- Duck 2 – downstream of the road alignment, approximately 20m upstream of our freshwater sampling site.

Locations of turbidity loggers are shown in **Appendix 15.C**.

6.2.6.Automatic Water Sampler Locations

Automatic water samplers were installed at three locations – on the Porirua, Horokiri and Pauatahanui Streams (shown in **Appendix 15.C**). These samplers are adjacent to flow gauges managed by GWRC and NIWA at the following sites:

- Horokiri at Snodgrass – GWRC
- Porirua at Town Centre – GWRC
- Pauatahanui at Gorge – NIWA.

6.3. Freshwater Sampling Results – All Catchments

This section summarises data collected for key parameters of interest in terms of road runoff and compares the data to relevant guidelines (as outlined in **Section 6.1**). Key parameters of relevance to road runoff in this location have been identified from relevant guidelines (CCC, 2003; NZTA, 2009; ARC, 2003) as including:

- Total suspended solids
- Nutrients (nitrogen and phosphorous)
- Metals (especially copper, zinc and lead)
- Hydrocarbons

A summary of lab and field results has been tabulated in **Appendix 15.D**. Median values for relevant parameters have been calculated and highlighted where guideline values are exceeded. An overview of general results for all catchments has been provided in **Section 6.3**, with further analysis on individual catchments following in **Section 6.3.2**.

6.3.1.1. Field Measurements and Observations

Dissolved oxygen measurements indicated well oxygenated water during all events. pH appeared to be slightly acidic in most catchments with the highest acidity measured at the most downstream site in Duck Creek – Duck 3. Turbidity and total suspended solids were mostly below detection limits in dry flow conditions with these being generally (but not always) more elevated in wet flows. Certain catchments seemed to give rise to higher suspended sediment concentrations than others and this may reflect local rainfall intensity, geology or landuse. This could also be due to the timing of samples collected in these catchments in relation to the storm peak. The visual pollution indicators detailed in the Wellington Regional Freshwater Plan (GWRC, 1999) were generally not in evidence in either dry or wet flows in most catchments. The following observations were made:

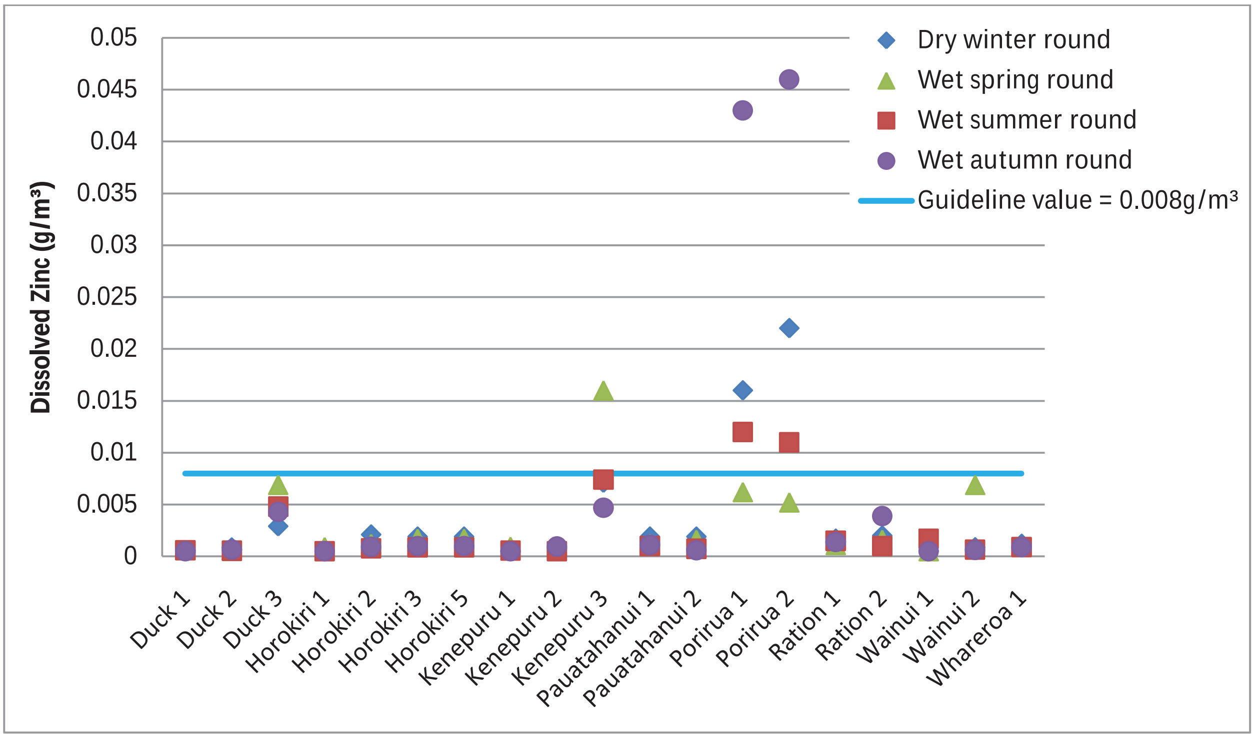
- Scums and foams were present in some catchments in wet flows including Kenepuru, Duck, Ration, Pauatahanui and Porirua stream catchments
- An objectionable odour was typically not present in water samples any of the catchments. It was only noted twice, once at Kenepuru 1 and once at Pauatahanui 1

- Floatable or suspended material was generally not present in any of the catchments. It was noted once, at Porirua 2
- No evidence of oil or grease films was noted at any of the sites
- Visual clarity was generally good and decreased with increased total suspended solids

6.3.1.2. Metals

Grab Sample Results

Total and dissolved arsenic, cadmium and nickel were always below guideline concentrations at all sites. Chromium and lead concentrations were occasionally above guideline values at some sites, but this was usually the total rather than the dissolved concentration. Copper and zinc concentrations above guidelines were noted within all catchments. Exceedances tended to occur more frequently at downstream sites and usually were for total rather than dissolved concentrations. The dissolved fraction represents a greater risk in terms of ecological impacts as it relates to the more bio-available metal fraction. Therefore, poor water quality and risk of toxicity effects on aquatic organisms is better highlighted by exceedances of dissolved metals in relation to guideline values. **Figure 15.22** and **Figure 15.23** show dissolved and total zinc concentrations compared to guideline values for all sites. Of note are particularly high dissolved concentrations at both Porirua sites. At the majority of other sites dissolved concentrations were below the guideline value. A similar pattern is evident in **Figure 15.24** and **Figure 15.25** showing dissolved and total copper concentrations for all sites compared with guideline values. Total copper was above the guideline value at a number of sites. Particularly high dissolved copper concentrations were often evident at Kenepuru 3 and both the Porirua sites.



- **Figure 15.22 Measured Dissolved Zinc Concentrations for All Sites**

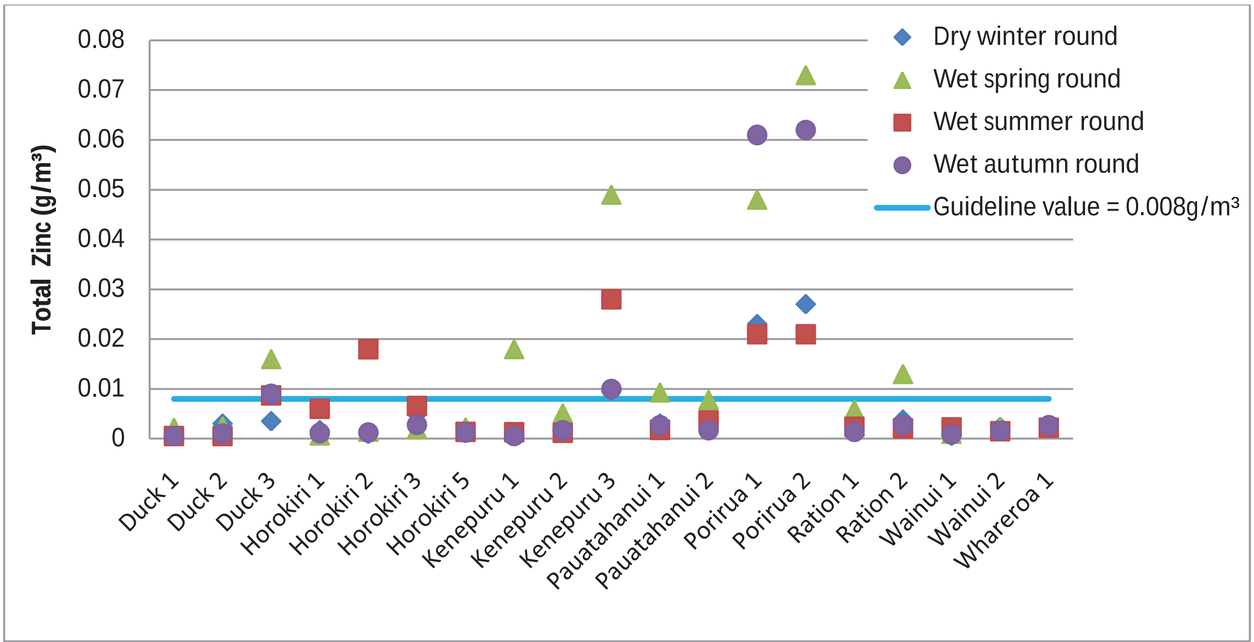


Figure 15.23 Measured Total Zinc Concentrations for All Sites

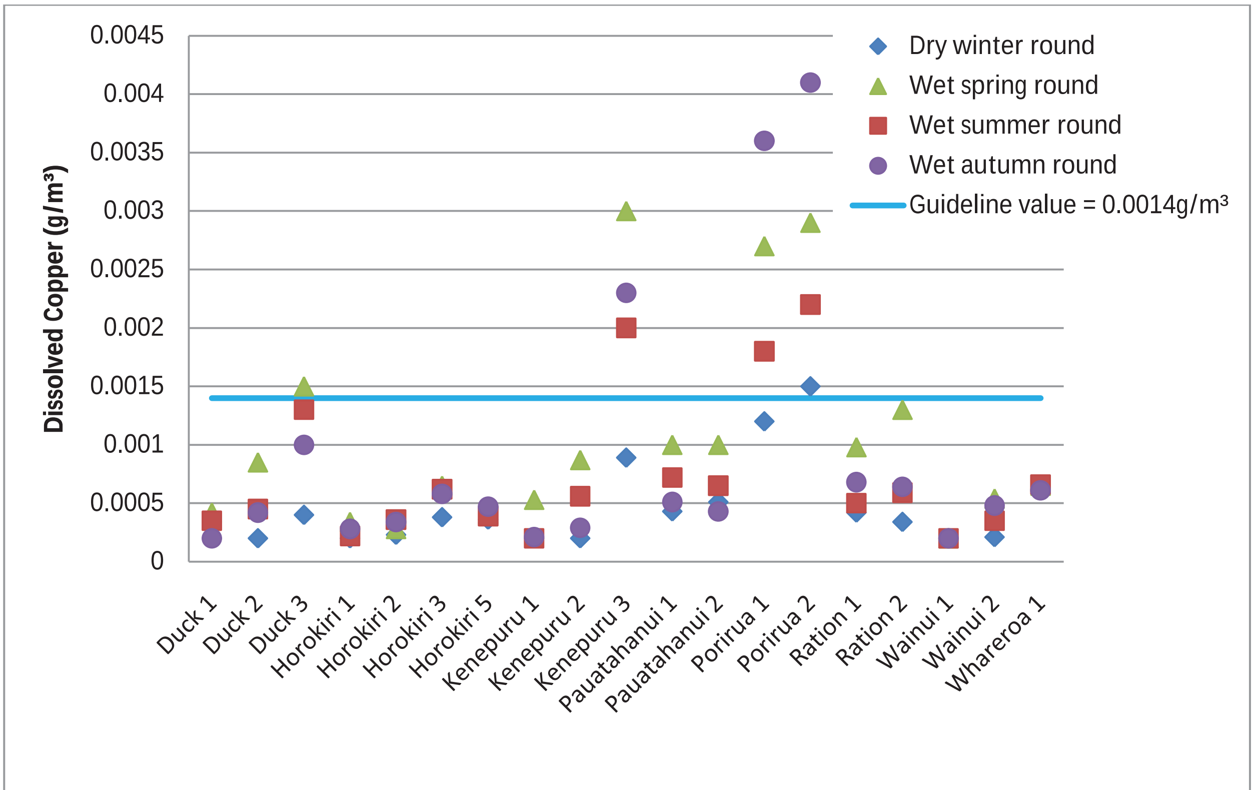
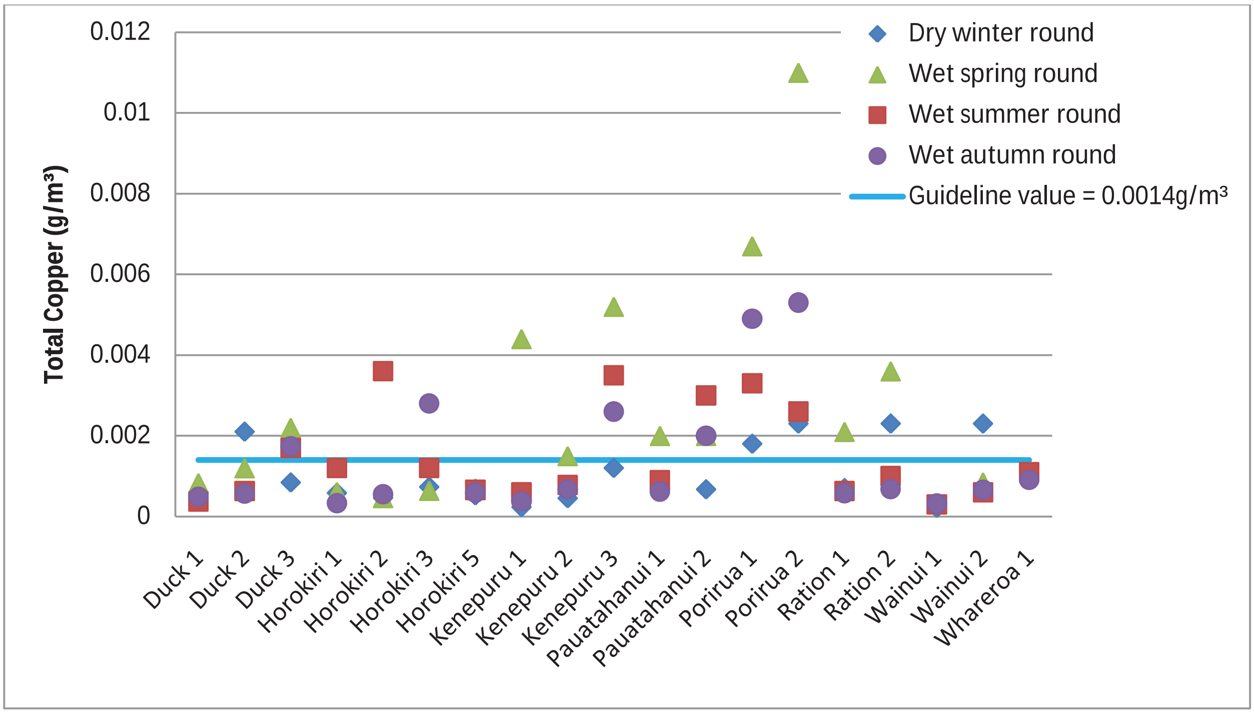


Figure 15.24 Measured Dissolved Copper Concentration at All Sites



- **Figure 15.25 Measured Total Copper Concentration at All Sites**

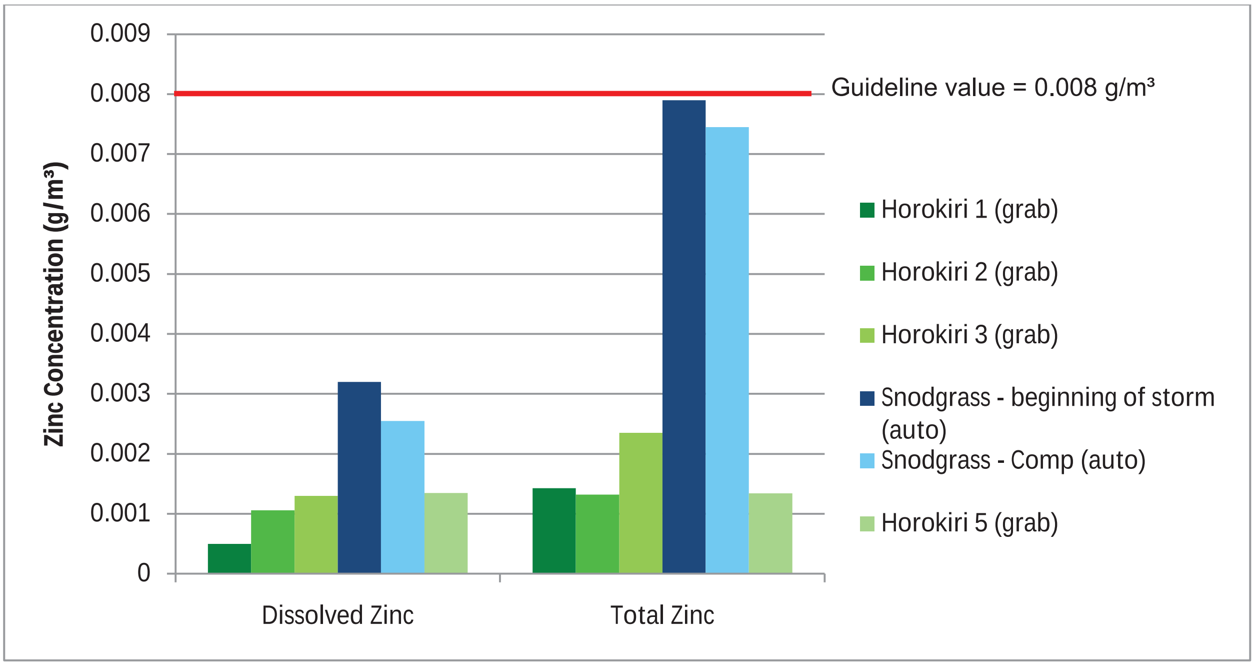
Note: The measurement from Whareroa 1 in the wet spring round has not been plotted on this graph. It was elevated well above other samples and made visual interpretation of the graph difficult (value = 0.023 g/m³ for wet spring round)

Automatic Sample Results

The automatic samplers started collecting samples during the rising limb of the hydrograph and continued to collect samples at 10 minute intervals throughout the storm.

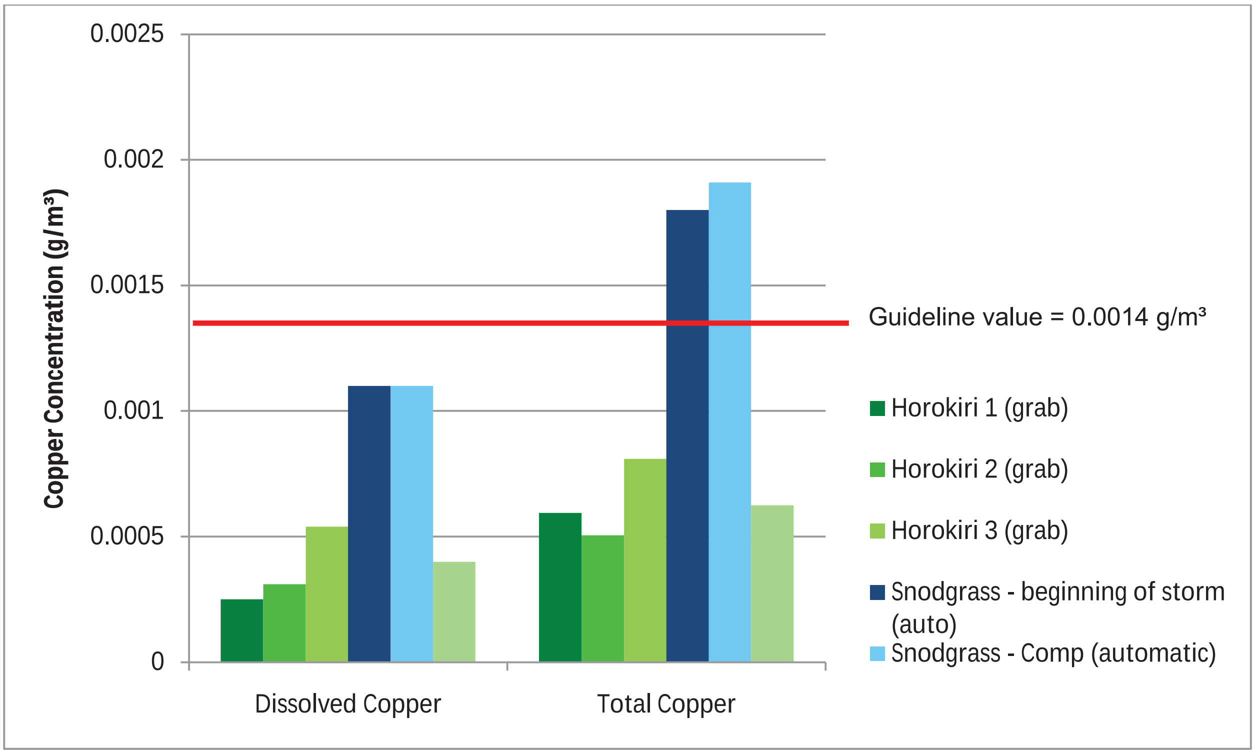
The quality of 'beginning of storm' and 'composite' samples were generally different. In some instances the 'beginning of storm' concentration was higher – as shown for total and dissolved zinc (**Figure 15.23**) and total copper (**Figure 15.24**) at Horokiri at Snodgrass. Varying patterns between 'beginning of storm' and 'composite' samples were also seen within the other two catchments, with no distinct trends. This is likely to be due to the nature of the source of the metals in the catchment (i.e. roads, stormwater, sediments etc.) This is to be expected in rural catchments where early runoff is often from interflow (increased flow through the soils) as opposed to runoff over land, but in road catchments higher heavy metal concentrations would be expected at the beginning of the storm.

Data collected by automatic samplers had higher dissolved and total metal concentrations on average than in grab samples at all three sites compared to their respective catchments (refer **Appendix 15.D** and **Appendix 15.F**). This trend is evident in **Figure 15.26** and **Figure 15.27** for the Horokiri Stream. This was potentially due to the timing of samples collected and the size of the rainfall events. Grab samples were generally collected on the falling limb of the hydrograph. This data demonstrates that the contaminant load varies significantly over each storm event and that the data from the automatic samplers adds considerable value to the analysis.



▪ **Figure 15.26 Median Total and Dissolved Zinc Concentrations for Horokiri Grab and Automatic Sample Sites (sites are ordered from upstream to downstream)**

Note 'Comp' refers to composite samples, 'Auto' refers to automatic samples and 'Snodgrass' refers to the Horokiri Stream at Snodgrass site.

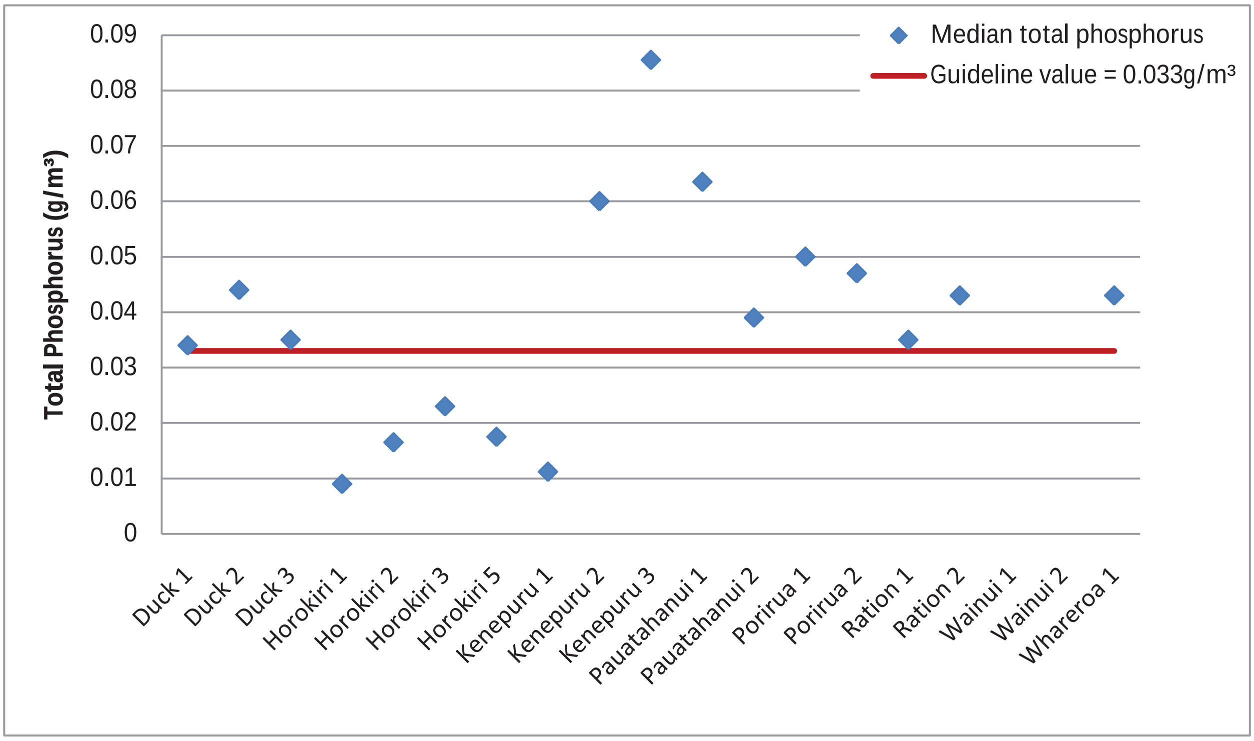


▪ **Figure 15.27 Median Total and Dissolved Copper Concentrations for Horokiri Grab and Automatic Sample Sites (sites are ordered from upstream to downstream)**

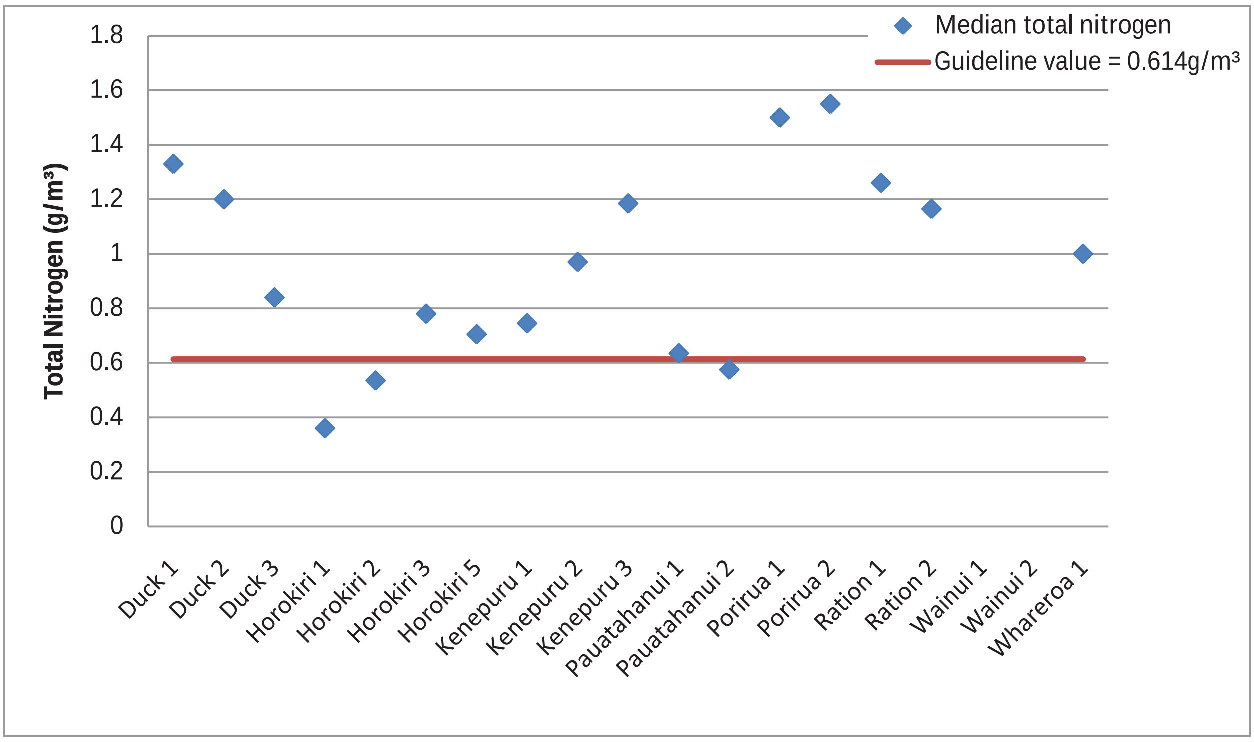
Note 'Comp' refers to composite samples, 'Auto' refers to automatic samples and 'Snodgrass' refers to the Horokiri Stream at Snodgrass site.

6.3.1.3. Nutrients

Nutrients, as indicated by total nitrogen and total phosphorus, were often elevated above the guideline values. In both ‘dry’ and ‘wet’ sample events almost all catchments had median total nitrogen and dissolved reactive phosphorus concentrations above guideline values. Median total phosphorus and total nitrogen have been plotted against guideline values for all sites in **Figure 15.28** and **Figure 15.29**. **Figure 15.28** indicates that median total phosphorus values for all sites are elevated above guideline values except for those within the Horokiri and Te Puka catchments. **Figure 15.29** shows that median total nitrogen concentrations are above guideline levels for all sites except for Horokiri 1 and Horokiri 2, Pauatahanui 2 and both sites in the Te Puka catchment.



- **Figure 15.28 Median Total Phosphorus at All Sites**



- **Figure 15.29 Median Total Nitrogen at All Sites**

6.3.1.4. Suspended Sediment and Turbidity

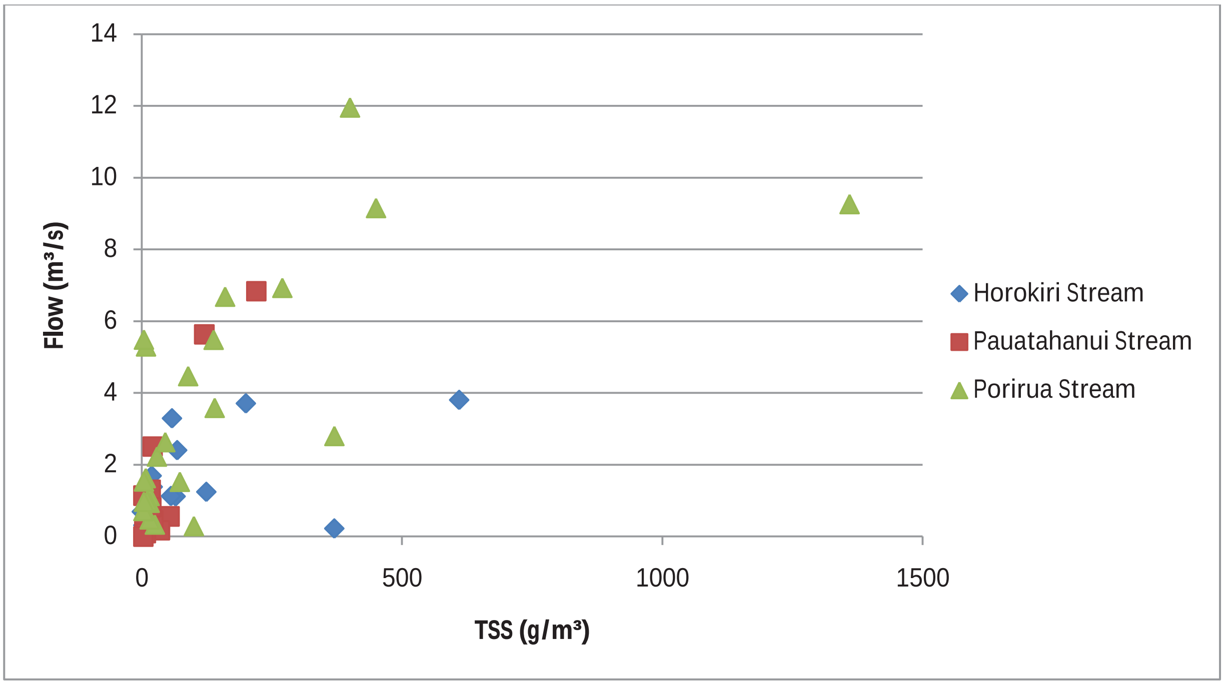
Suspended sediment and turbidity data collected at stream mouths during or after rainfall events and at grab sample locations was used to verify sediment yield estimations and a full analysis of this data is included in Section 10. Several trends on the data collected are outlined below.

Samples collected during or after rainfall events showed that total suspended solids (TSS) and turbidity varied markedly both between sites and between storm events. These differences could be due to several reasons including both climatic and catchment variations such as storm rainfall intensity and duration; antecedent soil moisture conditions; catchment slope, size, geology, soil and landuse. The time of sampling in relation to the storm peak may also have affected results.

Both median TSS and turbidity concentrations were the highest in the Porirua Stream catchment. Duck, Pauatahanui and Ration catchments had similar median concentrations in both these parameters. The Horokiri Stream catchment generally had lower total suspended sediment concentrations and turbidity was lower.

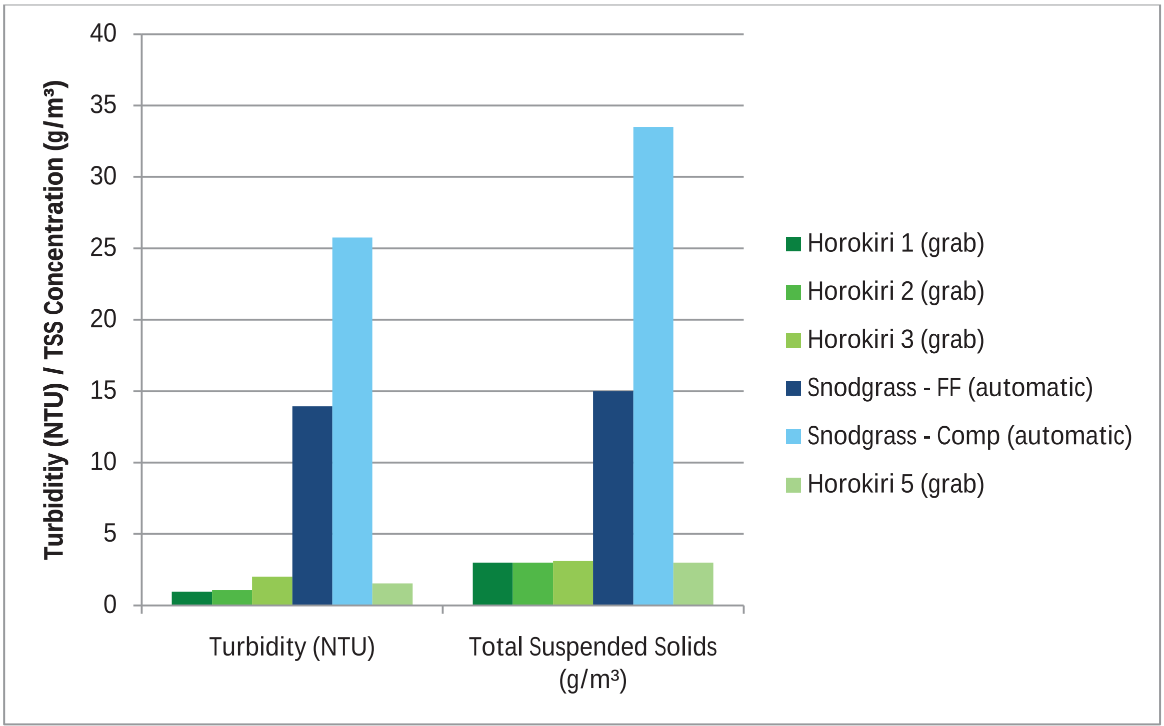
TSS and turbidity data were also collected in automatic samplers in the Horokiri, Porirua and Pauatahanui catchments. There were spatial differences between the sites, although samplers were not always triggered at each site in the same event. This was partly due to differences in rainfall intensity and equipment function. Generally concentrations of both TSS and turbidity increased with storm rainfall intensity and stream flow. TSS concentrations from both the automatic and event samples plotted against flow are shown in **Figure 15.30**.

The 'first flush' concentration collected from the automatic samplers is not strictly the first flush of the storm because it is not the first runoff from the catchment following a dry period. Rather, the sample contains water from the beginning of the storm within a larger catchment. Variable response times within the catchments mean that a 'first flush' for the whole catchment could not be collected.



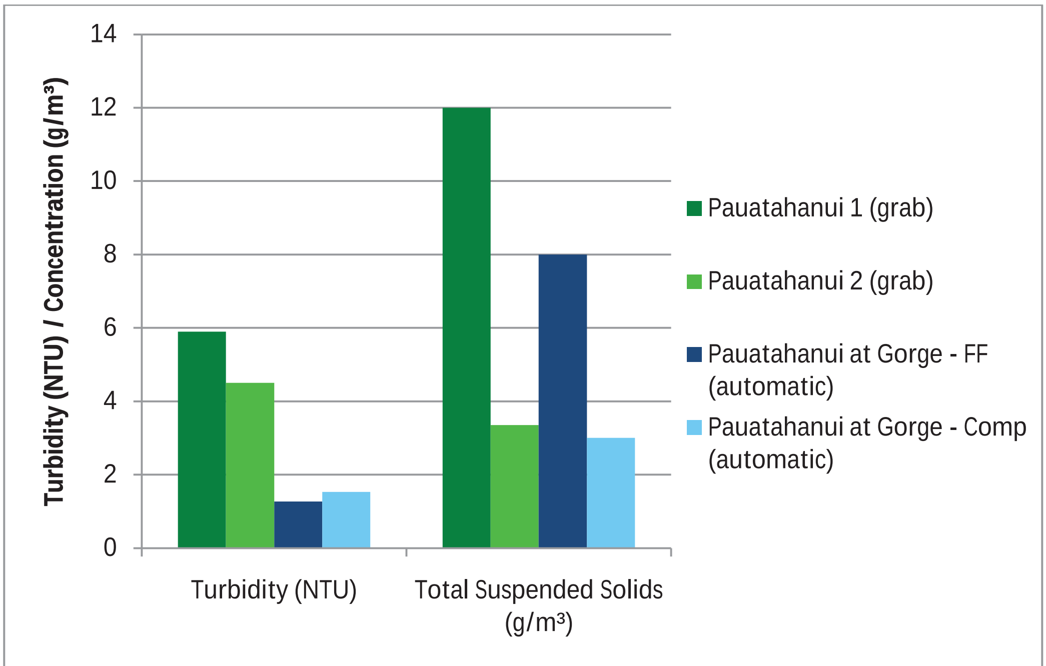
- **Figure 15.30 TSS in Grab Samples at Horokiri, Pauatahanui and Porirua Stream Mouths and Automatic Samples Collected at Horokiri at Snodgrass, Pauatahanui at Gorge and Porirua at Town Centre. Flow is taken from the appropriate flow gauge station for each site. For automatic 'beginning of storm' and composite samples the flow has been averaged over the sample period.**

TSS and turbidity concentrations were generally higher in event and automatic samples compared with the grab samples. This is demonstrated with median values for both these parameters plotted for the Horokiri, Pauatahanui and Porirua Streams in **Figure 15.31**, **Figure 15.32** and **Figure 15.33**. For the Pauatahanui and Porirua Streams, event samples had higher median values for both TSS and turbidity than for grab and automatic samples. However, on the Horokiri Stream, TSS and turbidity in the automatic 'composite' samples were markedly higher than all other sample types, with grab samples still having the lowest concentrations.



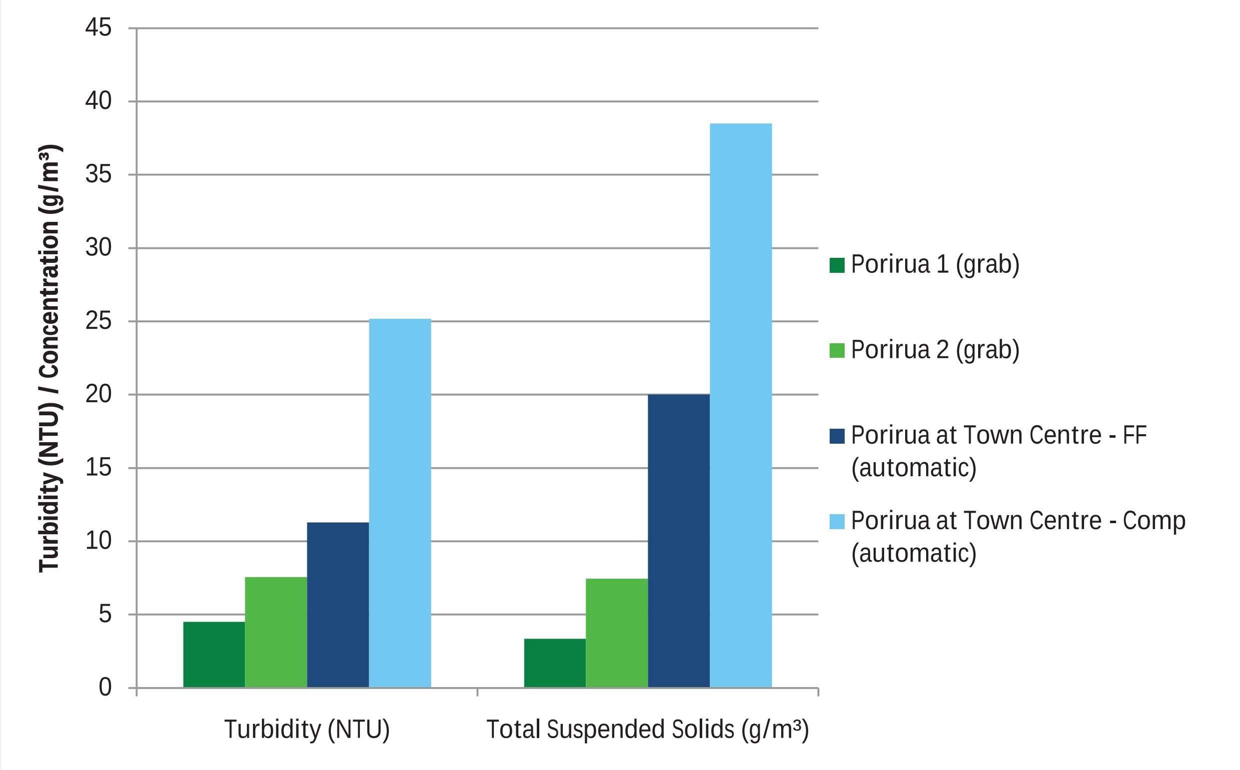
- **Figure 15.31 Median TSS and Turbidity for Grab Sample, Event Sample and Automatic Samples at Sites on the Horokiri Stream**

Note FF refers to 'first flush' samples and Comp refers to composite samples. 'Snodgrass' refers to the Horokiri Stream at Snodgrass site.



- **Figure 15.32 Median TSS and Turbidity for Grab Sample, Event Sample and Automatic Samples at Sites on the Pauatahanui Stream**

Note FF refers to 'first flush' samples and Comp refers to composite samples.



- **Figure 15.33 Median TSS and Turbidity for Grab Sample, Event Sample and Automatic Samples at Sites on the Porirua Stream**

Note FF refers to 'first flush' samples and Comp refers to composite samples.

6.3.1.5. Hydrocarbons

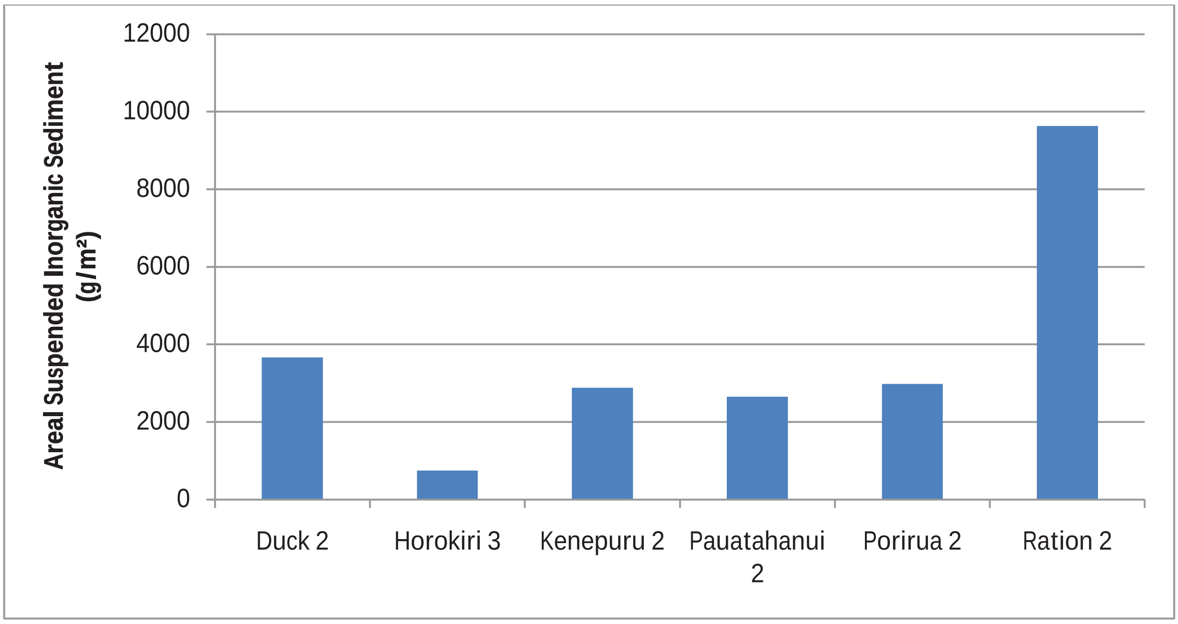
All BTEX and polycyclic aromatic hydrocarbons (PAHs) were almost always below detection limits and where detected were below guidelines. For PAHs the only median value that was above the detection limit was for Indeno (1,2,3-c,d) pyrene. No relevant guidelines exist for this compound.

6.3.1.6. Fine Sediment

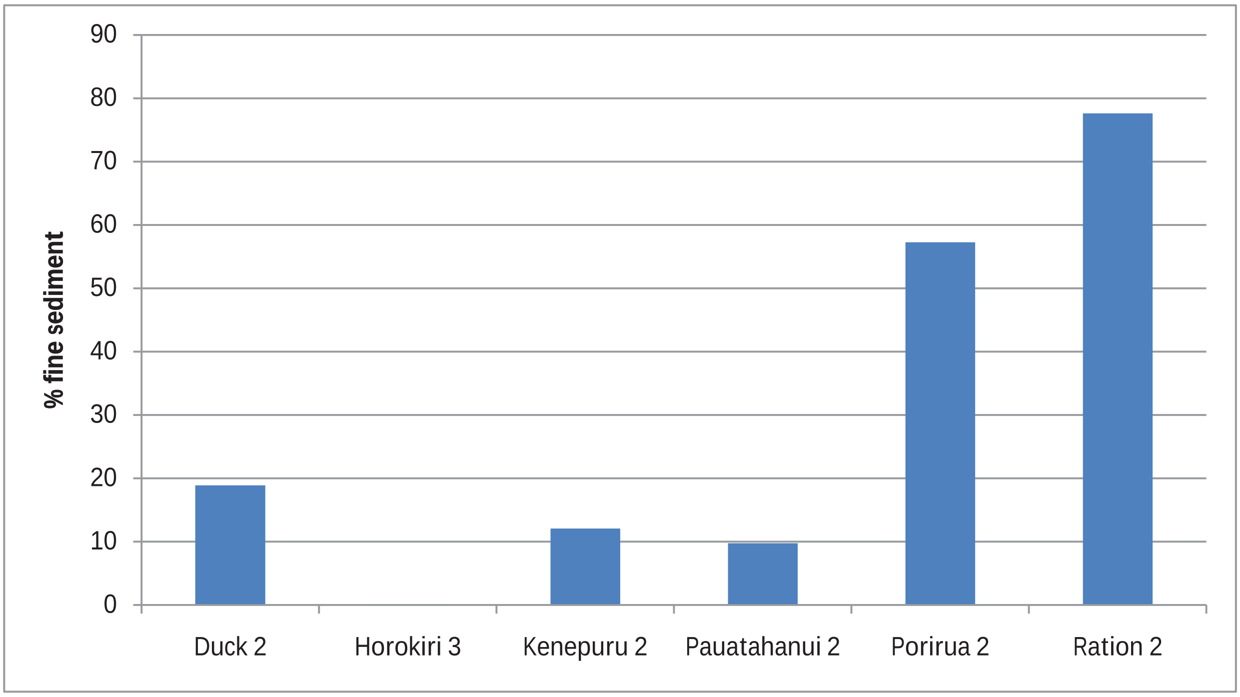
Quorer sample results give an estimation of the quantity of fine sediment deposited in the stream substrate. This includes the top few centimetres of the substrate known as the 'stirred depth'. The visual assessment only gives an indication of how much fine sediment is on the surface of the substrate. Results from both methods show that quantity of fine deposited sediment varies between catchments. Differences in results may be due to a variety of factors including catchment landuse, slope, geology, climate, soil and vegetation types and the degree of channel modification of the stream channel. Local channel morphology will also affect where deposition and erosion occurs at each site. Therefore, site selection will influence the results.

Studies in other catchments in New Zealand have also shown variations in the quantity of suspended areal inorganic sediment (SIS) with respect to landuse. Quinn *et al.,* (2009) found SIS differed 3-fold between native forest and pasture sites in catchments in the Waikato, with native forest catchments having less SIS than pasture catchments. They also found seasonal differences with results varying over the monitoring period. Similar spatial and temporal variations were also seen in our data.

Figure 15.34 shows that median SIS is the highest at the Ration 2 site. Duck 2, Kenepuru, Pauatahanui 2 and Porirua 2 all have median values in the same order of magnitude, whereas Horokiri 3 has markedly lower result. Ration 2 also has the highest percentage of fines in the visual assessment (**Figure 15.35**). Porirua 2 appears to have more superficial fine sediment than all other sites (except for Ration 2). Horokiri 3 also has the lowest visual assessment result compared to the other catchments.



- **Figure 15.34 Median Suspendable Inorganic Sediment (SIS) for All Sites**



- **Figure 15.35 Visual Assessment of Percentage of Fine Sediment at All Sites**

The quorer and visual assessment results displayed in **Figure 15.34** and **Figure 15.35** give an indication of the quantity of fine sediment and where it is deposited in the substrate. At Ration 2, results suggest that there is a high proportion of fine sediment on the substrate surface and that fines are probably throughout the stirred depth of the substrate. At Kenepuru 2, Pauatahanui 2 and Duck 3 results suggest that there is some fine sediment on the surface and also within the substrate dispersed between other particles. Conversely, at Porirua 2, there are a high proportion of fines evident on the substrate surface but comparatively less throughout the stirred depth. Results from both methods at Horokiri 2 indicate that the superficial fine sediment and fine sediment throughout the profile are both low.

6.3.1.7. Greater Wellington Water Quality Data

Greater Wellington collects monthly state-of-the-environment water quality data at various sites throughout the region for a variety of parameters. Sites within the Project area are shown in **Appendix 15.C** and median values for relevant parameter displayed in **Appendix 15.H**. This data provides an overview of long term water quality trends within relevant catchments. Note that water quality data for at these sites is collected in a range of flow events, but does not target event-based flows due to the nature of the sampling program.

Where appropriate, results for these catchments have been compared to our grab sample data for several parameters such as pH, black disc clarity and nutrients. In general, median values for most parameters were within guideline values. Exceptions to this were Porirua Stream at Milk Depot, Porirua Stream at Glenside Overhead Cables and Whareroa Stream at QEII Park, where several nutrient parameters (i.e. nitrite-nitrate nitrogen, total ammoniacal nitrogen, dissolved reactive phosphorus and total phosphorus) had median values above the guideline. At the other sites - Horokiri Stream at Snodgrass, Pauatahanui Stream at Elmwood Bridge and Whareroa Stream at Waterfall Rd, the median dissolved reactive phosphorus was above guidelines. 95th percentiles for turbidity were sometimes outside the recommended range and similarly 5th percentiles for clarity were sometimes below the guideline value indicating water clarity was sometimes poor.

The only metal parameter that was collected in both the GRWC data and in this report was for dissolved arsenic. All median concentrations at these sites were below guideline values. No other data on relevant metals was collected.

6.3.1.8. Suitability for Consumption by Farm Animals

The suitability of freshwater for consumption by farm animals is affected by a number of different factors such as:

- Biological parameters e.g. algal blooms, pathogens and parasites
- Major ions e.g. nitrate, nitrite, total dissolved solids (TDS)
- Heavy metals and metalloids e.g. aluminium, zinc, copper
- Pesticides.

Different types of farm animals have varying thresholds or tolerances to these water quality parameters, and as such may be affected by changes in these parameters in different ways (ANZECC, 2000). Water quality results for all streams have been compared to relevant parameters outlined above. The following observations were noted:

- No algal blooms were observed in any of the streams during both wet and dry weather events
- Concentrations of nitrate-nitrogen and nitrite-nitrogen from samples collected at all sites during Round 1 were below stock consumption guidelines at all sites during this round. Further data was not collected on these parameters as they are unlikely to increase due to the construction or operation of the road
- Median TDS concentrations (estimated from conductivity measurements, where TDS (g/m^3) = conductivity ($\mu S/cm$) x 0.67 for all streams in every round were below the lower threshold for all stock
- The total concentrations of heavy metals such as arsenic, cadmium, copper, chromium, nickel and zinc were all below their respective threshold at all sampling sites on all sampling occasions.

No data on pathogens and parasites was collected as they are unlikely to increase due to the construction or operation of the road.

These results and observations indicate that in general all sites meet livestock drinking water guidelines and as such are suitable for stock consumption.

6.3.2.Results – By Catchment

This section discusses the catchment water quality monitoring results by catchment.

6.3.2.1. Whareroa Stream Catchment

Overview of Catchment Water Quality

Three rounds of samples were collected on the Whareroa Stream at one site – Whareroa 1. All samples were 'wet' samples, collected during or after rainfall in the catchment.

Data collected indicates that water quality in this catchment is generally good compared with applicable guidelines. Metal concentrations are generally below guidelines and field parameters and visual observations indicated good water quality. However, nutrients were generally elevated.

Detailed Water Quality Analysis

Field and visual parameters were consistently above guidelines in this catchment. Median pH was within natural ranges applicable to slightly disturbed ecosystems in New Zealand. Visual observations consistently showed the absence of oil and grease, scums and foams, floating/suspended material and objectionable odour. Black disc water clarity was measured only once and was above the lower limit guideline value. Munsell colour at this time was in the green yellow hue range.

Median values for total and dissolved metals were all below guideline values. However, as shown in **Figure 15.23** and **Figure 15.25**, total copper and total zinc concentrations exceeded the guideline value once during the spring 'wet' round. Both dissolved zinc and dissolved copper concentrations were below guideline values in these samples (**Figure 15.22**, **Figure 15.24**), indicating the bioavailability of these metals and therefore ecological risk of toxicity effects was low.

Nutrient concentrations appear to be elevated in this catchment, with median values for total nitrogen (**Figure 15.29**), nitrite-nitrate nitrogen, total phosphorus (**Figure 15.28**) and dissolved reactive phosphorus all above guideline values. This could have long term implications for algae growth in this stream.

GWRC has two State of the Environment (SoE) sampling points in the Whareroa Stream. "Whareroa at Waterfall Rd" is on the northern branch of the Whareroa Stream and "Whareroa at QE II Park" is downstream of both Whareroa 1 and Whareroa at Waterfall Rd (**Appendix 15.H**). There were some general similarities between our data and GWRC's data at these two sample points. At both sites, median nutrient concentrations, total phosphorus and dissolved reactive phosphorus were above guideline concentrations. Total nitrogen and ammoniacal nitrogen median concentrations were also above guideline values at QE II Park. Other parameters of pH, conductivity, turbidity and total suspended solids concentration had fairly similar median values to Whareroa 1. Some variations were seen, for instance dissolved oxygen saturation was much lower at QE II Park than at Whareroa 1. Variations such as these could be due to several reasons, such as site specific water quality characteristics or ongoing seasonal or annual patterns apparent only through long term data collection.

6.3.2.2. Wainui and Te Puka Stream Catchments

Overview of Catchment Water Quality

Samples were collected at two sites in this catchment: Te Puka 1 and Te Puka 2.

This catchment has generally good water quality with the majority of water quality parameters meeting guideline values. The Te Puka Stream catchment appeared to be one of the better quality catchments in the

Project area. Water quality is very similar at both sites, although some parameters deteriorate downstream from Te Puka 1 to Te Puka 2. This may be due to differences in landuse, with scrub upstream of Te Puka 1, and a combination of scrub, planted forest and pastoral landuse upstream of Te Puka 2.

For the majority of 'wet' samples, concentrations were either equal to or greater than 'dry' samples for both sites.

Detailed Water Quality Analysis

Visual observations showed there was no conspicuous oil or grease, scums or foams, floating or suspended material or objectionable odour evident at either site. The median pH at both sites was slightly acidic. Clarity was measured twice during 'wet' flow events and medians were both above guideline values, with median clarity decreasing further downstream at Te Puka 2. Colour at both sites were within the green yellow Munsell Colour range.

All median dissolved and total metal concentrations were below guideline values at both sites. Metal concentrations tended to be slightly higher at the downstream site with median values either equal to or greater than concentrations at the upstream site. Total copper exceeded the guideline value once at Te Puka 2 during the dry weather sample, but the dissolved copper concentration was below this value on the same day.

Nutrient concentrations were generally below guideline values at both sites. The median dissolved reactive phosphorus concentration was above the guideline value at the downstream site. Other nutrients such as total nitrogen, nitrite-nitrate nitrogen and total phosphorus were also elevated at the Te Puka 2 on occasion during 'wet' sample events.

Based on graphs in **Section 6.2.2**, and median data in **Appendix 15.D** this catchment has comparatively good water quality to other catchments in the Project area, with a low number of exceedances. Water quality is comparable to the Horokiri catchment.

6.3.2.3. Horokiri Stream Catchment

Overview of Catchment Water Quality

Samples were collected at four sites within the Horokiri Stream catchment. Horokiri 1 and 3 are both upstream sample sites on separate tributaries. Horokiri 2 and 5 are downstream of both these sites. Although ideally samples from all sites were to be collected on the same day, during the winter round and the spring round samples at Horokiri 1 were collected on a different day to Horokiri 2, 3 and 5. This was due to access restrictions and timing issues. Samples in the remaining rounds were all collected on the same day.

Data collected showed that water quality at all sites was typically very good. The most upstream site – Horokiri 1 appears to have the best water quality with median concentrations of total and dissolved metals, nutrients, BTEX and PAHs all under guideline values. Visual observations also indicated good water quality and black disc clarity was on average higher than the downstream sites of Horokiri 2, 3 and 5. These patterns are probably indicative of landuse within the catchment, as upstream landuse at Horokiri 1 is mostly planted forest, and the downstream sites having a combination of scrub, planted forest and pastoral landuse.

Detailed Water Quality Analysis

Visual observations for all sample points consistently showed the absence of oil and grease, scums and foams, floating/suspended material and objectionable odour. Clarity was also good at all sites, with clarity generally lower at Horokiri 2, 3 and 5 than at Horokiri 1. Munsell colour was fairly similar at all sites, with hues all in the green yellow range. The pH of the stream is slightly acidic.

In the grab sample data median values for all sites for both total and dissolved metals were all under guideline values. Total copper and total zinc was above the guideline value once at Horokiri 2 and total copper and total chromium concentrations were above the guideline value once at Horokiri 3. These samples were all 'wet' samples and on every occasion the dissolved metal concentration was below the relevant guideline value, indicating the bioavailable fraction of these metals was not high.

Similar trends were observed in data collected by the automatic samplers. Median total and dissolved metals for both copper and zinc were higher in the automatic samples than for the grab samples (**Figure 15.26** and **Figure 15.27**). Total copper concentrations were higher than guideline in both the 'first flush' and composite samples. This is of interest because total copper only exceeded the guideline value on two occasions out of all the grab samples within the Horokiri catchment. Flow was typically higher when automatic samples were collected compared with when grab samples were collected. This suggests that higher metal concentrations may be found in this catchment during run-off generating flow events.

Nutrient concentrations were elevated at Horokiri 2, 3 and 5 on several occasions. The median total nitrogen concentration was above the guideline value at Horokiri 3 and Horokiri 5 (**Figure 15.29**) and the median dissolved reactive phosphorus concentration was above the guideline value for all three sites. High nutrient concentrations can create ideal conditions for algae growth. Biological growths were particularly noted in this stream at Horokiri 3 during the summer months. The high nutrient concentrations at these three sites are possibly related to upstream pastoral landuse in this catchment.

Based on graphs above (**Figure 15.22** to **Figure 15.27**) and median data in **Appendix 15.D**, this catchment has comparatively good water quality to other catchments in the study area.

GWRC has State-of-the-Environment water quality data for two sites on the Horokiri Stream – Horokiri Stream at Snodgrass and Horokiri Stream at Ongly. Both sites are on the main branch of the Stream, between Horokiri 2 and Horokiri 5. The Ongly site is no longer operational. Ongoing results at these two sites also indicate that this stream has generally good water quality when compared to guideline values (**Appendix 15.H**). All nutrient median concentrations are below guideline values at both sites except for dissolved reactive phosphorus at the Snodgrass site. This is consistent with data collected as part of this report, where median concentrations of dissolved reactive phosphorus were also above guidelines at three monitoring sites – Horokiri 2, Horokiri 3 and Horokiri 5. pH measurements gave slightly more alkaline results at both the Ongly and Snodgrass sites compared to our monitoring sites. Median dissolved oxygen saturation was also higher at the GWRC sites compared with our monitoring sites. Black disc clarity was comparable to the downstream sites Horokiri 2 and Horokiri 5.

6.3.2.4. Ration Stream Catchment

Overview of Catchment Water Quality

Samples were collected at two sites in the Ration Stream catchment – Ration 1 and Ration 2.

Water quality in this catchment is generally fairly good when compared to relevant guidelines, although nutrients were consistently higher than guideline values. Water quality is generally slightly worse further downstream with median concentrations of the majority of parameters at the downstream site (Ration 2) greater than or equal to concentrations further downstream at Ration 1.

Detailed Water Quality Analysis

pH at both sites is slightly acidic. Observations at both sites consistently showed that absence of visual parameters with the exception of Ration 1 where foams were noted on every sampling round. Water clarity is typically good at both sites, as median values for both sites above guideline values. Median clarity is shown to be slightly higher at the downstream site, although only one measurement was conducted at this site, compared with two further upstream at Ration 1. Munsell colour at both sites was in the yellow hue range.

Median total and dissolved metal concentrations for both sites were below guideline values, except for total copper at Ration 2. The total copper concentration also exceeded the guideline value during the spring 'wet' round at Ration 1. Total zinc and chromium concentrations were also above the guideline value during this round at Ration 2. However, in every instance, the dissolved metal concentration was below the guideline value, indicating the bioavailable fraction was not high.

Nutrient concentrations were generally higher than guidelines at both sites, with median total phosphorus (**Figure 15.28**), total nitrogen (**Figure 15.29**) and dissolved reactive phosphorus above guidelines for both sites. Median nitrite-nitrate nitrogen was above the guideline value at the upstream site.

Water quality in this catchment appears to be in the mid range compared to data for other catchments in the study area. Median data for many parameters are similar to Duck and Whareroa catchments (**Figure 15.22** to **Figure 15.25**, **Figure 15.28** and **Figure 15.29**).

6.3.2.5. Pauatahanui Stream Catchment

Overview of Catchment Water Quality

Samples were collected at two sites within the Pauatahanui Stream catchment – Pauatahanui 1 and Pauatahanui 2.

Water quality results for this catchment are variable, with median values for some parameters outside guideline values. For the majority of parameters, data shows water quality at the downstream site (Pauatahanui 2) is generally either the same or worse than at the upstream site (Pauatahanui 1). However, median nutrient concentrations and water clarity are typically higher at Pauatahanui 1. Similarly, when comparing data from ‘dry’ and ‘wet’ sample events, ‘wet’ sample concentrations are generally equal to or greater than ‘dry’ sample concentrations; this is particularly evident for total and dissolved metals.

Detailed Water Quality Analysis

pH in this catchment is slightly acidic. Median black disc clarity is lower at the Pauatahanui 1, than further downstream, and is also below the guideline value of 0.8 metres. However, clarity was only lower than the guideline value on one out of two measurements. Foams were consistently observed at the upstream site possibly as a result of organic matter near the stream, whereas they were only observed further downstream once. No other visual parameters were noted at either site. Turbidity and total suspended solids were elevated on occasion at both sites, this was apparent particularly after or during high flow events.

Grab sample median total and dissolved metal concentrations were below guideline values at both sites except for total copper, which exceeded the guideline value at Pauatahanui 2. Total copper was consistently above the guideline value during all ‘wet’ samples at this site. Other metals were exceeded once during a ‘wet’ round at Pauatahanui 1 were total copper, total chromium and total zinc. On all of these instances the dissolved metal concentration was below the respective guideline value, indicating bioavailable levels of these metals were low.

Data collected at the automatic sampler at Pauatahanui at Gorge showed similar trends in terms of metal concentrations. However, median concentrations were typically higher in automatic samples compared with grab samples. In the automatic samples both dissolved and total concentrations for both zinc and copper were above guideline values on several occasions. However, only median total zinc for ‘first flush’ samples was above guideline values (**Appendix 15.F**). Of note, is the fact that median total copper was below guideline for the automatic samples and was above the guideline value further downstream. This could be due to site specific water quality characteristics, particularly because the downstream sites have larger contributing catchments.

Some nutrient parameters are sometimes elevated in this catchment. Phosphorus concentrations were typically high at both sites, with median total phosphorus (**Figure 15.28**) and dissolved reactive phosphorus concentrations were above guideline values. Additionally, the median total nitrogen concentration (**Figure 15.29**) was above the guideline value at Pauatahanui 1. Nitrite-nitrate nitrogen was below guideline values at both sites during every round.

Compared with other catchments in the study area, data from the Pauatahanui Stream catchment is generally in the mid range of data. However, total phosphorus tends towards the upper range of data in the study area (**Figure 15.22** to **Figure 15.25**, **Figure 15.28** and **Figure 15.29**).

GWRC gathers State-of-the-Environment water quality data at one site on the Pauatahanui Stream, called "Pauatahanui at Elmwood Bridge". This site is between Pauatahanui 1 and Pauatahanui 2 (**Appendix 15.C**). GWRC data at this site indicates good water quality with median values for most parameters within guideline values. Most median nutrient concentrations were below guideline values, with the exception of dissolved reactive phosphorus. Comparatively, our data shows dissolved reactive phosphorus concentrations also elevated above guideline values. Although our data indicates slightly higher median values of other nutrients such as total nitrogen compared to the Elmwood Bridge site, our data is within the 95th to 5th percentile range. Other median values such as pH, dissolved oxygen, turbidity and clarity varied slightly between our sites and the Elmwood Bridge site, however this could be due to several reasons such as site specific water quality characteristics and seasonal or annual variations captured by long term monitoring of the Stream.

6.3.2.6. Duck Creek Catchment

Overview of Catchment Water Quality

Samples were collected at three sites within the Duck Creek catchment – Duck 1, Duck 2 and Duck 3.

Water quality appears to vary throughout this catchment. There were some exceedances above guideline values for metal concentrations, particularly at the downstream site (Duck 3). Nutrients were on average elevated at all three sites. Water quality typically worsens from upstream to downstream in the catchment. Median values of pH and dissolved oxygen indicate that pH appears to become more acidic and water becomes less oxygenated moving downstream. Most dissolved and total metal concentrations either progressively increase or stay the same moving downstream. Differences in water quality may be due to landuse changes within the catchment, as the stream moves through pastoral, scrub and forest in the upper catchment and urban landuse further downstream. The influence of tides may also be affecting water quality at Duck 3, as samples were sometimes collected at high tide when there was very little flow in the stream.

Detailed Water Quality Analysis

Visual observations were consistently good at all sites within this catchment. Water clarity measurements taken at Duck 2 and Duck 3 were above the guideline value, and were lower at Duck 3 compared with Duck 2. Munsell Colour was in the green yellow and green hues at Duck 2 and Duck 3 respectively. It was not possible to measure clarity or Munsell Colour at Duck 1 due to the size and depth of the stream at this site. pH appeared become more acidic downstream; with both Duck 2 and Duck 1 have slightly acidic pH values. A median pH of 4.8 at Duck 3 indicates higher acidity than further upstream.

Hardness was tested once at all sites. Duck 1 and Duck 2 were classified as 'soft'. Duck 3 had a hardness of 470 g/m³ as $CaCO_3$ and was classified as 'extremely hard' (ANZECC, 2000). This measurement could be due to the potential saline influence at this site, as the sample was collected at high tide. Other parameters such as conductivity and dissolved and total chromium were also markedly higher in this sample than other samples. The high hardness value seems unusual when compared to hardness further upstream at Duck 2 and Duck 3. State of the Environment data collected by Greater Wellington Regional Council in surrounding catchments also shows that hardness is typically either soft or moderate in the region. For these reasons, it is thought this high value may be an anomaly and metal trigger levels have not been adjusted for hardness at this site. This is a conservative decision as the trigger value is lower for soft waters.

Most median total and dissolved metal concentrations were below guideline values for all sites. Moreover, at Duck 1 and Duck 2, almost all dissolved and total metal concentrations were below guideline values during all sample rounds. One exception was for total copper at Duck 2. Dissolved copper was below the guideline value on this day, indicating the bioavailable fraction was low. At Duck 3, median total copper and total zinc concentrations were above guideline values. Both of these parameters were above guideline values on all three 'wet' sample events. However, median dissolved concentrations of these metals were low, indicating the bioavailable fraction was low. Dissolved copper and total and dissolved chromium were also above guidelines on several occasions. Duck 3 had noticeably worse quality in terms of metal concentrations than Duck 1 and 2.

Nutrient concentrations were typically high at all three sites, with median values of total nitrogen, total phosphorus and dissolved reactive phosphorus all above guideline values at all sites. Median nitrite-nitrate nitrogen was above guideline values at Duck 1 and Duck 2.

Water quality in this catchment appears to be in the mid range compared to data for other catchments in the study area. Median data for many parameters are similar to Ration and Whareroa catchments (**Figure 15.22** to **Figure 15.25**, **Figure 15.28** and **Figure 15.29**).

6.3.2.7. Kenepuru Stream Catchment

Overview of Catchment Water Quality

Samples were collected at three sites in the Kenepuru Stream catchment – Kenepuru 1, Kenepuru 2 and Kenepuru 3.

Data collected shows that water quality is generally good when compared with applicable guidelines. This was also verified by the majority of visual observations. However, some median values for total and dissolved metals and some nutrients were above guideline values, mainly at the downstream site. Water quality does tend to vary within the catchment, with water quality progressively worsening downstream. This was particularly evident in reduced water clarity further downstream and turbidity, some total and dissolved metals and some nutrients concentrations increasing further downstream. These trends are possibly due to landuse changes throughout the catchment, with pastoral landuse in the upper catchment and scrub and urban landuse further down.

Detailed Water Quality Analysis

Visual observations generally showed the absence of oil and grease, scums and foams, floating/suspended material and objectionable odour. However, scums were noted at the most downstream site (Kenepuru 3) once. The water in this stream was more alkaline than other streams in the area. Water clarity was mostly higher than guidelines, except at Kenepuru 3 where median black disc clarity was 0.67 metres. Munsell Colour in this stream was in the green and yellow hues.

Median dissolved and total metal concentrations were below guideline values at Kenepuru 1 and Kenepuru 2. However, several total metal concentrations were higher than guidelines during one 'wet' event at Kenepuru 1. Dissolved metal concentrations did not exceed guideline on these samples. Both total and dissolved metal concentrations were consistently higher at Kenepuru 3 compared with the two upstream sites. Median total and dissolved copper and total zinc were above guidelines at this site (**Figure 15.23** to **Figure 15.25**). Total and dissolved copper were above guideline values for all 'wet' event samples and total zinc was above guidelines in all samples. Kenepuru 3 appeared to be one of the worst sample points in the Transmission Gully catchments for metal concentrations.

Nutrient concentrations are typically elevated above guidelines in this catchment. In particular, median concentrations of total nitrogen (**Figure 15.29**) and dissolved reactive phosphorus were above guidelines at all sites. Median total phosphorus was above guideline values at Kenepuru 2 and Kenepuru 3 (**Figure 15.28**), while median nitrite-nitrate nitrogen was above guidelines only at Kenepuru 2.

Water quality in this catchment is variable compared to other catchments in the study area. Data for Kenepuru 1 and Kenepuru 2 is generally in the mid range of data. However, data for several key parameters at Kenepuru 3 is similar to those with poor water quality such as the Porirua Stream catchment. The change in water quality throughout this catchment may be due to landuse changes, as Kenepuru 3 is downstream of a large urban area.

6.3.2.8. Porirua Stream Catchment

Overview of Catchment Water Quality

Samples were collected at two sites on the Porirua Stream – Porirua 1 and Porirua 2.

Data collected indicates that water quality within this catchment is poor compared to guidelines and also against other streams monitored. Evidence of this was found in some visual observations and field measurements. Key nutrient concentrations and total and dissolved metal concentrations were almost always elevated above guidelines. Water quality was similarly poor at both sites, although some metals and nutrient concentrations were higher at the downstream site (Porirua 2).

Detailed Water Quality Analysis

Water in this stream is slightly acidic. Visual observations noted a continuing presence of scums and/foams on the water surface at both sites. Clarity was the lowest in this catchment compared to others in the area. Median clarity was below the guideline value of 0.8 metres at Porirua 2. Clarity was slightly higher at Porirua 2.

Grab sample median total and dissolved copper and zinc were all above guideline values at both sites. Total chromium was also above guidelines at both sites. The dissolved copper and zinc concentrations are of note as they represent the bioavailable fraction of these metals. Other metals that were above guideline values on 'wet' sample days were total lead and dissolved chromium.

Similarly in the automatic samples, both median concentrations for total and dissolved zinc and copper were all above guidelines. Median concentrations for both total and dissolved zinc and copper were markedly higher in both 'first flush' and composite samples compared with Porirua 1. However, similar median values were seen at Porirua 2 compared with automatic samples. This is possibly due to the differing proximity of the two sites to point source discharges.

The key nutrients of total nitrogen, nitrite-nitrate nitrogen, total phosphorus and dissolved reactive phosphorus had medians greater than guideline values. It is also notable that total nitrogen concentrations in this catchment were the highest compared to other monitored catchments.

GWRC has two State-of-the-Environment sampling locations on the Porirua Stream – Porirua Stream at Milk Depot and Porirua Stream at Glenside Overhead Cables. Porirua Stream at Glenside Overhead Cables is upstream of both Porirua 1 and Porirua 2. Porirua at Milk Depot is just downstream of Porirua 1. This data shows poor water quality in this catchment, which is highlighted by consistently elevated nutrient concentrations compared to guideline values (**Appendix 15.H**). In particular, median concentrations of nitrite-nitrate nitrogen, total ammoniacal nitrogen, total nitrogen and dissolved reactive phosphorus were above guideline values at both sites. A similar pattern is also seen at both Porirua 1 and Porirua 2 (**Appendix 15.C**).

6.3.2.9. Summary

In summary, data collected over the past year shows that water quality in the streams with Transmission Gully catchments is generally within existing aquatic ecological toxicity guidelines. There were some exceedances of guidelines particularly at the downstream sites of the Duck Creek, Kenepuru Stream and Porirua Stream catchments. Occasional exceedances were noted within other catchments. Water quality in most catchments generally does not meet guidelines that indicate adverse risk of effects from nutrients. This included both nitrogen and phosphorus constituents. This does not mean that adverse effects such as algal/bacterial growth and low dissolved oxygen were necessarily occurring or could occur, but it indicates that the streams could be at risk from these effects. Furthermore, additional nutrient inputs could add to this risk. Some differences were apparent between 'wet' and 'dry' sampling events, with 'wet' sample events typically having slightly poorer water quality. A summary table, which shows water quality trends for all grab sample sites, is displayed in **Table 15.7**.

Table 15.7 Summary of Water Quality for All Sites

Catchment	Sampling site	Location in relation to road	Turbidity	Metals	Nutrients	Hydrocarbons
Whareroa	Whareroa 1	Upstream	✓	✓	x	✓
Te Puka	Te Puka 1	Upstream	✓	✓	✓	✓
	Te Puka 2	Downstream	✓	✓	x	✓
Horokiri	Horokiri 1	Upstream	✓	✓	✓	✓
	Horokiri 2	Downstream	✓	✓	x	✓
	Horokiri 3	Control site	✓	✓	x	✓
	Horokiri 5	Downstream	✓	✓	x	✓
Ration	Ration 1	Upstream	✓	✓	x	✓
	Ration 2	Downstream	✓	x	x	✓
Pauatahanui	Pauatahanui 1	Upstream	✓	✓	x	✓
	Pauatahanui 2	Downstream	x	x	x	✓
Duck	Duck 1	Upstream	✓	✓	x	✓
	Duck 2	Downstream	✓	✓	x	✓
	Duck 3	Downstream	✓	x	x	✓
Kenepuru	Kenepuru 1	Upstream	✓	✓	x	✓
	Kenepuru 2	Downstream	✓	✓	x	✓
	Kenepuru 3	Downstream	x	x	x	✓
Porirua	Porirua 1	Upstream	x	x	x	✓
	Porirua 2	Downstream	x	x	x	✓

Note: ✓ indicates that median values are all within guideline values

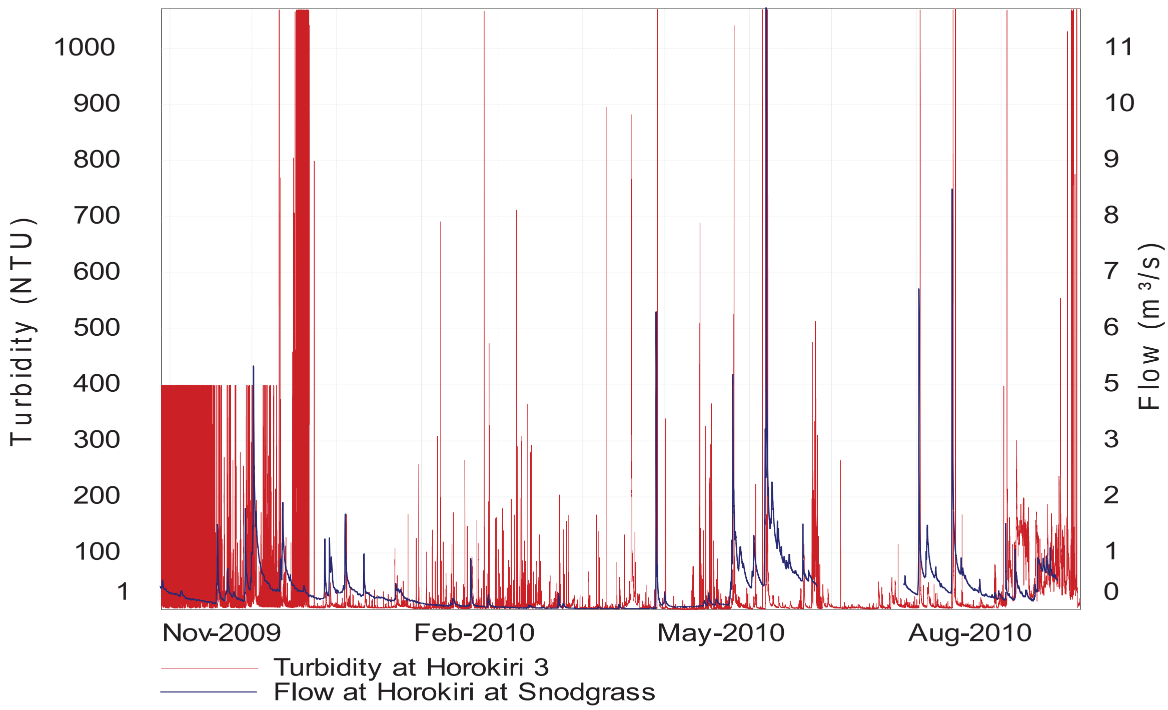
x indicates at least one median value in this group is outside guideline values

6.3.3. Turbidity Logger Results

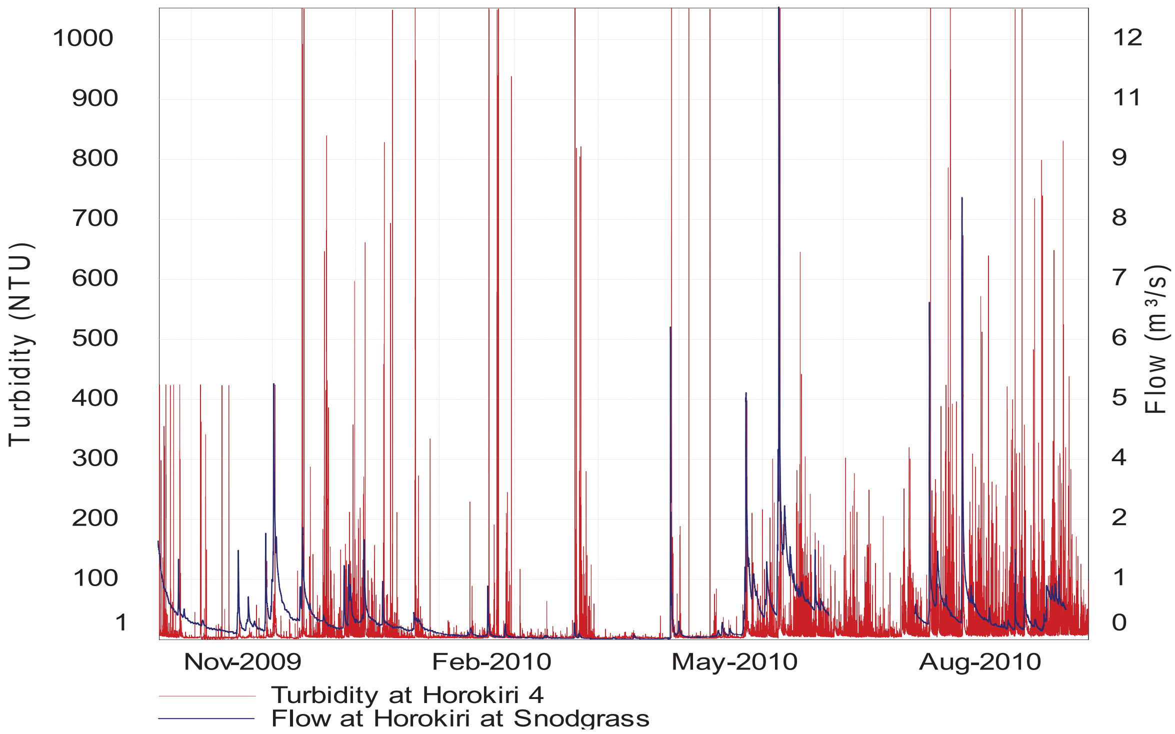
Loggers were installed in October 2009 and provide ongoing continuous monitoring. Site visits were done periodically to ensure the security and stability of the loggers and to download data. The purpose of the continuous turbidity record at these sites is primarily used to estimate stream sediment loads. Further details relating to these calculations are included in the Sediment Yield Calculations report. This section will discuss data collected from the loggers up to the current date. Where possible, turbidity data has been compared with relevant gauged flow data. Further details regarding the installation and data processing for each site are included in **Appendix 15.I**. The turbidity data presented in this report is raw data. Data analysis and processing of this is reported in the Assessment of road construction on sediment yield.

Continuous turbidity data at Horokiri 3, Horokiri 4 and Pauatahanui 2 has been appropriately compared to gauged flow data at Horokiri at Snodgrass and Pauatahanui at Gorge. The Horokiri Stream at Snodgrass site is downstream of the confluence of the two branches Horokiri 3 and Horokiri 4 are located on. Therefore, the flow record may not directly match either of the turbidity records, but should provide a good comparison of turbidity against flow. The Pauatahanui at Gorge site is between Pauatahanui 1 and Pauatahanui 2.

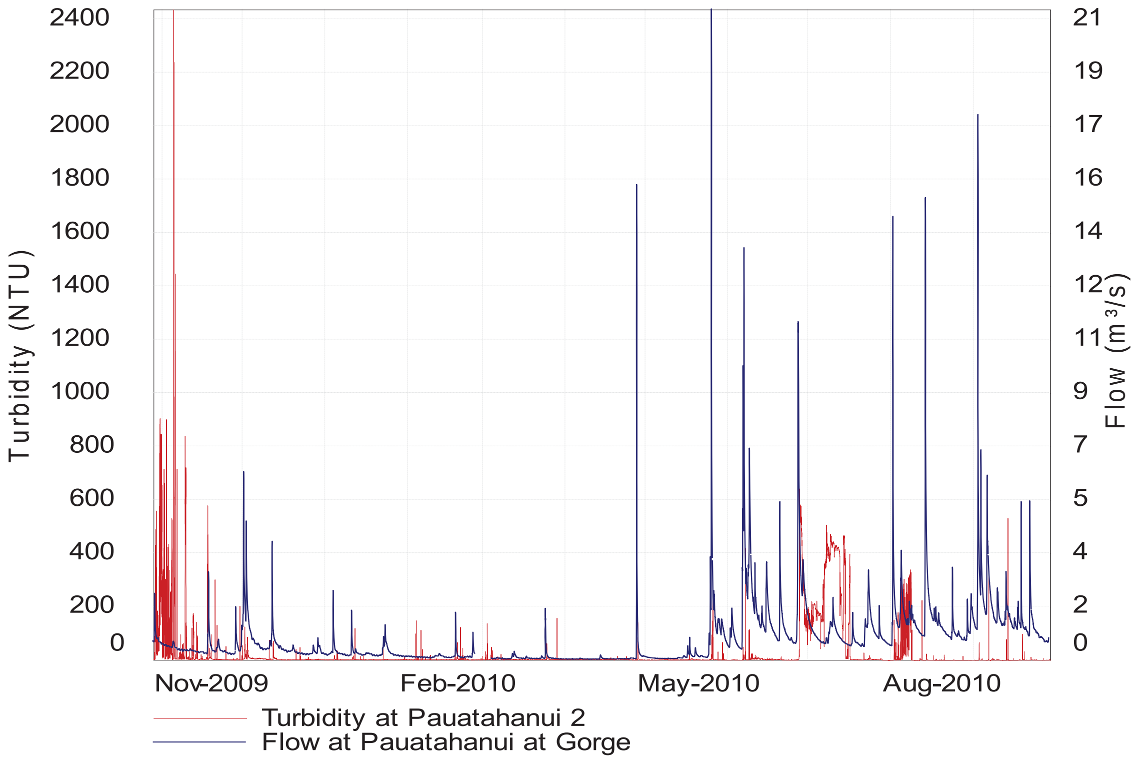
Figure 15.36 to **Figure 15.38** show recorded turbidity at Horokiri 3, Horokiri 4 and Pauatahanui 2 with flow at gauges on these streams. It is evident that increases in turbidity sometimes occur concurrently with increases in flow. However, many other increases in turbidity do not occur with increases in flow. Other causes of turbidity increases could be due to a variety of factors including upstream stock disturbances, upstream ford crossings, industrial discharges and changing sediment inputs into the stream caused by stream bank erosion.



- **Figure 15.36 Recorded Turbidity at Horokiri 3 and Flow at Horokiri at Snodgrass Between 28 October 2009 and 29 September 2010.**

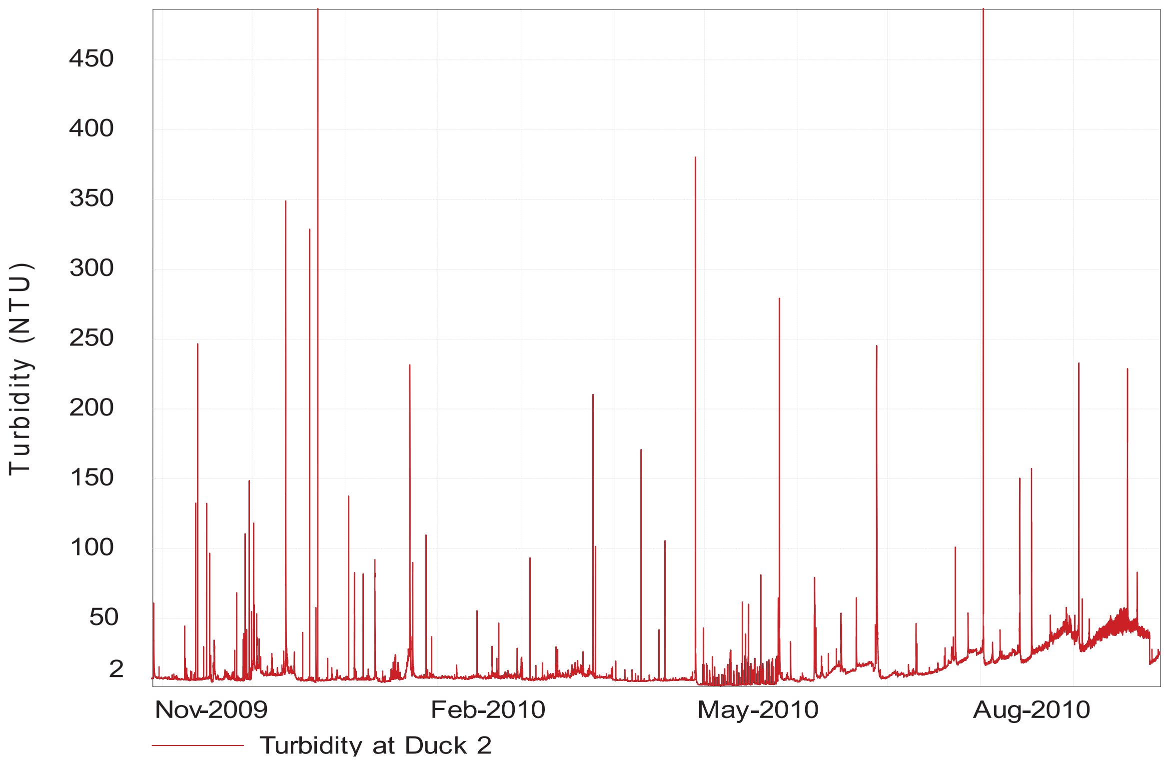


- **Figure 15.37 Recorded Turbidity at Horokiri 4 and Flow at Horokiri at Snodgrass Between 19 October 2009 and 29 September 2010**



- **Figure 15.38 Recorded Turbidity at Pauatahanui 2 and Flow at Pauatahanui at Gorge Between 18 November 2009 and 29 September 2010**

There is no flow gauge on Duck Creek. Therefore, turbidity data has not been compared to flow. Recorded turbidity at Duck 2 is shown in **Figure 15.39**.



- **Figure 15.39 Recorded Turbidity at Duck 2 between 29 October 2009 and 29 September 2010**

6.3.4.Quality Control Data

One quality control report was done by Hill Laboratories for each grab sampling round. All reports indicated that laboratory performance was good, as duplicates, blanks and standards were all within the required ranges for analytes.

Blank and duplicates samples were also collected as part of the grab sampling programme. All duplicate samples were within 10% of control samples which indicated field practices in the collection, storage and transportation of samples were of an appropriate standard. All blank samples were below detection limits, verifying the field and storage procedures were free from contamination.

7. Potential Effects

During construction activities earthworks have the potential to input sediment to the Project catchments and affect water quality in streams and the sediment load delivered to the coastal receiving environment. During operation the road surface and vehicle movements will increase the pollutants in stormwater runoff, which will be discharged to the receiving environment during wet weather.

As the discharge and deposition of sediment has the potential to impact on ecological receptors this report should be read in conjunction with Technical Report 11 *Ecological Impact Assessment*.

When determining the appropriate performance standard for mitigation devices and for assessing the significance of predicted changes in water quality, the management objectives for the receiving environments and water quality guidelines, identified in the Regional Freshwater Plan and the Regional Coastal Plan were considered to define the potential effects.

7.1. Streams

Table 15.8 outlines the data and modelling results that will be used for assessing the potential effects of the discharge of stormwater to stream during the construction phase of the project. The table summarises all of the potential effects that the streams are managed for. Not all of these effects are considered to be potential effects as a result of the proposed construction stormwater discharges.

▪ **Table 15.8 Potential Effects of Construction Stormwater Discharges on Freshwater**

Receiving Environment	Potential Effect	Assessment Required for Construction Effects	Assessment Required for Operational Effects
All streams	The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials	Predicted increase in total suspended sediment will be assessed.	Predicted increases in TPH and litter will be assessed.
	Any conspicuous change in the colour or visual clarity	Predicted increase in total suspended sediment will be assessed.	Change in TSS will be assessed.
	Any emission of objectionable odour	Predicted increase in total suspended sediment will be assessed.	Predicted increases in TPH will be assessed.
	The rendering of freshwater unsuitable for consumption by farm animals	The predicted increase in sediment load will be assessed.	Predicted increases in metals will be assessed. Operational stormwater discharges are not expected to contain or result in increased levels of : ▪ blue-green algae ▪ pathogens or parasites ▪ calcium and magnesium ▪ nutrients

Receiving Environment	Potential Effect	Assessment Required for Construction Effects	Assessment Required for Operational Effects
			▪ sulphates ▪ total dissolved solids (TDS) ▪ pesticides
	Any significant adverse effects on aquatic life	Predicted increases in sediment load will be assessed. Potential increases in pH and aluminium will be assessed. Potential increases in contaminants from soils will be assessed. Stream sediment transport and deposition will be assessed. See TR11 *Ecological Impact Assessment.*	Predicted increases in TSS, metals and TPH will be assessed. Stream sediment transport and deposition will be assessed. Predicted increases in connected impervious area will be assessed. See TR11 *Ecological Impact Assessment.*
	Concentrations of acid-soluble aluminium in the discharge are more than 0.15g/m³	Potential increases in aluminium will be assessed	Operational stormwater discharges are not expected to contain or result in increased levels of aluminium.
	Erosion at the point of discharge	Proposed outlet designs	Proposed outlet designs
	Alteration in the natural course of the river or stream	Proposed outlet designs	Predicted increases in connected impervious area will be assessed. Proposed outlet designs.
Aquatic ecosystems; Nationally threatened indigenous fish and aquatic plants; Fish spawning; High degree of natural character	An increase in natural temperature of the water by more than 3° Celsius	Sediment ponds will be assessed	Stormwater management ponds will be assessed
	Any pH change	The predicted discharges from chemically treated ponds will be assessed. See TR11 *Ecological Impact Assessment.*	Operational stormwater discharges are not expected to result in pH change outside of acceptable range See TR11 *Ecological Impact Assessment.*
	Any increase in the deposition of matter on the bed of the water body	Stream sediment and transport modelling will be assessed. See TR11 *Ecological Impact Assessment.*	Stream sediment transport and deposition will be assessed See TR11 *Ecological Impact Assessment.*
	Any discharge of a contaminant into the water	An increase in sediment load will be assessed. See TR11 *Ecological Impact Assessment.*	Predicted increases in metals and TPH will be assessed See TR11 *Ecological Impact Assessment.*
	The concentration of dissolved oxygen (DO) to fall below 80% of saturation concentration.	Construction stormwater discharges are not expected to result in DO change outside of normal fluctuations	Operational stormwater discharges are not expected to result in DO change outside of normal fluctuations
	Undesirable biological growths as a result of any discharge of a contaminant into the water	An increase in total suspended sediment will be assessed.	Operational stormwater discharges are not expected to result undesirable biological growths

Receiving Environment	Potential Effect	Assessment Required for Construction Effects	Assessment Required for Operational Effects
Fishery and aquatic ecosystems	An increase in the natural temperature of the water exceeding 25 degrees as a result of the discharge	Construction stormwater discharges are not expected to result in temperature change exceeding 25 degrees.	Operational stormwater discharges are not expected to result in temperature change exceeding 25 degrees
	Fish rendered unsuitable for human consumptions by the presence of contaminants	An increase in sediment load will be assessed.	Predicted increases in metals and TPH will be assessed

7.2. Coast

There are no discharges directly to the coastal marine environment, but the assessment accounts for the potential for the discharge into freshwater to cause effects in the coastal area.

The Regional Coastal Plan (GWRC, 2000) identifies management objectives for the coast, including:

- Area of significant conservation value (Pauatahanui Inlet)
- Contact recreation (Porirua harbour and Kapiti Coast).

Potential effects, and comment on their assessment for the Project are provided in **Table 15.9**.

- **Table 15.9 Potential Effects of Construction Stormwater Discharges on Coastal Areas**

Receiving Environments	Potential Effect	Assessment Required for Construction Effects	Assessment Required for Operational Effects
Porirua Harbour and Kapiti Coast	The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials	Predicted increases in TSS will be assessed.	Predicted increases in TPH and litter will be assessed
	Any conspicuous change in the colour or visual clarity	Predicted increases in TSS will be assessed.	Change in TSS will be assessed.
	Any emission of objectionable odour	Predicted increases in sediment load will be assessed.	Predicted increases in TPH will be assessed
	Any significant adverse effects on aquatic life	Predicted increases in sediment load will be assessed. Harbour sediment transport and deposition will be assessed	Predicted increases in metals and TPH will be assessed Harbour sediment transport and deposition will be assessed

Receiving Environments	Potential Effect	Assessment Required for Construction Effects	Assessment Required for Operational Effects
		See TR 11 *Ecological Impact Assessment*	See TR 11 *Ecological Impact Assessment*
	The rendering of water unsuitable for bathing by the presence of contaminants	Predicted increases in sediment load will be assessed.	Predicted increases in metals and TPH will be assessed
	Undesirable biological growths	Predicted increases in total suspended sediment will be assessed.	Operational stormwater discharges are not expected to result in biological growths
	Increase in bacterial contamination	Construction stormwater discharges are not expected to result in a change in bacterial content	Operational stormwater discharges are not expected to result in a change in bacterial content

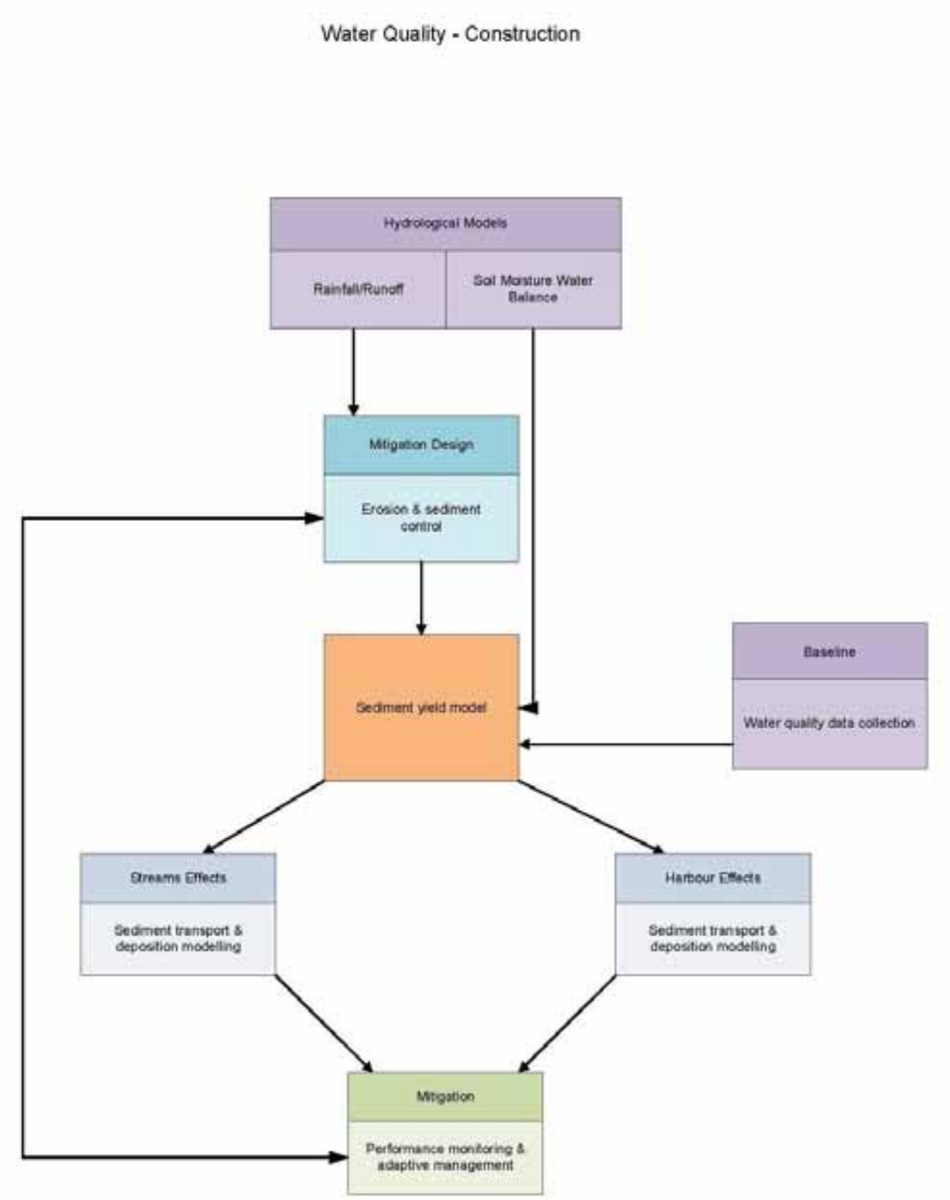
8. Construction - Assessment Methodology

The discussion of modelling effects during the construction phase is split into three chapters:

- Sediment yield
- Streams
- Harbour

Figure 15.40 illustrates how the modelling of construction effects was undertaken.

- **Figure 15.40 Construction Assessment Methodology**



9. Construction - Erosion and Sediment Control Philosophy

9.1. Erosion and Sediment Control Philosophy

This erosion & sediment control (ESC) philosophy is based around the GWRC's *Sediment and Erosion Control Guidelines* (2006). These guidelines are not a statutory document, but are "intended to assist all persons working in earthworks situations with implementing methods and devices for minimising erosion and sedimentation". The guidelines draw on material from the Auckland Regional Council (ARC) Technical Publication 90 (TP90) *Erosion and Sediment Control Guidelines for Land Disturbing Activities* (1999).

This section sets out the ESC to be applied during construction of the Project in order to control and mitigate the effects of erosion and sedimentation to the streams and harbour.

The principles identified in this document have been used to develop example site plans for several focus areas along the Main Alignment. These are provided in the SSEMPs in Volume 5.

9.2. Principles

Consistent with the GWRC *Erosion and Sediment Control Guidelines*, the following key principles will be applied during construction.

Minimise Disturbance

Earthworks should be limited to the footprint of the works. In addition to the road alignment and associated cut and fill areas, this will include designated access roads, the contractor's yard, stockpiled material and temporary services.

For the construction of the Project, the footprint of works will be well defined as all earthworks and associated ESC activities will take place within the road designation.

Minimising disturbance will be particularly important in areas along the Project alignment that have highly erodible colluvium soils, such as in the upper Horokiri and Te Puka catchments. In these locations strict care and supervision will be required to ensure existing vegetation is retained where possible.

The current programme of works (MacDonald International, 2010) for construction of the motorway indicates that construction will be undertaken on three fronts simultaneously. To minimise disturbance the total length of bare earth area will be limited on each front and the road will be sealed progressively.

Stage Construction

Details for staged construction are undergoing refinement as part of the assessment of earthworks and construction. The key focus has been to limit the areas of open earthworks and pavement construction as per the GWRC guidelines.

Protect Steep Slopes

The Project will involve constructing a road across some very steep hillsides. The implications of this for construction are that steep slopes have a much higher sediment producing potential than flat slopes. To minimise erosion on these steep slopes, "clean" runoff will be diverted away from any exposed slopes.

Diversion drains, drop structures, flumes and culverts should also be employed to convey clean water around and through earthworks areas. As much as possible, permanent cross-drainage culverts should be constructed early in the construction sequence so they are available to convey clean water through the site. Care will need to be taken to prevent the mixing of clean water with water from inside the earthworks area.

Protect Water Bodies

Construction of the road will require in the vicinity of 100 structures (culverts or bridges), as well as temporary and permanent stream diversions. This will require significant investment in ESC measures to protect waterways. Waterways potentially affected range from small ephemeral streams to larger and more significant waterways such as the Pauatahanui and Horokiri streams. Erosion and sediment control mitigation measures will need to consider the specific requirements of each structure and diversion to be constructed.

The design of ESC is to GWRC guidelines and additional controls will also be applied to protect water bodies and in particular those identified as significant in the RFP.

Explanation of what is meant by additional controls in terms of sediment detention devices is discussed in **Section 9.3**.

Stabilise Exposed Areas Rapidly

The proposed alignment has numerous high and steep cut/fill slopes. In sections of the alignment, such as in the upper Te Puka catchment, cuts of up to 50m high are proposed. In areas of large cut involving benched earthwork slopes, the exposed face of each “lift” should be stabilised as soon as practicable after it is cut.

Stabilisation by traditional methods such as top soiling and seeding are not likely to be sufficient due to the steep grades. Wire blankets, geotextile, mulching and specialised hydro-seeding will be required.

Install Perimeter Controls

Perimeter controls, such as diversion drains, silt fences and earth bunds, should be used both above and within the earthworks site. Above the site they should be used to divert clean runoff out of the working area, and within the site they should be used to divert sediment laden runoff to proposed treatment devices. All channels will need surface water lining to avoid erosion from water velocities.

Surface Water Controls

Site surfaces will need careful planning and placement of diversion bunds, rock check dams and erosion control techniques for soil treatment. This will avoid uncontrolled release of sediment during rain events and greatly improve the effectiveness of sediment retention devices.

Spillway Design

All ponds and bunds are to have an emergency spillway to control flow designed to a minimum standard of the 50-year Annual Return Interval (ARI) storm event (in accordance with GWRC, 2006), also referred to as the Q50 storm. Where a pond is in operation for an extended period (i.e. greater than 1 year) the pond spillway should be designed for a 100-year ARI storm event, referred to as the Q100. In the situation where there is a risk to human life if a pond should fail, the spillway should be designed up to probable maximum flow (PMF).

These factors will need to be considered when channelling flow to the receiving body.

Sediment Retention Devices

Sediment retention devices will be installed prior to the commencement of works in each area during construction. In areas where space is limited, earth decanting bunds, structures or traps may need to be used instead of ponds. Where these are used, they will be designed to provide an equivalent treatment quality as a chemically treated pond.

The design of sediment retention ponds is proposed to be to an additional standard. **Table 15.10** summarises and compares what providing an additional standard of protection means in terms of pond sizing. Applying an additional standard will also require that sediment all retention ponds are chemically treated. This will involve the specific calibration of catchment soil characteristics with the best fit chemical suite for retaining sediment onsite and in the retention ponds.

Table 15.10 Sediment Retention Pond Treatment Standards

GWRC Erosion & Sediment Control Practice	Additional Erosion & Sediment Control Practice
On earthworks sites with slopes <10% construct a sediment retention pond with a minimum volume of 2% of contributing catchment (200m^3 for each hectare of contributing catchment).	On earthwork sites with slopes less than 10% construct a rain gauge and flow activated sediment retention pond with a minimum volume of 3% of the contributing catchment (300m^3 for each hectare of contributing catchment). Sediment retention ponds to be chemically treated.
On sites with slopes >10% construct sediment retention ponds with a minimum volume of 3% of the contributing catchment (300m^3 capacity for each hectare of contributing catchment). An additional 10% of this volume is to be used as a fore bay.	On sites with slopes greater than 10%, rain gauge and flow activated sediment retention should be designed to have an area of 3% of the catchment size with a minimum depth of 1m. Sediment retention ponds to be chemically treated.

Make Sure the ESC Plan Evolves and Adapts

The adaptive management principles of wet and dry weather monitoring of erosion and sediment control performance will be addressed as part of the ESC plans to be developed prior to construction.

In the drafting of plans consideration will need to be given to providing erosion and sediment mitigation solutions that are accessible for inspection and maintenance.

9.3. Erosion & Sediment Control Measures

The GWRC's *Erosion and Sediment Control Guidelines (2006)* provide a suite of measures for avoiding the effects of earthworks associated with the proposed construction. The measures that are likely to be adopted for the Transmission Gully Project are detailed below in **Table 15.11** to **Table 15.13**.

Table 15.11 Erosion Control Measures

Erosion Control Measure	Specific Use during the Construction of the Transmission Gully Project
Control and retention of disturbed soil at earthwork sites	Progressive stabilisation of exposed soil. The choice of method will be dictated by site specific requirements. Use of stepped slopes, roughening of soil and spreading of imported topsoil/mulch
Provide soil cover and improve soil health	Use of mulch or compost blankets
Provide short term soil cover	Use of sprayed and bound straw mulch or hydro seeding
Provide long term soil cover	Use of rolled erosion control blankets or netting
Steep slope techniques	Use of wire blankets or cellular confinement

Table 15.12 Surface Water Control Measures

Surface Water Control Measure	Specific Use during the Construction of the Transmission Gully Project
Clean water diversion bund	"Clean" water diversions to existing waterways above road construction "Clean" water diversion to sheet flow above the road construction "Dirty" water diversion within earthworks to direct surface water to sediment control devices
Rock check dam	Surface water control channels where the gradient exceeds 2% or velocity exceeds 1m/s
Pipe drop structure/ flume	"Clean" water diversions above road construction "Dirty" water diversion to retention and treatment devices within site Where the use of a channel or bund would result in excessive velocities or gradients When sediment retention pond placement (due to space restrictions) requires complex a transport route i.e. across Horokiri stream valley
'Pinned' silt socks or gravel check dams	Temporary surface water controls to avoid high surface water velocities. The choice of method will be dictated by site specific requirements

Table 15.13 Sediment Control Measures

Sediment Control Measure	Specific Use during the Construction of the Transmission Gully Project
Sediment retention pond	Retention and treatment of sediment laden runoff along the alignment. Ponds will need to be fitted within the consented designation. Where the designation needs to change to incorporate sediment retention ponds this needs to be flagged very early on. Alternative methods of pond construction, e.g. the use of tanks or shipping containers, should be investigated if topography requirements are an issue.
Chemical treatment	In all sediment retention ponds and earth decanting bunds.
Sediment fence	Perimeter controls both around and within earthworks site. Sediment fences may be required in areas where the topography does not allow for construction of sediment retention devices and the catchment area <0.3ha.
Silt socks	Silt socks will be used in areas requiring continual access and can be pinned to steep slope areas. Another advantage of silt socks is they can be chemically dosed.
Decanting earth bund	Treatment of sediment laden runoff when space requirements restrict the use of sediment retention ponds. These will be chemically treated.
Stormwater inlet protection	Protection of existing stormwater networks, for example in eastern Porirua

ESC plans will be developed for the Project. These will specify the measures used in each location to minimise erosion and control sedimentation in accordance with this report and appropriate guidelines. The ESC plans will specifically document methods to operate and maintain the sediment devices (including chemical treatment); install and maintain erosion control devices; and to minimise disturbance of stream bed and banks and minimise erosion for all planned in river works, including any temporary stream crossings.

The following additional management and monitoring will occur:

- Strict control of chemicals and other construction materials used on site will be outlined in the Project's Environmental Management Plan. This will specify factors surrounding their delivery, storage, use, and disposal and also outline methods in place and procedures to prepare for and respond to any accidental spills
- Performance monitoring will be specified within each ESC plan. The intent of the monitoring will be to confirm that effects that are occurring are within the predicted range and if unanticipated effects are occurring then management changes can be made to rectify the discharge issues. The monitoring will include assessment of the downstream changes in environmental factors including water quality, sediment deposition and ecology (note: any ecology performance measures would be advised as an output of Technical Report 11: *Assessment of Ecological Effects*).

9.4. Temporary Works within Watercourses

Within each catchment there are a large number of small tributaries and some larger rivers to be crossed. Bridged crossing points are proposed for many of the major stream crossing points including the main Pauatahanui Stream, Porirua River, Duck Creek, and Te Puka Stream. All other crossings are likely to be culverted and thus require direct in stream works. There may also be a need for either temporary or permanent diversions of some stretches of waterway. During the construction phase the construction traffic will be working near and in these catchments and there will be a need for machinery to cross these.

Temporary works within water bodies, both waterway diversions and crossings, have a high potential for erosion and discharges of sediment. The GWRC's *Erosion and Sediment Control Guidelines* (2006) provide a series of design steps and advice for mitigating the effects of temporary works within water bodies. As an overview these are:

- In the construction of the Project, temporary diversions will be required for the construction of the majority of permanent structures. Diversion channels should be stabilised using geotextile liner and discharge back into channel below the area of works to avoid scour of the channel bed and banks
- Temporary crossings are constructed where heavy equipment is required to be moved from one side of a water body to the other, or where traffic must cross the water body frequently for a short period of time. Crossings should be planned to minimise the total number required. If crossings cannot be avoided, locations should be selected where the potential effects of the construction and operation of the crossing are minimised. Crossing construction should take place as rapidly as possible during a period of dry weather. All areas of disturbed soil should be stabilised immediately during and post construction. Where possible precast concrete blocks will be considered and set level with the existing bed and banks.
- Ongoing inspection and maintenance of any works within a water body is important to minimise erosion and sediment generation. Common issues that can result from a lack of maintenance can include the ripping or undercutting of the geotextile liner and stream bed scouring where flows re-enter the channel.

9.5. Discharges during Construction Works

During construction the primary discharges would occur as a result of rain generated erosion and sediment laden runoff from construction sites. Rain falling onto bare earth can cause erosion and would entrain sediment as it flows off site. The resulting runoff would have the potential for elevated concentrations of suspended solids as the primary contaminant of concern. Associated with this could be some nutrients associated with soil particles (nitrogen and phosphorous) and minor amounts of other materials in the soils (metals etc). If any historic land uses caused soil contamination this could also become entrained in the runoff.

Other discharges during the construction works may include:

- Clean water discharges from cut off drains and diversions
- Dewatering water from deeper earthworks
- Discharges associated with in stream works and channel disturbance
- Accidental discharges such as spills of fuels, oils, concrete etc.

Point source discharges from the site can also cause or exacerbate erosion in the receiving channel, which will increase the sediment load.

In the detailed design phase for the project, the designer of the erosion and sediment control system may not be able to design controls that would comply with the traditional GWRC guidelines (2006) due to the topography of certain sections of the alignment. In this situation extra erosion control precautions will be required and site specific sediment control devices can also be constructed in sequenced containers or using geotechnical fabrics. The ESC design objective would be to demonstrate and meet equivalent removal efficiency as the standard erosion and sediment control practices (i.e. a chemically treated pond set at 3% of catchment size).

In events larger than a Q_{10} (e.g. Q_{50}), the performance of sediment ponds is likely to be compromised. This due to:

- Increased velocity through the pond
- The staged storage will be exceeded
- The ponds would likely be operating in bypass.

9.6. Performance Assessment

This section summarises information relating to a review of the effectiveness of the key measures to avoid sediment release from road construction. The results of this assessment have then been used in quantifying how much sediment removal is able to be achieved for the Project.

9.6.1.Erosion Control Performance

As lands are disturbed, erosion and sediment control professionals are looking for erosion control practice measures that can be specified, installed, and inspected with confidence around their anticipated performance. For the purposes of the Project assessment of effects it was assumed that all areas of active earthworks will be managed with erosion control practice measures and that these measures will achieve a level of performance which reduces the effective yield by 75% (as a loss rate as suspended sediment on an average annual basis).

This relates to a literature cover factor expressed as the ratio of sediment yield in the protected condition to unprotected (normalised with respect to measured rainfall). The cover factor in the USLE (C) is comparable to the stabilisation requirements in this assessment for sections of the road where the bulk earthworks phase has been completed and stabilisation has been achieved via application of road surfacing or compacted basecourse.

Current practice measures such as the use of rolled erosion control blanket measures have demonstrated performance as C of over 98% effective on both the sand and loam plots and reduced erosion on the clay plot by nearly 80% (Lipscomb, et.al. 2006). These practice measures are robustly tested in American soil labs like the California Transport (Caltrans) Soil Erosion Research Lab. ASTM International maintains a refereed standard (D6459) for the large-scale evaluation of erosion performance on a slope. The ASTM standard requires the product to be tested on a 3:1 (H:V) slope and be subjected to a series of controlled rainfall events while monitoring sediment migration and runoff. The ASTM standard provides a consistent methodology for testing and a means of comparison to evaluate competing products and technologies.

The decision to select a performance of 75 percent is based on a high level of performance on low to medium gradient slopes, with a decreasing level of performance as gradients increase. This effect will be moderated by changing soil profiles as steep slopes as cut batters are rock with lower sediment yields.

The selection of the performance measure is based on field observations and experience with erosion control methodologies for slope stabilisation during active earthworks. The 75% factor is based on the international literature values for the recommended practice measures for erosion control. American manufactures of erosion control products and various other stakeholders within the erosion control community formed the Erosion Control Technology Council (ECTC). The ECTC endeavours to develop testing protocols, installation guidelines, and application specifications from a non-biased industry perspective. The ECTC provides a literature resource including comparative studies for techniques which are applicable as practice measures for the Project.

The erosion removal efficiencies used for the assessment of effects are given in **Table 15.14**.

- **Table 15.14 Erosion Control Efficiencies**

Erosion Control Average Annual Performance	Inadequate maintenance
75%	50%

These values are used in the sediment yield model to evaluate the catchment yields, where 75% performance for erosions control is calculated as a loss rate as suspended sediment on an average annual basis. Sensitivity analysis was undertaken assuming reduced efficiency

9.6.2.Sediment Removal

Sediment retention ponds operate by allowing the sediment to settle out of suspension of the main runoff, and be retained in the pond. The rate at which sediment falls is called the particle settling velocity (or particle fall velocity). The settling velocity is governed by the flow regime in the pond, particle size and the density of the particle (relative to water). In general, as particles increase in size they have an increased settling velocity. The effectiveness of these ponds can be improved by adding a chemical reagent which binds multiple particles together forming a larger particle with accelerated settling properties.

Performance of sediment ponds is difficult to model as there are many variables that influence the settling characteristics of a given gravity pond. A recent literature review by Semadeni-Davies (2008) highlighted the uncertainty in sediment settling rates within ponds and identified that stormwater sedimentation, as a whole, is a largely under-researched area.

Chemically treated ponds are even more difficult to model than traditional ponds and are typically dealt with experimentally (Jones, 2010).

Due to these uncertainties in the literature it was decided to base this assessment on a relevant motorway construction project as a case study, to identify the treatment efficiency of ponds.

9.6.3.Case Study Investigation

In 2007, the ALPURT B2 motorway construction was being undertaken for NZTA. This project included earthworks in excess of 1,000,000m³. Within this project, sediment control was designed to meet ARC's TP90 guidelines. The majority of the sediment in runoff from the project was <30µm, which is likely to be similar to the soils in the Project area.

During construction NIWA (Moores and Pattison, 2008) conducted a study of two sediment control ponds. Each pond received half of the flow from a 4.4ha catchment. The ponds were designed to be 3% of their portion of the catchment size. One pond was treated with PAC flocculent while the other was not.

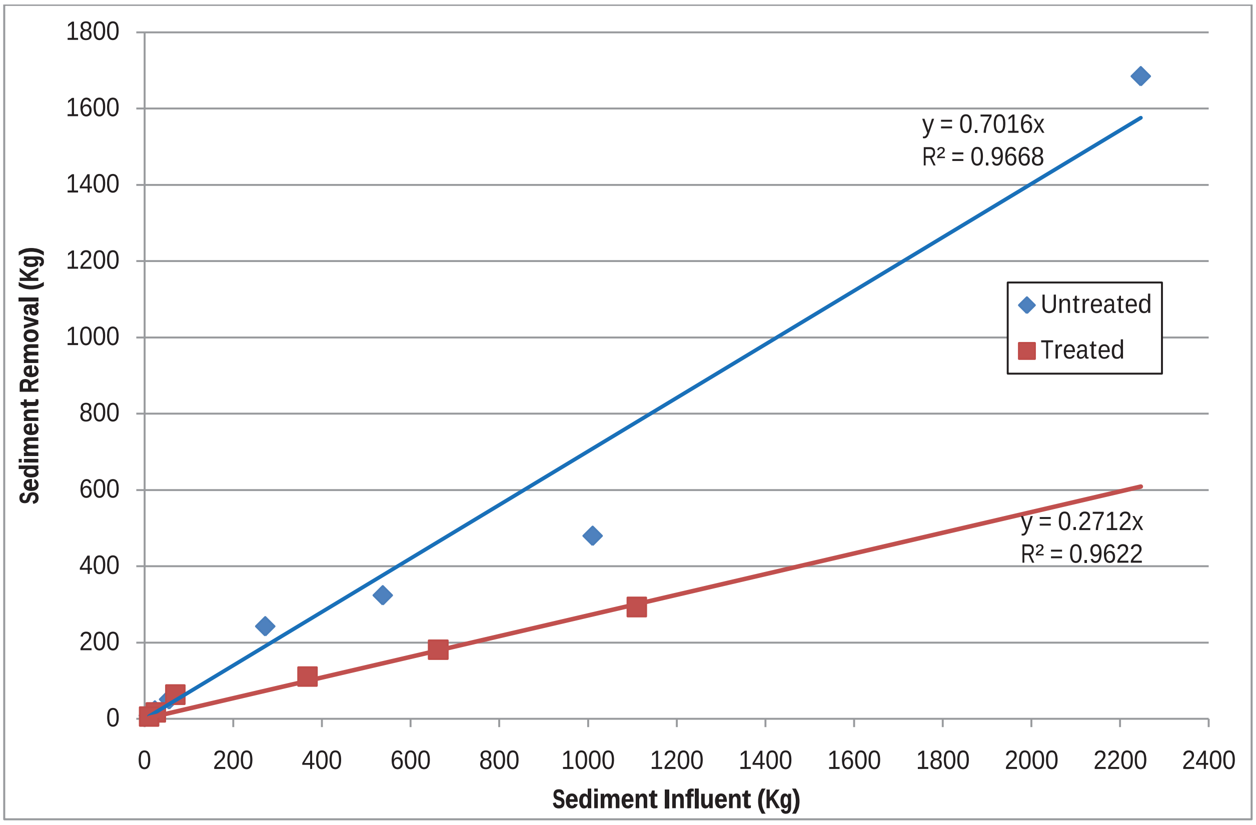
The data from the Moores and Pattison (2008) study is given in **Table 15.15**. Performance is graphically represented in **Figure 15.41**, which shows the effluent solids load and therefore performance of the ponds correlates closely with the influent TSS concentration. The chemically treated pond removed approximately 70% of influent TSS and the untreated pond 30% of the influent TSS load.

These performance results will form the basis of performance measures for the sediment control devices on the Project.

- **Table 15.15 Case Study of the Performance of Sediment Treatment Ponds (Moores and Pattison (2008))**

Flow				Chemically Treated Effluent			Untreated Effluent			
Event	Peak Inflow (l/s)	Peak Outflow (l/s)	Total Inflow (m³)	Load in (kg)	Load out (kg)	Efficiency	Peak Outflow (l/s)	Load in (kg)	Load out (kg)	Efficiency
1[2]		41.6		>4942	1235	N/a	40.6	>5286	5286	N/a
2	25.3	8.2	703	599	64.8	89%	9.2	808	564	30%
3	91.2	20.9	1019	1182	469	60%	27.9	1457	1058	27%
4	275.4	53.7	1528	2223	1167	48%	43.7	2442	1797	26%
5	6.9	2.1	183	51.6	3.07	94%	2.7	55.7	18.4	67%
6	5.7	1.8	123	21.6	2.05	91%	2.3	22.7	9.15	60%
7	51	3.5	177	122	9.34	92%	4.5	153	13.8	91%

[2] Note that Event 1 for the untreated pond was not used in the graph or calculations as the loads were not explicit and therefore removal could not be accurately quantified.



- **Figure 15.41 Performance of Case Study Sediment Treatment Ponds**

9.6.4. Adopted Standards for the Transmission Gully Project

Table 15.16 summarises the efficiencies adopted for the Project. These efficiencies have been used in the calculation of sediment load for the peak construction scenarios as described in **Section 10.6**. They assume that all ponds are chemically treated and are sized at 3% of the contributing area.

- **Table 15.16 Sediment Pond Efficiencies**

Pond Efficiencies			Inadequate Pond Maintenance		
Q2	Q10	Q50	Q2	Q10	Q50
70%	70%	40%	50%	50%	25%

These removal efficiencies represent best practice, which is considered an appropriate standard for this Project. Conservatism in the assessments has been built into other areas of the assessment, for example in the:

- Staging assumptions
- Event based calculation of sediment load
- Sediment particle size
- Harbour sediment loads not accounting for stream deposition.

Evidence from the case study indicates that in events less than a Q_2, much higher removal rates can be achieved.

Sand Particles

The Moores and Pattison (2008) study showed that the runoff (in all events and treatments) did not contain significant quantities of particles greater than 60μm (above which the size is classified as sand (NZGS, 2005)). Pitt *et al.* (2007) states a particle of 60μm would have a settling velocity of 0.002 m/s (given a density of 2.65 kg/m³). If a particle is considered settled after it reaches 500mm, to allow for the pond dead storage, the time for this particle to settle in this distance would be 0.5 [m] / 0.002 [m/s] = 250 [s]. Given that the ponds for the Project will be designed to the GWRC guideline (2006) standard they will have a peak storage volume of 300m³/ha of land. In a Q10 ARI rainfall event this would result in a peak flow retention time of more than an hour, sufficiently more than the 250s required for sand to settle. To allow for conservatism this removal rate is reduced to 90% to allow for the occasional large particle to pass.

Oversized Events

The Moores and Pattison (2008) study suggests that for relatively small events sediment retention can be achieved by ponds where there is enough settling time. However for large events when ponds are loaded with suspended sediments at high flow rates, settling times will not be achieved and chemical treatment will greatly improve sediment retention.

Published data of pond operation in larger events was not available at the time of writing. Given that in the Moores and Pattison (2008) study there were problems evaluating the flow and TSS in event 1 (a Q_{10}) monitoring performance in a larger event would be difficult. A Q_{50} flow is approximately 50% higher than a Q_{10}; as such the predicted removal rate in a treated pond will be reduced by 50% (to 35%) for particles smaller than 60μm and particles smaller than 125μm (to 45%), particles larger than this will still settle at approximately 90%. It is assumed an untreated pond will be ineffective at removing any particle smaller than 125μm.

For the purposes of the assessment of effects it was assumed that all areas of active earthworks will be managed with chemically treated sediment control ponds and that these ponds will achieve 70% removal of TSS in events up to the Q10 event and a 40% removal rate in the Q50 event.

9.7. Detailed Erosion and Sediment Control Plans

Detailed ESC plans will be developed and submitted for approval once the design of the road has been developed and prior to construction. The ESC plans will include a monitoring plan, an example of which is provided in **Appendix 15.L**. The ESCP will also include a Chemical Treatment Plan (CTP).

Example ESC plans were developed for key construction areas, as provided in the SSEMPs in Volume 5. The purpose of these examples was to test the ESCP philosophy. These plans propose control options including diversion channels for surface water control and sediment control devices. The sub-catchments have been sized and an indication of retention pond volume given for total sediment control. The pond footprints relate to the catchment size and orientation and surface water runoff.

On sites with complex topography and may be subject to other constraints such as maintaining traffic diversions during the period of works, the construction of sediment and erosion controls and associated earthworks may be carried out in stages in order to meet the objectives set out above. The stages are shown as Phase 1, Phase 2 etc on the drawings in the SSEMPs in Volume 5.

The example ESC plans were also used as inputs for the example Site Specific Environmental Management Plans (SSEMP).

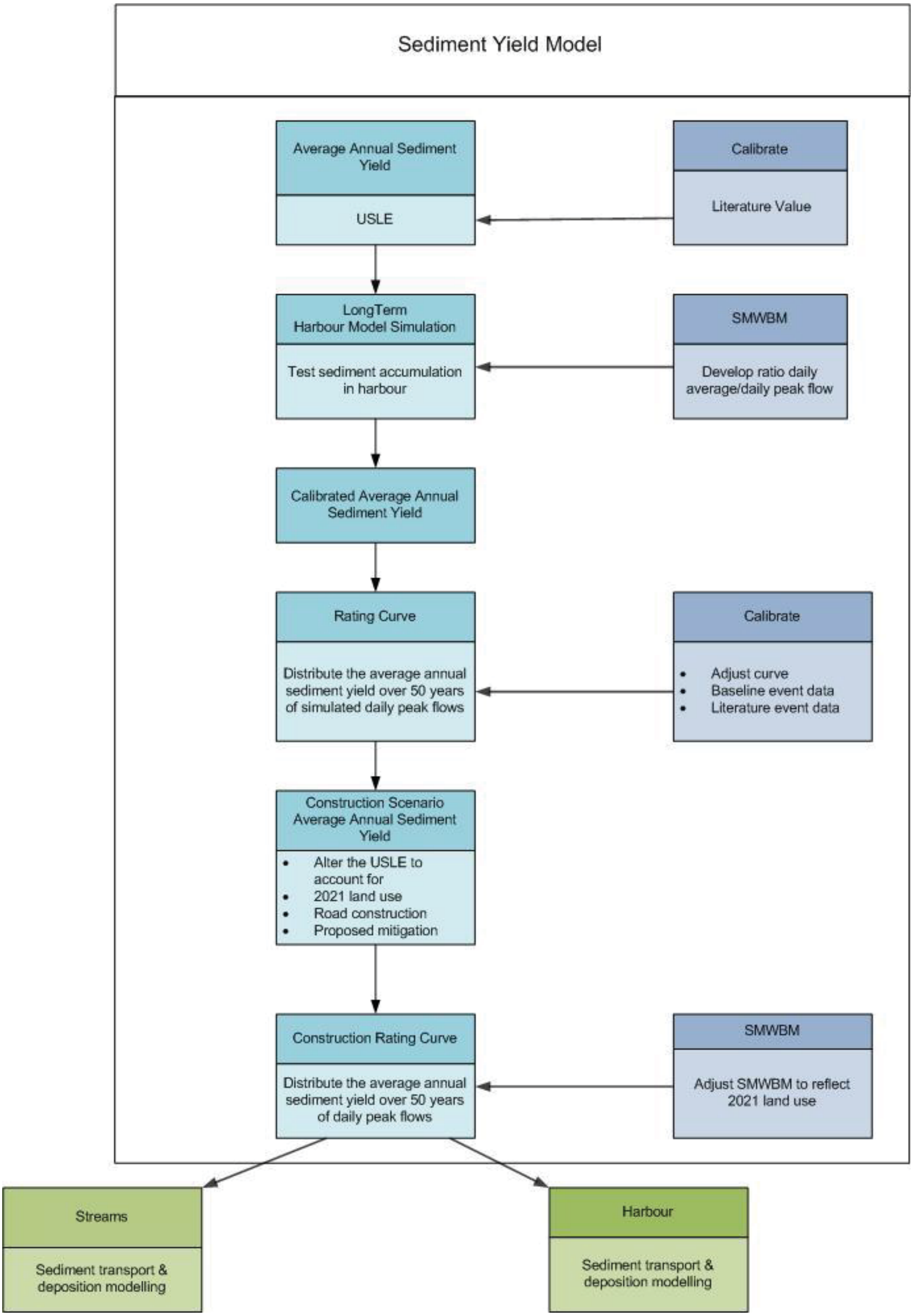
10. Construction Modelled Effects – Sediment Yield

10.1. Sediment Yield Baseline

This section outlines the methodology used for estimating the sediment yield for the catchments affected by the Project and/or that drain to Porirua harbour.

A theoretical method was used to estimate the sediment yield. The method used to estimate the baseline sediment yield has been verified against field data and national data sets. The methodology has then modified to reflect the construction scenario, including mitigation, as discussed in Section 10.6

It is acknowledged that this assessment is an empirical assessment using modelled data at a relatively broad catchment scale. This is appropriate given the need to predict the future land use and construction activities proposed by the Project in this assessment. Additionally, where relevant, the sensitivity of any assessment outcomes to any assumptions that have been made has been noted.



▪ **Figure 15.42 Sediment Yield Calculation Method**

10.2. Assessing Sediment Yield – Theoretical Basis

Rainfall is the key driver for sediment runoff in Transmission Gully Project catchments. Sediment loads in streams will be high after rainfall resulting in catchment runoff. Small catchments are likely to respond quickly to rainfall with flow declining quickly.

In an ideal situation there would be enough observed data to develop the relationship between flow and sediment. However this has not been attempted for the sediment yield model, as data was only collected from targeted catchments affected by the Transmission Gully alignment. Since data was only collected for one year, it was not possible to reliably estimate the volume of sediment that would be transported during large events by directly extrapolating from the observed flow and turbidity data.

A modelling approach based upon physical and empirical understanding of the relationships between flow, TSS and sediment yield supported by empirical data was used to estimate sediment yields. This is not unusual in physical science and empirical models are developed for the purpose of 'estimating' a range of physical relationships.

10.3. Sediment Yield Estimation

This section describes the theoretical method used to supplement the observed data and to estimate future sediment yields during construction and over the long term once the Project has been built.

Some field data has been collected over the past 30 years, namely:

- Data collected for part of the Ministry of Works Study in the 1970s (Curry, 1981) and discussed in more detail in *Pauatahanui Inlet – An Environmental Study* (Healy, 1980)
- Some ongoing water quality measurements taken by the Wellington Regional Council as part of the State of Environment report. However many of the samples were taken in dry weather conditions where total suspended solids (TSS) on streams is low
- Data collected as part of this report (see **Section 6**). This commenced in September 2009 and was completed in July 2010.

This data is useful in understanding the relationship between sediment load in streams, flows and land use in the catchments but is not on its own sufficient to draw conclusions about average annual sediment loads that could be used for assessing long term effects. It is also not sufficient to understand the impact of land use on TSS loads and how the proposed change in land use associated with the construction of the Transmission Gully Project will affect the sediment loads in the receiving environment.

A modelling approach is required to supplement field data, so that:

- Average annual sediment loads can be estimated for the existing situation
- The effect of land use change during construction of the road can be assessed.

The USLE was chosen as the method for estimating the average annual sediment yield for a future land use scenario. The NIWA Suspended-Sediment Yield Estimator tool was used as a supplementary method to confirm that the calculation of sediment yields (using the USLE) was in the correct order of magnitude for the catchments for a 'current' year's estimation.

Refer to **0** for further information and discussion on methods for estimating annual sediment load.

10.4. Universal Soil Loss Equation

The General form of the universal soil loss equation is:

A = R x K x LS x C x P as Kg/hectare/year

Where:

A = annual soil loss from sheet and rill erosion in tons/km^2
R = rainfall erosivity factor
K = soil erodibility factor
LS = slope length and steepness factor
C = cover and management factor
P = support practice factor

The USLE equation factors provide a method of estimating sediment yield from a catchment, however it does not take account of the proportion of that sediment that is delivered to the receiving environment, nor does it account for mitigation measures which are designed to intercept sediment runoff to reduce the impact on the receiving environment.

There are two additional factors that are applied to account for these processes:

Sediment Removal Efficiency (SRE)

This describes the effectiveness of methods designed to retain the soil in situ and mitigate the effects of rainfall erosivity. The sediment yield model uses this factor, on an average annual basis, to determine the contribution of the erosion control methodology along the Transmission Gully Project alignment. Discussed in Section 9.6.1

This does not include the effectiveness of sediment control ponds. The design efficiency of the ponds was applied on a sub-catchment, rather than land area basis and is discussed in Section 9.6.2

Sediment Delivery Ratio (SDR)

This describes the amount of sediment that is delivered to receiving environments. This factor is used to adjust the estimates of sediment yield calculated by the USLE with observed loads in receiving environments. The sediment yield model has allowed for this by a dual calibration between the observed data and the ratio between the NIWA model and the combined USLE prediction.

The revised form of the equation used becomes:

A = R x K x LS x C x P x SRE x SDR as Kg/hectare/year

The following factors were assumed for calculation of the USLE (**Table 15.17**):

- **Table 15.17 USLE Factors**

Factor	Description	Value
R	Rainfall erosivity	Catchment rainfall based
K	Soil erodibility	Catchment geology based

LS	Slope length steepness	Catchment topography based
C	Bare soil	1.0 (otherwise catchment land use)
P	Bare soil	0.9 rough irregular surface
SRE	Erosion control measures	0.25 (75% Efficiency)
SDR	USLE to NIWA ratio	0.17

The details of the factors used in the calculation of the USLE predictions are discussed fully in Appendix 15.N.

10.4.1. Factors within the USLE Estimate

The factors used for the USLE yield calculations have been derived from existing data wherever possible and calculated from measures or sources related to the Project catchments. This means that all of the USLE factorials have a spatial resolution and for some factors like the land use factor C have a temporal resolution as well.

10.4.2. Verification of the Universal Soil Loss Equation Results

Verification of USLE sediment yield estimations has been undertaken by comparing the calculated average annual sediment yield against literature (namely data collected during a Ministry of Works Study of catchments draining to the Pauatahanui Inlet in the 1970s and described in Healy, 1980) and the NIWA Suspended-Sediment tool. The results of this comparison are shown in **Table 15.18.**

- **Table 15.18 Sediment Yield Estimates (tonnes/yr)**

Large Catchments	NIWA Suspended Sediment tool	USLE from this Study	Ministry of Works Study (Healy, 1980)	Diff USLE/Healy (%)	Diff USLE/NIWA (%)	Diff NIWA/Healy (%)
Duck	1263	1144	1650	-31	-9	-23
Horokiri	5443	5296	3980	33	-3	37
Kenepuru	1168	826	N/A	N/A	-29	N/A
Pauatahanui	3409	5889	4670	26	73	-27
Porirua	3974	3970	N/A	N/A	0	N/A
Ration	841	793	470	69	-6	79
Te Puka/Wainui	1175	1520	N/A	N/A	29	N/A
Whareroa	1906	2022	N/A	N/A	6	N/A

As can be seen from **Table 15.18**, estimation of sediment yield calculated using the USLE and compared with the NIWA Suspended-Sediment Tool is in the correct order of magnitude. The most significant differences between the theoretical USLE calculation and the NIWA data are at the Kenepuru, Pauatahanui and Wainui/Te Puka catchments. In the Kenepuru, the NIWA data may not be accurately reflecting the urbanisation of the catchment and hence over estimating the sediment yield, in the Pauatahanui the NIWA data will not reflect 2010 active earthworks which increase sediment yields, something the USLE calculation has taken into account. In the Wainui/Te Puka the USLE calculation of the erosivity and steepness factors has produced a more conservative result.

The comparison to data described by the Healy (1980) data has mixed results when compared to the USLE calculation and the NIWA data. It should be noted that this data set is on average only a three year time period during the 1970s and does not necessarily reflect a long term average as the USLE and NIWA does. The data described by Healy (1980) however does confirm order of magnitude estimates as calculated using the USLE.

A further breakdown by catchment for the USLE estimates is provided in **Table 15.19.** This table summarises the results of the USLE and provides a useful measure of the relative sediment yields per catchment by displaying sediment on a yield per unit area basis.

- **Table 15.19 Comparison of USLE Sediment Yield per Catchment**

USLE Estimate (Sediment Delivery Ratio 0.17)				
Catchment	Annual Sediment Yield (tonnes)	Catchment Area (km²)	Annual Tonnes per km (g/m²)	Comment
Duck	1144	11.6	99	Built/ rural
Horokiri	5296	33.1	160	Rural/agriculture
Kenepuru	826	12.7	65	Built/rural
Pauatahanui	5889	41.7	141	Rural/agriculture
Porirua	3970	41.1	97	Built /rural
Ration	793	6.8	117	Rural/agriculture
Te Puka/Wainui	1520	7.7	197	Rural/agriculture
Whareroa	2022	16.7	121	Rural/agriculture

10.5. Development of Sediment Rating Curves

The methodology used to develop the sediment rating curves is outlined in Appendix 15.Q. The following details their application to streams with the Transmission Gully Project alignment, both with and without observed data. Findings on the use of the curves are also presented.

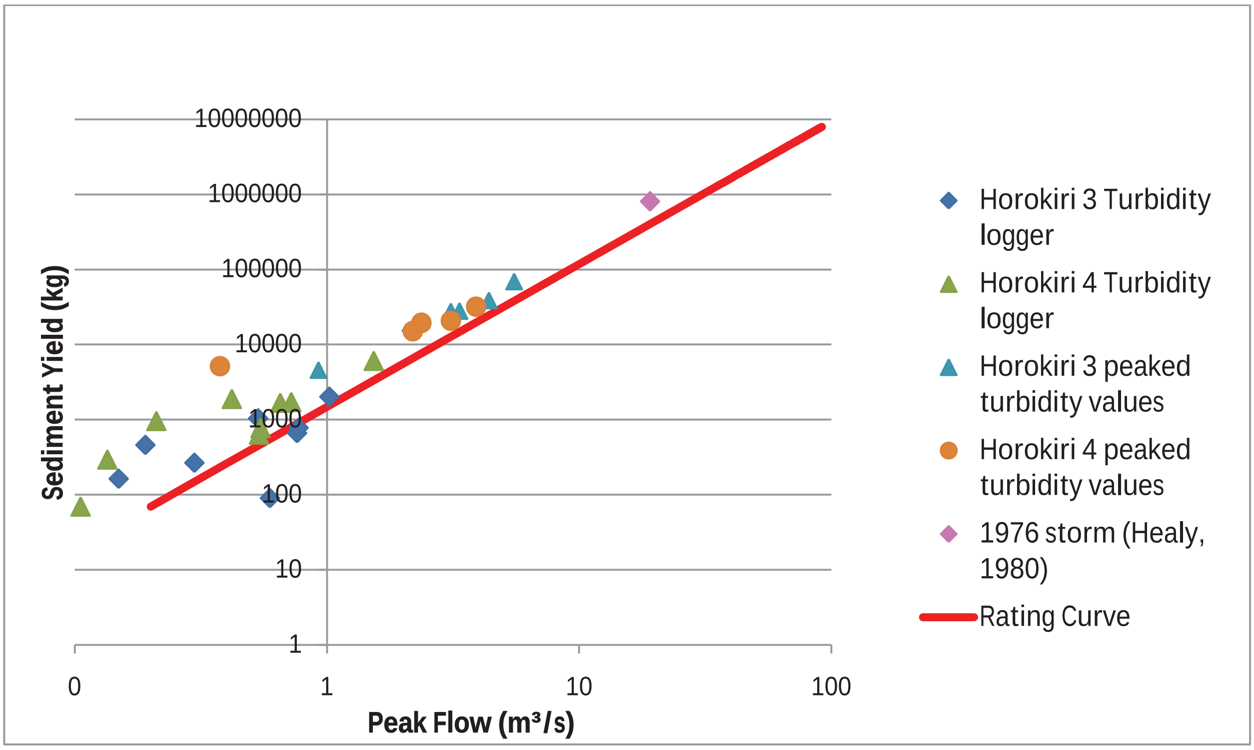
10.5.1. Curve Application to Streams without Observed Data

The majority of the streams in the Transmission Gully Alignment are without observed data, this is a factor in requiring modelling for peak flow and sediment. The SMWBM has generated a stream flow time series for each of the catchments and USLE generates an annual sediment load for each catchment. The rating curves for the Horokiri and Pauatahanui Streams have been verified against observed data. No observed data was available for the remaining catchments with streams crossing the Transmission Gully alignment. In order to develop sediment rating curves for other stream catchments, the same process has been applied for the curve development above. The scaling process to determine the appropriate coefficient A for the Whareroa and Wainui Catchments was based on the assumption that the peak flow from a two year 24hr storm event would yield the mean annual sediment for the catchment. As above the exponent value B was used for all catchments.

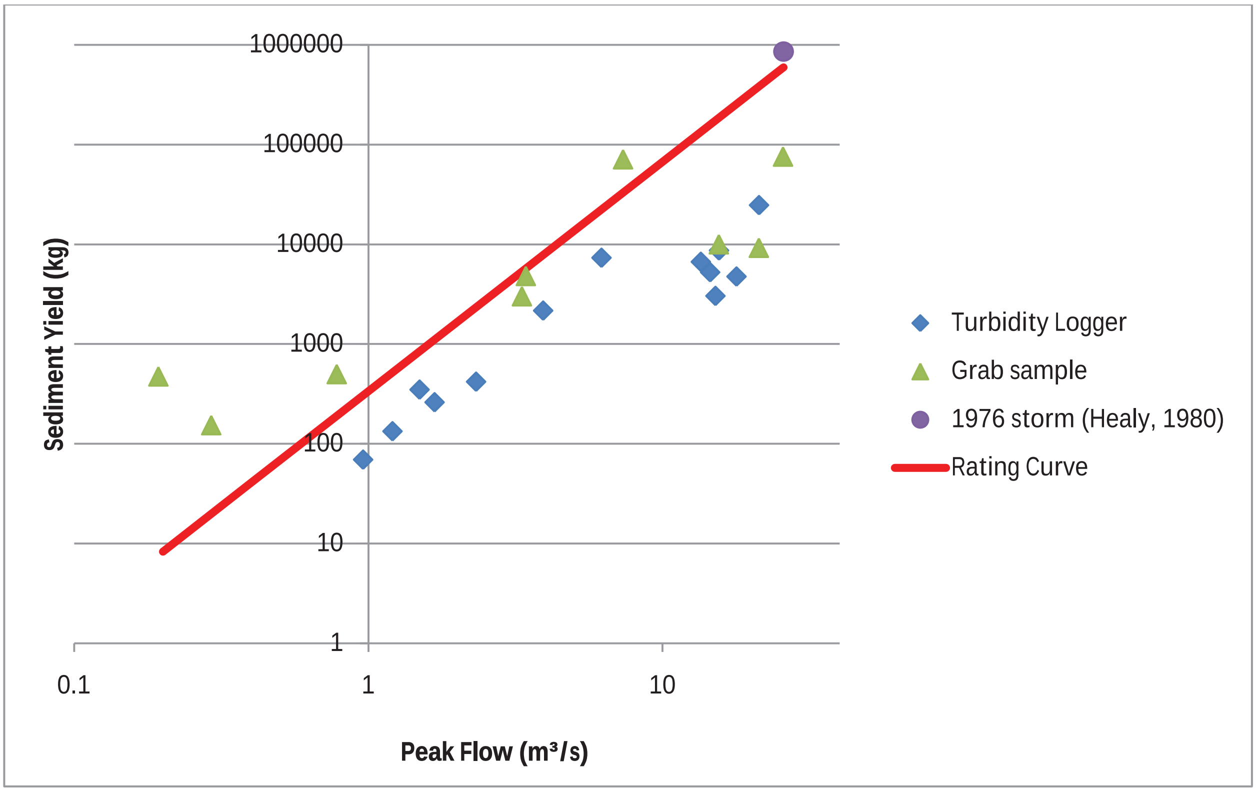
Once the curve had been applied to the overall stream catchments, individual sub-catchment curves were created by rescaling the overall sediment rating curve by dividing the coefficient A by the relative catchment proportion. The scaling factor used was the relative sediment yield from the sub-catchment compared with the overall catchment. This is an approximation that ensures that the yield attained by the summation of all sub-catchment curves for a given catchment flow is equal to the sediment yield from the overall catchment.

10.5.2. Sediment Rating Curves for Catchments with Observed Data

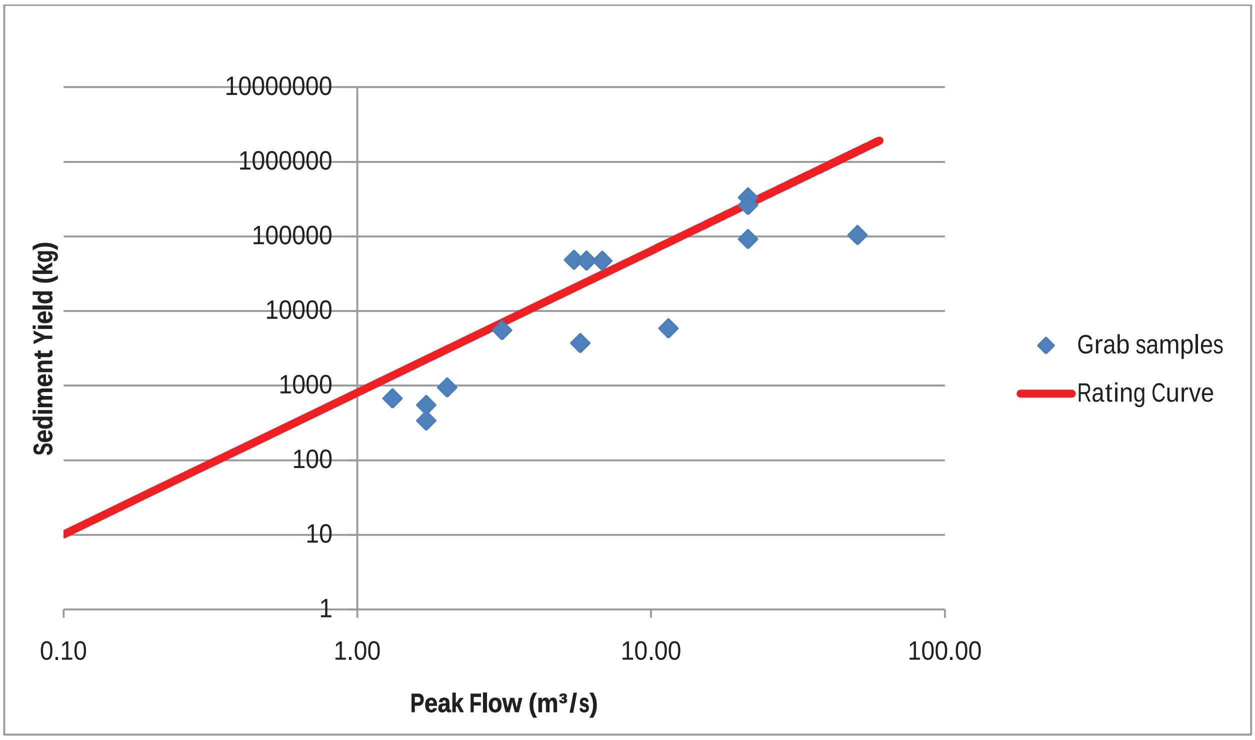
The calculated sediment-rating curves for three catchments with observed data are shown in **Figure 15.43** through **Figure 15.45**.



- **Figure 15.43 Sediment Yield and Peak Flow for Horokiri Catchment**



▪ **Figure 15.44 Sediment Yield and Peak Flow for Pauatahanui Catchment**



▪ **Figure 15.45 Sediment Yield and Peak Flow for Porirua Catchment**

10.5.3. Findings on Use of Rating Curves

The method of developing sediment rating curves has been built from catchment characteristics and validated with observed data where possible. We are confident that the sediment yields generated provide a sound estimate of sediment generated from these catchments.

The method of developing sediment yields has the advantage that it enables the sediment discharged from the construction period of Transmission Gully to be considered in the context of the larger catchment, and enables cumulative effects to be considered.

It is important to provide a realistic estimation of the sediment generated in the existing situation, so that changes in sediment yields, as a result of the project, are not obscured by an overly conservative estimate of current yields.

The conservatism in the calculation of sediment yields comes in the scenarios that have been applied for testing the effect of the project on the receiving environments.

10.6. Construction period scenarios

In order to adjust the sediment rating curve that was developed for the 2010 scenario, to reflect the Transmission Gully Project at 2021, a number of new USLE scenarios were developed.

- A scenario representing situation without the Transmission Gully road in place. This scenario is necessary in order to isolate the effects of the road under each of the future modelled scenarios
- A peak construction scenario for sediment loads to the Porirua Harbour from road construction
- A peak construction scenario for sediment loads to each of the streams from road construction
- A long-term simulation estimating sediment loads over the whole construction period.

10.6.1. 2021 without the Transmission Gully Project

In this USLE scenario all factors are the same as the Baseline – 2010 scenario, with the exception of the Cover 'C' factor.

C factor

The Cover 'C' factor which is altered to reflect the project population and associated urban growth at 2021.

10.6.2. 2021 with the Transmission Gully project

In this USLE scenario all factors are the same as the Baseline – 2010 scenario, with the exception of the Cover 'C' factor and the Sediment Removal Efficiency 'SRE' factor. Sensitivity analysis was undertaken to test the effect of altering the Soil 'K' factor. In addition, the sediment removal efficiency of ponds for various return period events was accounted for.

C factor

In this USLE scenario the Cover,' C' factors is altered in two ways to represent the Transmission Gully project.

- 'C' factor is altered to reflect the project population and associated urban growth at 2021.
- 'C' factor is altered to 1, to reflect earthworks for a 75m wide area along the proposed alignment. The amount of area that is classified as 'active' at any one time depends on the staging proposed in the construction scenario. This is outlined in **Section 10.6**.

SRE factor

The sediment removal efficiency factor is altered to reflect the proposed erosion control measures discussed in Section 9.3. A factor of 0.25 (75% efficiency) was applied to all areas of the Motorway under construction within each of the catchments. For the sensitivity analysis, an SRE factor for inadequate erosion and sediment control of 0.5 (50% efficiency) was used to demonstrate the magnitude change for this change in practice.

K Factor

The K factor for the 2010 scenario is based on the test pits along the Transmission Gully Project alignment and the NZLRI soil polygons, as discussed in **Section N.7**. The same 'K' value was used for the 2021 with Transmission Gully project scenario. This scenario is conservative because it assumes the soil is more erosion prone than the lower soils are likely to be.

During construction, the topsoil will be stripped from the alignment and the soil that is exposed will be representative of lower layers of soils with different characteristics. The test pit data is provided in **Appendix 15.P.**

- **Table 15.20 Average Clay and Gravel Content of Test Pits**

	Top layer 100-4550mm	Mid layer 400-6500mm	Deeper layer 1350-7000mm
Clay content	36%	43%	51%
Gravel content	43%	56%	63%
Number of test pits samples in layer	191	162	82

Table 15.20 illustrates that the top layer has the lowest clay and gravel content. Clay and gravel both increase the 'K' value resulting in less sediment being eroded. This can be seen from the nomographs in Appendix 15.O.

A sensitivity analysis was undertaken where the 'K' value was modified to reflect a sub-soil with the characteristics of 80% clay, 10% silt and 10% sand. No allowance was made for gravel. In addition to changing the 'K' value, a reduction in the SRE value from 0.25 to 0.5, was undertaken to reflect less effective erosion control. In this sensitivity analysis, the 'peak' harbour scenario was assumed and resulting sediment yield were within -0.5% (increase in soil loss) to 3% (decrease in soil loss) for all catchments.

It should be noted, that while clay soil is less erosion prone than silt and sand, it is more resistant to erosion and sediment control. This is discussed in 9.6.2**.** This is accounted for in the effects modelling, in the particle size that was assumed as summarised in **Section 11.1.3**.

Sediment control ponds

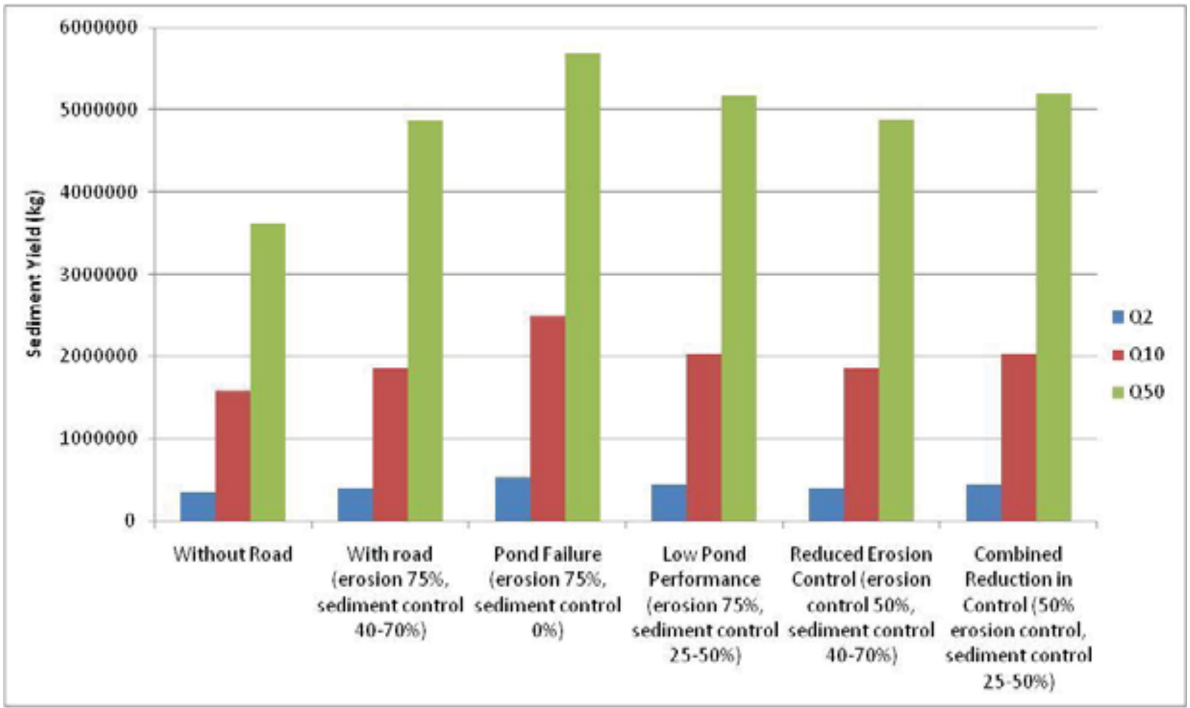
Table 15.21 outlines the proposed pond efficiencies during the Project and those used for the sensitivity analysis.

- **Table 15.21 Sediment Pond Efficiencies**

Pond Efficiencies			Inadequate Pond Maintenance		
Q2	Q10	Q50	Q2	Q10	Q50
70%	70%	40%	50%	50%	25%

These sediment removal efficiencies were applied to the calculated USLE for each scenario.

Figure 15.46 illustrates the sensitivity analysis that was undertaken to test the effect of the Erosion control efficiency (75% SRE) and the sediment pond efficiency (70% - 40%) and various scenarios with less than design performance.

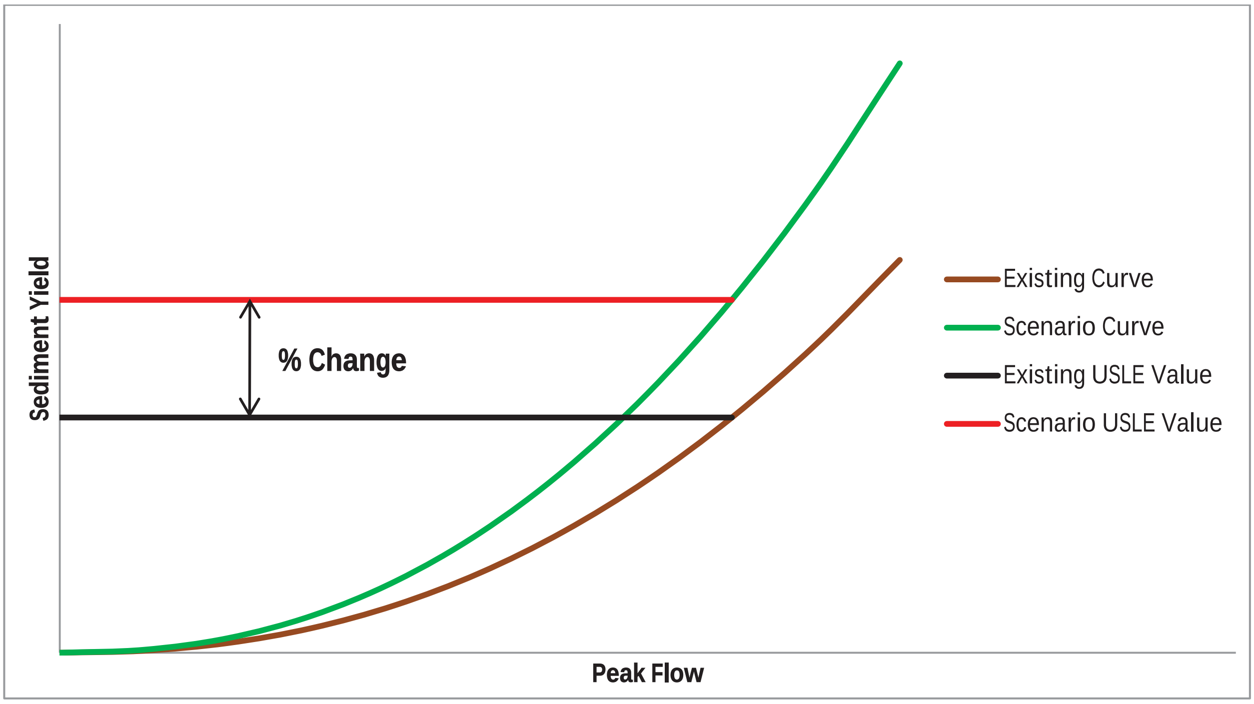


- **Figure 15.46 Sediment Yield for Duck Creek Catchment for Q2, Q10 and Q50 Events for a Range of Different Scenarios**

10.7. Use of the Rating Curves to Predict Scenarios

Sediment rating curves have been developed for each of the Transmission Gully catchments based on existing sediment yields, as discussed in **Section 10.5**. These curves have then been modified for each of the above scenarios in order to estimate future sediment yields under these scenarios. The process for this modification is as follows (refer to **Figure 15.47**):

- The existing curve is referenced (brown curve below)
- Average annual sediment yield value is associated with existing curve (black line)
- Average annual sediment yield is calculated for the modelled scenario (red line)
- The percentage change is calculated between each USLE value
- This percentage change is used to create a scenario curve (green curve)



- **Figure 15.47 - Conceptual Overview of Estimation of Sediment Yield for Future Scenarios**

10.8. Peak construction scenario for effects modelling in streams

Table 15.22 summarises the sediment loads calculated using the sediment rating curve for the modelling to assess the effects of increased sediment loads on stream sediment transport and deposition.

The staging scenario used for this assessment is described in **Section 3.1.1**. The hydrology used for the calculation of peak flow was calculated on a sub-catchment basis. The modelling of these sediment loads is described in **Section 11**.

Within each catchment there are a large number of small tributaries and some larger rivers to be crossed. Bridged crossing points are proposed for many of the major stream crossing points including the main Pauatahanui Stream, Porirua River, Duck Creek, and Te Puka Stream. All other crossings are likely to be culverted and thus require direct in stream works, the sediment yield calculations account for sediment generated by in stream works.

- **Table 15.22 Construction Sediment Load for Stream Catchments**

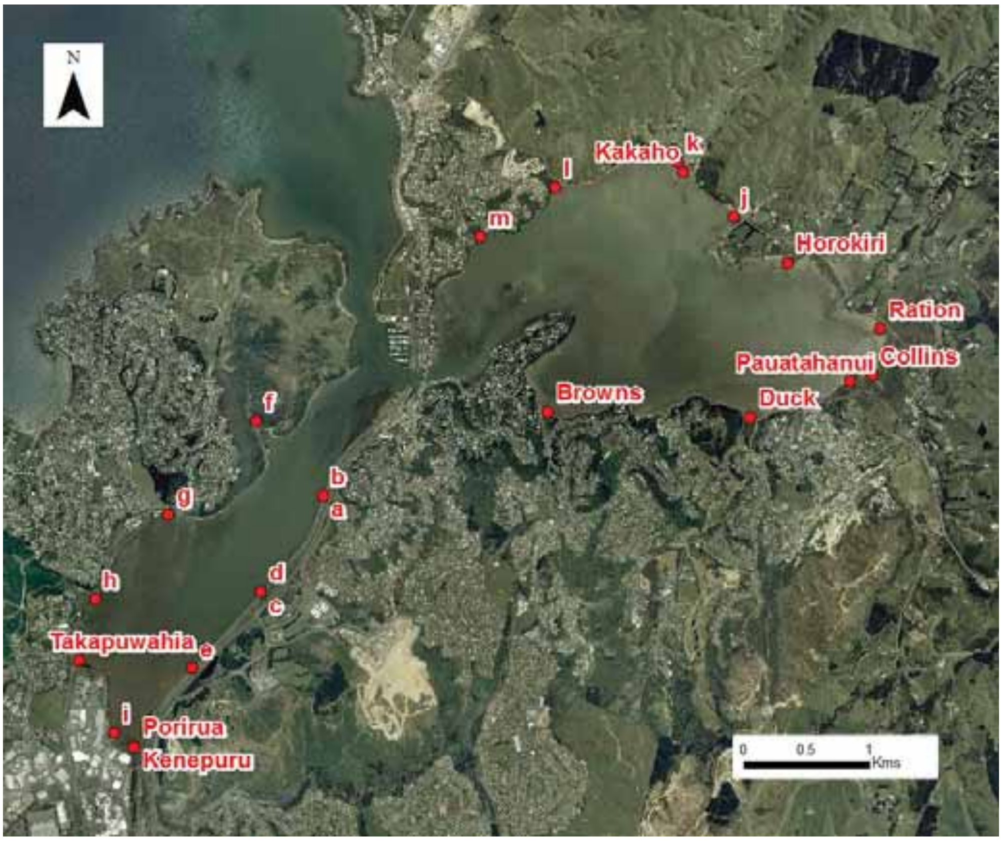
Catchment	Without Transmission Gully Project Stream modelling Scenario - Sediment Load (Tonnes/day)				With Transmission Gully Project Stream modelling Scenario - Sediment Load (Tonnes/day)			
	1/3 Q2	Q2	Q10	Q50	1/3 Q2	Q2	Q10	Q50
Duck	11	343	1582	3617	14	434	2004	5546
Horokiri	11	689	3754	8289	12	785	4281	10615
Kenepuru	18	375	1051	2346	20	413	1156	2818
Pauatahanui	11	695	4426	10117	11	711	4526	10576
Porirua	23	481	1417	3194	23	491	1446	3322
Ration	4	271	1353	2942	6	387	1931	5454
Collins		21	107	222		38	192	571

Te Puka/ Wainui	24	1710	8688	19431	31	2212	11237	30836
Whareroa	33	1948	9595	20497	35	2041	10050	22443

10.9. Construction Period Harbour Modelling Scenarios

During the proposed 6 year construction timeframe for the highway there will be large areas of open earthworks created. Based on the likely construction programme developed by Macdonald International, the peak construction scenario was derived by identifying the maximum area of open earthworks. These areas of open earthworks are shown in Section 3 in **Figure 15.1**. This 'peak construction' scenario that was used to test the effectiveness of the proposed sediment and erosion controls and to model the changes in sediment deposition and suspended sediment patterns within the harbour.

For each of the 23 sub-catchments the sediment yield model was used to predict the quantity of sediment that would be discharged from the stream mouths under a range of rainfall events. The stream mouths are labelled as shown in **Figure 15.48**. **Table 15.23** shows the predicted sediment loads entering the harbour in the 2, 10 and 50 year ARI rainfall events in each sub-catchment. In the peak construction scenario the predicted erosion and sediment control efficiencies have been included in the calculation of the sediment loads.



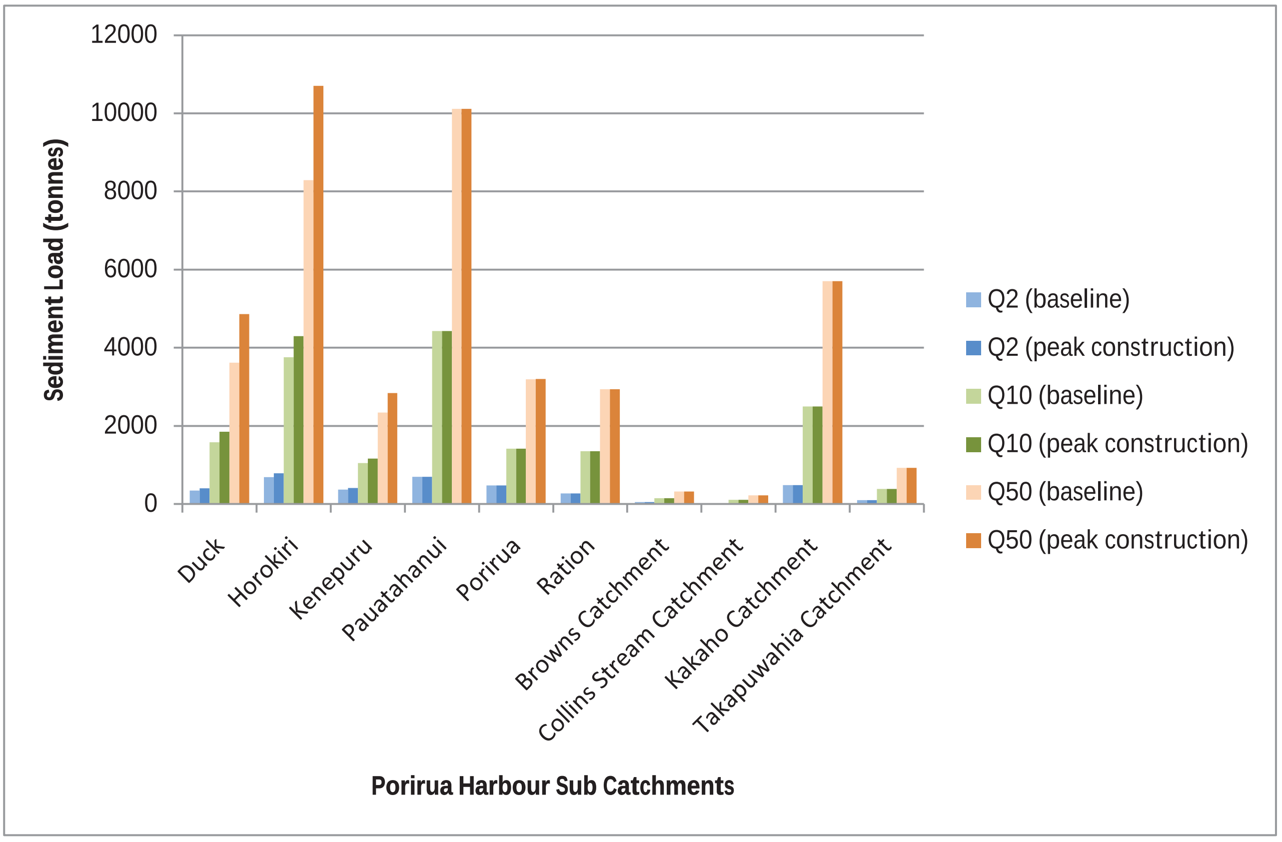
- **Figure 15.48 Location of Freshwater and Sediment Inflows with Associated Catchments**

Table 15.23 Predicted Sediment Loads Discharging from the Stream Mouths in Various Rainfall Events in The Pre And Peak Construction Scenarios

Catchment	Baseline (Without Road) Sediment Loads (tonnes)			Peak Construction Scenario Sediment Loads (tonnes)		
	Q2	Q10	Q50	Q2	Q10	Q50
Duck	343	1582	3617	402	1854	4861
Horokiri	689	3754	8289	789	4300	10700
Kenepuru	375	1051	2346	415	1162	2841
Pauatahanui	695	4426	10117	696	4426	10118
Porirua	481	1417	3194	481	1419	3199
Ration	271	1353	2942	271	1353	2942
Browns Catchment	51	147	323	51	147	323
Collins Stream Catchment	21	107	222	21	107	222
Kakaho Catchment	487	2498	5707	487	2498	5707
Takapuwahia Catchment	100	390	925	100	390	925
a	64	169	337	64	169	337
b	37	81	170	37	81	170
c	47	159	342	47	159	342
d	74	246	517	74	246	517
e	55	171	350	55	171	350
f	16	89	216	16	89	216
g	24	69	150	24	69	150
h	21	81	188	21	81	188
i	178	450	913	178	450	913
j	31	162	359	31	162	359
k	29	142	308	29	142	308
l	56	254	528	56	254	528
m	110	256	502	110	256	502
Total	**4257**	**19053**	**42561**	**4456**	**19983**	**46717**

The predicted sediment loads from the main catchments in **Table 15.23** are graphed below in **Figure 15.49**.

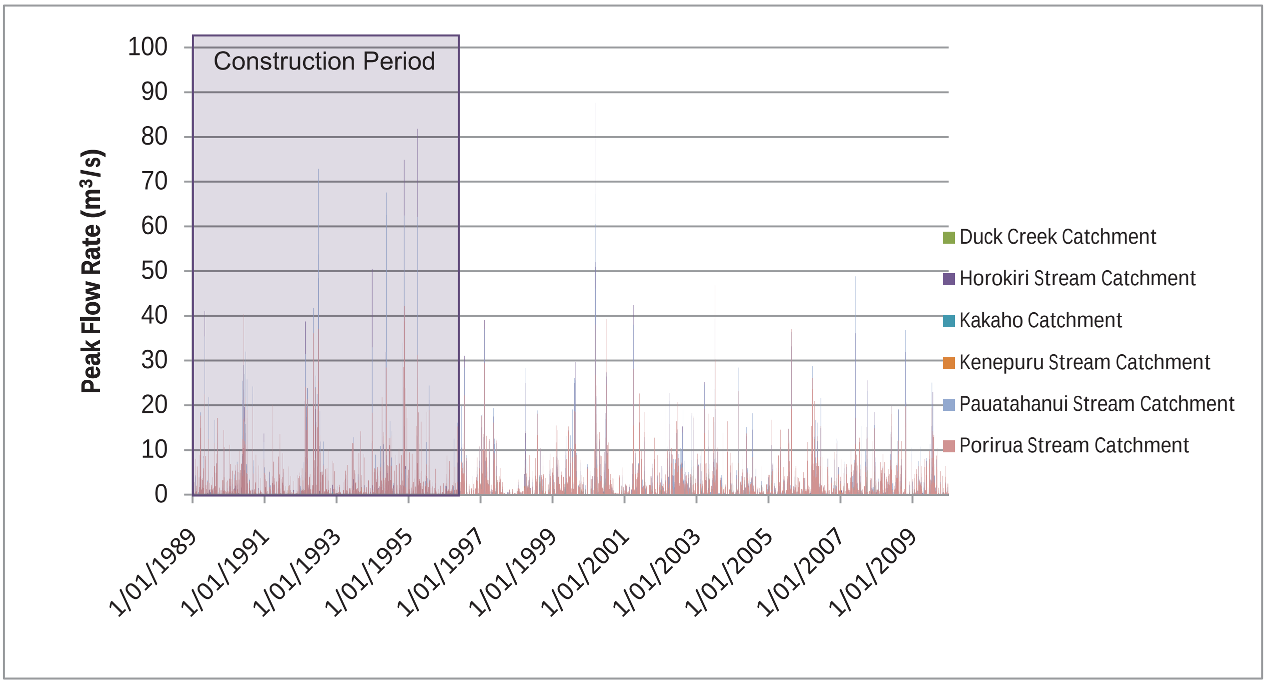
Figure 15.49 Predicted Sediment Loads from the Main Porirua Harbour Catchments Discharging in Various Rainfall Events in The Pre And Peak Construction Scenarios



10.10. Long Term Assessment

In addition to the event based assessment the model was also modified and used to assess the long term impact of increased sediment loads to the harbour resulting from the full six year construction period. The long term simulations cover the different weather and oceanographic conditions that could occur over a 20 year duration. To generate the flow and sediment inputs into the model the historical rainfall records were used between 1989 and 2009. However as there were a cluster of extreme rainfall events towards the end of this period a conservative approach was taken and the record flipped so that these extreme events would coincide with the construction period during the first six years of the simulation. This can be seen in Table 24 of the peak flows predicted in the major catchments over the 20 year simulation.

▪ **Table 24 Peak flow rates for the major harbour catchments during the 20 year simulation**



Based on MacDonald International's broad brush staging plan of open earthworks the 6 year construction programme was combined with the rainfall data and used to predict the changes in sediment loads into the harbour. Table 25 summarises the predicted difference in sediment loads over the 20 year simulation. It should be noted that only the construction phase was considered in the development of sediment inputs. Changes in the sediment inputs in the operational phase were not considered in this scenario.

▪ **Table 25 Predicted Sediment Loads into Porirua Harbour during the 20 year of simulation data.**

Catchment	Total Sediment Load Over a 20 Year Period: No Construction (tonnes)	Total Sediment Load Over a 20 Year Period: With Construction (tonnes)	Additional Sediment Load with Construction
Browns Catchment	655	655	0
Collins Stream Catchment	219	242	23
Duck	12905	13667	762
Horokiri	72653	74371	1717
Kakaho Catchment	19414	19414	0
Kenepuru	9076	9242	167
Pauatahanui	72829	73070	241
Porirua	41492	41576	84
Ration	9139	9169	30

Takapuwahia Catchment	1531	1531	0
A	317	317	0
B	160	160	0
C	199	199	0
D	171	171	0
E	169	169	0
F	225	225	0
G	347	347	0
H	258	258	0
I	1895	1895	0
J	240	240	0
K	137	137	0
L	318	318	0
M	327	327	0
Total	**244678**	**247702**	**3024**

10.11. Effect of Planting on Sediment Yield

The planting of existing catchment areas has the potential to reduce the amount of sediment delivered to streams and to the estuary in the long term. A number of areas are proposed for retirement to planting and/or pasture, for a range of reasons including ecological, aesthetic and habitat reasons, the planting is described in Technical Report 11: *Ecological Impact Assessment*.

It is difficult to quantify the effect that these mitigation areas will have on reducing sediment the streams and Harbour there are real opportunities through improved land cover to reduce peak flows (and associated sediment yields) from improved infiltration and attenuated runoff. An estimation can be approximated using the USLE as one of the factors used in this equation accounts for land cover type. However, the USLE does not differentiate significantly between 'plantation forest' and 'pasture' but it does account for 'native bush/forest' where the structure and complexity of this type of land cover would have an effect on sediment runoff.

Table 15.26 below provides an estimation of the effect of proposed planting on reducing the long-term annual sediment yield for each of the catchments where planting is proposed. This estimation is based on assuming that these areas would eventually be re-vegetated to a standard similar to that of native bush/forest. It should be noted that achievement of this type of reduction in sediment load would be a long-term strategy.

- **Table 15.26 Reduction in Annual Sediment Due to Planting Mitigation**

Catchment	Baseline Annual Sediment (tonnes)	Revised Annual Sediment with Planting Mitigation	Decrease from Baseline
Porirua	3478	3478	0%
Kenepuru	650	647	0.5%
Duck	979	884	9.7%
Pauatahanui	5735	5728	0.1%
Collins	17	17	0%
Ration	689	689	0%
Horokiri	5455	5258	3.6%
Te Puka/Wainui	1710	1555	9.0%
Whareroa	1948	1948	0%

11. Construction Modelled Effects - Streams

11.1. Sediment Transport Modelling

Sediment transport was modelled in seven freshwater streams along the Transmission Gully Project alignment in HEC-RAS 4.1.0. In order to model sediment transport a simple 1D hydraulic model was created. The hydraulic model contains geometry and flow information. The hydraulic model is coupled to a 1D sediment model and an analysis is carried out over time to provide accumulated sediment mass and depth along the length of each stream.

The tables in the following subsections discuss the results from the modelling and the potential effects on the streams from the yields during construction of the Project.

11.1.1. Model Principles

HEC-RAS has seven standard transport functions; a single function was used to model sediment for all streams along the Project alignment. The Laursen-Copeland method was chosen as the most appropriate for the type of grading expected in the soil of the region and for its use in sand-bed streams. This is the only HEC-RAS equation that was developed to include silt in the sediment transport calculation. The other equations are best suited for sand-gravel stream beds or large catchments with a flatter grade. The parameters for the Lauren-Copeland method are derived from Laursen (flume) parameters displayed in **Table 15.27**.

- **Table 15.27 Lauren (flume) Input Values for Sediment Transport Functions within HEC-RAS**

Function	d	d_m	s	V	D	S	W	T
Laursen (flume)	N/A	0.011-29	N/A	0.7-9.4	0.03-3.6	0.00025-0.025	0.25-6.6	46-83

Where d = overall particle diameter, mm
dm = Median particle diameter, mm
s = Sediment specific gravity
V = Average channel velocity, fps
D = Channel depth, ft
S = Energy gradient
W = Channel width, ft
T = Water temperature, °F

This transport function was used in conjunction with the standard HEC-RAS sorting method (Exner 5) and the standard fall velocity method (Ruby). The Exner 5 method assumes a course surface layer simulating bed armouring and limiting the erosion of deeper material. This was selected over the Active Layer method that is only appropriate for gravel beds and intended for use with the Wilcock transport method. The standard fall velocity method of Ruby was selected. This is appropriate for the finer sediment found within the catchments. Sensitivity analyses showed deposition with the Ruby fall velocity equation was generally conservative.

11.1.2. Model Development

Two models were created for each level of design storm on each stream. A baseline model was created in order to indicate expected levels of sedimentation in a design level storm before road construction takes place within the catchments. A second model was created to predict the expected level of sedimentation for a design storm during the construction scenario for each stream. The construction scenario is based on the year that the largest portion of road is under construction within the individual stream catchment to provide a conservative estimate of effects. In order to assess the effect of the Project construction in isolation, the ability to transport material from the channel bed was removed from the model as a variable.

11.1.3. Model Inputs

The inputs into the hydraulic and sediment yield model are detailed below.

Geometry

Geometry for the hydraulic models was developed from a mixture of survey, LiDAR and contour information supplied to SKM. This information was used to create a variety of cross-sections indicative of various reaches in each of the eight streams. The availability and accuracy of the geometric data was limited by the resolution of LiDAR in many cases which was not high enough to pick small changes in elevation across a relatively small stream channel. The limitations were found to be acceptable and appropriate for the creation of relatively coarse hydraulic models. Cross-sections were interpolated between those that were created manually. The stream sections that were modelled were all downstream of the Project alignment. The cross-sections, included interpolated sections were spaced approximately every 20 metres.

Flow

Quasi-unsteady hydrographs were used in the creation of the hydraulic models. The hydrographs were created in HEC-HMS with 1 hour time intervals for normalised 24-hour design storms. Constant baseflow was added to each storm hydrograph and extended over a period of a month in order to model sediment movement in the long term. Storm hydrographs created were for the 1/3 of 2, 2, 10 and 50 year design storm at the sub-catchment level. All flow information was entered into the models as point sources. The catchments modelled are provided in **Appendix 15.T**.

The hydrology methodology is generally consistent with the hydrology used for Porirua Harbour Scenarios, discussed in Technical Report 14: *Assessment of Hydrology and Stormwater Effects*. The only difference is that hydrology for the harbour modelling was calculated on a whole catchment basis and represents the Q2, Q10, and Q50 at the mouths of the streams, and the stream modelling was calculated on a sub-catchment basis and reflects the 1/3 Q2, Q2, Q10, and Q50 on a sub-catchment basis. Flows from the sub-catchment calculation are conservative when compared with the whole catchment calculation, because the sub-catchment does not account for areal reduction factors.

Boundary Conditions

Boundary conditions define sediment entering the model from the various contributing catchments. Boundary conditions were entered as point sources at the same locations as flow information, representing sediment entering the main stream from tributary environments.

Sediment was entered into the models as a mass time-series corresponding to the inflow hydrographs. The sediment input into each model was calculated based on sediment yield calculations described in detail in **Section 10**.

All sediment entered into the model was given the same particle size distribution. This distribution was defined in HEC-RAS according to **Table 15.28**.

- **Table 15.28 Modelled Particle Size**

Class	Diameter (mm)	Incremental Percentage
Coarse Mud	0.0625	60
Very Fine Sand	0.125	20
Fine Sand	0.25	20

This sediment distribution is skewed towards clays. Clays make up less than 20% of the soils used for the USLE calculations, as illustrated in **Table 15.28**. The skew towards clays is to represent the greater efficiency of erosion and sediment control measures at removing larger particle sizes, discussed in **Section 9.6.2**. This particle size distribution is for the whole catchment sediment load, of which the construction area is a small proportion.

11.2. Model Calibration

Hydrological inputs into the HEC-RAS model were calibrated against flow data, and sensitivity analyses of input sediment yields and manning's *n* roughness were conducted to check the reliability of results.

The hydrological inputs into the model were calibrated against the gauging stations at "Pauatahanui Stream at Gorge", "Porirua Stream at Town Centre" and "Horokiri Stream at Snodgrass". Curve numbers and storage coefficients were adjusted to calibrate the actual flood peak with the modelled flood peak. The modelled runoff hydrographs matched the observed events with a reasonable fit. Details are contained in Technical Report 14: *Assessment of Hydrology and Stormwater effects*.

Point source sediment yield releases into the HEC-RAS model were increased and modelled to determine the impact greater sediment releases had on deposition, and to ensure the model was responding to changes in yield. By increasing the sediment yield into the model the deposition also increased by a proportional amount. This is to be expected as the sediment transport equations are governed chiefly by stream hydraulics, rather than sediment concentration. Therefore with a greater sediment load, more sediment may be deposited, but only in those locations that are identified as having conditions that would allow deposition in the modelled scenario.

The manning n roughness coefficient was set at 0.035 for all stream reaches within the HEC-RAS model. This value is based on roughness characteristics of New Zealand rivers provided by Hicks and Mason (1998) and reflects the stream bed and overhanging vegetation from stream banks. Raising the manning's *n* roughness coefficient from 0.035 to 0.04 models a coarser terrain whereby greater deposition occurs. In the sensitivity check deposition increased by approximately 25%.

As the HEC-RAS model is a high-level catchment deposition model, the 0.035 manning's *n* value was selected for the entire reach. When the stream is confined within the channel, a roughness of 0.035 is most appropriate. However, in larger events when the flows overtop the stream banks a higher roughness coefficient may be more appropriate. This is most likely to occur at the base of catchments where the grade reduces and forms the floodplain. This will have little impact on the 1/3 of the Q2 and the Q2 events where the majority of flow is confined. It is these two events that have a greater probability of occurring within the construction period of the Project. Sediment deposition in larger events where flood flows have the potential to extend over the floodplain may be underestimated in parts of the catchment by up to 25%. However, this deposition would occur outside of the stream channel where ecological impacts would be limited.

Model continuity balance checks and reasonability of outputs were also assessed as a final logic check of results. The continuity balance compared the input yields to the volume of sediment discharged at mouth and deposited within the stream. Peak velocities, maximum water levels, and continuity balance were reasonable.

11.3. Catchment Inputs and Stream Description

The sediment yield assessment is based on the peak construction scenario. This is the maximum sediment concentration released per catchment over the construction period, so is in effect a combination of different construction years. The probabilities of the modelled events occurring during any given year are displayed in (**Table 15.29**). The model results for the peak construction (greatest section of road in that catchment open during construction) are therefore not going to affect all catchments at the same time and for years either side of construction, sediment runoff will be less. A 50 year return period event (50 year ARI) has a 2% probability of occurring in any given year during construction, or an 11% probability of occurring during six years of construction, though for years when the maximum section of road is not open, sedimentation will be less than presented here.

Table 15.29 Probability of Rainfall Events

Rainfall Event	Probability of Occurring in Any Given Year
1/3 2 Year ARI	approximately 90th percentile storm
2 Year ARI	39%
10 Year ARI	10%
50 Year ARI	2%

Table 15.30 gives an overall indication of the steep nature of the streams though calculation of the average catchment slope. This is taken from the furthest point in the catchment to the outflow. The catchments typically have very steep headwaters, and commonly drain over flatter floodplains to where they discharge into the coast or harbour.

Table 15.30 Average Catchment Slopes

Catchment	Average Catchment Slope
Porirua	2%
Kenepuru	5%
Duck	4%
Collins	6%
Ration	5%
Pauatahanui	3%
Horokiri	3%
Wainui/Te Puka	11%
Whareroa	5%

Table 15.31 contains the catchment peak flows and sediment yield inflows used in the HEC-RAS model. The calculation of these inflows is described in **Section 10.8**.

- **Table 15.31 Catchment Peak Flows and Sediment Yield Inputs into the HEC-RAS model**

Catchment	Event	Peak Flows (m^3/s)	Sediment Yield without Project (Tonnes)	Sediment Yield with Project (Tonnes)
Porirua	1/3 of 2 Year	6.3	23	23
	2 Year	31.2	481	491
	10 year	55.1	1417	1446
	50 year	84.5	3194	3322
Kenepuru	1/3 of 2 Year	3.8	18	20
	2 Year	18.9	375	413
	10 year	32.5	1051	1156
	50 year	49.6	2346	2818
Duck	1/3 of 2 Year	1.8	11	14
	2 Year	11.3	343	434
	10 year	25.3	1582	2004
	50 year	39.1	3617	5546
Pauatahanui	1/3 of 2 Year	3.2	11	11
	2 Year	29.2	695	711
	10 year	77.4	4426	4526
	50 year	119.6	10117	10576
Ration	1/3 of 2 Year	0.9	4	6
	2 Year	8.6	271	387
	10 year	20.0	1353	1931
	50 year	30.1	2942	5454
Horokiri	1/3 of 2 Year	2.8	11	12
	2 Year	24.9	689	785
	10 year	60.9	3754	4281
	50 year	92.4	8289	10615
Wainui/Te Puka	1/3 of 2 Year	1.3	24	31
	2 Year	12.6	1710	2212
	10 year	29.6	8688	11237
	50 year	45.2	19431	30836
Whareroa	1/3 of 2 Year	2.5	33	35
	2 Year	21.0	1948	2041
	10 year	48.6	9595	10050
	50 year	72.5	20497	22443

11.3.1. Stormwater Discharge Water and Sediment Quality

Sediment Quality

The sediment quality of the additional sediment load predicted as result of the Transmission Gully Project is expected to be the same as the existing quality of sediment discharged from the catchments.

Water Quality

The increased sediment yield will result in an increase in TSS as summarised in **Appendix 15.S**.Associated with this could be some nutrients associated with soil particles (nitrogen and phosphorous) and minor amounts of other materials in the soils (metals, pesticides etc). If any of the historic land uses caused soil contamination this could also become entrained in the runoff.

The largely insoluble contaminants that may be present in the soils are not expected to be released into the freshwater at a greater rate than they are currently, provided the acidity of stream water is not affected by the discharge of chemically treated construction discharges. While the concentrations of contaminants found in soils are not expected to change, an increase in load is expected.

All of the stormwater discharged from the active construction areas is proposed to be chemically treated in sediment retention ponds. Chemical treatment can result in decreases in pH and depending on chemical treatment used can result in the release of elevated levels of aluminium. The toxicity of aluminium, and other contaminants in soils, is increased with low pH. Some of the soils in the Project area already have slightly acidic soils (see **Section 6.3**), therefore pH from chemically treated ponds will have to be carefully managed to ensure any pH change is within an acceptable range. The erosion and sediment control plans that will be developed prior to construction will include a chemical treatment plan (CTP) which will outline how pH and aluminium will be managed. Experience from ALPURT (Moores and Pattison, 2008) has shown that well managed chemically treated ponds in acidic clay soils can operate successfully.

Other discharges during the construction works may include:

- Clean water discharges from cut off drains and diversions
- Dewatering water from deeper earthworks
- Discharges associated with in stream works and channel disturbance (accounted for in the sediment yield calculations)
- Accidental discharges such as spills of fuels, oils, concrete etc.

Management of these discharges is discussed in **Section 9**.

Point source discharges from the site will be managed by point source erosion protection, detailed in Technical Report 14: *Assessment of Hydrology and Stormwater Effects*.

The ecological effects of the sediment quality and water quality of the construction discharges are discussed in Technical Report 11: *Ecological Impact Assessment*.

11.3.2. Model Results - Suspended Sediment

A table summarising the total suspended sediment input to the model at locations along the stream catchments is provided in **Appendix 15.S**. This information is conservative because it does not account for the sediment that is deposited in the streams.

The effects of TSS in streams are restricted to the rainfall events. **Table 15.32** summarises the change in TSS for the smallest of the modelled events - the 1/3 of the 2 year. This storm is approximately equivalent to the 90th percentile storm, so is a storm expected to occur on a regular basis. **Appendix 15.S** contains TSS results across all events. The ecological effects of TSS are discussed in Technical Report 11: *Ecological Impact Assessment*.

- **Table 15.32 Total Suspended Sediment Downstream of Project 1/3 of 2 year**

Catchment	Without Road	With Road
	1/3 of Q2 Sed (g/m³)	1/3 of Q2 Sed (g/m³)
Duck	189	240
Horokiri	83	95
Kenepuru	165	182
Pauatahanui	78	80
Porirua	75	76
Ration	139	198
Wainui	729	943
Whareroa	482	505
Collins	123	221

Visual Clarity and Colour

TSS is related to turbidity, visual clarity and colour (Packman et al., 1999). The water quality characterisation data analysis indicated that all streams with the exception of the Porirua and Kenepuru have visual clarity that is within guideline values for black disk analysis. These samples were taken during small rain events.

Road construction does increase TSS. These increases occur in storm events, when the visual clarity even without the Project will be above guidelines values in all streams. While the changes may be conspicuous, the effect of the increased TSS on visual clarity and colour is only expected to occur for the duration of storm events with no lasting effect. The effect is considered minor.

Biological Growths

The nutrient load is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. pH will be managed by the erosion and sediment control plans, the development of which is described in **Section 9**. Other factors that contribute to biological growth, such as changes in temperature and flow regime, are not predicted to occur as a result of the construction stormwater discharges. Therefore undesirable biological growths are not expected as result of the discharges. Algae blooms and associated odour are not expected as a result of increased nutrient load.

11.3.3. Model Results - Deposited sediment

Results from the HEC-RAS stream modelling are given below. Results are tabulated as maximum sediment deposited on any given cross-section in **Table 15.33**, and as the total sediment deposition and percentage change throughout the stream in **Table 15.34**. It should be noted that the maximum deposition on any given cross-section is approximate. The resolution of the model does not enable accurate deposition at this detailed scale. The effects of sediment deposition are discussed in Technical Report 11: *Ecological Impact Assessment*.

Maps illustrating the sediment deposition in mm for each stream are provided in **Appendix 15.T**. The baseline maps also plot the location of the quorer samples where samples were taken in that catchment. From the quorer visual analyses both the Ration and Porirua catchments had a high percentage of fines at over 50%. This coincides with the sediment deposition maps in **Appendix 15.T** that show deposition close to quorer sites.

The sediment deposition maps in **Appendix 15.T** and the values in **Table 15.33** assume sediment is deposited across the wetted perimeter. In the 1/3 of the Q2 and Q2, flow is mostly contained within the channel so sediment deposition will be confined to the channel. In the larger events of the Q10 and Q50 sediment will be deposited across the stream channel and in the flat areas across the floodplain.

Based on the depth of sediment deposition in **Table 15.33**, when the frequency of an event occurring is multiplied by the probability of that event over the construction period, the cumulative change in deposition of the 1/3 of the Q2 and the Q2 is less than 1mm. That is, the events more likely to occur during construction of the Project will contribute less than 1mm of sediment over that period.

Table 15.33 Maximum Sediment Deposited (mm)

Stream	Storm	Modelled Sediment Deposition (mm)		
		2021 without Transmission Gully Project (mm)	2021 with Transmission Gully Project (mm)	Change in modelled sediment deposition (mm)
Whareroa	Q50	11	19	8
	Q10	7	7	0
	Q2	7	7	0
	1/3 Q2	7	7	0
Te Puka / Wainui	Q50	6	9	3
	Q10	4	4	0
	Q2	3	3	0
	1/3 Q2	3	3	0
Horokiri	Q50	5	5	0
	Q10	5	5	0
	Q2	4	4	0
	1/3 Q2	2	2	0
Ration	Q50	7	10	3
	Q10	4	8	4
	Q2	3	3	0
	1/3 Q2	3	3	0
Pauatahanui	Q50	1	1	0
	Q10	2	2	0
	Q2	1	1	0
	1/3 Q2	0	0	0
Duck	Q50	1	1	0
	Q10	2	2	0
	Q2	1	1	0
	1/3 Q2	0	0	0
Kenepuru	Q50	5	5	0
	Q10	4	4	0
	Q2	3	3	0
	1/3 Q2	1	1	0
Porirua	Q50	3	3	0
	Q10	3	3	0
	Q2	3	3	0
	1/3 Q2	3	3	0

Table 15.34 Change in Sediment Deposition between the Baseline and Peak Construction Scenario

Catchment	Sediment deposited in streams (tonnes)											
	2021 without Transmission Gully Project				2021 with Transmission Gully Project				Change in modelled sediment deposition (%)			
	1/3 Q2	Q2	Q10	Q50	1/3 Q2	Q2	Q10	Q50	1/3 Q2	Q2	Q10	Q50
Porirua	6	32	46	75	7	32	47	76	2	1	1	1
Kenepuru	14	247	664	1416	16	291	787	1953	14	18	19	38
Duck	4	63	265	308	5	80	280	440	30	28	6	43
Pauatahanui	8	244	1460	5316	8	246	1472	5369	1	1	1	1
Ration	4	241	780	1232	6	282	1708	2357	43	17	119	91
Horokiri	8	376	1573	2978	9	429	1780	3576	16	14	13	20
Wainui	13	170	403	638	17	222	480	921	29	31	19	44
Whareroa	31	1809	9254	19642	32	1913	9801	21959	5	6	6	12

12. Construction Modelled Effects – Porirua Harbour

12.1. Introduction

The assessment of the potential water quality effects is one of the key components of this Technical Report of the Transmission Gully Project. This includes effects during any enabling and construction works and subsequently as part of the ongoing operation. The assessment takes into account the high environmental status afforded to many of the streams and catchments that could be crossed by the proposed Transmission Gully Project, and the nationally significant receiving environment of Porirua Harbour. The Pauatahanui Inlet is identified in the Regional Coastal Plan as an Area of Significant Conservation Value (ASCV). The Plan describes the Pauatahanui Inlet as having "natural, conservation, geological and scientific values. A wildlife reserve with a diverse waterfowl and wading-bird habitat (local and migratory), threatened fish species (including Galaxias spp) and endangered vegetation."

An assessment of the effect of construction sediment on the Kapiti Coast receiving environment, which will receive sediment discharged from the Wainui (Te Puka subcatchment) and the Whareroa catchments, has not been considered as part of this assessment. This is a high energy coastal environment and as such is not considered to be vulnerable to the additional sediment predicted to be discharged as a result of the construction of the Transmission Gully Project.

12.2. Objectives of the Study

The assessment of effects covered in this report involves identifying the fate of any additional sediment entering the harbour associated with the construction of the Transmission Gully Project. This includes developing an understanding of the quantity, location and duration of both suspended and deposited terrestrial sediment entering the harbour. To develop this understanding, advanced and integrated analytical techniques using numerical models are required. A modelling approach was selected with consideration of the following:

- Availability of input data
- The resolution in space and time
- Essential features and processes represented
- Output formats which can be readily appreciated by a range of specialists.

In particular, the modelling provides data for the ecologists to enable them to assess the ecological effect of the Transmission Gully Project construction and to assist in the design of the proposed mitigation measures.

12.3. Description of Porirua Harbour

Porirua Harbour is a natural inlet located on the west coast of the North Island, north of Wellington City. The city of Porirua, which is one of the four cities in the Wellington conurbation, surrounds it. The city centre is located to the south of the harbour, see **Figure 15.50**.

The harbour has an entrance only a few hundred metres in width, close to the suburb of Plimmerton. It opens up into two arms. The southern Onepoto Arm has an area of approximately 240ha (35% of the harbour area), of which around 80% is sub-tidal. The eastern arm - the Pauatahanui Inlet, is 470ha (65% of the harbour area), of which around 60% is sub-tidal.

The wetland where Pauatahanui Stream enters the Pauatahanui Inlet is the largest remaining estuarine wetland in the lower North Island. Pauatahanui Inlet is recognised for its high ecological, aesthetic and recreational values and is classified as a Site of Special Wildlife Interest (SSWI) by the Department of Conservation.

The harbour has historically been affected by impacts of both rural and urban development. Much of the contributing catchment is currently utilised for sheep and cattle farming or has been developed for residential, commercial and industrial use. There are approximately 100,000 people residing in the 175km^2 catchment. There are a number of local roads that constrain the harbour edge and parts of the harbour have been reclaimed. The eastern edge of the Onepoto Arm was reclaimed for a causeway for the construction of the North Island Main Trunk Railway. Further filling was undertaken when State Highway 1 was re-aligned in the 1970s alongside the railway.

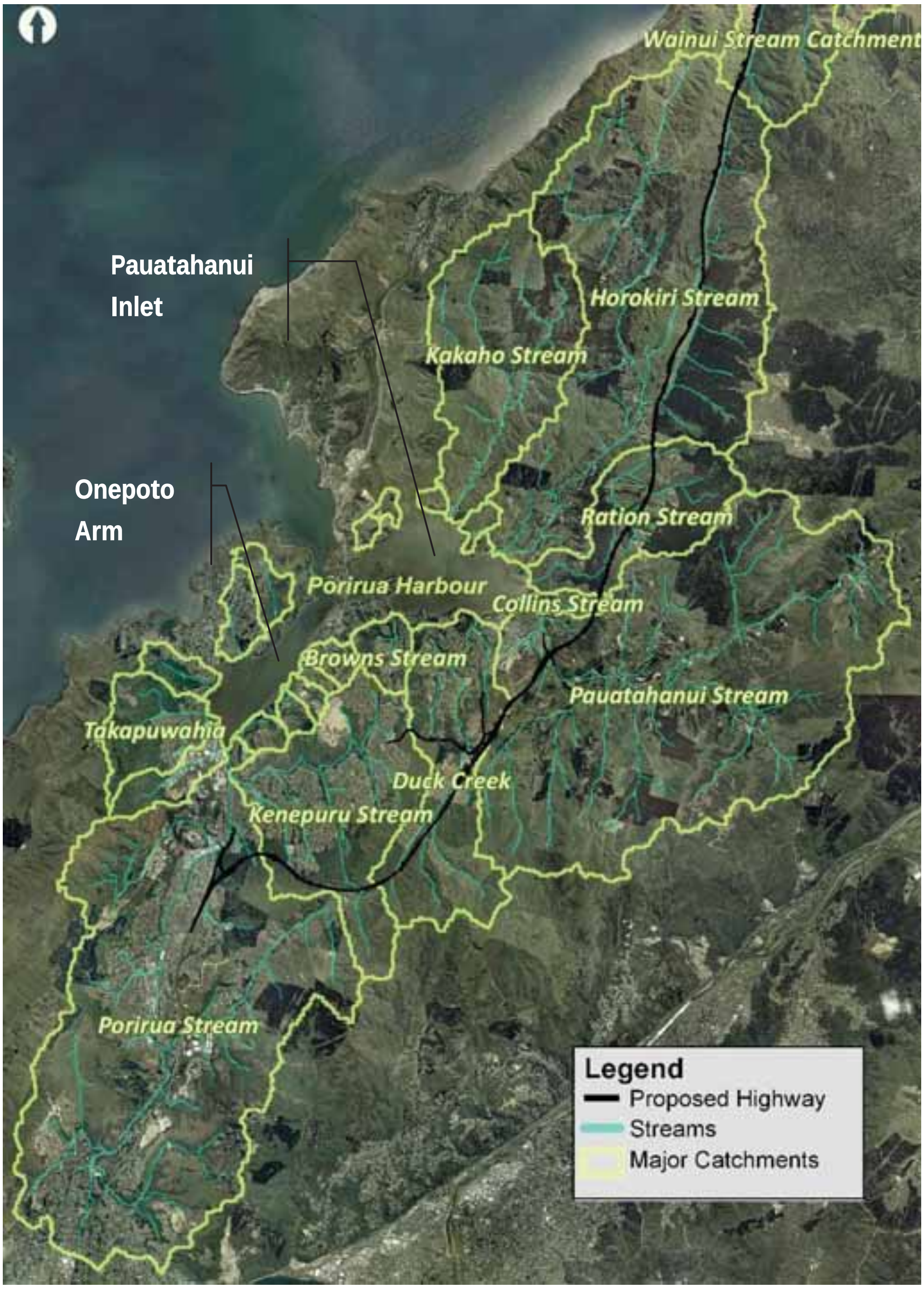
12.3.1. Porirua Harbour Sedimentation Background Information

To obtain an understanding of the historical sedimentation processes in the harbour this study has drawn on a range of previous studies, in particular on the report *Patterns and Rates of Sedimentation within Porirua Harbour* by Gibb *et al.* (2009). This report has documented the patterns and rates of sedimentation in Porirua Harbour largely based on an analysis of a number of hydrographic surveys.

The main findings from these studies of relevance to the harbour modelling investigation were:

- Both marine and terrestrial environments are suppliers of sediment to the harbour. However terrestrial derived sediment appears to dominate.
- No silts and clays are found in the marine sands located in the outer seafloor. Therefore, the most likely source of mud to the harbour is the streams which drain into both arms of the harbour.
- Within both arms of the harbour there are basins which are mostly composed of mud with less than 10% sand (Healy, 1980).
- Most marine derived sediment which enters into the harbour arms is deposited onto the flood tide deltas.
- Sand and gravel is supplied to the harbour via streams, which is then transported via wave action to form narrow beaches surrounding the harbour.
- There appears to be little mixing of marine and terrestrial supplied sand. Very little terrestrial derived sediment is able to migrate across the harbour arms to deposit on flood deltas.
- The relatively larger streams that enter into the harbour arms have complex “bird foot” deltas – with dynamic, often multiple channels within the inter-tidal zone.
- There are circulation eddies that occur in both arms of the harbour which probably contributes to the muddy basins in the centre of the arms.
- The locations that have been shown to have the most deposition in Pauatahanui Inlet are the western and eastern parts of the central mud basin. This occurs as a result of only weak tidal currents and circulation eddies in these areas.
- Sediment which enters into Onepoto Arm accumulates in the central muddy basin.
- There is a pattern of erosion along much of Onepoto shoreline, which is probably a result of wave reflections from reclaimed land and shoreline response to sea level rise.
- Significant sedimentation occurred in the Browns Bay in mid 1970s as result of urbanisation (Swales et al., 2005). However Browns Bay appears to also be a sediment trap for sediments sources outside the bay.

- Between 1974 -2009, the net average deposition rates within Pauatahanui Inlet were 9.1 mm/year (42,000 – 43,000 m^3/year) and within Onepoto Arm were 5.7 mm/year (13,500 – 14,000 m^3/year).
- Since 1974, the tidal prism for Pauatahanui Inlet has reduced by 8.7% and 1.7% in Onepoto Arm.
- At current sedimentation rates, Pauatahanui Inlet will fill in the next 145 – 195 years and the Onepoto Arm will fill in next 290 – 390 years.



- **Figure 15.50 Porirua Harbour and Surrounding Catchments**

12.3.2. Physical Processes

The following is a summary of the physical processes, relevant to this study, which occur within the harbour. Section 10 contains a detailed discussion on the terrestrial sediment processes that occur in stream catchments and contribute sediment loads to the harbour.

The main driver for the movement of water in and out of Porirua Harbour is tides. The approximate tide amplitude for the spring tide = 0.8 m and neap tide = 0.3 m, with approximately 60% of the water volume that enters the harbour, flowing into Pauatahanui Inlet and 40% into Onepoto Arm. There are strong tidal currents through the entrances of the harbour, while only weak tidal currents are experienced in the middle of the harbour arms. It appears that low velocity eddy circulation occurs within the arms of the harbour.

Other important drivers for the movement of water within the harbour are winds, waves and freshwater inflows from the surrounding catchments. Wind is able to generate currents within the harbour arms as its momentum is transferred throughout the water column. The fetch in the harbour means that winds of a strong enough magnitude can generate and propagate surface waves within the arms of the harbour, which in turn generates wave driven currents.

The movement of water throughout the harbour and associated movement of sediment, results in the development of estuarine and coastal features, such as deltas, tidal channels, spits, sand bars, etc. There are two sources of sediment into the harbour – marine and terrestrial sources.

Firstly, marine based sediment (mostly sand) which is predominantly transported into the harbour as bed load via a combination of tidal and wave driven currents. It supposedly settles on flood tide deltas at the entrance to the harbour arms (Gibbs et. al., 2009). In this investigation, marine sands have not been accounted for in the model. This is considered appropriate for the assessment of effects associated with the Transmission Gully Project because the impacts being assessed will be almost exclusively on terrestrial rather than marine sediment. Moreover, 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.

Secondly, terrestrial based sediment (silt/clay, sand and gravel) which enters into the harbour via the freshwater inflows surrounding the harbour catchment. Coarse non cohesive sediments are deposited close to freshwater inputs and are transported to the surrounding narrow beaches of the harbour via both bed load transport and suspended load transport generated by wave action. Fine cohesive sediments (mud and silt/clay) are transported via suspended load as sediment plumes with accumulation being observed in the central basins of the arms of the harbour. Some fine material may also be transported out of the harbour altogether.

For cohesive sediments, when suspended concentrations are large enough, flocculation will occur resulting in sediment particles joining together and settling out of water column due to their increased mass. Cohesive sediments that settle in tidal channels are likely to be re-suspended due to tidal currents that are strong enough to cause bed erosion. Cohesive sediments are re-suspended from the muddy basins of the harbour arms when a wave event is large enough to generate currents that cause the bed to erode.

The “bird-feet” like deltas that exist near the larger streams discharging into the harbour are likely to be transient. During large flood events these deepen and then become filled again via wave action. The freshwater inflows to the harbour are not large enough create well defined stable channels. A possible exception to this is the Porirua Stream where the stream exit has been confined by reclamation of the harbour.

12.4. Harbour Modelling

To represent the harbour and 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. A detailed description of the construction, calibration and verification of the models is included in **Appendix 15.V**.

The model was constructed to identify the potential changes in the quantity, location and duration of both suspended and deposited terrestrial sediment entering the harbour. With the available information an acceptable calibration was achieved. The model has also been reviewed by DHI technical specialists and has been confirmed as suitable to meet the objectives of the investigation.

12.4.1. Methodology Overview

Construction of the Transmission Gully Project will require large areas of open earthworks that have the potential to add to sediment loads entering the harbour. The potential changes in the sediment patterns in the harbour associated with the project construction, are dependent on a variety of environmental conditions. Early testing of the model and previous studies on similar projects indicated that the key influencing environmental factors are:

- Rainfall intensities/duration - Terrestrial sediment inputs into the harbour are almost entirely associated with rainfall in the surrounding catchments. During the proposed six year construction timeframe for the Project, there will be large areas of open earthworks created. Exposed or recently disturbed earth is more prone to erosion during rain than existing vegetated land use. While there are a range of measures that can be taken to reduce erosion or intercept sediment runoff from the construction site, for any given rainfall event there is potential for the construction to increase the sediment loads into the harbour.
- Wind conditions during and following the sediment inputs into the harbour - In shallow estuarine environments, such as both the Pauatahanui and Onepoto Arms of the harbour, wind has an important influence on the circulation patterns. Wind also generates waves that can re-suspend and keep sediment in suspension.

As the impacts on the harbour are dependent on environmental factors, the modelling philosophy has been to develop an ‘envelope of potential impacts’ on which to base the assessment of effects. A range of rainfall and wind events have been modelled and the results were used to understand the spectrum of potential effects on the harbour.

Two types of modelling have been undertaken:

- Event based modelling - to identify impacts on sediment patterns during a range of storm events and wind conditions. This modelling has primarily been used for the assessment of ecological effects.
- A long term simulation using a simplified model - to understand the cumulative effects of the construction of the Project on the harbour. This model simulated the predicted sediment inputs into the harbour over a 20 year period with and without the Transmission Gully Project construction. This modelling has primarily been used to assess the cumulative impacts on sediment deposition in the harbour.

The calibrated hydrodynamic, wave and sediment transport models were used to carry out both event based and long term impact assessments to determine the impact of increased sediment loads which may occur during the construction of the proposed Transmission Gully Project.

12.5. Event Based Assessment

The purpose of the event based modelling is to understand the fate of sediment that is washed off surrounding stream catchments and enters the harbour during heavy rainfall. It is also to quantify the impacts of the construction associated with the Transmission Gully Project. This information is primarily used to assist the coastal ecologists in their assessment of ecological effects.

12.5.1. Event Based Rainfall Scenarios

Terrestrial sediment inputs into the harbour are dependent on the frequency, intensity and duration of rainfall in stream catchments. Early testing of the hydraulic model provided an indication of the range of potential impacts under a variety of rainfall events. Based on this analysis, the coastal ecologists focused the harbour modelling investigation on the 2 and 10 year ARI rainfall events. The 50 year ARI rainfall event was considered to be an extreme event with a low probability of occurring during the construction period.

Macdonald International has predicted a likely construction programme for the Transmission Gully Project. They have suggested that the over the six year construction programme the duration of construction within any of the major stream catchments feeding into the harbour is likely to be between 2-4 years. The peak of construction is likely to occur over a 2 year period. The peak construction period is the duration when there will be the greatest area of open earthworks exposed during the project.

Based on these time frames the probability of a rainfall event occurring during the construction period can be estimated using the following equation. This is also represented in Table 15.35.

$$P_T = 1 - (1-P_f)^n$$

Where:
P_T is the probability of occurrence for the entire period
P_f is the probability of occurrence in any single year
n is the duration of exposure in years

- **Table 15.35 Probability of a rainfall occurrence for a range of construction periods.**

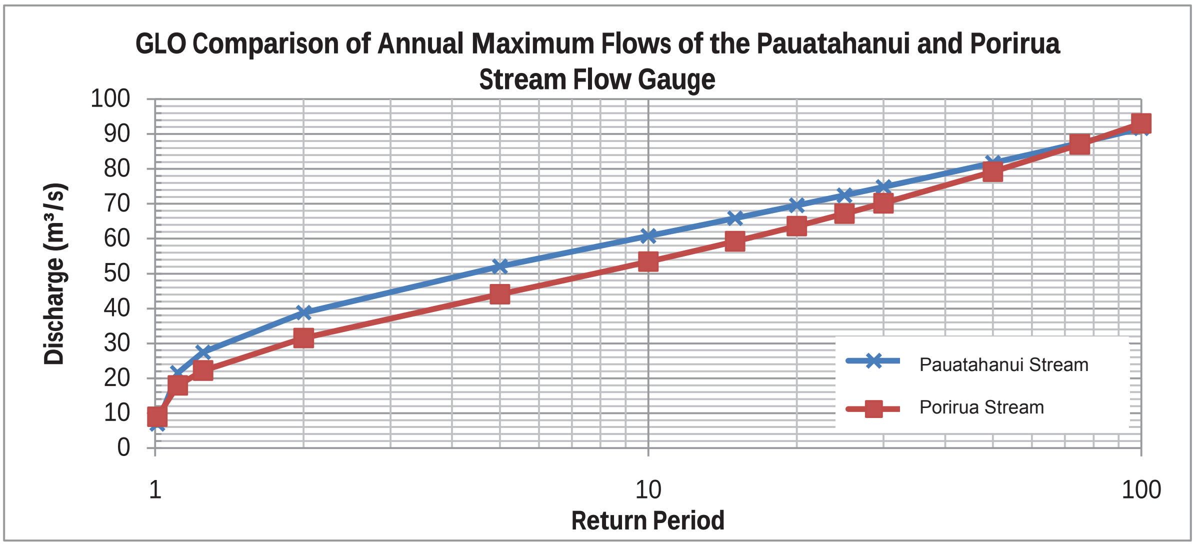
ARI	AEP	Construction Period (Years)				
		1	2	4	6	10
1	63%	63%	86%	98%	100%	100%
2	39%	39%	63%	86%	95%	99%
5	18%	18%	33%	55%	70%	86%
10	10%	10%	18%	33%	45%	63%
20	5%	5%	10%	18%	26%	39%
50	2%	2%	4%	8%	11%	18%
100	1%	1%	2%	4%	6%	10%

During the 2 year peak construction period the 2, 10 and 50 year ARI events would have a 63%, 18%, and a 4% probability of occurring.

Over the full six year construction period these probabilities are 95%, 45% and 11% for the 2, 10 and 50 Year ARI rainfall events respectively.

It is unlikely that a 10 or 50 year ARI rainfall event will occur across the whole of the Porirua Harbour catchment during the same storm event. Analysis of the historical rainfall records was undertaken to indicate a realistic rainfall pattern across the catchment during an extreme storm event.

Using the 35 years of coincident data from the Porirua and Pauatahanui Stream gauges the annual maximum flood events were identified and a GLO distribution fitted, see **Figure 15.51**. Based on this data we have quantified the return period of the major flood events on record for the two streams. This has been compared with the return period of the coincident peak flow from the same storm event in the other stream. This comparison is shown in Table 15.36.



- **Figure 15.51 GLO Distribution of the Maximum Annual Flood Events in the Porirua and Pauatahanui Streams**

- **Table 15.36 Comparison of Return Periods in the Pauatahanui and Porirua Streams During an Extreme Event in one of the Catchments**

Major Flood Events in Pauatahanui Stream			Major Flood Events in the Porirua Stream		
Year	Pauatahanui Return Period	Porirua Return Period	Year	Porirua Return Period	Pauatahanui Return Period
20/01/1980	8	1	20/12/1976	>100	1.1
21/12/1982	17	1.7	22/11/1977	14	5
19/08/1985	22	1.1	11/06/1980	62	1.6
13/03/1990	15	5	22/11/2001	9.5	2.5
3/10/2003	15	2.3	16/02/2004	7.5	15
16/02/2004	15	7.5			
5/01/2005	15	2.1			

The comparison shows that generally during a major flood event, there is a significant difference in the return period of the peak flows in the Porirua and Pauatahanui Streams. The only recorded exception is on the 16

February 2004, where there was a 15 year ARI flow in the Pauatahanui Stream and between a 7 and 8 year ARI flow in the Porirua Stream. This event aside, the comparison shows that during a major flood event in one of the streams the average return interval of the flow in the other catchment is around a 2 year event. The analysis also revealed that during more regular flood events (less than a 5 year ARI) on average there are similar ARI return intervals in each of the streams for the same storm event.

Based on this analysis, for all the 2 year rainfall scenarios a 2 year ARI rainfall was applied across each of the 23 catchments feeding into the Porirua Harbour. However in the 10 year ARI rainfall event three separate models were run:

- 10 year ARI rainfall in the Porirua and Kenepuru catchments, with a 2 year ARI rainfall elsewhere
- 10 year ARI rainfall in the Pauatahanui and Duck catchments, with a 2 year ARI rainfall elsewhere
- 10 year ARI rainfall in the Horokiri catchment, with a 2 year ARI rainfall elsewhere.

The catchments used in these scenarios are shown in **Figure 15.52**.

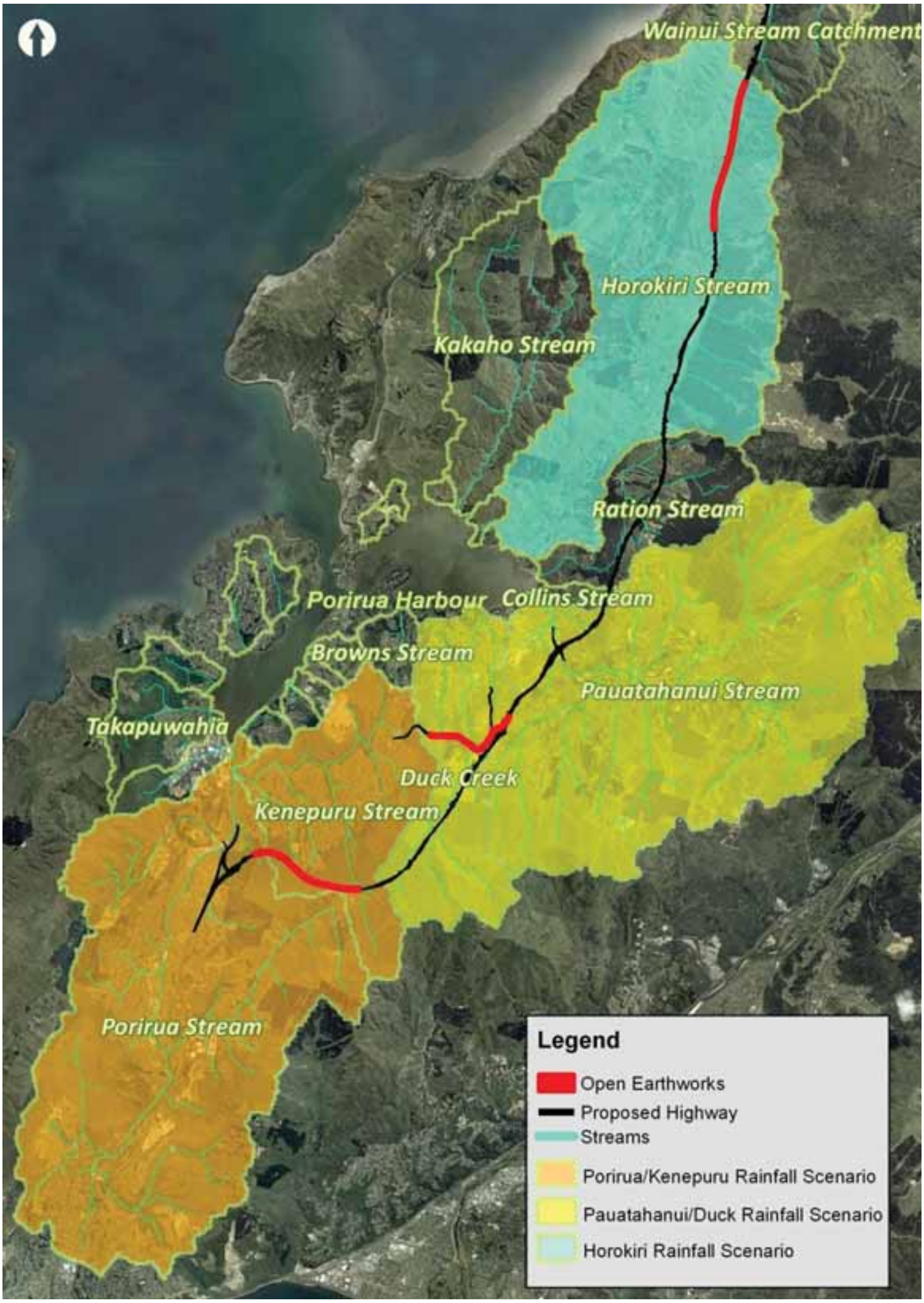


Figure 15.52 Catchments Where the 10 Year Rainfall was Applied to Generate Terrestrial Sediment and Hydrological Inputs to the Harbour Model

12.5.2. Event Based Wind Scenarios

In addition to rainfall, another significant factor that impacts sediment patterns within the harbour is wind magnitude and direction. During the model calibration wind was found to play an important role in influencing currents within the arms of the harbour as well as generating waves which can re-suspend sediment or keep sediment in suspension. Analysis of wind patterns, (see **Appendix 15.V**) indicated there are two predominant wind directions in the harbour area; the south-south-easterly (170°) and the north-north-westerly wind (340°). With this consideration each rainfall/sediment scenario was run for the 90th percentile wind speed for these directions as well as for the calm scenario. The two wind scenarios were a 10.2 m/s south-south-easterly wind herein referred to as a southerly wind and a 11.4 m/s north-north-westerly wind, herein referred to as the northerly wind. The average wind speed on any given day is 7.2m/s.

The following analysis was undertaken to assist in quantifying an indicative probability of a northerly, southerly or calm wind coinciding with heavy rainfall during construction of the Transmission Gully Project:

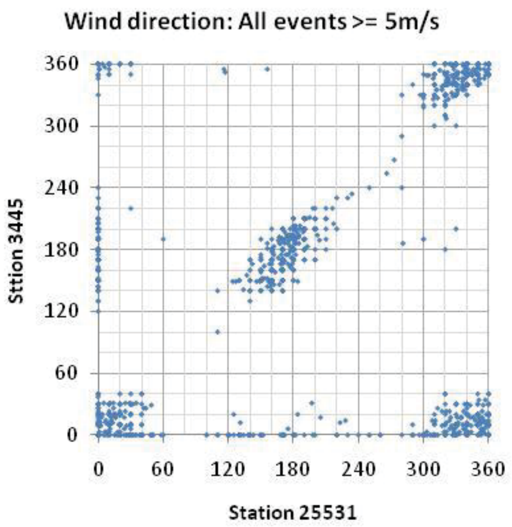
1) A comparison of the Mana Island (25531) wind record to the Wellington Aero (3445) records to assess correlation.
2) An assessment of the probability of a 2, 5 or 10 year ARI rainfall occurring in the Porirua harbour area together with northerly or southerly wind and calm conditions.
3) An assessment of the probability of one or more events occurring during the construction period.

Comparison of wind records

The wind recorder on Mana Island, has been shown to correlate reasonably well with wind direction in Porirua Harbour (see **Appendix 15.V**). However, the record for Mana Island is from September 2004 to December 2010, which is too short for analysing the probability of the direction and magnitude of a wind event coinciding with an extreme rainfall occurring. However the records for Wellington Aero start in 1960 and are long enough for analysing probabilities.

Comparisons were made to assess the correlation between the Mana Island wind direction records and the Wellington Aero direction records. Comparative wind direction for events where wind speed at one of the stations was greater than or equal to 5 m/s were plotted. The 5 m/s wind speed was chosen as an indicator of a direction wind event with wind conditions less than 5m/s being considered calm. The results in **Figure 15.53** show that there is a strong relationship between wind direction at Mana Island and that at Wellington Aero.

Based on this analysis the Wellington Aero records can be used as a good substitute for the wind direction at Mana Island during rainfall events in the Porirua Harbour Catchment.



- **Figure 15.53 Wind direction comparisons between the Gauges at Mana Island (25531) and the Wellington Aero (3445)**

Frequency of rainfall corresponding to wind conditions

Daily rainfall data from the NIWA grid station (29677, Porirua) was analysed together with the wind data from Wellington Aero to determine the number of days when daily rainfall exceeded a 10-year and 2-year ARI rainfall and wind speed was in a northerly or southerly direction or calm conditions (less than 5m/s). The 24-hour storm rainfall was estimated from the storm isopleths and divided by 1.16 to approximate 1-day rainfall. The results are shown in Table 15.37.

- **Table 15.37: Results using the wind direction as measured at Wellington Aero**

Event		Northerly		Southerly		All	
Rainfall ARI (years)		10	2	10	2	10	2
24-hour storm rainfall depth (mm)		110	75	110	75	110	75
Daily rainfall (mm)		95	65	95	65	95	65
No. coincident events		3	17	2	11	6	35
ARI of coincident events (years)		16.8	3.0	25.1	4.6	8.4	1.4
Probability of one or more events in the construction period (%)							
Construction Period (years)	1	6	29	4	20	12	50
	2	12	49	7	35	23	75
	3	17	64	10	48	32	88
	4	22	74	14	58	40	94
	5	27	82	17	67	47	97
	6	31	87	20	73	54	98

To calculate the probability of one or more events occurring during the construction period, the following methodology was used:

The probability of at least 1 event is given by the formula,

$Pt = 1-(1-P_f)^n$

where:
Pt = probability of at least one event occurring over a period of n years;
Pf = probability of occurrence in any one year;
n = duration of exposure in years.

Based on both the ARI 2 and ARI 10 data, when either of these rainfall events occurred with coincident wind, 50% of the events had a northerly wind, 30% of the events had a southerly wind. The remainder of these events occurred when there was either no wind (calm) or the wind came from neither of these directions. It is therefore assumed that for major rainfall events accompanied by wind in the Porirua Basin, 50% of these would be northerly and 30% southerly.

For the ARI 10 year event, the probability of an ARI 10 rainfall event plus wind from either northerly or southerly or all directions was calculated. Then the exact 95% confidence interval using a Binomial probability distribution was calculated. The probabilities for an event with Northerly or Southerly winds were calculated by multiplying these probabilities by 0.5 and 0.3 respectively.

A simplified method was used for the calculation of the ARI 2 year event. The probability of an ARI 2 rainfall event plus wind from either northerly or southerly or all directions was calculated. Confidence limits were not calculated.

Table 15.37 details probabilities of rainfall events coinciding with northerly and southerly events over the construction period.

Assuming a 2 year peak construction time frame, as indicated by the Macdonald International indicative programme and using the analysis of the frequency of rainfall and wind directions, the probabilities of a severe rainfall occurring during this period have been estimated, see Table 15.38 below. Also included in Table 15.38 are the threat likelihood descriptors as defined in the *NZTA Risk Management Process Manual* (NZTA, 2004).

- **Table 15.38 Summary of the wind probability analysis for the peak construction period**

Event	Northerly		Southerly		All	
Porirua Rainfall ARI (years)	10	2	10	2	10	2
Probability of one or more events occurring during the 2 year peak construction period (%)						
Wellington Aero Wind Data	12	49	7	35	23	75
NZTA Risk Management Process Manual Likelihood Description	Unlikely	Quite Common	Unusual	Quite Common	Quite Common	Likely

Should heavy rainfall occur outside of the peak construction period the area of open earthworks will be less. Therefore, it is likely that the sediment loads entering the harbour will be less than those developed for the peak construction scenarios. However, over the estimated 6 year construction period the probability of a heavy rainfall occurring increases. Based on the analysis of the available wind and rainfall data Table 15.39 shows the probabilities of a 2 and 10 year rainfall event coinciding with a northerly, southerly or calm wind condition over the 6 year construction period.

▪ **Table 15.39 Summary of the wind probability analysis for the full 6 year construction programme**

Event	Northerly		Southerly		All	
Porirua Rainfall ARI (years)	10	2	10	2	10	2
Probability of one or more events occurring during the 6 year construction period (%)						
Wellington Aero Wind Data	31	87	20	73	54	98
NZTA Risk Management Process Manual Likelihood Description	Quite Common	Likely	Quite Common	Likely	Likely	Likely

It should be noted that there will be variable responses of rainfall to wind direction within the sub-catchments feeding into the harbour depending on their aspect and topography. There is insufficient available local data to be able to accurately quantify these differences.

12.5.3. Event Based Sediment Inputs

Based on a possible six year construction programme developed by Macdonald International the maximum areas of open earthworks were identified. These "peak construction" areas are shown in **Figure 15.1** in Section 3. The following approximate areas of open earthworks were assessed in the peak construction scenarios (Table 15.40).

▪ **Table 15.40 Approximate Areas of Open Earthworks in the Harbour Sub-Catchments**

Sub-catchment	Length (km)	Area (ha)
Pauatahanui Inlet		
Horokiri	3.0	22.5
Duck	1.9	14.25
Pauatahanui	0.1	0.75
Onepoto Arm		
Kenepuru	2.1	15.75
Porirua	0.2	1.5

Incorporating a range of erosion and sediment control measures, predictions of sediment inputs into the harbour have been made with and without these open earthworks areas to identify the likely impacts of the construction of the Project. Further detail on the generation of the sediment inputs into the model can be found in Section 10. The following assumptions should be noted:

- As a conservative assumption all sediment entering the streams during the rainfall events are deposited into the harbour.
- The sediment loads into the harbour are proportional to flow (i.e. the peak sediment load will occur during the peak of the flood event)

12.5.4. Event Based Model Set Up

A total of 24 event based scenarios have been modelled. The simulations have been carried out for both the pre construction situation and the peak construction situation, which is the predicted maximum area of open earthworks. Table 15.41 presents an outline of the scenarios that were assessed.

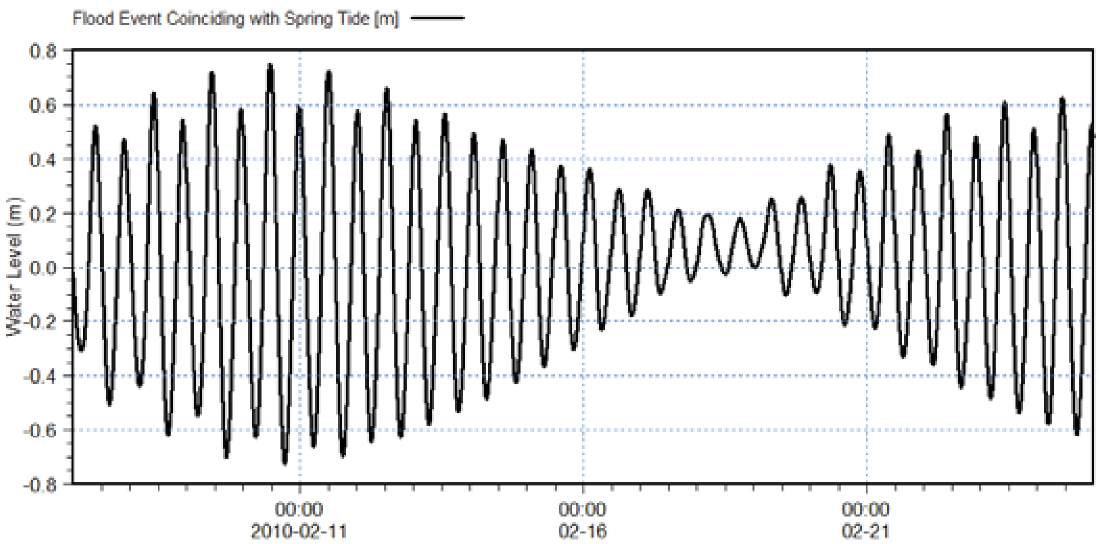
- **Table 15.41 Scenarios for Event-Based Assessment**

Wind	Freshwater and Sediment Inflows
Calm	2 year ARI for all catchments
Northerly	2 year ARI for all catchments
Southerly	2 year ARI for all catchments
Calm	10 year ARI in Kenepuru and Porirua catchments, 2 year ARI elsewhere
Calm	10 year ARI in Pauatahanui and Duck catchments, 2 year ARI elsewhere
Calm	10 year ARI in Horokiri catchment, 2 year ARI elsewhere
Northerly	10 year ARI in Kenepuru and Porirua catchments, 2 year ARI elsewhere
Northerly	10 year ARI in Pauatahanui and Duck catchments, 2 year ARI elsewhere
Northerly	10 year ARI in Horokiri catchment, 2 year ARI elsewhere
Southerly	10 year ARI in Kenepuru and Porirua catchments, 2 year ARI elsewhere
Southerly	10 year ARI in Pauatahanui and Duck catchments, 2 year ARI elsewhere
Southerly	10 year ARI in Horokiri catchment, 2 year ARI elsewhere

The following should be noted for the event based scenarios:

- Based on the available wind information there appears to be similar probabilities of heavy rainfall occurring during the three predominant wind scenarios, calm, southerly and northerly. In keeping with the modelling philosophy of assessing an 'envelope of effects', the model was used to simulate the rainfall events coinciding with calm conditions as well as a 90th percentile northerly and southerly wind.
- Flood events were developed with a 24 hour duration, with the beginning of the flood event timed to occur on the second day of the simulation (10th February 2010), excluding a two day warm up period.
- Simulations were carried out for a 15 day spring/neap tide cycle, to include a full tidal range in the scenarios, with the flood event coinciding approximately with a spring tide. Real water level data collected in the approaches to the harbour was used for the open ocean boundary of the simulations. The water level boundary for the simulations is shown in **Figure 15.54**. Sensitivity tests confirmed that due to weak tidal currents in the basins of the harbour arms, the impact of the storm coinciding with a spring or neap tide was negligible.

- The wind conditions were kept constant throughout the modelling period. This was considered appropriate for the modelling scenario for two reasons. Firstly the coastal ecologists are primarily interested in the impacts in the first three days following the sediment inputs and therefore most of the results reported are taken in this period. The wind records indicated that it is not uncommon for wind events (calm, southerly or northerly) to last for 3 days. Secondly the initial modelling of the harbour confirmed historical observations that there is little loss of terrestrial sediment to the open ocean. The constant wind is therefore representative of a series of similar wind conditions acting on the harbour.
- The sediment loads were generated using the sediment yield model as reported in Section 10. Table 15.42 summarises the sediment and hydrological inputs for key catchments.
- All other water column and bed parameters for the sediment transport model were taken from the calibration model.



- **Figure 15.54 Open Ocean Boundary Water Levels (MSL) for Event - Based Scenarios with Flood Event Coinciding with Approximately Spring Tide**

- **Table 15.42 Summary of Freshwater and Sediment Inflows for 2 and 10 Year ARI Flood Events for the Pre and Peak Construction Scenarios for Catchments Where Sediment Loads May Increase**

ARI			Catchment				
			Kenepuru	Duck	Porirua	Horokiri	Pauatahanui
2 Year	Peak Flow (m³/s)		19	11	31	25	29
	Total Sediment Load (tonnes)	Pre Construction	375	343	481	689	695
		Peak Construction	415	402	481	789	696
	Percentage Increase (%)		11%	17%	0%	15%	0%
10 Year	Peak Flow (m³/s)		32	25	55	61	77
	Total Sediment	Pre	1051	1582	1418	3754	4426

	Load (tonnes)	Construction					
		Peak Construction	1162	1854	1419	4300	4426
	Percentage Increase (%)		11%	17%	0%	15%	0%

12.5.5. Event Based Results

The focus of the modelling investigation was to identify changes in the patterns of sediment deposition and concentrations as a result of additional sediment entering the harbour associated with the construction of the Transmission Gully Project. The event based harbour model results have been analysed and processed in close co-ordination with the coastal ecologists who are undertaking the harbour environmental assessment of effects. The event based results are presented in two main formats:

- **Appendix 15.CC** of this report contains the plots of deposition, suspended sediment and pre and peak construction comparison maps.
- The model results have also been processed to quantify the areas impacted by bands of sedimentation deposition or suspended sediment concentrations. These results are presented as tables in the CD attached to this report.

Within **Appendix 15.CC** there are three main types of assessments of changes in the sediment deposition and concentration patterns:

1) Deposition Comparison Plots - these plots were developed by calculating the difference in deposition between the pre and peak construction scenarios for any given event. These maps are used to identify where the major changes occur on the harbour bed. Typically these results are reported for both 1 day and 3 days following the rainfall/sediment event.
2) Total Suspended Solids (TSS) Comparison Plots – similarly to the deposition comparisons the potential changes in concentrations of sediment in suspension were also calculated. Typically these results are reported for the comparison in maximum concentrations at any given location in the harbour as well as the predicted concentrations 1 day following the rainfall/sediment event. It should be noted that for any given wind condition, the TSS plots for the three 10 year ARI rainfall scenarios, as discussed in Section 12.5.1, were combined into a single plots.
3) 5mm and 10mm Threshold Plots - the coastal ecologists identified both 5mm and 10mm of sediment deposition as key indicators of ecological effects. By comparing the plots of the pre and peak construction scenarios the new locations have been identified where the deposition depths exceed these thresholds as a result of the increased sediment associated with the peak construction scenario. For any given wind and rainfall event these areas of new threshold exceedances have been overlaid on the plot of sediment deposition in the pre construction scenario.

12.5.5.1. General Event Based Results Discussion

The model results show that much of the terrestrial sediment entering the harbour is deposited near the stream mouths, particularly in areas where the stream inflows begin to slow and dissipate. These areas often also have high TSS concentrations which are increased by the wave induced suspension of bed material in the shallows. The finer sediment material with lower settling velocities is transported via fluvial, tidal and/or wave induced currents around the arms of the harbour and especially towards the deeper basins in the centre of the arms. There are noticeably lower TSS concentrations in the main channels at the entrances to each of the harbour arms as the catchment runoff mixes with the sea water.

The direction and magnitude of the wind at the time of the storm plays a significant role in determining the fate of sediment in the harbour. The results shown in **Appendix 15.CC** of this report, illustrate the following wind related observations:

- Both northerly and southerly winds help keep sediment in suspension as well as re-suspending some of the sediment that settles. This results in the TSS concentrations being higher and more persistent than in the calm situations. As seen in the plots of TSS, a day following the 10 year ARI rainfall event (Figures 10Yr1D-04, 10Yr1D-05 and 10Yr1D-06 in **Appendix 15.CC**) there are much higher concentrations of sediment still in the harbour in the northerly and southerly conditions compared with the calm scenario.
- Under the modelled windy conditions the higher and more persistent TSS concentrations result in a wider area being affected by bed deposition. The sediment distribution under calm conditions is less wide spread and therefore contains deeper deposits, particularly near the stream mouths.
- Under northerly wind conditions the TSS concentrations and bed deposition tend towards the eastern side of the Onepoto Arm of the harbour and towards the southern side of the Pauatahanui arm. In contrast, under southerly wind conditions the TSS concentrations and bed deposition tend towards the western side of the Onepoto Arm of the harbour and in the Pauatahanui Arm towards the northern side. This is significant as the intertidal areas often contain the highest diversity and concentrations of organisms vulnerable to sediment deposition and high TSS concentrations. The modelling indicates that the ecological consequences of high sediment loads entering the harbour are dependent on the coinciding wind conditions.

As seen in the 10 year ARI event, TSS plots in **Appendix 15.CC** (Figures 10YrMax 04 - 09 and 10Yr1D 04 – 09), a comparison of the results over time indicates that much of the sediment drops out of suspension during or shortly after the peak of the storm event. Over the 24 hours following the peak of the storm the sediment is distributed around the harbour via the currents. After only a day following the storm event, the sediment deposits are close to stabilised with only gradual redistribution occurring over time. The model results suggest that there are almost no TSS concentrations in the harbour greater than 0.25kg/m^3 three days following either the 2 or 10 year sediment inputs.

The open earthworks associated with the peak construction of the Transmission Gully Project are expected to increase the sediment loads into the harbour during heavy rainfall. The sediment yield model predicts the overall increase in sediment loads in a 2 and 10 year ARI rainfall event to be 4.7% and 4.9% respectively. In general, the deposition comparison plots show that much of the additional sediment deposits in areas that are already heavily affected by sediment running off the catchment during the storm.

The complexity of the coastal processes being modelled, including flocculation and wave re-suspension, means that slight changes to the sediment inputs can result in changed patterns of sediment movement in the harbour. This is observed in the model results by the presence of areas of reduced deposition in some areas even though sediment inputs have increased. With consideration of the coastal complexity, the model results should be treated as indicative of the locations, extents and quantities of the potential effects. The range of scenarios should be considered to provide a results 'envelope' for the assessment of effects.

12.5.5.2. 2-Year Rainfall Event Scenario Assessment of Effects

The probability analysis indicates that a 2 year ARI rainfall event has a 95% chance of occurring during the 6 year construction period and a 63% chance of occurring during the peak construction period. A 2 year ARI rainfall event is considered to be a likely event that will occur during construction.

In a 2-year ARI rainfall scenario the terrestrial sediment input into the harbour is predicted to be approximately 4260 tonnes. There is predicted to be a 4.7% (200 tonnes) increase in sediment entering the harbour if the rainfall occurred at the time of peak construction associated with the Transmission Gully Project. However the percentage increase is more apparent within the individual catchments where the peak construction scenario has been modelled, particularly the Duck (17%), Horokiri (15%) and Kenepuru (11%) see Table 15.42. Figure 2Yr-1D-TA 01, 2Yr-1D-TA 04 and 2Yr-1D-TA 07 in **Appendix 15.CC** provide an indication of the likely location for much of the additional sediment to deposit under the three different wind conditions.

The threshold analysis indicates that, depending on the wind conditions, if a 2 year ARI rainfall event was to occur during peak construction there is likely to be between 3.8 and 5.3 additional hectares within the harbour that will receive 5mm or greater deposition, see Table 15.43. Similarly the analysis of the 10mm threshold indicates that there will be between 0.7 and 1.9 additional hectares within the harbour effected by depths greater than 10mm. Figures such as Figure 2Yr-3D-TA 05 in **Appendix 15.CC** indicate that under all three wind conditions the majority of the additional exceedences in the 5mm and 10mm thresholds are likely to occur in sub tidal areas near the centres of the arms of the harbour.

- **Table 15.43 Changes in the Sediment Deposition Depths: Pre and Peak Construction for the 5mm and 10mm Thresholds, 3 days Following the Rainfall Event**

Sediment Deposition Depth	Area (m²)					
	5mm Threshold			10mm Threshold		
	Calm	Northerly	Southerly	Calm	Northerly	Southerly
Reduction in deposition below threshold	80	12,248	12	72	7,116	60
Increase in deposition above threshold	61,144	47,212	55,188	12,600	14,748	20,200
Net change in deposition above threshold	61,064	34,964	55,176	12,528	7,632	20,140

The comparison of the pre and peak construction TSS concentrations show that the impacts on suspended sediment are largely contained to the areas surrounding the stream mouths, see Figure 2YrMax-01, Figure 2YrMax-02 and Figure 2YrMax-03. Furthermore 1 day following the rainfall event there is almost no difference in TSS concentrations between the pre and peak constructions scenarios, Figure 2Yr1D-01, Figure 2Yr1D-02 and Figure 2Yr1D-03. The concentration differences and their short durations, suggested by the model results, indicate that there will be a less than minor visual impact should a 2 year rainfall occur during the peak construction of the highway.

12.5.5.3. 10-Year Rainfall Event Scenario Assessment of Effects

Three 10 year ARI rainfall scenarios have been modelled to reflect the joint probability analysis undertaken in Section 12.5.1. The scenarios include a 10 year ARI rainfall event over the Kenepuru and Porirua catchments, the Duck and Pauatahanui catchments or the Horokiri catchment, with all other catchments receiving a 2 year ARI rainfall. The total sediment loads into the harbour in these three 10 year rainfall scenarios are shown in Table 15.44. Each of these scenarios was run under the three wind conditions (calm, southerly, and northerly).

- **Table 15.44 Total Sediment Loads Input into the Model in the Three 10 year ARI Rainfall Scenarios**

10 Year ARI Rainfall Scenario	Pre Construction Total Sediment Load (tonnes)	Peak Construction Additional Sediment Load (tonnes)	Percentage Increase

Kenepuru	5869	271	5%
Duck/Pauatahanui	9226	412	4%
Horokiri	7322	645	9%

The probability analysis indicated that there is an 18% chance of a 10 year rainfall occurring at least once during the peak construction period. This probability increases to 45% over the full 6 year construction period. It is considered unlikely for a 10 year ARI rainfall to occur during the peak construction period but quite common during the 6 year construction period.

Similar to the 2 year ARI rainfall events much of the additional sediment from the peak construction open earthworks in the 10 year ARI rainfall scenarios is expected to be deposited into the deeper sub tidal areas in the centre of the arms of the harbour. However, there are three 10 year rainfall events where the coincident wind conditions result in significant quantities of the additional sediment being deposited in the intertidal zones near the shore:

- 10 year ARI rainfall in the Horokiri catchment during a southerly, see Figure 10Yr-3D-TA 11
- 10 year ARI rainfall in the Duck and Pauatahanui catchments during a northerly, see Figure 10Yr-3D-TA 19
- 10 year ARI rainfall in the Kenepuru catchment during a southerly, see Figure 10Yr-3D-TA 12

The threshold analysis, as seen in Figures 10Yr-3D-TA 15 and Figures 10Yr-3D-TA 16, reveals that during a southerly wind much of the additional sediment entering the harbour from the Horokiri catchment is pushed towards the northern coast, particularly towards the shallows near the mouth of the Kakaho Stream. Similarly, in a southerly the additional sediment from the Kenepuru Stream, generated in the peak construction scenario, is pushed towards the intertidal areas near the western shores of the Onepoto Arm (see Figures 10Yr-3D-TA 17 and Figures 10Yr-3D-TA 18). The model also indicates that a northerly wind coinciding with large sediment discharges from Duck Creek will result in additional deposition in the bays on the southern side of Pauatahanui Inlet (see Figures 10Yr-3D-TA 22 and Figures 10Yr-3D-TA 23). The areas of the exceedances in the 5mm and 10mm thresholds in these three critical scenarios are shown in Table 15.45.

- **Table 15.45 Total areas subject to exceedances of the 5mm and 10mm Thresholds under the three critical scenarios 3 day following the rainfall/sediment event**

Scenario	Sediment Deposition Depth	Area (m²)							
		5 mm Threshold				10 mm Threshold			
		Northerly		Southerly		Northerly		Southerly	
		Onepoto Arm	Pauatahanui Arm	Onepoto Arm	Pauatahanui Arm	Onepoto Arm	Pauatahanui Arm	Onepoto Arm	Pauatahanui Arm
10 Year ARI Rainfall in the Kenepuru and Porirua Catchments. 2 Year ARI rainfall elsewhere	Reduction in deposition below threshold			89,112	148,016			13,659	54,569
	Increase in deposition above threshold			52,952	104,784			41,064	43,400
	Net change in deposition above threshold			-36,160	-43,232			27,405	-11,169

10 Year ARI Rainfall in the Duck and Pauatahanui Catchments. 2 Year ARI rainfall elsewhere	Reduction in deposition below threshold	26,292	103,204			6,856	32,632		
	Increase in deposition above threshold	27,252	132,108			8,840	62,560		
	Net change in deposition above threshold	960	28,904			1,984	29,928		
10 Year ARI Rainfall in the Horokiri Catchment. 2 Year ARI rainfall elsewhere	Reduction in deposition below threshold			16,652	201,168			7,408	73,896
	Increase in deposition above threshold			54,824	177,912			20,840	68,080
	Net change in deposition above threshold			38,172	-23,256			13,432	-5,816

Even in these events there is unlikely to be any visual impact associated with the additional sediment as the model results indicate that these affected areas will have received similar quantities of sediment in the pre construction scenario. This is emphasised in the comparison plots of TSS, (Figures 10YrMax 02 and 10YrMax 03) where the model predicts that much of the harbour will have less than a 0.1kg/m^3 increase in suspended sediment concentrations associated with the peak earthworks.

12.5.6. Sensitivity Check: Pauatahanui Catchment Intensive Construction Scenarios

The event based simulations attempted to model the 'peak construction' situation as suggested by the staging programme considered as likely by Macdonald International. This worst case situation was chosen as a conservative approach to assessing the impacts on the additional sediment in the harbour. However the peak construction scenario predicted by Macdonald International, as illustrated in Figure 15.1 contains only a short section of road construction in the Pauatahanui Catchment. Considering the ecological significance of the area surrounding the mouth of this stream an additional model scenario was developed to investigate the impacts on sediment deposition in the harbour under the scenario where there is predicted to be the maximum area of open earthworks in the Pauatahanui Catchment. This scenario also provides a check on the sensitivity of the harbour sedimentation patterns to alternative sediment input locations and quantities. In the 'Pauatahanui intensive construction period' we have used the following approximate areas of open earthworks in our modelling. This scenario is predicted by Macdonald International to have a duration of approximately 1 year.

- **Table 15.46 Length and Areas of Open Earthworks for the Pauatahanui Intensive Construction Period**

Catchment	Length (km)	Area (ha)
Pauatahanui Inlet		
Horokiri	2.5	18.75
Pauatahanui	1.7	12.75

Onepoto Arm		
Kenepuru	2.1	15.75
Porirua	0.2	1.5

The rainfall event selected for this scenario was a 10 year ARI rainfall on the Pauatahanui and Duck catchments with a 2 year ARI rainfall elsewhere. This event was run in the pre construction and 'Pauatahanui intensive construction' scenarios for all three wind conditions (calm northerly and southerly). The sediment loads used in this scenario are recorded in **Table 15.47**.

- **Table 15.47 Sediment Loads in the Pauatahanui Intensive Construction Scenario**

Catchment	Baseline Scenario (Without Road) Sediment Loads (tonnes)	Pauatahanui Intensive Construction Scenario (With Road) Sediment Loads (tonnes)	Additional Sediment (tonnes)	Percentage Increase
Duck	1582	1582	0	0%
Horokiri	689	785	96	14%
Kenepuru	375	415	40	11%
Pauatahanui	4426	4526	100	2%
Porirua	481	481	0	0%
Ration	271	271	0	0%
Browns Catchment	51	51	0	0%
Collins Stream Catchment	21	21	0	0%
Kakaho Catchment	487	487	0	0%
Takapuwahia Catchment	100	100	0	0%
a	64	64	0	0%
b	37	37	0	0%
c	47	47	0	0%
d	74	74	0	0%
e	55	55	0	0%
f	16	16	0	0%
g	24	24	0	0%
h	21	21	0	0%
i	178	178	0	0%
j	31	31	0	0%
k	29	29	0	0%
l	56	56	0	0%
m	110	110	0	0%
Total	9225	9462	239	3%

12.5.6.1. Pauatahanui Intensive Construction Scenario Results

The results of this scenario are shown in Figures 10Yr-3D-SC 01 to 10Yr-3D-SC 09 in Appendix 15.CC. The comparison plots of the with and without road construction scenarios, (Figures 10Yr-3D-SC 01, 10Yr-3D-SC 04, 10Yr-3D-SC 01 07) show very little changes in bed level as a result of the additional sediment except in the scenario with a northerly wind. As found in the peak construction scenario the northerly wind results in much of the additional sediment depositing in the intertidal zones near the coast. This is also seen in the analysis of the 5mm and 10mm deposition thresholds, Figures 10Yr-3D-SC 05, 10Yr-3D-SC 06 and **Table 15.48**.

- **Table 15.48 Total Areas Subject to Exceedances of the 5mm and 10mm Thresholds in the Pauatahanui Intensive Construction Scenarios 3 days Following the Rainfall/Sediment Event**

	Area (m²)					
	10 Year					
	Calm		Northerly		Southerly	
	Onepoto Arm	Pauatahanui Arm	Onepoto Arm	Pauatahanui Arm	Onepoto Arm	Pauatahanui Arm
	5mm Bed Deposition Threshold Areas					
Reduction in deposition below threshold	0	156	25,992	102,924	0	44
Increase in deposition above threshold	5,884	32,916	27,792	131,776	15,584	16,316
Net change in deposition above threshold	5,884	32,760	1,800	28,852	15,584	16,272
10mm Bed Deposition Threshold Areas						
Reduction in deposition below threshold	0	312	8,628	32,396	0	48
Increase in deposition above threshold	5,740	19,192	7,296	61,700	5,360	26,492
Net change in deposition above threshold	5,740	18,880	-1,332	29,304	5,360	26,444

The effects on sediment deposition in the ‘Pauatahanui intensive construction scenario’ were compared with the effects predicted by the model in the Peak construction scenario (see Figure 10Yr-3D-CS 05 in Appendix 15.CC). In nearly all locations in the harbour the increase in deposition with the additional sediment associated with the ‘peak construction’ scenario was greater than the effects observed in the ‘Pauatahanui intensive construction scenario’. This provides further confidence in the selection of the ‘peak construction scenario’ as the basis to assess the impacts on sedimentation patterns in the harbour.

12.6. Long Term Assessment

In addition to the event based simulations, the harbour model was also utilised to predict the longer term impacts of the Transmission Gully Projects. A 20 year model run was undertaken with and without the Project constructed to quantify the effects. For these scenarios historical rainfall and wind data was used. The generation of the sediment inputs into the harbour are discussed in Section 12. The likely 6 year staging programme for the entire project, predicted by MacDonald International was combined with historical rainfall data and used to predict the long term changes in sediment loads into the harbour. **Table 15.49** summarises the predicted difference in sediment loads at various intervals in the 20 year simulation.

- **Table 15.49 Predicted Sediment Loads into Porirua Harbour during the 20 year of simulation data.**

	Total Sediment Load after 6 Years at completion of construction (tonnes)	Total Sediment Load after 10 Years (tonnes)	Total Sediment Load after 20 Years (tonnes)
No Construction Scenario	99200	143600	244700
During Construction Scenario	102200	146600	247700
Difference	3000	3000	3000
% Difference	3.0%	2.1%	1.2%

To achieve realistic run times a simplified model mesh was used. The following should be noted for the long term simulations:

- A 20 year time series for wind was produced by taking the available five years of scaled Mana Island wind data and repeating this four times.
- A 20 year time series for the open ocean tidal boundary condition was produced by carrying out a harmonic analysis for one year of water level data from Mana Marina. The harmonic analysis calculated the phase and amplitude for 32 tidal constituents from which a twenty year time series of water level was generated.
- Only the fate of cohesive mud has been predicted with the long term simulations, which is approximately 80% of terrestrial sediments which enter into harbour. The model was not appropriate to predict the long term fate of non-cohesive sand, since the sediment transport model does not include bed load transport (the predominant method of transport for sand within the harbour). Sand would build up close to sediment inflows, obscuring the findings of long term simulations, when in reality it would be distributed to the local beaches. This approach is still considered appropriate for the long term modelling and assessment of effects of the Transmission Gully Project which is predicted to contribute largely finer material from the catchment.
- A 20 year time series for daily averaged inflow hydrographs and associated TSS concentrations for cohesive mud for the 23 catchments surrounding Porirua Harbour was used as inputs.
- All model parameters are the same for the coarse model compared with higher resolution model used in the event based simulation.

12.6.1. Long Term Model Results

To assess the ability of the coarse model to predict the long term movement of sediment within Porirua Harbour the predicted rates of sedimentation within Onepoto Arm and Pauatahanui Inlet were compared with the observed rates of sedimentation. Measurements from 1974 – 2009 show a net average deposition rate of 5.7 mm/year (13,500 - 14,000 m^3/year) in the Onepoto Arm and a net average deposition rate of 9.1 mm/year (42,000 - 43,000 m^3/year) in the Pauatahanui Inlet (Gibb *et. al.,* 2009).

The rates of sedimentation were calculated for Onepoto Arm and Pauatahanui Inlet from the long term model for the existing situation after 10 years and 20 years. The predicted rates of sedimentation are shown in **Table 15.50**. The approximate seabed areas have been taken from Gibb *et. al.* (2009).

- **Table 15.50 Predicted rates of sedimentation for Onepoto Arm and Pauatahanui Inlet for existing situation from long term situation model after 10 and 20 years.**

Location	Onepoto Arm		Pauatahanui Inlet	
Simulation	10 Year	20 Year	10 Year	20 Year
Approximate Seabed Area (m²)	2,400,000		4,600,000	
Volume Change (m³)	66,000	118,500	186,000	310,700
Net Rate of Sedimentation (m³/yr)	6,600	5,900	18,600	15,500
Net Rate of Sedimentation (mm/yr)	2.8	2.5	4.1	3.4

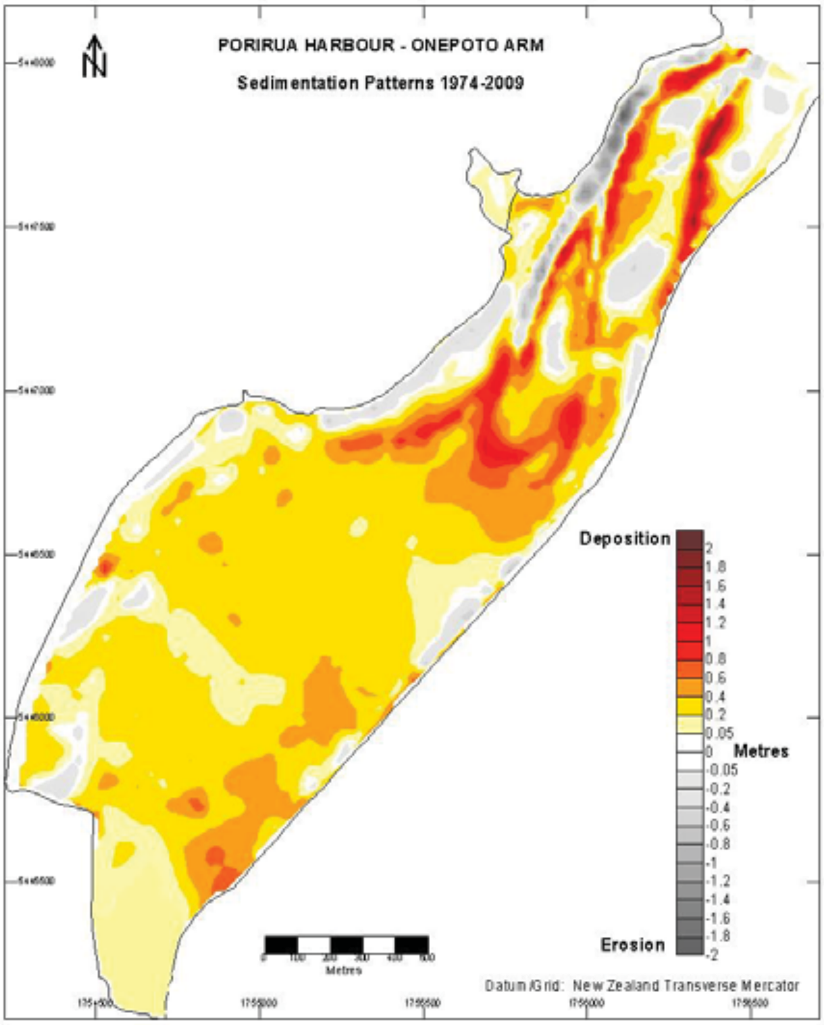
The long term model predicts a net sedimentation of rate of 2.5 – 2.8 mm/year for Onepoto Arm, 44 - 49% of the sedimentation rates calculated for period 1974 – 2009. The model also predicts a net sedimentation of rate of 3.4 – 4.1 mm/year for Pauatahanui Inlet, 37 - 45% of sedimentation rates calculated for period 1974 – 2009. Examination of the results and the methodology suggests two main reasons for discrepancies between the observed and predicted rates of sedimentation within the harbour. These are:

- Marine and terrestrial supplied sand are not accounted for in the long term simulation model
- Between 1974 – 2009 there was considerable urban development in the catchments surrounding the harbour (especially Whitby, Papakowhai and Browns Bay), which would have resulted in significantly increased sediment loads to the harbour.

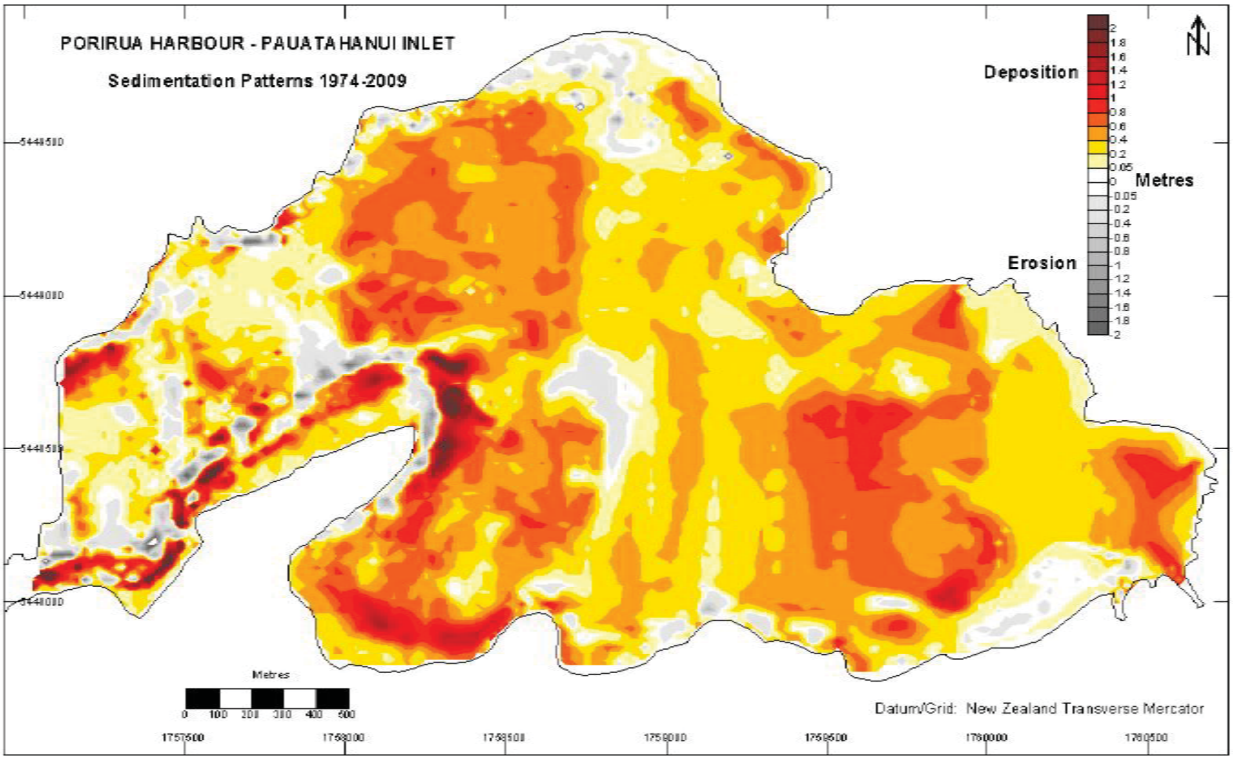
This is supported by plots of the final bed thickness after 10 and 20 year for the no construction scenario (see Figures LTS-2 to LTS-5 in **Appendix15.CC**). Compared with sedimentation patterns from Gibb *et. al.* (2009), (see **Figure 15.55** and **Figure 15.56**.

There is a good agreement between the deposition patterns in the muddy basins of Pauatahanui Inlet and Onepoto Arm. There is not such a good agreement around the mouth of the Pauatahanui Stream and the entrances of both Arm of the harbour. These are areas where sedimentation patterns are likely to be influenced by marine supplied sediment and from coarser sediments entering the harbour from the catchment. As the purpose of the model is to undertake an assessment of effects based on changes in terrestrial sediment loads the marine sediment has not been included in the model.

The similarity in the comparison with historical sedimentation records provides further confidence that the model produces results that are reflective of the actual quantities and fate of terrestrial based sediment loads into the harbour.



- **Figure 15.55 Sedimentation Patterns in the Onepoto Arm 1974-2009 Gibb *et. al.* (2009)**



- **Figure 15.56 Sedimentation Patterns in the Pauatahanui Arm 1974-2009 Gibb et al (2009)**

The 20 year long term simulation predicts the cumulative impact of the construction of the Project on the harbour sedimentation rates. The results suggest that there is very little loss of terrestrial sourced sediment out of the harbour and nearly all the fine sediment settles within the deeper basins in the centre of the arms.

Over a 20 year simulation period the model suggests that the construction of the Project, with the planned erosion and sediment controls is likely to have some impact on the sedimentation rates in the Pauatahanui Arm of the harbour, but almost no detectible impact in the Onepoto arm, see Table 15.50. In the Pauatahanui Arm the model predicts that 20 years following the start of construction there is likely to be an average increased sedimentation rate of between 0.1 and 0.2 mm/yr. Part of the reason for this low level of impact is that much of the harbour is predicted by the model to receive high levels of deposition over the 20 year simulation. Table 15.51 shows the models predictions that approximately a quarter of the harbour will receive over 100mm or more of deposition over 20 years and an eighth of Pauatahanui Inlet will receive over 200mm of deposition.

- **Table 15.51 Areas of the Harbour Arms that are Predicted to Experience greater than 100mm, 200mm and 300mm of Sediment Deposition in 20 years with and without the Transmission Gully Project Construction**

	Onepoto Arm		Pauatahanui Arm	
	No Construction	With Construction	No Construction	With Construction
Total Area (m^2)	2,400,000		4,600,000	
Total Area >100mm (m^2)	576,822	577,708	1,141,842	1,152,769
Total Area >200mm (m^2)	37,556	41,478	577,968	589,065
Total Area >300mm (m^2)	0	28	321,165	332,077

12.7. Conclusions

While the harbour has high ecological, cultural and recreational value it is located in a heavily modified catchment. An implication of the current catchment land use is the potential for high sediment loads entering the harbour. This provides both a context and an imperative for understanding and quantifying and the potential impacts of the Transmission Gully Project on sediment patterns in the harbour.

Porirua Harbour is a complex environment with many factors influencing the patterns of sedimentation. This complexity has lead to this detailed modelling study that seeks to predict the fate of additional sediment entering the harbour associated with the construction of the highway under a range of climatic conditions. This includes developing an understanding of the quantity, location and duration of both suspended and deposited terrestrial sediment entering the harbour. The modelling results and analysis have identified an envelope of impacts that can be used as a foundation for assessing the consequences and likelihood of effects in the harbour.

The hydrodynamic, wave and sediment transport models constructed as part of this study demonstrate acceptable calibration with the available data. The calibration results combined with the sensitivity analysis gives confidence that the model provides an acceptable tool to use in the assessment of effects on terrestrial sediment entering the harbour. This is further verified by the long term results which demonstrate a reasonable correlation with historical sediment patterns. In addition, the sensitivity check on alternative sediment sources confirmed that the peak construction scenarios represented the likely period when the harbour was at the greatest risk.

It is likely that during the construction of the Transmission Gully Project there will be one or more 2 year ARI rainfall events. The modelling results suggest that in a 2 year ARI rainfall event the additional 200 tonnes (5%) of sediment that is predicted to enter the harbour as a result of the Project construction will result in little change to the sediment deposition patterns. The peak construction results show isolated pockets of increased sedimentation, typically less than 5mm deep, and these are largely in the sub tidal areas of the harbour. The quantified increases in suspended sediment in a 2 year ARI rainfall event are unlikely to be visually detectable for an extended period of time.

While it is unlikely that a 10 year ARI rainfall event will occur during the peak construction period a rainfall of this magnitude should be anticipated during the full construction duration. Should a 10 year ARI rainfall event occur during the peak construction period it is predicted that between 271 and 645 tonnes of additional sediment will enter the harbour. This is estimated to be an increase of between 4 and 9%. The model results predicted that the effects of this additional sediment are dependent on both where it enters the harbour and the coincident wind conditions. The majority of the 10 year ARI events modelled indicated that much of the additional sediment would be deposited in the deeper central basins of the arms in areas already experiencing high levels of deposition. However three events were singled out as having a greater impact on the more vulnerable intertidal zones. These three events were:

- High sediment loads entering the harbour from the Horokiri catchment during a southerly wind event. The probability of a 10 year rainfall occurring in this catchment during a southerly wind has been calculated to be approximately 7% over the 2 year peak construction period.
- High sediment loads entering the harbour from the Duck and Pauatahanui catchments during a northerly wind event. The probability of a 10 year rainfall occurring in these catchments during a northerly wind has been calculated to be approximately 12% over the 2 year peak construction period.

- High sediment loads entering the harbour from the Kenepuru catchment during a southerly wind event. The probability of a 10 year rainfall occurring in this catchment during a southerly wind has been calculated to be approximately 7% over the 2 year peak construction period.

The long term model results provide an indication of the cumulative effects of deposition in the harbour from the full construction period. In the long term simulation an additional 3000 tonnes of sediment is estimated to enter the harbour as a result of the construction activities. This represents around 2% of the total terrestrial sediment load entering the harbour over a 10 year period. The modelled results indicated that there was little loss of terrestrial sediment from the harbour and that much of the sediment would be deposited over time in the deeper central basins. There results indicated that after 20 years there would be almost no detectable increase in sedimentation in the Onepoto arm of the harbour and only an average increase of between 0.1 and 0.2mm/yr in the Pauatahanui Arm.

13. Construction Assessment of Effects

This assessment addresses the potential effects on fresh and coastal water quality from the construction of the Transmission Gully Project. It does not address effects of stormwater discharge on aquatic ecosystems, which are assessed in Technical Report 11: *Ecological Impact Assessment*.

This assessment accounts for the application of erosion protection measures to all active earthworks areas and chemical treatment in sediment retention ponds of all discharge, as outlined in **Section 9.**

Table 15.52 assesses of effects on streams, and **Table 15.53** and **Table 15.54** summarise the effects on the Porirua Harbour and the Kapiti Coast.

Table 15.52 Construction Stormwater Discharge Assessment of Effects on Streams

Assessment Criteria	Assessment of Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	A manageable change in the production of conspicuous oil or grease films or floatable or suspended materials is predicted as a result of the discharge. The load of nutrients is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. A manageable effect on scums and foams is predicted as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	A manageable change in conspicuous change in the colour or visual clarity is predicted as a result of the discharge.
Any emission of objectionable odour.	A manageable change in objectionable odour is expected as a result of the discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	A manageable change is expected as a result of the discharge in the rendering of freshwater unsuitable for consumption by farm animals.
Any significant adverse effects on aquatic life.	See Technical Report 11: *Ecological Impact Assessment* for further information.
The natural temperature of the water shall not be changed by more than 3° Celsius.	A temperature change of >3 degrees is not predicted as a result of the discharge. A manageable change is expected as a result of the discharge.
Any pH change.	Monitoring and adaptive management will be utilised to manage the pH of the discharge. The management will be outlined in the Chemical Treatment Plan developed as part of the Erosion and Sediment Control Plan. See Technical Report 11: *Ecological Impact Assessment*
Any increase in the deposition of matter on the bed of the water body.	No increase in sediment deposition of greater than 1mm is expected in approximately 90% of storms. Some additional increase in deposition is expected in some streams in 10 and 50 year events. See Technical Report 11: *Ecological Impact Assessment* for further information.
Any discharge of a contaminant into the water.	TSS concentration is expected to increase. Increases in other contaminants are not expected, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. The load of contaminants attached to soils is expected to increase. See Technical Report 11: *Ecological Impact Assessment* for further information.
The concentration of dissolved oxygen falls below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.

There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	The load of nutrients is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. Other factors which contribute to biological growth such as changes in temperature and flow regime are not predicted to occur as a result of the construction stormwater discharge. The effect of the discharge on undesirable biological growths is manageable.

- **Table 15.53 Construction Stormwater Discharge Assessment of Effect on Porirua Harbour**

Assessment Criteria	Assessment of Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	A manageable change in the production of conspicuous oil or grease films or floatable or suspended materials is predicted as a result of the discharge. The load of nutrients is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. A manageable effect on scums and foams is predicted as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	A manageable change in conspicuous change in the colour or visual clarity is predicted as a result of the discharge.
Any emission of objectionable odour.	A manageable change in objectionable odour is predicted as a result of the discharge.
Any significant adverse effects on aquatic life.	See Technical Report 11: *Ecological Impact Assessment* for further information.
The rendering of water unsuitable for bathing by the presence of contaminants.	A manageable change in water quality for bathing is predicted as a result of the discharge.
Undesirable biological growths.	The load of nutrients is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. The effect of the discharge on undesirable biological growths is manageable.

- **Table 15.54 Construction Stormwater Discharge Assessment of Effect on Kapiti Coast**

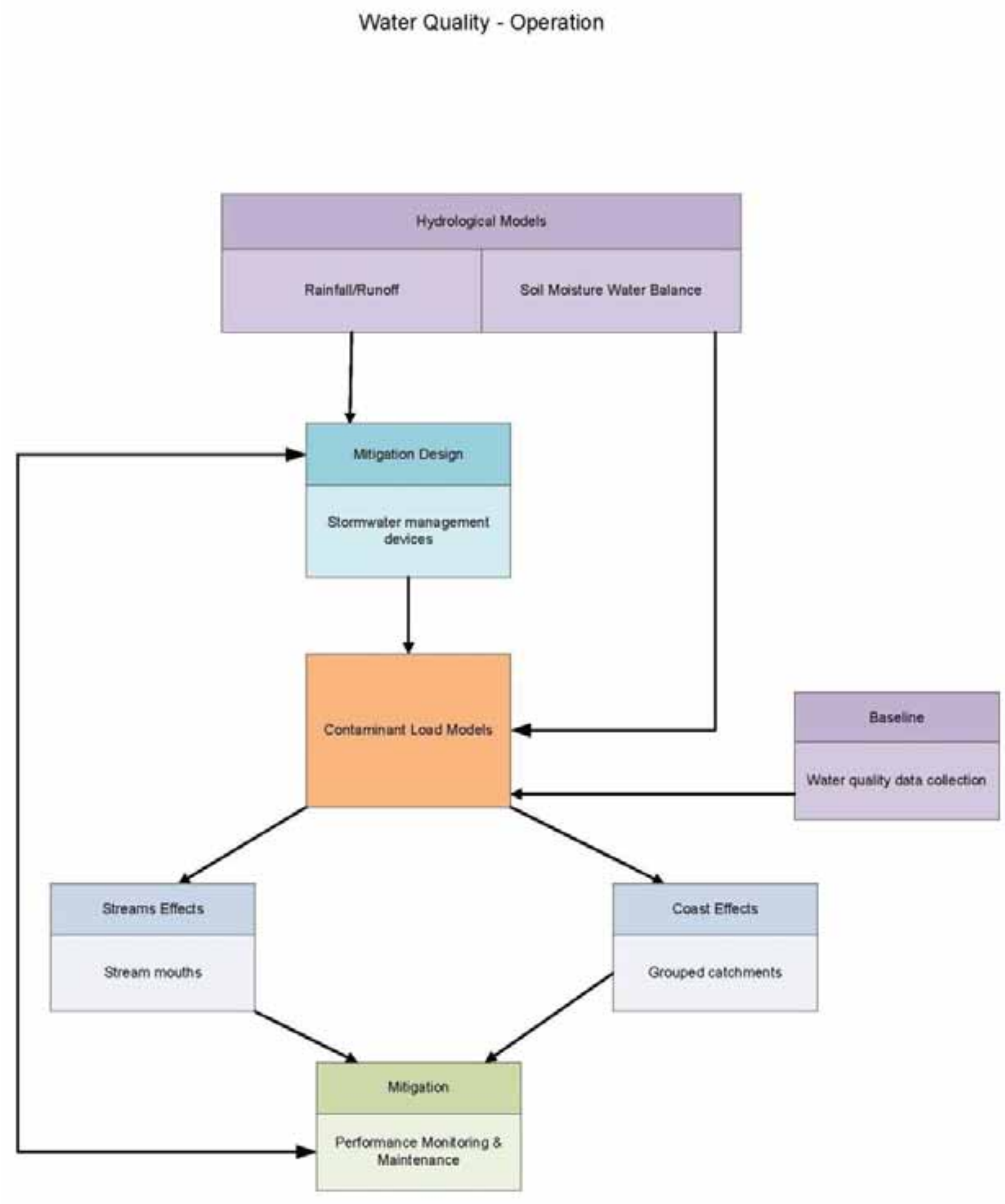
Potential Effect	Assessment of Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	A manageable change in the production of conspicuous oil or grease films, or floatable or suspended materials is predicted as a result of the discharge. The load of nutrients is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. A manageable effect on scums and foams is predicted as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	A manageable change in conspicuous change in the colour or visual clarity is predicted as a result of the discharge.
Any emission of objectionable odour.	A manageable change in objectionable odour is predicted as a result of the discharge.
Any significant adverse effects on aquatic life.	See Technical Report 11: *Ecological Impact Assessment* for further information.
The rendering of water unsuitable for bathing by the presence of	A manageable change in bathing is predicted as a result of the discharge.

contaminants.	
Undesirable biological growths.	The load of nutrients is expected to increase, but the concentration is not, provided the pH of the stream water is not affected by the discharge of chemically treated stormwater. The effect of the discharge on undesirable biological growths is manageable.

14. Operational Assessment Methodology

Figure 15.57 illustrates the methodology used to assess the potential effects (see **Section 7**) during the operational phase of the Project.

- **Figure 15.57 Operational Assessment Methodology**



15. Operational Stormwater Treatment

15.1. Stormwater Treatment Philosophy

The level of service proposed to achieve the stormwater treatment philosophy is based on input from the project ecologists and the following rules and guidance:

- Rules set out in the Greater Wellington Regional Council's *Regional Freshwater Plan*
- New Zealand Transport Agency's *Stormwater Treatment Standard for State Highway Infrastructure* (2010)
- Auckland Regional Council's (ARC) *Stormwater Treatment Devices: Design Guidelines Manual* 2003 (referred to as TP10).

The target standard considered as acceptable for long term water quality treatment has been set at removal of 75% of total suspended solids (TSS). This level of removal is considered best practice within existing standards, and is known to remove the great proportion of heavy metal solids and, when retrofitted to existing stormwater systems, result in general environmental benefits (Livingston, 2001).

The treatment volume for stormwater management devices is based on the volume of the 90th percentile storm. In the current climate in this area NZTA guidance equates this to approximately 25mm of rainfall. However, because of the Project design life, it is more conservative to use the 2090 climate. The 90th percentile storm for 2090 has been calculated[3] as an average of 27mm of rainfall across the Project catchments.

The actual level of service provided will depend on the best practicable option for water quality treatment for each part of the alignment.

A Contaminant Load Model (see **Section 17**) has been used to assess the effectiveness of the proposed devices in removing TSS and contaminants from the Project discharges, and is used to inform the assessment of effects of stormwater discharges on the receiving environment.

15.2. Source Separation

All stormwater that comes into contact with the Project road surface will pass through a treatment device. Contamination of other runoff will be avoided, where possible, by limiting runoff onto the road from cut slopes or surrounding land. This can be achieved by the construction of separate collection systems or stormwater diversions, depending on space limitations. The runoff from these slopes and land will be discharged into the freshwater environment untreated since there will be negligible contamination of these areas from the roadway.

Although there may be additional costs associated with the separation of runoff in terms of extra channelling and road width, the overall cost is expected to be lower as fewer treatment devices are required (since less runoff is being treated) and treatment efficiency rates are expected to be higher.

15.3. Stormwater Collection and Conveyance

Collection and conveyance of runoff will be via 'V' shaped concrete channels. These will typically be 1m wide and 100mm deep.

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[3] Based on 1/3 of the 2090 2-year rainfall event. Research undertaken by NZWERF (2004) in New Zealand has shown that 1/3 of the 2 year rainfall provides an accurate estimate of the 90th percentile storm.

It is proposed that stormwater will be collected on each side of the road by these concrete drains and conveyed to catchpits located every 50m along the road. The runoff collected in these catchpits will then be conveyed into a single carrier pipe located in the shoulder of the road, which will transport the runoff to a stormwater treatment device.

15.4. Stormwater Management Devices

A range of options are available for treatment systems. The ARC's TP10 (ARC, 2003) provides useful information on various stormwater management/treatment techniques.

The devices proposed for the Project are detailed below in **Table 15.55**. Other devices such as water quality ponds, sand filter boxes, infiltration trenches and rain gardens have not been considered due to the size and nature of the road making them unsuitable.

Swales and filter strips were included in the preliminary design. However, swales require significant extra road width (if treating both sides of the road) as compared to using concrete channel drainage. This is not likely to be cost-effective in narrow sections of the road such as when the road alignment is in cut, thus in later designs swales were not included.

Using wetlands is preferred to using wet ponds as they have better overall water quality treatment and do not have the safety concerns that deeper wet ponds have, as outlined in the NZTA stormwater guidelines (NZTA, 2004).

Each treatment system has a certain range of applications which depends on site constraints. Section 16 of this report describes the method for designing and locating stormwater treatment devices having regard to site constraints for the alignment.

- **Table 15.55 Stormwater Treatment Devices**

Device	Specific Use	Controlling Factors
Proprietary Devices	Small catchment area Allows for steep slopes Space constraints (cut/fill areas)	Runoff Volume
Wetland/Pond	Medium-large catchments	Available space Slope Soil Hydrology

Where proprietary devices are required it is proposed a Stormwater360 StormFilter with ZPG media be used. If in the subsequent detailed design an alternative technology is employed, the system will be required to be at least as effective as the Stormwater 360 StormFilter for removal of TSS, TPH and metals.

15.5. Performance Recommendations for Use in Assessment of Effects

The removal efficiencies in **Table 15.56** were used to assess the effects in the Contaminant Load Model (CLM); these are the default removal rates in the ARC CLM model.

Table 15.56 Stormwater Treatment Devices

	TSS	Total Zinc	Total Copper	TPH
Wetland	0.77	0.54	0.69	0.1
StormFilter	0.75	0.55	0.65	0.75

These performance standards are for the removal of total metals. The performance of devices for the dissolved fraction is likely to be less. ARC (2003) suggests removal rates of 42 - 62% for dissolved copper and 46% - 86% for zinc in wetlands. For this assessment we have assumed 40% removal of copper and 50% removal of zinc by wetlands. For StormFilters the literature suggests removal rates of 20 - 60% for both copper and zinc (Minton, 2004 and NSF international, 2004). For this assessment we have assumed a 20% removal of dissolved metals by the StormFilter.

Stormwater treated in ponds can result in temperature increases due to solar heating. However, the planting associated with the proposed wetland will limit any temperature increases to an acceptable level. The StormFilter is not expected to contribute to an increase in temperature.

15.6. Operational Performance Monitoring Plan

A crucial element of the successful operation of the stormwater treatment devices will be appropriate monitoring to ensure they are working as desired. **Appendix 15.W** provides an example of an operational performance monitoring plan, such as will be used on the Transmission Gully Project.

16. Operational Location of Mitigation Devices

The overall approach to locating and sizing the stormwater treatment devices was as follows:

Identify site constraints	Site constraints were identified and considered in determining where it was possible for wetlands or proprietary devices to be used.
Evaluate best-practice stormwater treatment	The merits of each treatment method were discussed and the road was categorized according to which treatment method would be best at each particular section of the alignment.
Determine appropriate catchment sizes and location of devices	Appropriate sized catchment areas for each treatment method were assessed and the categorized road sections were divided into sub-catchment areas accordingly. Treatment devices were then located within these sub-catchments. A map showing the final location of the treatment devices and the treatment catchment areas was created (see **Appendix 15.U**).
Preliminary design of stormwater treatment devices	Preliminary sizes and designs for the treatment devices were developed according to their respective catchment areas, design flow and design water quality volumes.

16.1. Site Constraints

There are a number of site issues along the alignment to be considered when determining the most appropriate form of stormwater treatment. These include:

- Soil conditions
- Available space within the road designation
- Longitudinal slope of the road
- Other general constraints.

These are discussed in detail in the following sections.

16.2. Soil Conditions

The effectiveness of treatment options is very dependent on the underlying soil. Wetlands require permeable soils with an impermeable liner such as loam or silty loam over clay (although a clay liner can be installed). The permeable soil allows vegetative growth and pollutant removal while the impermeable sub-layer retains water in the wetland.

Proprietary devices can be located in any soils types as their treatment process is independent of surrounding soil.

16.3. Space Constraints

Wetlands require a relatively large and accessible open-space area, preferably within the road designation. An area of approximately 800m^2 is deemed to be the minimum area to construct a wetland.

Proprietary treatment devices take up minimal room in the road alignment but still require forebay areas beside the road for maintenance. Ideally these devices should not be located in sections of the road in deep cut, however, this has been unavoidable in some sections of the alignment.

16.4. Longitudinal Slope of the Road

The longitudinal slope of the road alignment is a major constraining factor in stormwater treatment due to the many steep sections of the terrain.

Wetlands should be close to level when constructed to allow appropriate detention time and flow of stormwater through the wetland system. As the construction costs for locating a level wetland in steep sections will be quite high, wetlands have only been proposed where the longitudinal slope is less than 4%.

Proprietary devices are capable of being used in both flat and steep slopes.

16.5. General Constraints

Other constraints such as local hydrology, proximity to bedrock, slope stability and sediment loading have also been taken into account.

With respect to wetlands, the hydrology of the site is essential in determining its treatment success. A site is required to have sufficient runoff entering the system and/or high groundwater levels to ensure the wetland has sufficient year-round water supply for long-term viability. It is also essential that there are no slope stability issues on proposed wetland areas. With a large rainfall event, a constructed wetland can add significant weight to a slope and can cause surface slips in unstable soils.

16.6. Summary of Site Constraints

Table 15.57 summarises the above site constraints in relation to wetland and proprietary devices.

- **Table 15.57 Site Constraints**

Site Constraints	Wetlands	Proprietary Devices
Soil Conditions	Require loam or silty loam soils with impermeable rock or clay subsoils (although clay liner can be constructed)	No constraints
Available space within road designation	Requires at least 1000m^2 adjacent to road and within current road designation	Preference to avoid placement of devices in significant cut
Longitudinal Slope	Longitudinal slope angle should be less than 4%	No constraints
Other specific constraints	Sufficient runoff and/or groundwater to maintain water levels in wetland year-round No slope stability issues	No constraints

16.7. Treatment Catchments

Once the treatment method for each section of the alignment was identified then suitable locations and catchment areas were determined.

Catchment boundaries naturally occur at hill peaks where stormwater runoff flows in opposing directions. Catchment delineation was also determined to a certain extent by natural constraints such as bridges and longitudinal slope on the road alignment. As no carrier pipes will be installed across bridges, treatment of stormwater runoff must occur up-slope of the bridge and be discharged into the water below the bridge. However, each of the devices chosen can only effectively treat a certain catchment area.

The proposed stormwater sub-catchments are shown in **Appendix 15.U**. The catchment boundaries are shown in as black lines with two arrow heads indicating flow direction. The further division of treatment sub-catchments has been established around these natural catchment boundaries.

The proposed sub-catchment areas are based on road catchments and on the assumption that that only stormwater that makes contact with the road will be treated. Runoff from cut slopes and surrounding land will be collected via separate drains and discharged untreated.

16.8. Evaluation of Best-Practice Stormwater Treatment

Constructed wetlands are highly effective treatment systems designed to utilise the benefits of natural wetlands. Our review of device effectiveness in **Section 15.5** shows wetlands are capable of 70% removal of influent TSS as well as significant removal of dissolved heavy metals such as copper, zinc and phosphorous. Wetlands are also capable of providing flow attenuation, flood protection, public amenity, and support for aquatic life and wildlife (Wong et al., 1999). For these reasons, wetlands were considered as the best-practice treatment option wherever site constraints were met.

16.8.1. Proposed Locations of Wetlands

Four specific areas in the road alignment met the site criteria and have been considered for constructed wetland treatment. These areas are detailed in Table 15.58 and outlined in Plans 1 and 2 in **Appendix 15.U**.

- **Table 15.58 Details of Proposed Wetlands**

Proposed Wetland	Location	Approximate Station	Treated road section
W1	McKay's Crossing - Te Puka Terrace (SH1)	St 940m	St 0m to 2,100m
W2	Horokiri Valley	St 7.550m	St 5,550 to 7,550m
W3	Horokiri Valley, adjacent to Battle Hill Farm Station	St 10,200m	St 8,600 to 10,200m
W4	Horokiri Valley South	St 11,200m	St 10,200 to 11,800m
W5	SH58 Intersection	St 17,500m	St 15,600 to 17,700m

Potential Wetland 1	Located between McKay's Crossing and Te Puka terrace at approximately St 940m. This section of the alignment is the existing State Highway 1, so a proposed wetland would only be appropriate if existing stormwater treatments are insufficient or cannot be utilised.
Potential Wetland 2	Located in Horokiri Valley at approximately St 7,550m. There is suitable flat and low-lying land on the other side of the Horokiri stream to the road alignment for a wetland. It is proposed that runoff is transported from the road across the stream into the wetland via an open-flow rectangular channel. There is potential for flooding at this site but an assessment showed that there was approximately 10-12mm of flooding in a 10-year AEP event which is acceptable for wetland use.

Potential Wetland 3	Located immediately after deep cut sections of the road in Horokiri Valley at approximately St 10,200m where the road is at grade and the surrounding land is relatively flat. There is sufficient space between the road alignment and Horokiri Stream for a suitably sized wetland.
Potential Wetland 4	Located in the lowest-lying section Horokiri valley. There are steep hills to the west of the road alignment but a large, flat space suitable for wetland use to the east of the alignment. There is also proposed vegetation planting in the surrounding area so the use of a wetland could be complementary with this
Potential Wetland 5	Located at the intersection of the TG highway with SH58 at St 17,500m. There is designated land to the south-east of this intersection that is suitable and large enough for wetland use. There is also some spare capacity within the intersection itself that could be used creatively for wetland use. Although there is insufficient space for an entire wetland system within this area, a forebay area and sediment pond could be created in this space and connected to a larger banded bathymetric pond to the south-east of the intersection. Considering a design like this could create additional public amenity to the intersection and help visually tie the intersection to its rural surroundings. A constructed wetland at this location may also provide additional habitat and spawning areas for native fish which should be taken into consideration with more detailed design.

Wetlands are most effective when they are treating large catchment areas. This ensures that sufficient water levels are retained in the wetland. Also, larger wetlands are more likely to be able to support a natural eco-system with habitat for fish-species and native birds and also serve as a public amenity.

The areas proposed for wetland stormwater treatment make up approximately 34% of the proposed road alignment.

16.8.2. Proposed Locations of Proprietary Treatment Devices

Proprietary treatment devices have few site constraints and will be effective in treatment at almost any section in the road alignment. They will be used wherever stormwater treatment via wetlands is not possible. They are very effective in treating runoff with high-sediment load and meet the project service level requirements, but do not offer some of the potential benefits of well-maintained wetlands. However due to the steep nature of the road precluding use of wetlands, proprietary devices are proposed for a significant proportion of the road alignment wherever the use of wetlands is not suitable.

Treatable areas are proposed to be a minimum of 15,000m^2 where possible for economic reasons. They are also not designed to be larger than 25,000m^2. This is because smaller devices better assimilate natural pre-development stormwater flows, and reduce the risk posed by large attenuation volumes.

It has been determined that the treatable catchment areas for proprietary devices should preferably be between 15,000m^2 and 25,000m^2.

Table 15.59 below shows the sub-catchment delineation according to the minimum and maximum area requirements.

- **Table 15.59 Proposed Treatable Sub-Catchments for Use of Proprietary Treatment Devices**

Proprietary Treatment Device	Location of Catchment	Treatable Catchment Area (m²)	Approximate Location of Proprietary Treatment Device
P1	Stn 2,100m to 2,830m	18,250 m²	Stn 2110m
P2	Stn 2,830m to 3,310m	12,000 m²	Stn 2840m

Proprietary Treatment Device	Location of Catchment	Treatable Catchment Area (m²)	Approximate Location of Proprietary Treatment Device
P3	Stn 3,310m to 4,030m	18,000 m²	Stn 3320m
P4	Stn 4,030m to 4,700m	16,750 m²	Stn 4040m
P5	Stn 4,700m to 5,550m	18,750 m²	Stn 4710m
P6	Stn 7,550m to 8,000m	11,250 m²	Stn 7990m
P7	Stn 8,000m to 8,600m	15,000 m²	Stn 8590m
P8	Stn 11,800m to 12,800m	25,000 m²	Stn 11810m
P9	Stn 12,800m to 13,550m	18,750 m²	Stn 12810m
P10	Stn 13,550m to 13,980m	10,750 m²	Stn 13970m
P11	Stn 13,980m to 14,780m	20,000 m²	Stn 14770m
P12	Stn 14,780m to 15,600m	20,500 m²	Stn 15080m
P13	Stn 17,700m to 18,450m	18,750 m²	Stn 17710m
P14	Stn 18,450m to 19,500m	26,250 m²	Stn 18460m
P15	Stn 19,500m to 20,200m	17,500 m²	Stn 20190m
P16	Stn 20,200m to 21,020m	20,500 m²	Stn 20600m
P17	Stn 21,020m to 21,600m	14,500 m²	Stn 21030m
P18	Stn 21,600m to 22,000m	10,000 m²	Stn 21610m
P19	Stn 22,000m to 22,930m	23,250 m²	Stn 22010m
P20	Stn 22,930m to 23,550m	15,500 m²	Stn 22940m
P21	Stn 23,550m to 24,480m	23,250 m²	Stn 24470m
P22	Stn 24,480m to 25,300m	20,500 m²	Stn 25290m
P23	Stn 25,300m to 26,080m	19,500 m²	Stn 26070m
P24	Stn 26,080m to 26,700m	15,500 m²	Stn 26690m
P25	Stn 26700m to 27,300m	15,000 m²	Stn 27290m
P26	Stn 27,300m to 28,000m	17,500 m²	Stn 27990m

The devices are positioned adjacent to culverts or bridges so that treated runoff from the device can be efficiently discharged into natural waterways. The devices are also located at the low-point of every sub-catchment to ensure that all runoff is captured and treated. The direction of runoff and location of each proprietary device is given on the maps in **Appendix 15.U**.

In some cases within the alignment, the road catchment is smaller than the recommended maximum area due to natural catchment boundaries mentioned earlier. In contrast, Proprietary Device 8 (P8) treats an area that is larger than the recommended maximum due to no suitable discharge outlets occurring between Stn 18,450m to 19,500m.

16.9. Preliminary Sizing of Stormwater Treatment Devices

16.9.1. Wetlands Design and Sizing

It is proposed that banded bathymetric wetland design be used, as recommended by the NZTA Stormwater Treatment Standard Manual (2009). A banded bathymetric design has bands of interchanging variable depths which allows for uniform dispersion of stormwater flow and prevents short-circuiting, and also provides deeper habitat areas for fish.

The wetlands will be designed according to Auckland Regional Council's TP10 Design Guidelines. The wetlands will be designed to allow for the stormwater runoff to have an extended detention time. The wetlands will be sized to be able to store and release the extended detention water quality volume over a 24-hour period. This volume is based on a uniform 34.5mm of rainfall over the sub-catchment being treated by the wetland, which is the rainfall depth determined by previous research (Auckland Regional Council) to minimise potential for stream channel erosion.

A well-maintained wetland sized to these requirements is expected to achieve a 70% TSS removal rate. Table shows the minimum surface areas for each wetland and the approximate wetland dimensions. These are based on an approximate length: width ratio of 3:1, as recommended by the NZTA Stormwater Treatment Standard Manual.

- **Table 15.60 Proposed Sizings and Dimensions of Wetlands**

Wetland	Treatable Catchment Area	Minimum surface area of Wetland	Approximate Dimensions of Wetland design
W1	52,500 m²	1980 m²	26m x 78m
W2	50,000 m²	1920 m²	25m x 77m
W3	40,000 m²	1650 m²	23m x 72m
W4	52,500 m²	1980 m²	26m x 78m
W5	40,000 m²	1650 m²	23m x 72m

16.9.2. Proprietary Treatment Device Sizing

The design of proprietary treatment devices is dependent on the treatable catchment area, design water quality volume and sediment loading. At this stage of design, it has been approximated that one treatment cartridge will be able to treat 500m^2 of catchment area. It is relatively flexible as to how the devices are designed to house these media cartridges but emphasis will be placed on keeping the required forebay area and additional road width to a minimum.

Table 15.61 details the approximate number of cartridges required for each proprietary treatment device. It also shows the design water quality volumes for each device.

- **Table 15.61 Proposed Cartridges and Design Water Quality Volume for Proprietary Treatment Devices**

Proprietary Treatment Device	Approximate Treatable Catchment Area	Minimum Number of Media Cartridges Required	Design Water Quality Volume
P1	18,250 m^2	37	456 m^3
P2	12,000 m^2	24	300 m^3
P3	18,000 m^2	36	450 m^3
P4	16,750 m^2	34	419 m^3
P5	18,750 m^2	38	469 m^3
P6	11,250 m^2	23	282 m^3
P7	15,000 m^2	30	375 m^3
P8	25,000 m^2	50	625 m^3
P9	18,750 m^2	38	469 m^3
P10	10,750 m^2	22	269 m^3
P11	20,000 m^2	40	500 m^3
P12	20,500 m^2	41	513 m^3
P13	18,750 m^2	38	469 m^3
P14	26,250 m^2	53	656 m^3
P15	17,500 m^2	35	438 m^3
P16	20,500 m^2	41	513 m^3
P17	14,500 m^2	29	363 m^3
P18	10,000 m^2	20	250 m^3
P19	23,250 m^2	47	581 m^3
P20	15,500 m^2	31	388 m^3
P21	23,250 m^2	47	581 m^3
P22	20,500 m^2	41	513 m^3
P23	19,500 m^2	39	488 m^3
P24	15,500 m^2	31	388 m^3
P25	15,000 m^2	30	375 m^3
P26	17,500 m^2	35	438 m^3

17. Operational Modelled Effects

This section discusses the modelling and analysis undertaken to assess the effects of operational stormwater discharges on:

- The change in contaminant loads in the streams and harbour
- The change in connected impervious area.

The analysis accounts for the development in the wider catchment predicted to occur at 2031, to account for cumulative effects. It also accounts for the proposed mitigation outlined in **Section 16**. Two methods have been undertaken:

- Stream water quality data collected as part of the water quality characterisation combined with motorway stormwater quality data from five New Zealand motorway monitoring sites.
- A Contaminant Load Model

17.1. Motorway and Catchment Data

Motorway stormwater quality data obtained from two New Zealand studies were used to estimate the effects of the road on different sub-catchments which the road discharges to. The following studies were used:

- Sherriff's (1998) study of stormwater quality on SH1 at Tawa, Wellington.
- Moore *et al*.'s (2009) study of stormwater quality at four motorway locations in Auckland – Westgate, Redvale, Huapai and Northcote.

The advantage of this method is that it provides site specific estimates of water quality. The expected contaminant concentrations in operational stormwater discharges from the Transmission Gully Project, accounting for site specific traffic data and the proposed treatment devices for different sections of road, is coupled with site specific water quality data collected from the streams close to future discharge sites, and at sites that will be influenced by upstream discharges. The estimated concentrations using this method provide the most appropriate data for undertaking ecological assessments.

However, the method has some limitations:

- It does not account for the change in traffic volumes, associated with the shift of traffic off existing roads and on to the Transmission Gully Project, and therefore does not represent the change in contaminant distribution that is expected, including the reduction in contaminant load in some catchments
- It does not account for cumulative effects associated with other development that is predicted to occur within these catchments in the future case.
- Most of the sites from both the Auckland and Wellington studies had greater traffic volumes than is predicted for the Transmission Gully Project. The only exception to this is the Huapai site in the Auckland study
- The motorway data is based on a limited dataset in two New Zealand cities.

To address these limitations, and to provide an assessment of relative change in freshwater and marine water quality at a catchment level, contaminant load models have been developed for all of the catchments that will receive operational stormwater discharges from the Transmission Gully Project or that drain to the Porirua Harbour. The contaminant load model is discussed in **Section 17.2.**

17.1.1. Motorway and catchment data methodology

For each sub-catchment, the proportion of the sub-catchment which will be converted to road was calculated. This was then weighted with median concentrations from the motorway studies for TSS, total and dissolved zinc and total and dissolved copper. The proportion of the catchment which will not be converted to road was weighted with the median concentration for each parameter using the 2010 collected water quality characterisation data, described in **Section 6**.

This method was used to estimate impacts in different parts of each stream catchment:

- The most upstream discharge point: To assess the estimated water quality changes where discharges are likely to have the greatest impact in the catchment. This is likely to occur in the upper sub-catchments where the road is a high proportion of the sub-catchment and water quality is typically the highest quality in the catchment. This provides data for assessment of site specific ecological effects.
- Immediately downstream of the road: To assess estimated water quality changes immediately downstream of the road. This is useful to assess the overall effects of the road and on stream quality and provides data for a broader assessment of ecological effects.
- Most downstream sampling location: To assess estimated water quality changes at the mouths of the streams. This is useful to assess the cumulative effects of the road and on stream quality and provides data for a catchment wide assessment of ecological effects. This data is most comparable with the estimates made using the contaminant load model, discussed in **Section 17.2**

For each scenario concentrations of TSS, total and dissolved zinc and total and dissolved copper were compared for each site using the following data:

- 2010 water quality characterisation median concentrations
- Weighted 2010 water quality characterisation median concentrations plus weighted Wellington and Auckland motorway data (Sherriff, 1998; Moore *et al*., 2009)
- Weighted 2010 water quality characterisation median concentrations plus weighted Wellington and Auckland motorway data with treatment devices applied.

A sensitivity analysis was undertaking using the water quality characterisation median concentrations plus weighted Wellington motorway data only (Sherriff, 1998). There were minor differences with the Auckland Studies having more zinc and the Wellington study having more copper. These minor differences do not alter any of the conclusions of the assessment based on the combined data, discussed in **Sections 17.1.2** and **17.1.3.**

17.1.2. Impact of Motorway Data to Specific Locations

Table DD.1 in Appendix 15.DD summarises the locations where the analysis was undertaken and the catchment areas upstream of these locations. Maps displayed in DD.4 illustrate the catchment boundaries, the road area, the treatment devices and the relevant sampling locations.

For each site, estimated traffic volumes are provided. The predicted traffic volumes along the road are similar and the decision was made to use the median of the Wellington and Auckland motorway studies rather than selecting different studies for various sections for the road. This is because the studies, with the exception of Huapai, had greater traffic volumes than are predicted for the Transmission Gully Project, and therefore the combined median is considered conservative.

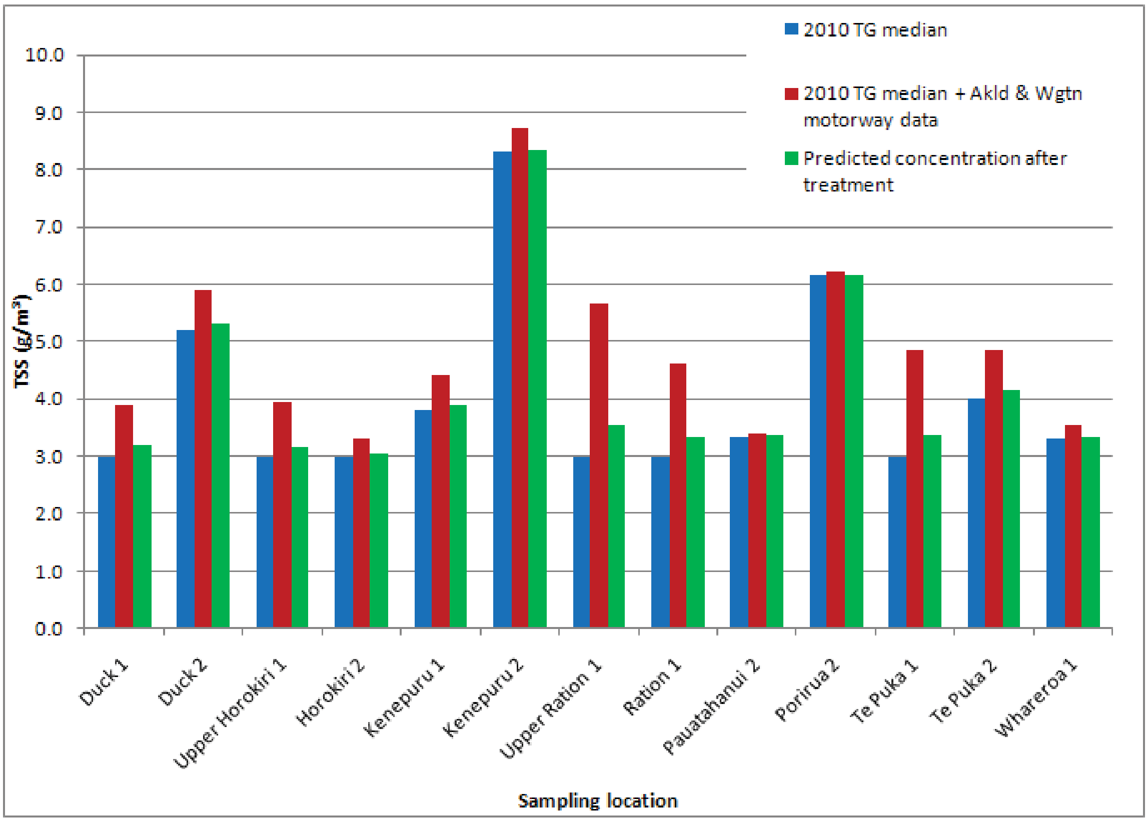
For each location the treatment devices that have been proposed for treatment, as discussed in section 16, are assessed.

The graphs in Figure 15.58 to Figure 15.62 compare concentrations for each of the following:

- 2010 water quality characterisation median concentrations
- Weighted 2010 water quality characterisation median concentrations plus weighted Wellington and Auckland motorway data (Sherriff, 1998; Moore *et al*., 2009)
- Weighted 2010 water quality characterisation median concentrations plus weighted Wellington and Auckland motorway data with treatment devices applied.

The results show that the addition of motorway data increases concentrations at all sites. With treatment devices applied, concentrations are then reduced in all catchments. The predicted concentrations, for the total and dissolved fractions, are not expected to exceed ecological guideline values at any locations, which do not already exceed ecological guideline values at that location. This is important because it highlights that in the upper catchment, the proposed treatment devices are effective at reducing the increase in contaminants that are predicted to be discharged from the Transmission Gully Project.

Figure 15.58 to Figure 15.62 includes the ANZECC (2000) guidelines in ecological trigger levels.These guideline trigger values provided for context and should not be interpreted as assessments of ecological effect. The ecological assessment of effect is described in Technical Report 11: *Ecological Impact Assessment.* The graphs also include the ANZECC (2000) guidelines for stock drinking water, contact recreation and fish for human consumption. The guidelines exceed the estimations by some margin, indicating that stormwater discharges from the Transmission Gully Project are unlikely to affect any of these management purposes.



- **Figure 15.58 TSS Concentration for Selected Stream Sites: 2010 Median Concentration; 2010 Median Concentration with Motorway Data; Predicted Concentration After Treatment**

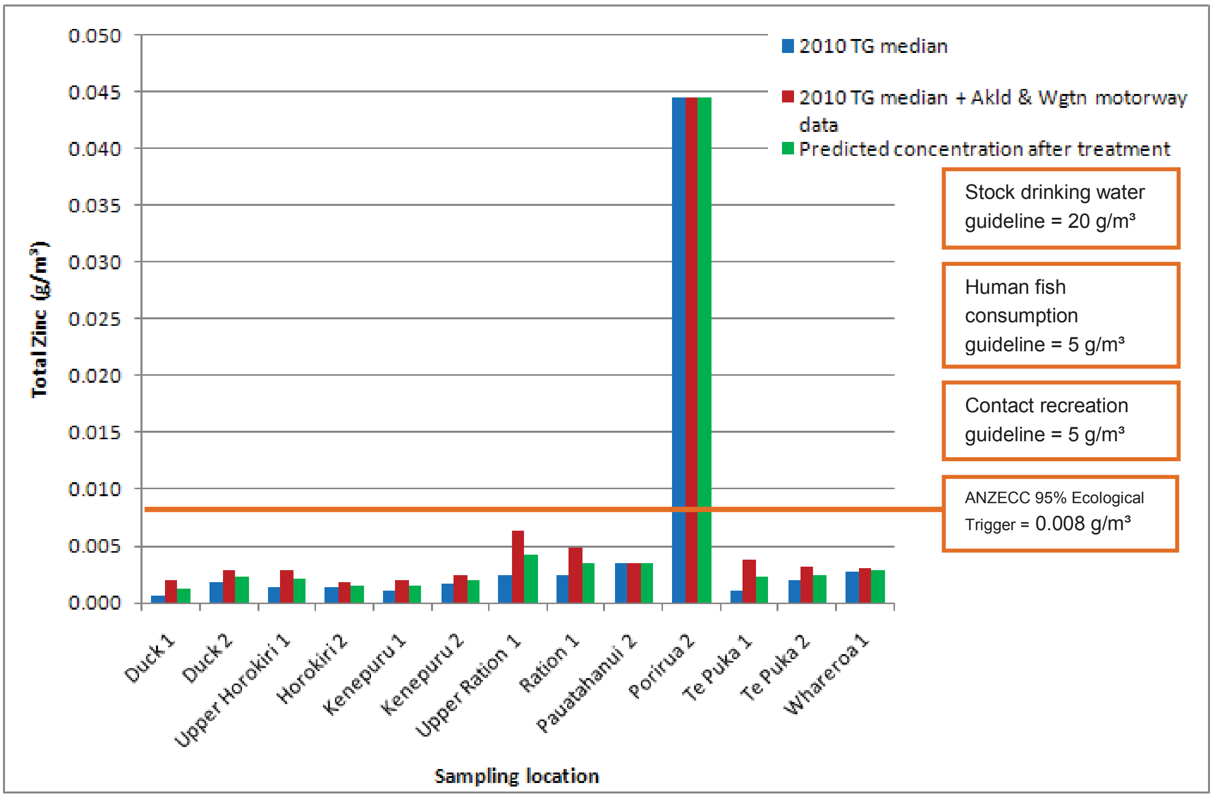


Figure 15.59 Total Zinc Concentration for Selected Stream Sites: 2010 Median Concentration; 2010 Median Concentration with Motorway Data; Predicted Concentration After Treatment

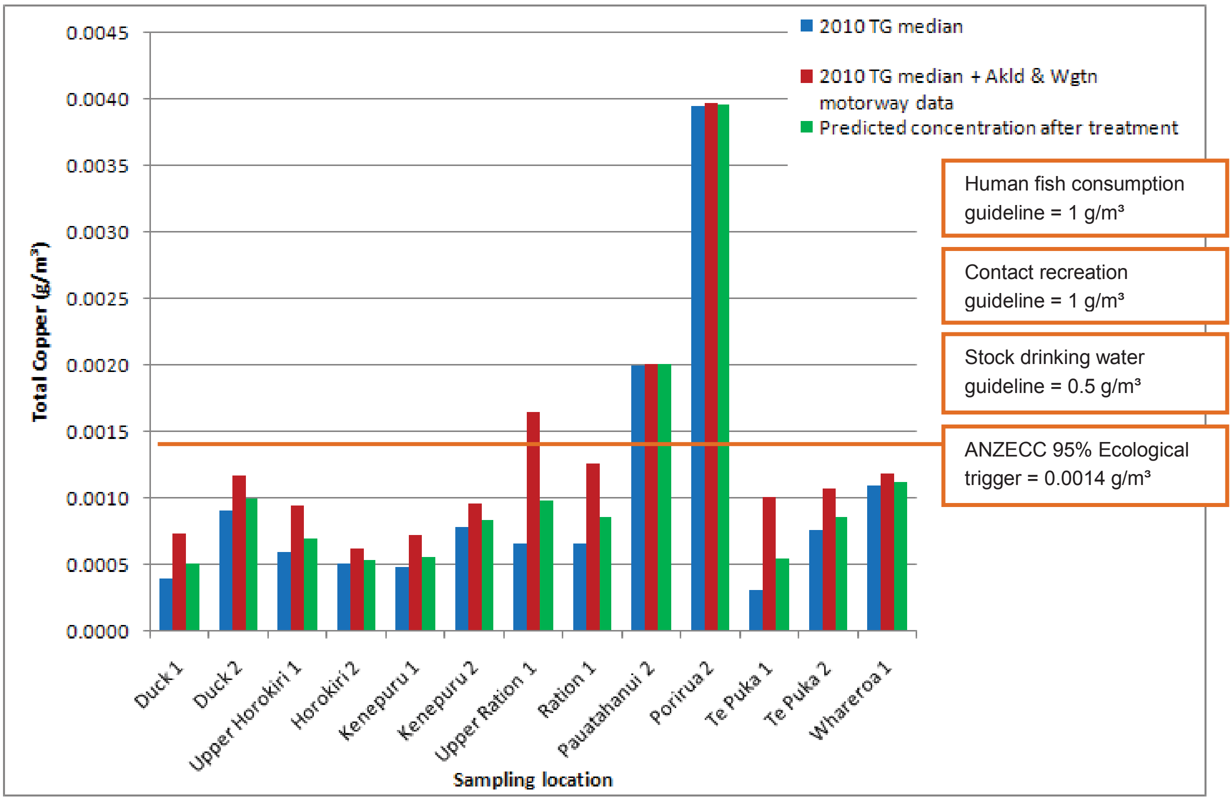
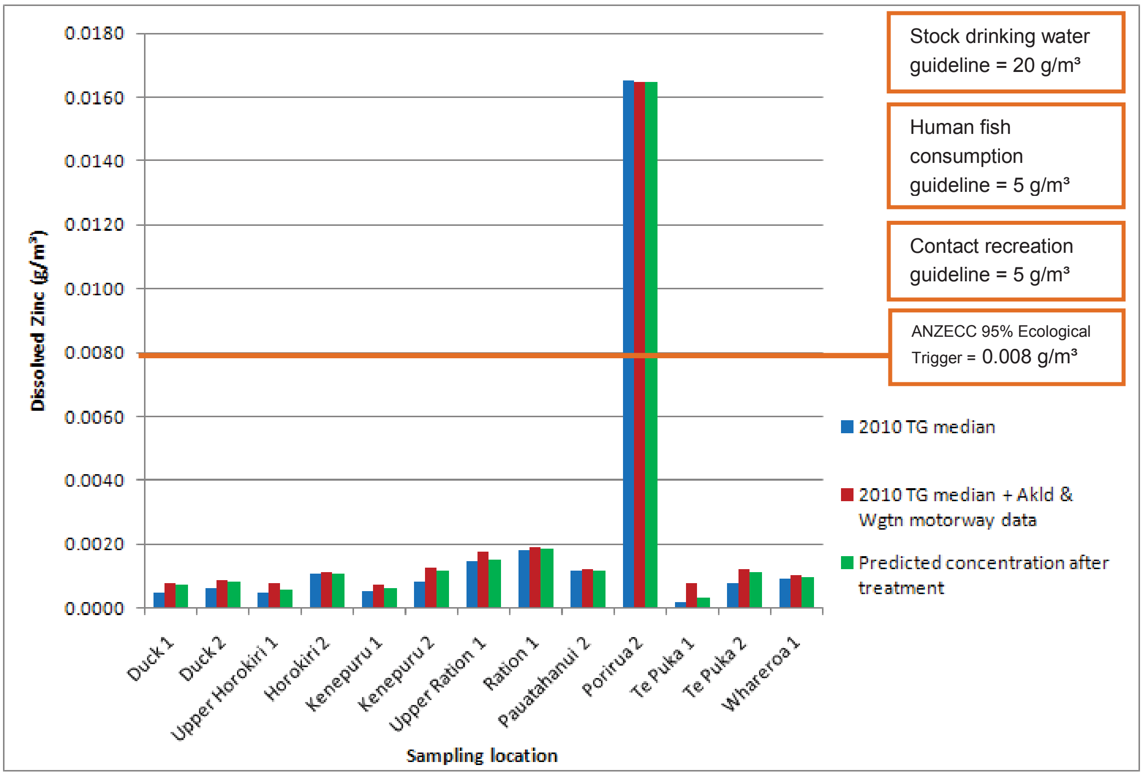
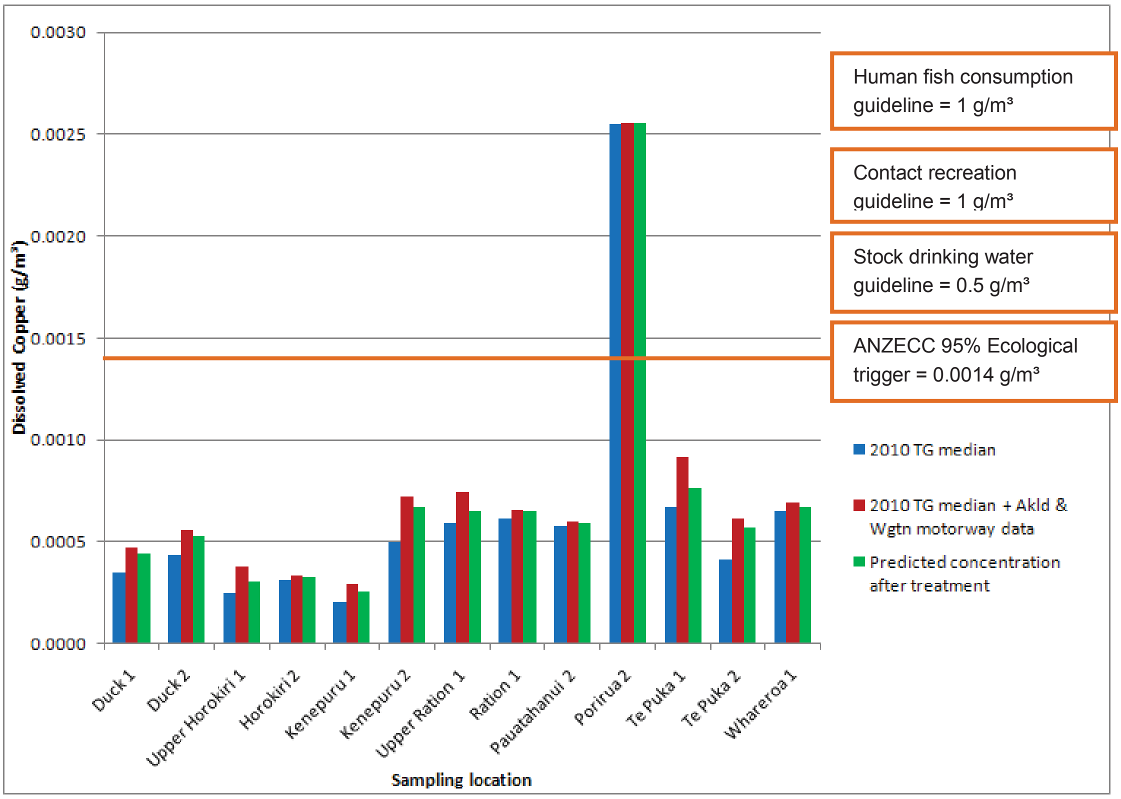


Figure 15.60 Total Copper Concentration for Selected Stream Sites: 2010 Median Concentration; 2010 Median Concentration with Motorway Data; Predicted Concentration After Treatment



- **Figure 15.61 Dissolved Zinc Concentration for Selected Stream Sites: 2010 Median Concentration; 2010 Median Concentration with Motorway Data; Predicted Concentration After Treatment**



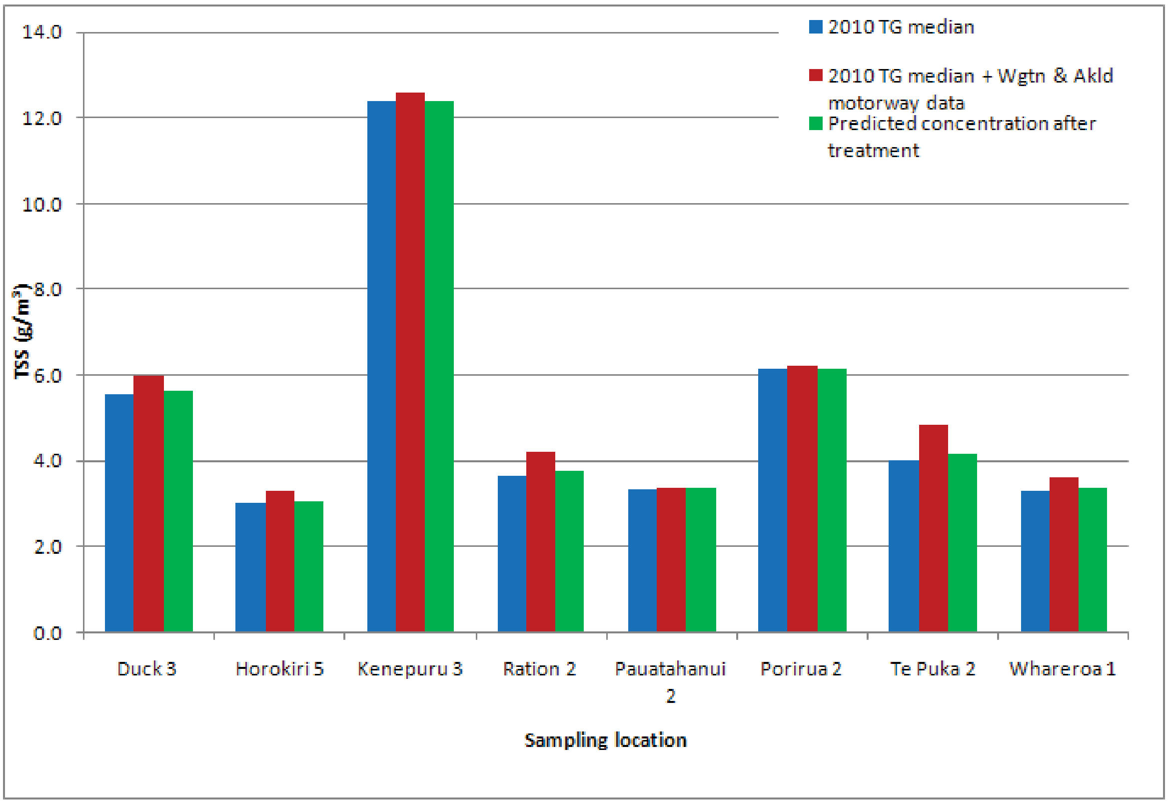
- **Figure 15.62 Dissolved Copper Concentration for Selected Stream Sites: 2010 Median Concentration; 2010 Median Concentration with Motorway Data; Predicted Concentration After Treatment**

17.1.3. Impact of Motorway Data to Overall Catchment

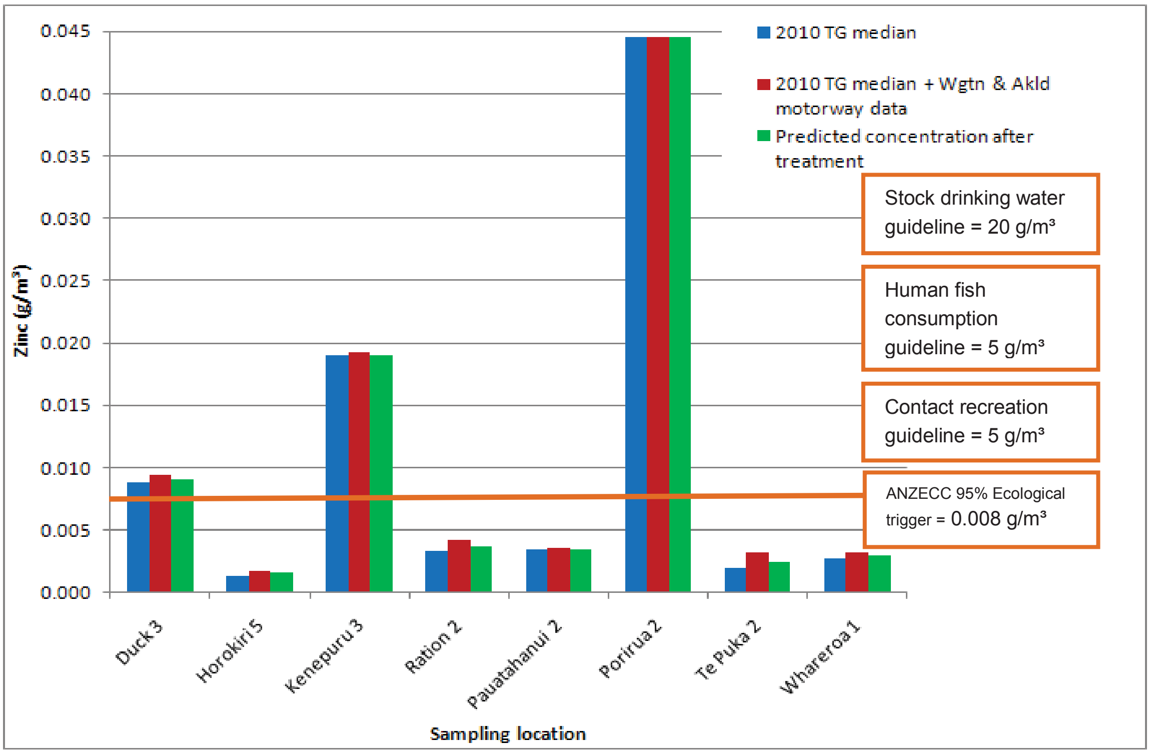
The graphs in **Figure 15.63** to **Figure 15.65** compare three concentrations for each of the parameters.

The results show that the addition of the motorway data increases concentrations of all three contaminants. With treatment devices applied, concentrations are then reduced in all catchments. The predicted concentrations are not expected to exceed ecological guideline values for any of the catchments that do not already exceed ecological guideline values. This is important because it highlights that the proposed treatment devices are effective at reducing the increase in contaminants that are predicted to be discharged from the Transmission Gully Project, and limit the cumulative effect of these discharges on the overall stream quality.

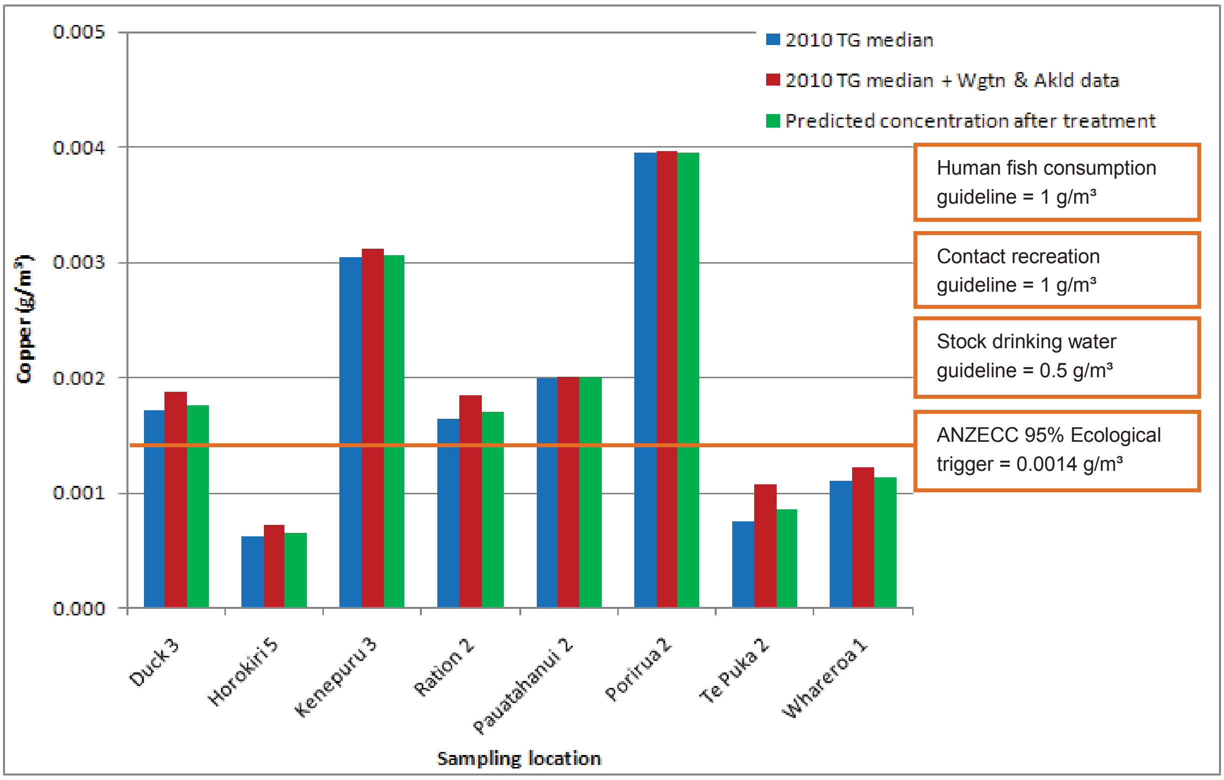
Figure 15.63 to Figure 15.65 includes the ANZECC (2000) guidelines in ecological trigger levels .These guideline trigger values are provided for context and should not be interpreted as assessments of ecological effect. The ecological assessment of effect is described in Technical Report 11: *Ecological Impact Assessment.* The graphs also include the ANZECC (2000) guidelines for stock drinking water, contact recreation and fish for human consumption. The guidelines exceed the estimations by some margin, indicating that stormwater discharges from the Transmission Gully Project are unlikely to affect any of these management purposes.



- **Figure 15.63 TSS Concentration at Most Downstream Sampling Location: 2010 Median Concentrations compared with Weighted Concentrations from Wellington and Auckland Stormwater Quality Studies**



- **Figure 15.64 Zinc Concentration at Most Downstream Sampling Location: 2010 Median Concentrations compared with Weighted Concentrations from Wellington and Auckland Stormwater Quality Studies**



- **Figure 15.65 Copper Concentration at Most Downstream Sampling Location: 2010 Median Concentrations compared with Weighted Concentrations from Wellington and Auckland Stormwater Quality Studies**

17.2. Development of the Contaminant Load Model

The ARC's Contaminant Load Model (CLM) (ARC, 2006) has been used to estimate contaminant loads for sediment, zinc, copper and petroleum hydrocarbons likely to be generated from the operation of the Transmission Gully Project. This section outlines application of the model to the Wellington region, model inputs and 2010 baseline model results generated for Project catchments.

The ARC CLM model was developed from data obtained from three key projects in the Auckland region which quantified different sources of metal contaminants in urban catchments. These were:

- Stormwater quality and quantity in Auckland City (NIWA)
- Vehicle contributions of metals to road run-off reaching urban stormwater networks (NIWA)
- Roof run-off quality (Diffuse Sources Ltd and Kingett Mitchell Ltd, 2005).

A spreadsheet based model combining data from this work was developed enabling yields for catchments to be calculated for TSS, zinc, copper and total petroleum hydrocarbons (TPH). Zinc and copper were used as indicators for metals in stormwater, as these are the contaminants usually found in the greatest loads. This is illustrated by the baseline water quality data summarised in **Section 6**.

For TSS, zinc, copper and TPH the spreadsheet calculates the expected bottom of site outfall loads, annual average yields and the average concentration of zinc, copper and TPH per unit of sediment. The proposed different management options (wetlands and proprietary devices) can then be applied to model the expected reduction in contaminant loads.

The contaminant load model allows for the assessment of the change in traffic associated with the proposed Transmission Gully project and allows for the assessment of cumulative effects that account for other changes in landuse planned to occur in the catchments.

The contaminant load model is most appropriate for assessing relative change in contaminant load on a catchment basis. The contaminant load provides useful information on sediment quality that can be used for ecological assessments for freshwater and coastal environments. For predictions of change in freshwater water quality on a site specific basis for ecological assessment, the analysis described in section 17.1, should be used.

17.3. Application of the Contaminant Load Model to Wellington

Kingett Mitchell (2005) produced the report *Assessment of Urban Stormwater Quality in the Wellington Region*, which analysed stormwater data collected between June 2002 and September 2004 by GWRC at 11 different sampling sites throughout the region. The sites drained catchments with a variety of different land uses including newer residential to older industrial areas. Data was compared to that from other urban environments in New Zealand and elsewhere in the world. In general it concluded stormwater quality in Wellington is comparable to other regions with similar catchment land uses in New Zealand, including the Auckland region (Kingett Mitchell, 2005).

A range of different parameters were measured in the study, including nutrients, dissolved and particulate metals and organic compounds. In summary, the following points were made about Wellington stormwater quality:

- pH is similar to stormwater quality in other New Zealand studies
- Total suspended solids (TSS) concentrations are similar to elsewhere in New Zealand, particularly compared with Auckland. Differences in TSS concentrations between catchments with different land uses were also similar to other studies
- The size of particles in stormwater is also comparable to that reported in both the international and New Zealand literature
- Concentrations of dissolved copper and zinc in stormwater are generally elevated above concentrations of other metals in stormwater in the region. Concentrations were typically above the ANZECC (2000) trigger values and sometimes exceeded the USEPA (2002) ‘chronic’ guidelines for aquatic life protection. Copper is generally in the lower range of concentrations when compared with data from other New Zealand regions. Zinc concentrations are also comparable to those found in other areas.
- Polycyclic aromatic hydrocarbons (PAH) were found in 8 out of 11 sampling sites, and were highest in industrial catchments. Although particulate concentrations were generally high, this was not always the case for the dissolved fraction.

It was therefore considered appropriate to use the Auckland based CLM to model the estimated contaminant load from the Transmission Gully Project.

17.4. Model Inputs and Assumptions

A CLM was computed for each of the twenty-three streams that drain to the Porirua Harbour. The Te Puka and Whareroa catchments which drain in the northern section of the alignment were also modelled. Ten of the streams modelled are crossed by the Project.

The model was first run for the current landuse scenario (2010). Models for each catchment were then run for three future scenarios:

- 2031 without the Transmission Gully Project constructed
- 2031 with the Transmission Gully Project constructed (no treatment)
- 2031 with the Transmission Gully Project constructed and treatment devices applied.

All model outputs are for these scenarios are provided in **Appendix 15.Z** and **Appendix 15.AA**. The following data and assumptions were used to calculate inputs to the model.

17.4.1. Landuse

All landuse was compiled first in GIS. Maps showing landuse for all catchments with and without Transmission Gully Project constructed in 2031 are shown in **Appendix 15.Y**. The default estimates for contaminant loads for different land uses were used in this assessment. Inputs included:

- Area of different roof surface types
- Length of roads divided into traffic flow categories (in vehicles per day). Each length was converted to an area assuming different roads for each vehicle per day category
- Areas of paved surfaces other than roads for residential, commercial and industrial land uses
- Area of ‘urban grasslands’, including parks, school playing fields and reserves – divided into different slope categories
- Length and width of urban stream channels
- Area of other landuse such as plantation forest, stable bush, horticulture, farmed pasture and retired pasture – divided into different slope categories.

17.4.2. Paved Surfaces

GIS was used to determine current paved surfaces, including roads, driveways and car parks.

For the 2031 model scenarios, the population growth data from the Wellington Transport Strategy Model developed by GWRC was used. This Wellington Transport Strategy Model identified projected population growth at 2031 within spatial units.

The increase in developed area associated with the population growth within each spatial unit was assumed to be contained within areas that are currently zoned for future development within the spatial unit. The density of development was assumed to be similar to the adjacent land use in the zoned areas.

17.4.3. Urban Grasslands

Aerial photography in GIS was used to identify pervious areas within urban catchments with low erosion rates such as parks, school playing fields and reserves.

17.4.4. Urban Stream Channel

Areas of open channel within urban areas were identified using aerial photography in GIS. Streams through rural and forest land were not included.

17.4.5. Rural Landuse

Rural landuse as defined by the Ministry for the Environment’s (MfE) Landcover Database (LCDB) was divided into exotic production forest, stable bush, farmed and retired pasture and horticulture areas. These areas were further categorised by slope using a digital terrain model.

17.4.6. Roof Surface Types

Wellington building age data supplied by the Territorial Authorities was used along with roof type fractions developed by ARC to estimate proportions of different roof surface types. A visual check was undertaken using aerial photographs to ensure the estimations were largely representative. **Table 15.62** shows land use proportions applied to estimate areas of different roof types.

For the 2031 scenarios, roof areas were estimated using a percentage of future planned land use, where 65% of the predicted future residential area, 72% of the predicted future industrial area and 85% of the predicted commercial area, was assumed to be roof. These roof areas were divided into different roof types using estimated fractions for buildings constructed after 2010 as shown in **Table 15.62**.

- **Table 15.62 Landuse and Roof Surface Types (Res = Residential, Com = Commercial, Ind = Industrial)**

Roof Type	Building Construction Date											
	Pre 1995			1995-2000			2000-2010			After 2010		
	Res	Com	Ind	Res	Com	Ind	Res	Com	Ind	Res	Com	Ind
Galvanised unpainted		0.05	0.32		0.005	0.12						

Roof Type	Building Construction Date											
	Pre 1995			1995-2000			2000-2010			After 2010		
	Res	Com	Ind	Res	Com	Ind	Res	Com	Ind	Res	Com	Ind
Galvanised poor paint	0.005	0.05	0.08	0.001	0.005							
Galvanised well painted	0.005			0.001								
Zinc/aluminium unpainted		0.04		0.003	0.04	0.2		0.04	0.2		0.17	0.17
Colorsteel/colorcote	0.004	0.04		0.04	0.04	0.08	0.04	0.04	0.2	0.17	0.17	0.17
Decramastic	0.02			0.01								
Other materials	0.13	0.22		0.135	0.31		0.14	0.32				
Unknown (no galvanised steel/copper)				0.01			0.02					
Concrete										0.17		

17.4.7. Roads

Vehicles per day for roads in the study area were modelled using the Hutt Bridges (HB) SATURN Models. This work was undertaken by SKM traffic modellers and was peer reviewed by Flow Transportation Specialists in 2009. Further details of the modelling methodology can be found in Technical Report 4: *Assessment of Traffic and Transportation Effects.*

Matrices (SKM, 2009) were adjusted so that outputs were in vehicles (SATURN generally outputs in passenger car units (PCUs) where one heavy commercial vehicle (HCV) is equal to two PCUs).

Sense checks have been carried out and also spot checks to the actual flows in the models. These show a slight underestimation of the peak flows due to the exclusion of preloaded flows (pre-existing queues at the start of the model period). The annual average daily traffic (AADT) volumes were then calculated using the formula 2*AM flows + 12.4*IP flows+2*PM flows. These peak factors were generated from a linear regression of observed traffic counts on State Highway 1, State Highway 2 and State Highway 58.

The CLM assumes a relationship between traffic volume and road width (**Table 15.63**). In the CLM, a road with 20,000 to 50,000 vehicles per day equates to a three lane-road. A road with 50,000 to 100,000 vehicles per day equates to a four lane road.

Lengths of roads for the Project in vehicle per day categories were calculated using ArcGIS. A verge width of 10m was assumed for all roads.

- **Table 15.63 Assumed Relationship Between Traffic Volume and Number of Lanes on Road**

Vehicles per day	Number of lanes
<1000	2
1000-5000	2
5000-20000	2
20,000-50,000	3
50,000-100,000	4
> 100,000	6

Although the Project alignment is a four-lane highway, with some sections of six-lanes and some link roads with two lanes, the traffic volumes are less than the CLM predicts at mostly between 5,000 and 20,000 vehicles per day (**Table 15.63**). Therefore, if these sections of road were input into the CLM we would effectively underestimate the contaminant load. An exception to this is in the northern section of the alignment, in the Te Puka and Whareroa catchments where traffic volumes are between 20,000 and 50,000 vehicles per day.

To compensate for this, the length of the road with 5,000 to 20,000 vehicles per day and four lanes has been duplicated in the <1000 vehicles per day category (which adds two lanes to the road width for this length). Similarly, for the length of road with 20,000 to 50,000 vehicles per day and six lanes – the road length has been duplicated in the <1000 vehicles per day category.

17.5. Contaminant Load Model Verification

A version of the CLM that represents 2010 land use was developed. For streams this was compared to measured water quality data to verify the model results. For the Porirua Harbour it was compared to measured sediment quality data collected in 2009. Full CLM outputs for all catchments are included in Appendix 15.Z Conversion to a Concentration

Loads in the CLM were converted to a concentration. In the majority of catchments this was using the average daily flow for wet days as predicted using the Soil Moisture Water Balance Model (SMWBM - see **Appendix 15.K**). For the Te Puka and Whareroa catchments, one-third of the Q2 event flows were used. In both cases this conversion is approximate, due to the number of inputs and assumptions in the CLM, but is useful to put the CLM predictions in the context of measured data.

17.5.1. Comparison against Baseline Data

The graphs below (**Figure 15.66** to **Figure 15.68**) compare the CLM estimates with grab samples collected as part of the baseline sampling.

The CLM is conservative compared with grab samples, but has acceptable agreement with the samples collected in automatic sampling for zinc and copper. The CLM estimates that total zinc and copper exceed guideline values in wet weather within all catchments. Concentrations in the majority of grab sample data were below guidelines in the Duck, Horokiri, Ration, Pauatahanui, Te Puka and Whareroa catchments. The CLM estimates for TSS are also conservative when compared with the baseline data.

The comparison of the CLM predictions with water quality data indicates that the CLM provides an acceptable estimator of 'first flush' or maximum storm water concentrations, but is likely to provide higher than reality estimates of average concentrations. Therefore, the CLM is an appropriate tool to use for predicting stormwater discharges likely to be generated from the Transmission Gully Project as long as it is recognised that any outputs from the model are likely to be conservative.

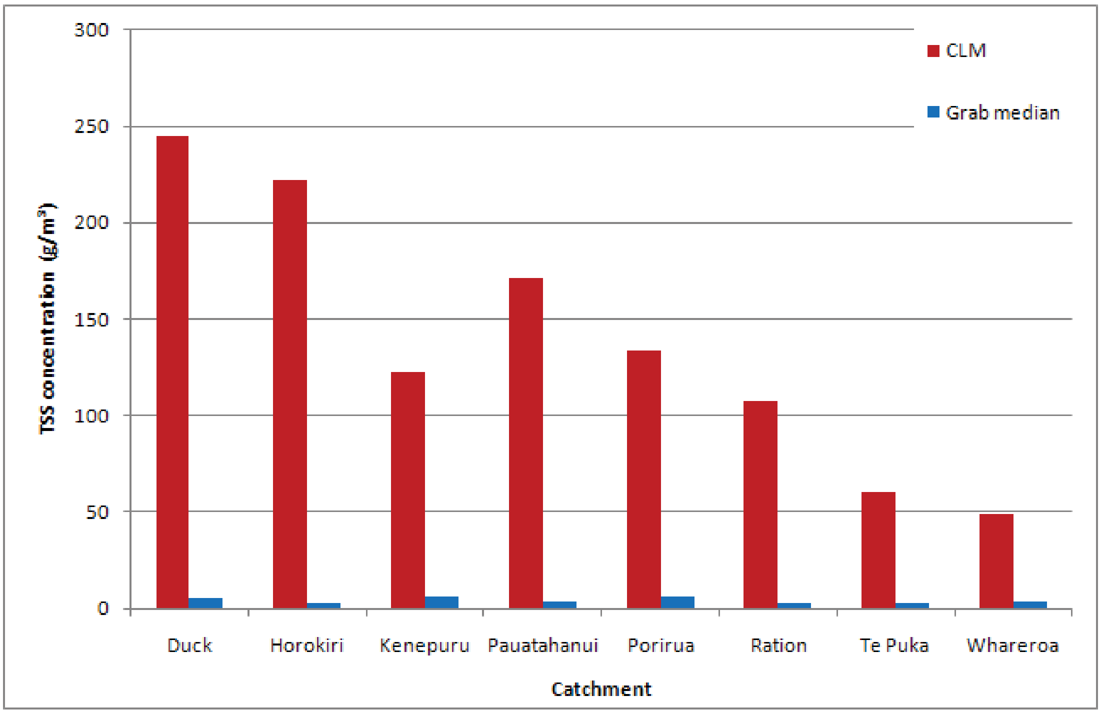


Figure 15.66 Total Suspended Solids Concentration for CLM and Grab Samples

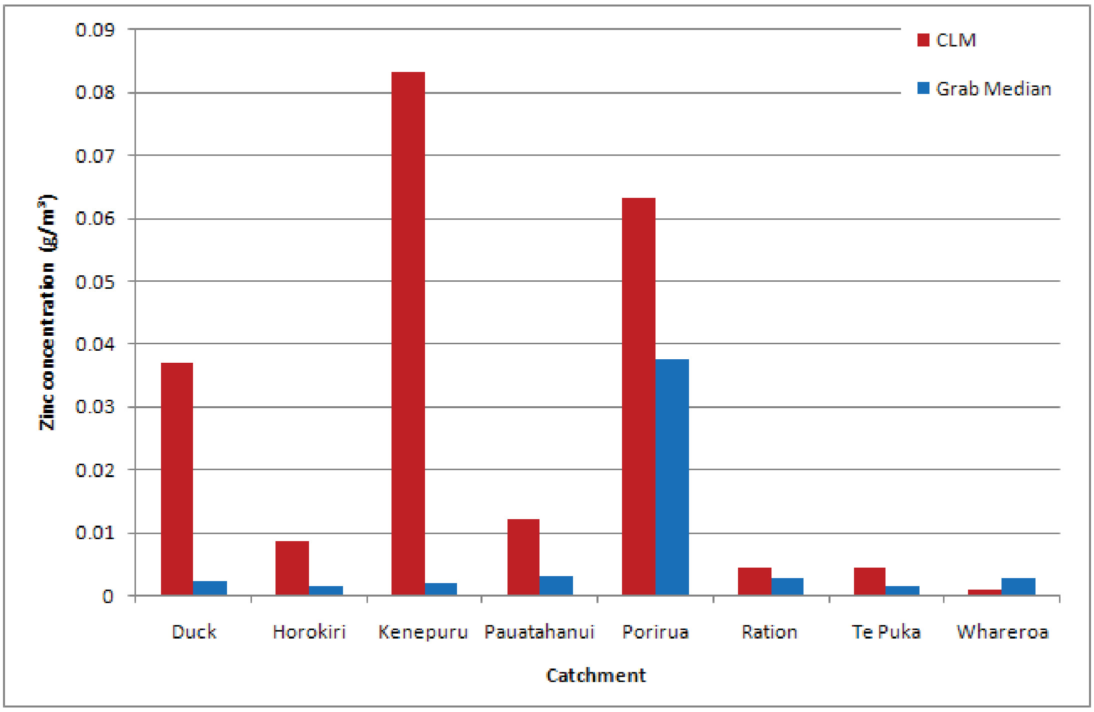


Figure 15.67 Total Zinc Concentration for CLM and Grab Samples

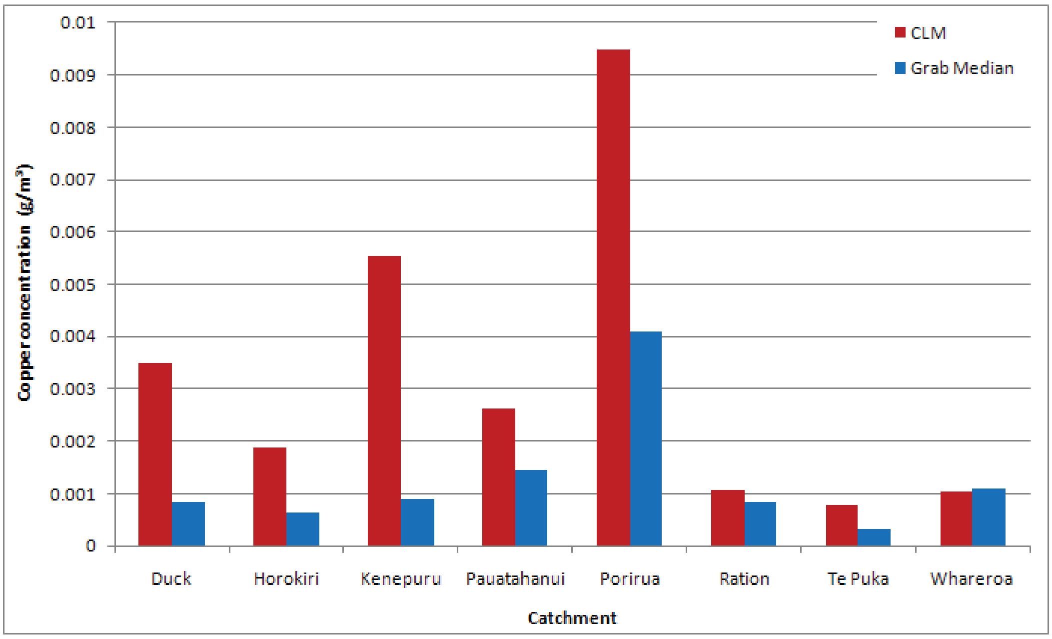
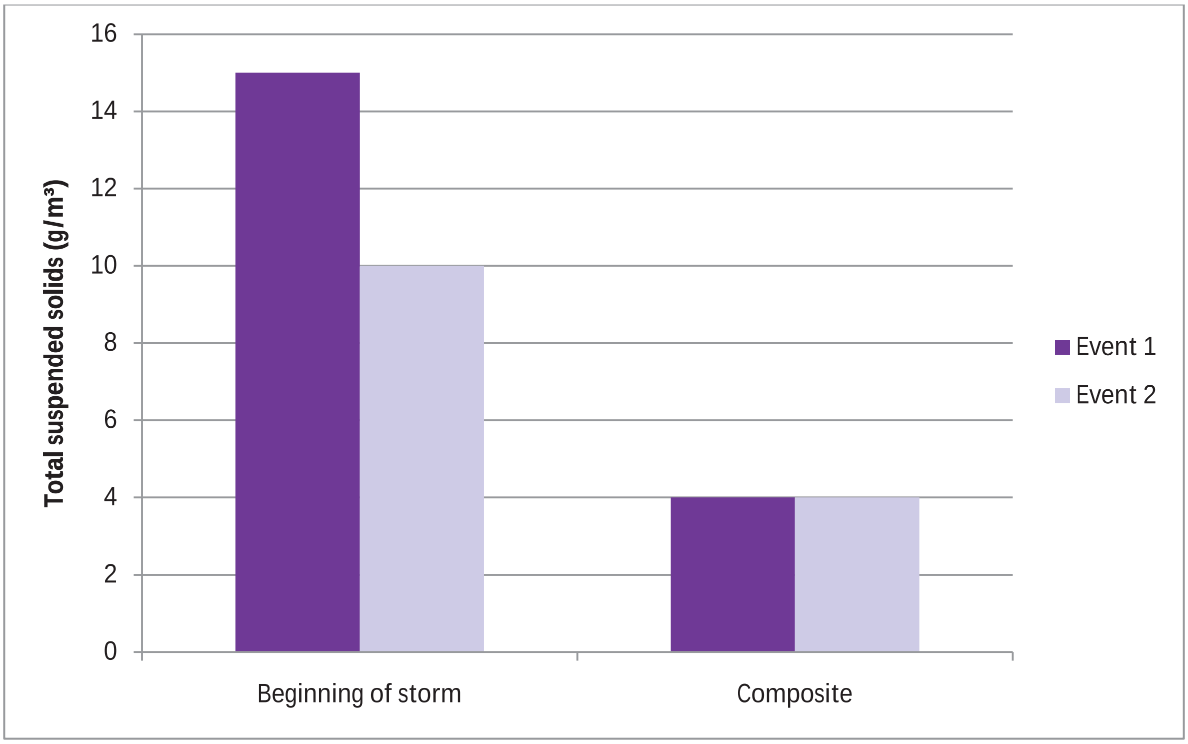


Figure 15.68 Total copper concentration for CLM and Grab Samples

Research generally shows that contaminant concentrations are much higher in the first flush period than in the rest of the storm. The City of Austin's 1990 study estimated that the first flush typically contains about 40% of the total storm contaminant load. Moreover, high first flush concentrations compared with event mean concentrations are particularly apparent for total suspended sediment and heavy metals (including zinc and copper) (Kim, 2003). Lee (2005) collected stormwater data from road runoff and estimated that the first 50% of the runoff volume contained 60% of the TSS mass, 59% of the total copper mass and 55% of the total zinc mass for the whole storm. The first flush phenomenon has also been shown to exist in New Zealand, such as in a study in Auckland on urban stormwater (Shamseldin *et al*., 2011).

This research shows that concentrations collected at the beginning of storms are expected to be higher than the event mean concentration for TSS, zinc and copper. Examples of this phenomenon occurring were also apparent in data collected by automatic samplers on the Porirua Stream (**Figure 15.69**).



- **Figure 15.69 Comparison of TSS Concentration for Beginning of Storm and Composite Samples Collected by Automatic Samplers on the Porirua Stream**

The CLM prediction of the first flush or beginning of storms in the catchments is acceptable; however, it is likely to overestimate average loads of contaminants discharged to the streams over the duration of storm events. When interpreting data, consideration should also be given to likely average concentrations.

An appropriate use of the data is in the relative change between the scenario with and without the Project, and relating this to current measured levels of contaminants in streams.

17.5.2. Comparison against Motorway Data

The CLM was used to compare actual stormwater data collected from a section of motorway in the Wellington region with CLM predictions for the same section of road.

Sherriff (1998) conducted a study on SH1 at Tawa, north of Wellington City. The study area was approximately 700m². Manning's automatic samplers (triggered by flow) collected samples from the end of the motorway culvert, which discharges stormwater into the Wellington City Council stormwater system.

Samples were collected at regular intervals for four rainfall events between March and May 1998. Samples were analysed for TSS, several heavy metals, total petroleum hydrocarbons (TPH) and polynuclear aromatic hydrocarbons. Flow data was presented and event mean concentrations calculated for each rainfall event. Peak flows for the rainfall events ranged between 100 L/s to approximately 7722 L/s.

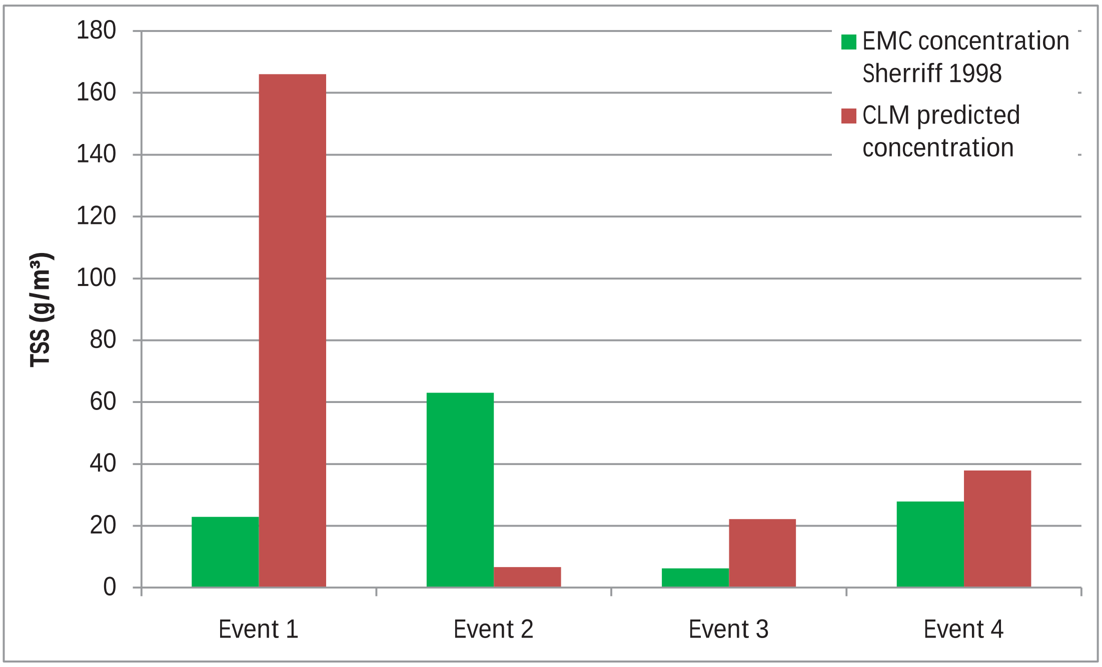
Traffic data from Transit New Zealand (1998) gave an annual average daily traffic (AADT) count for this section of road as 36,800 vehicles. The road had two lanes in each direction. However, only the south bound traffic drained to the culvert.

The study area was entered into the model under the 20,000 – 50,000 vehicles per day road category, which represents a three lane road. The model overestimates the road width, but more accurately predicts the traffic volume.

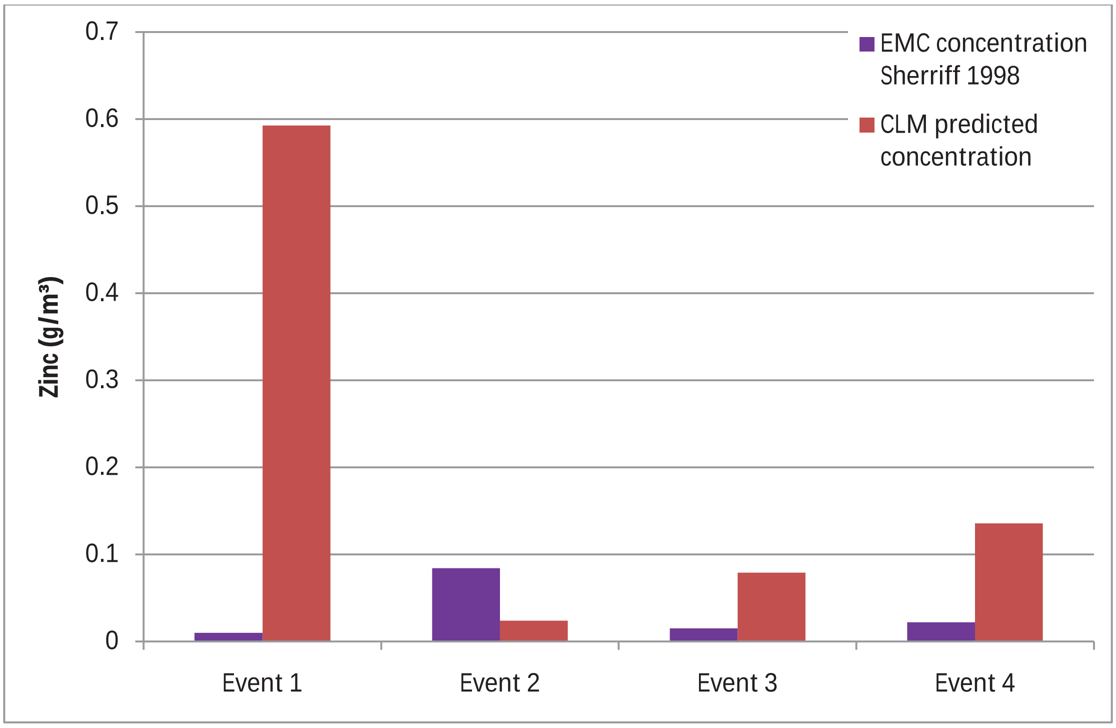
We input the area of road studied into the CLM. This produced a yield for each contaminant, which was then used to calculate the concentration for each of the four rainfall events using the average flow over that event. This was done for TSS, zinc, copper and TPH. The conversion of the load calculated by the contaminant load model to a concentration is approximate, but is useful to put the CLM predictions in the context of measured data.

Contaminant concentrations calculated from the CLM for each of the four events were compared to event mean concentrations from the Sherriff (1998) study. The comparison shows that predicted concentrations are in the same order of magnitude as the collected motorway data. For three out of the four events, the predicted concentrations from the CLM were more conservative than the motorway data. This comparison was consistent for all contaminants (see **Figure 15.70** to **Figure 15.73**). TPH was only detected in one event in the motorway data (Event 3). Because of the volatile nature of TPH, it is sometimes difficult to detect in water samples. Therefore, the CLM predicts much higher levels than were actually detected in the samples.

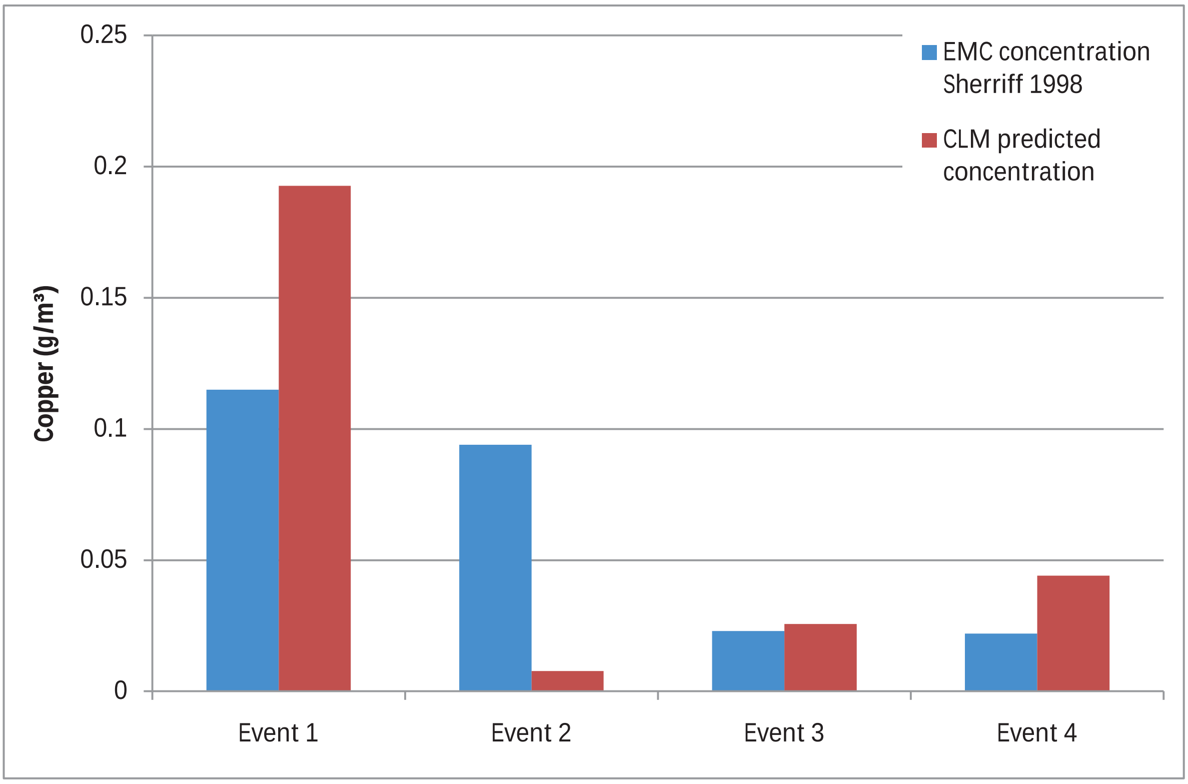
The comparison shows that the CLM predicts loads which are comparable to motorway data over a range of different sized events, and again confirms that the CLM is an appropriate model for the Transmission Gully Project. As with the comparisons to the baseline water quality data it is recognised that any outputs from the model are likely to be conservative.



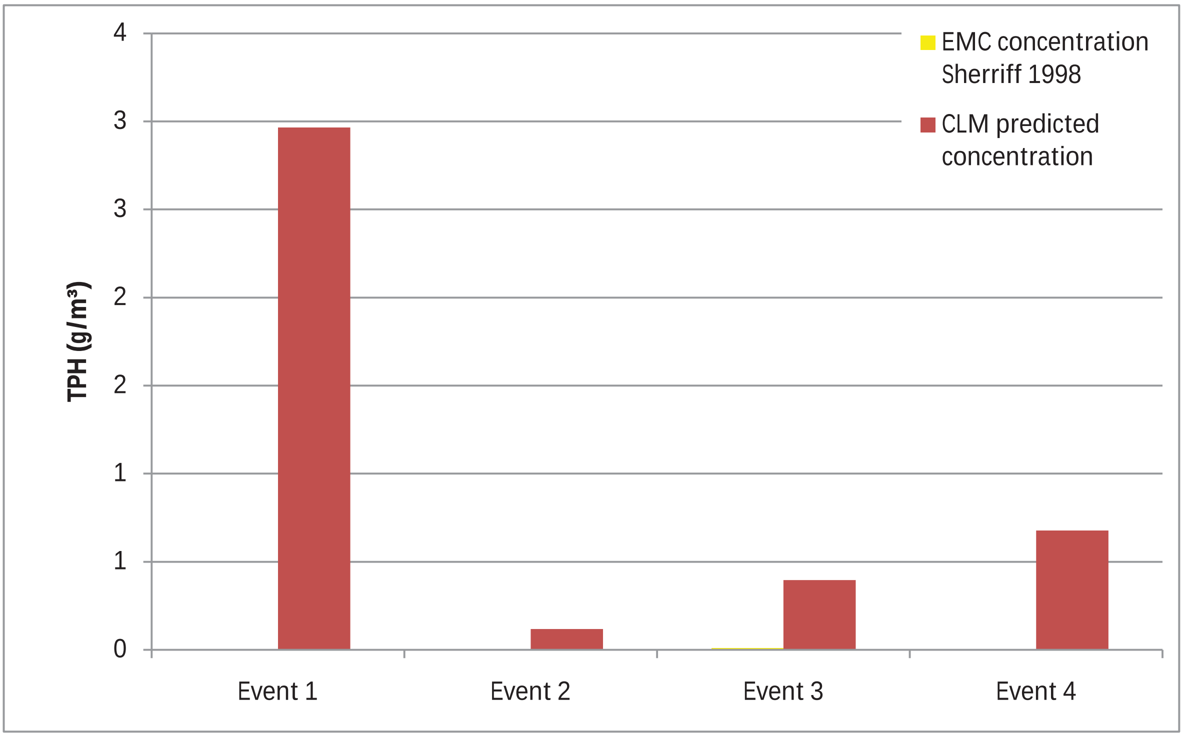
- **Figure 15.70 TSS concentration for Four Events Comparing Collected Motorway Data and Contaminant Load Model Predictions**



■ **Figure 15.71 Zinc Concentration for Four Events Comparing Collected Motorway Data and Contaminant Load Model Predictions**



■ **Figure 15.72 Copper Concentration for Four Events Comparing Collected Motorway Data and Contaminant Load Model Predictions**



- **Figure 15.73 TPH Concentration for Four Events Comparing Collected Motorway Data and Contaminant Load Model Predictions**

17.5.3. Comparison against Harbour Sediment Quality

Several studies have assessed surface sediment quality in the Porirua Harbour, including Glasby *et al*. (1990), Botherway & Gardner (2002), Stevenson & Mills (2006), Milne & Watts (2008), Robertson & Stevens (2008) and Sorenson & Milne (2009). Investigations have been carried out determining levels of various heavy metals, nutrients and organic compounds such as DDT and polyaromatic hydrocarbons (PAHs). In general results of these studies indicate that several contaminant concentrations are elevated at sites throughout the harbour. Contaminant concentrations are typically higher at the Onepoto Arm of the harbour, around the Porirua Stream mouth and other nearby stormwater outfalls.

Most recently, a GWRC study conducted by Sorenson & Milne (2009) collected data at seventeen intertidal sites and adjacent to stream mouths around the harbour. Surface sediments were collected at ten sites at the southern end of the harbour adjacent to the Porirua Stream mouth and other stormwater outfalls. Samples were also collected in the Pauatahanui Inlet near Browns Stream and Duck Creek mouths. Sediments were tested for a range of heavy metals, nutrients, organic compounds such as DDT, dieldrin and PAHs.

Concentrations were compared to the ANZECC (2000) guidelines for both the ISQG 'low' trigger values (where the onset of biological effects could occur) and the ISQG 'high' trigger values (where significant biological effects are expected). Where available, concentrations were also compared to the ARC's amber and red Environmental Response Criteria (ERC) (ARC, 2004) which provides a trigger to begin investigative action to address pollution causes. The ARC ERC guidelines are all lower than the ANZECC guidelines.

In summary, the following observations were made:

- Zinc concentrations in surface sediment are elevated in some areas of the harbour, especially in the Onepoto Arm, where the ANZECC ISQG 'low' trigger was exceeded at seven sites and a further three sites exceeded the ARC ERC amber threshold. Zinc concentrations were also above the ARC ERC amber threshold adjacent to the Onepoto Stream mouth

- In the Onepoto Arm, several sites exceeded the ARC ERC amber threshold for copper and lead
- One site exceeded the ANZECC ISQG 'low' trigger for mercury
- DDT concentrations are elevated at several sites in both arms of the harbour. Eight of the ten sites in the Onepoto Arm and sites adjacent to the Onepoto Stream, Duck Creek and Browns Stream mouths all exceeded the ARC ERC amber and ANZECC ISQG 'low' trigger.
- Some tested PAHs were also elevated above ARC ERC amber and ANZECC ISQG 'low' guidelines at several sites in both arms of the harbour.

Figure 15.74 and **Figure 15.75** compare CLM mg of zinc and copper per kg of sediment with measured sediment quality data from the Porirua Harbour (Sorenson *et al.*, 2009). The sites used for each stream were BB-C (Browns Stream), DC-B (Duck Creek) and POR-B (Porirua Stream). These were selected based on their proximity to each respective stream mouth. These comparisons show that the CLM predictions are very conservative when compared with the collected data.

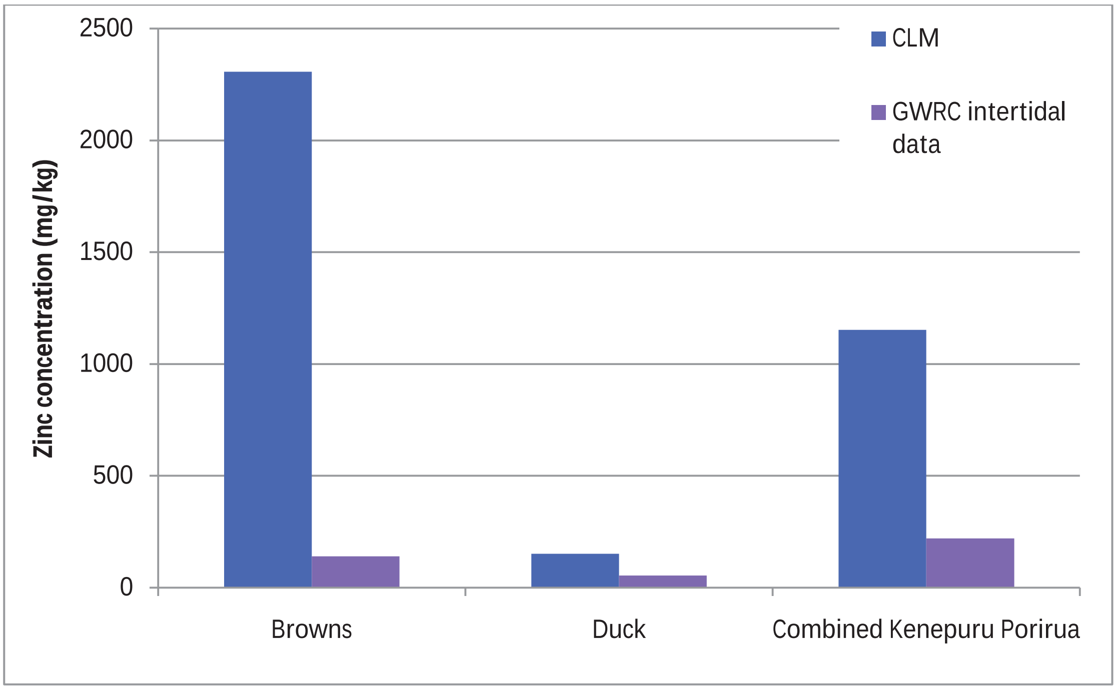


Figure 15.74 Zinc Concentrations in Sediment - CLM Compared with Measured Data

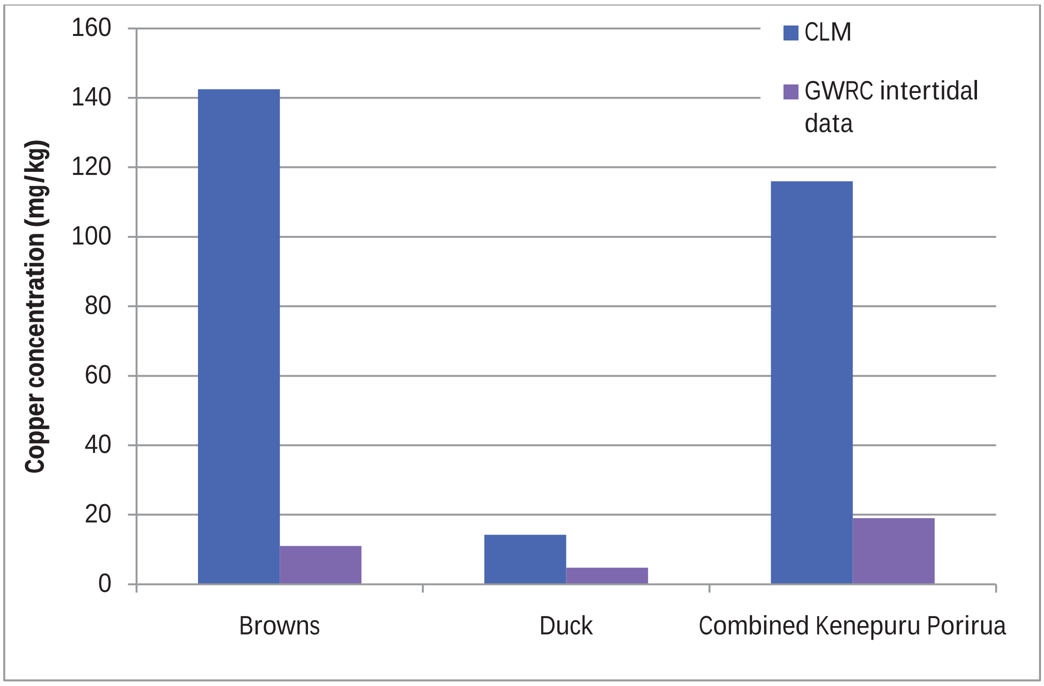


Figure 15.75 Copper Concentrations in Sediment - CLM Compared with Measured Data

The CLM predicts loads at the mouths of the streams and does not account for processes within the harbour. A sediment transport model of the Porirua Harbour was developed to assess the effects of construction on the harbour, discussed in **Section 12**. This model does not include water quality modelling. However, the model can be used in aiding our understanding of the movement and deposition of contaminants in the harbour as these are attached to sediment.

When interpreting CLM data for the harbour, it is not appropriate to use the loads predicted by the CLM as estimations of future sediment quality concentrations in the harbour. The most appropriate use of the data is in the relative change between the scenario with and without the Project. This can then be related to current measured levels of contamination in the harbour.

17.6. Stream Contaminant Load

A CLM was computed to estimate catchment contaminant loads for three future scenarios:

- 2031 without Transmission Gully Project constructed
- 2031 with Transmission Gully Project constructed (no treatment)
- 2031 with Transmission Gully Project constructed and proposed treatment devices applied.

Figure 15.76 to **Figure 15.82** provide graphical representation of the CLM results. **Figure 15.76** to **Figure 15.77,** which show the concentration of contaminants compared to sediment yields and include the ISQG ecological trigger levels from the ANZECC (2000) guidelines. These guideline trigger values provided for context and should not be interpreted as assessments of ecological effect. The ecological assessment of effect is described in Technical Report 11: *Ecological Impact Assessment.*

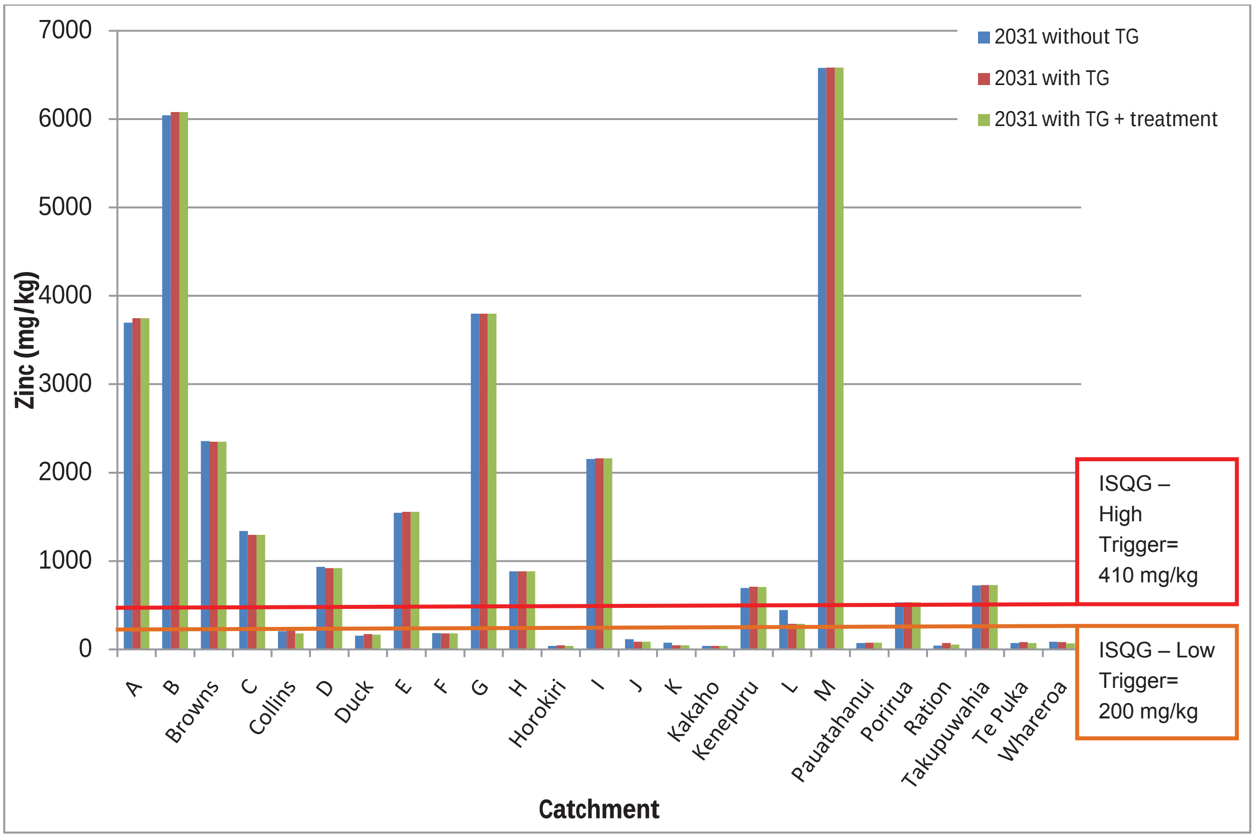
Graphs **Figure 15.79** and **Figure 15.80** includes the ANZECC (2000) guidelines in relation to stock drinking water, contact recreation and fish for human consumption. The CLM provides a useful comparison to these guidelines, because the CLM is considered conservative and these guidelines exceed the CLM estimations by some margin.

Of 25 streams draining to the Porirua Harbour, eleven are expected to have reduced contaminant loads as a result of the Project. The contaminant loads in a further nine are not predicted to change. **Appendix 15.X** illustrates the location of these catchments.

Many of the streams where reduced loads are predicted will not receive discharges from the Transmission Gully Project. The predicted reduction is due to the diversion of traffic off existing roads. This includes the Kakaho and the Browns streams, as well as many of the small watercourses that currently convey stormwater to the harbour.

The Porirua, Collins, Te Puka and Whareroa catchments will receive stormwater discharges from the Transmission Gully Project, and are also expected to have reduced contaminant loads. This is as a result of the diversion of traffic off existing roads that have no stormwater treatment and the effectiveness of the Project stormwater treatment devices.

The Kenepuru, Duck, Pauatahanui, Ration and Horokiri catchments are predicted to receive increased loads of metals and TPH. The effect of this increase should be considered within the context of the existing stream quality and stream flows.



▪ **Figure 15.76 Average Zinc Concentration for All Catchments**

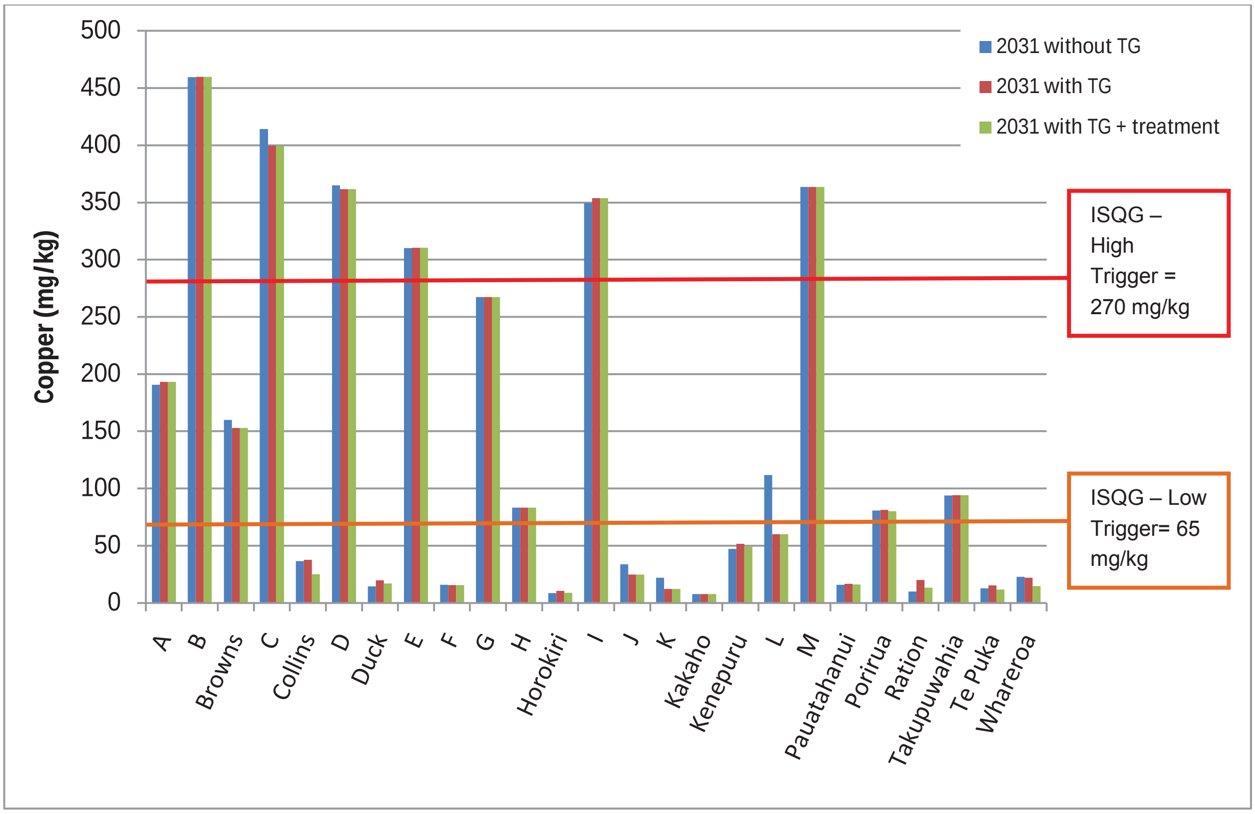


Figure 15.77 Average Copper Concentration for All Catchments

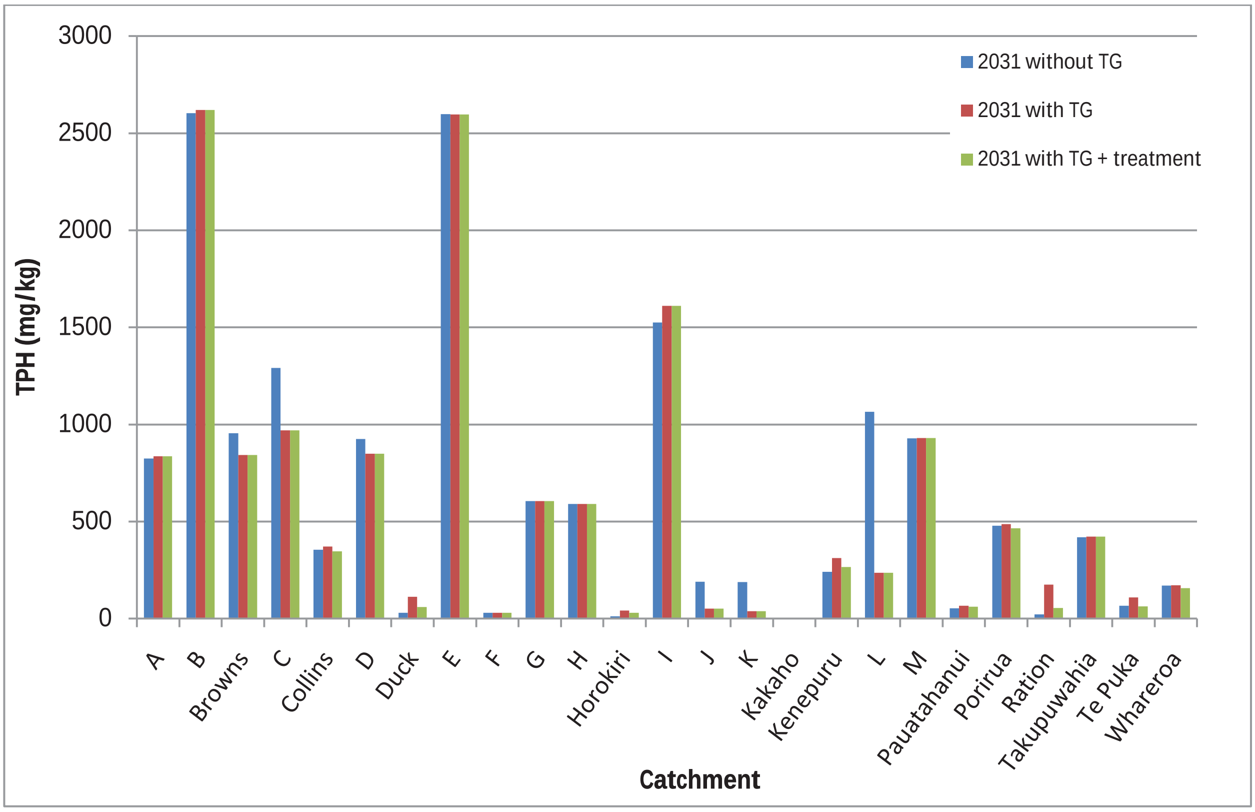
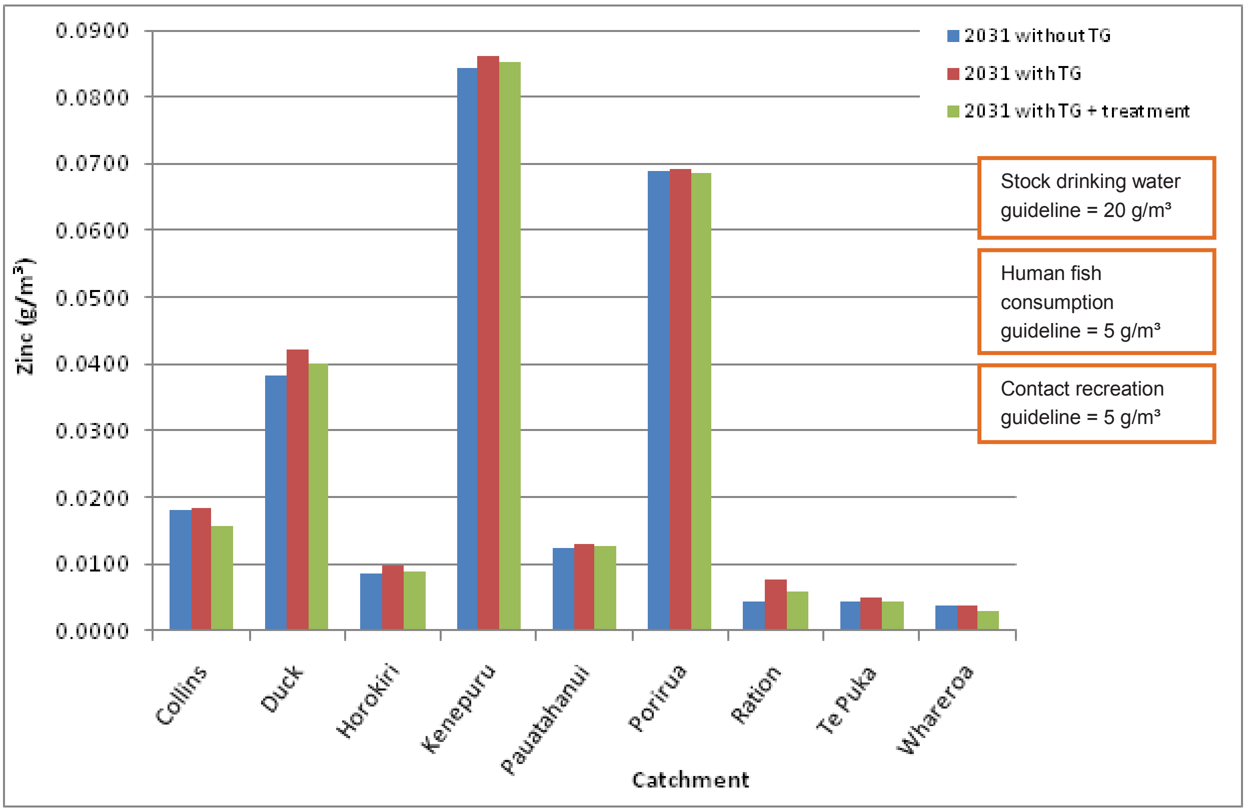


Figure 15.78 Average TPH Concentration for All Catchments



- **Figure 15.79 Average Zinc Concentrations for All Catchments**

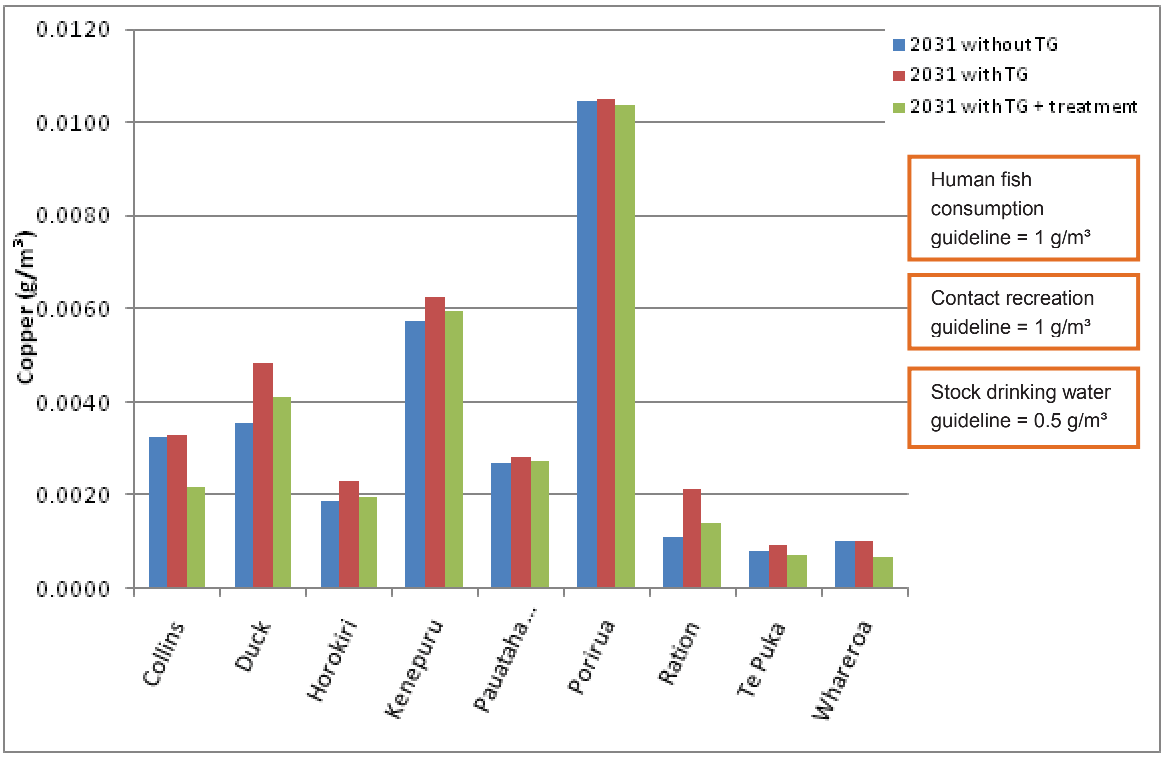
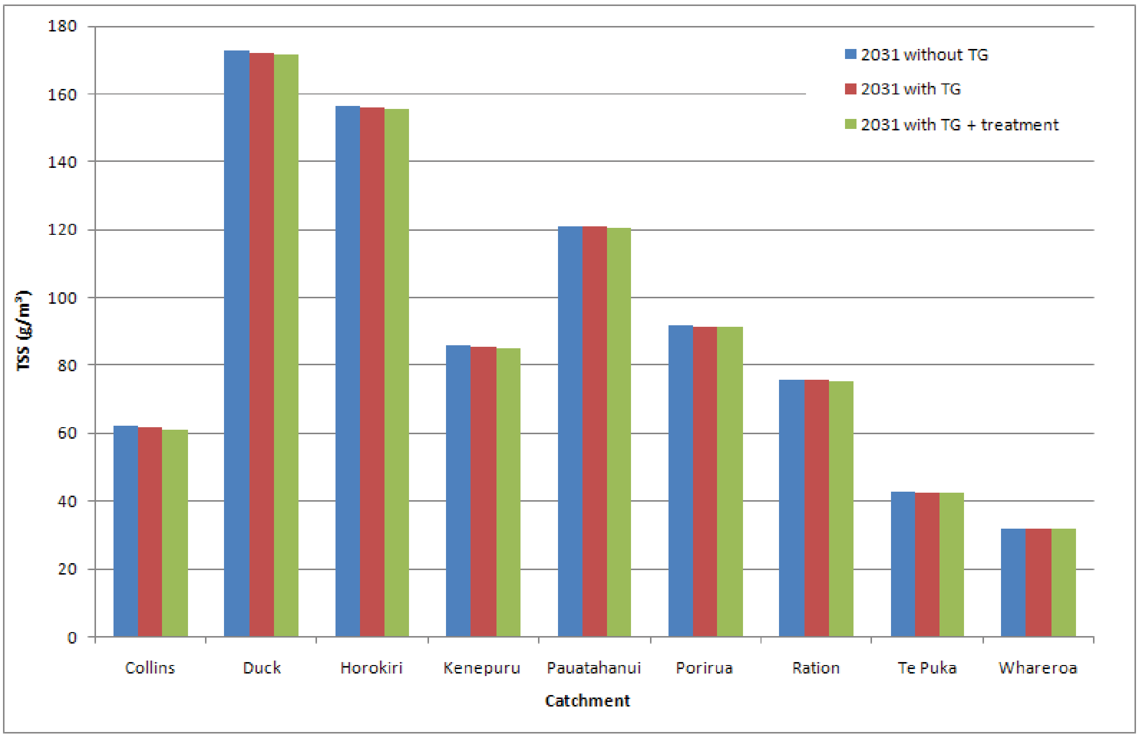
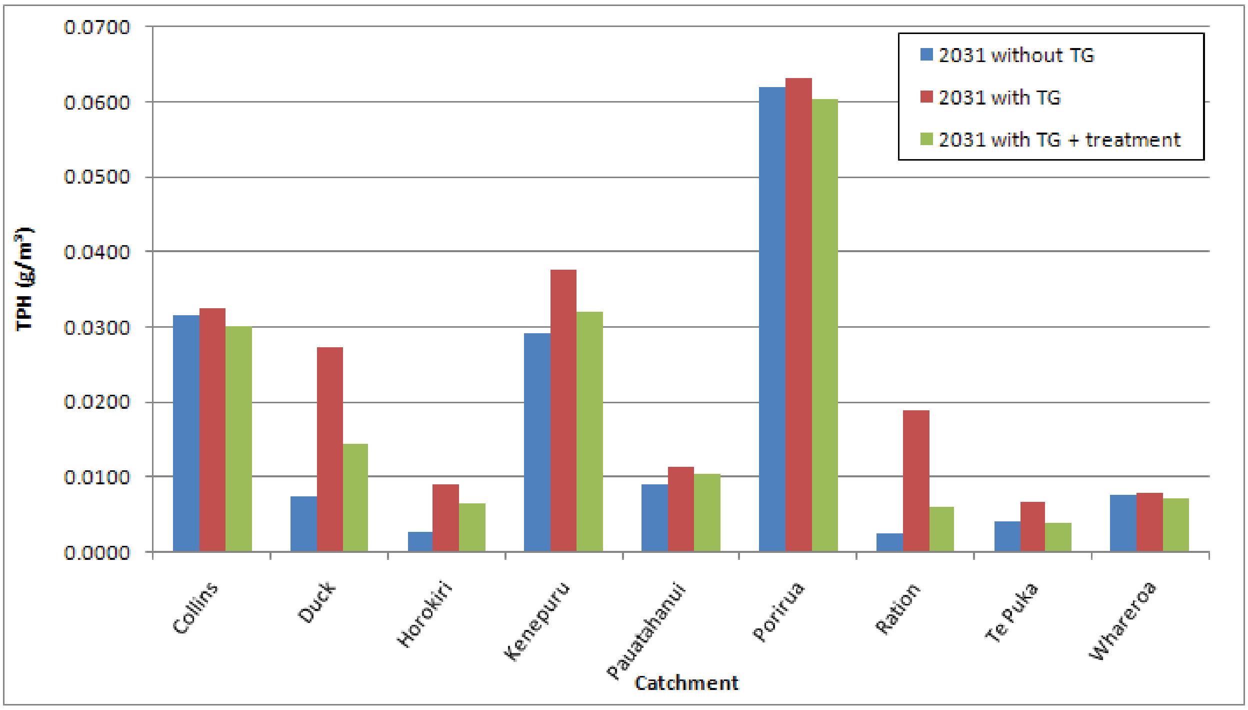


Figure 15.80 Average Copper Concentration for All Catchments



▪ **Figure 15.81 Average TSS Concentration for All Catchments**



▪ **Figure 15.82 Average TPH Concentration for All Catchments**

17.6.1. Metals

Figure 15.79 and **Figure 15.80** illustrate that the Horokiri, Pauatahanui and Ration catchments currently have relatively low levels of metals as result of their largely rural character. The Duck and Kenepuru catchments include residential development, and currently have higher levels of metals. The Transmission Gully Project will increase will increase concentrations of these metals in all these catchments, but the increase is small. Therefore the water quality in the streams is predicted to be similar to the situation without the road.

The CLM considers total metals. The water quality classification discussed in **Section 6** found that approximately 60% of total metals were in the dissolved fraction. The treatment removal of dissolved metals is less than for the particulate fraction. Wetlands remove approximately 40% of dissolved copper and 50% of dissolved zinc. The StormFilter can remove approximately 20% of dissolved copper and zinc. The dissolved fraction is important for the assessment of ecological effects, as it is bioavailable; this is discussed in **Section 17.1.**

17.6.2. TSS

Figure 15.81 illustrates that the predicted TSS concentrations are slightly less for all catchments; this is due to change in land use to paved road surface, which will generate less sediment than the existing pastoral landuse.

17.6.3. TPH

Figure 15.82 illustrates the predicted increase in TPH in the Duck, Horokiri, Kenepuru, Pauatahanui and Ration streams. The treatment devices are effective at removing TPH, but the increases as a proportion of the existing TPH is high in some catchments.

TPH can result in visual and odour effects. These effects are usually associated with high concentrations of untreated stormwater discharging to low energy environments where the mixing is limited. It should be noted that in the baseline sampling no conspicuous oil or grease and no objectionable odour associated with hydrocarbons was noted in any stream. It is anticipated that the predicted increase in TPH in all stream will result in visual or odour effects that are no more than minor.

17.7. Sediment Transport in Streams

The streams receiving discharges from Transmission Gully Project are steep high energy streams. Stream sediment transportation modelling was undertaken to assess the effect of the construction stormwater discharges on stream water quality. This work is discussed in **Section 11**.

Sediment loads are not predicted to increase in the operational phase. The particle size of sediment from the road may be marginally smaller than discharged from the rural land it displaces, but the effect of this on potential sediment deposition is considered very minor. The hydraulic characteristics of the streams will remain largely unaffected by the increased imperviousness associated with the road.

The results of the construction modelling in the scenario without the Project (see **Table 15.33** and **Table 15.34**) are relevant to the operational stormwater discharges when considering the potential for contaminated sediment to be deposited in the streams. The results illustrate that sediment is deposited in all streams in the 1/3 of the 2 year event and that a greater proportion of the sediment that is input into the stream in this smaller event is deposited, with larger more infrequent events transporting the majority of the sediment load, and scouring fines from the stream bed.

17.7.1. Sediment Quality

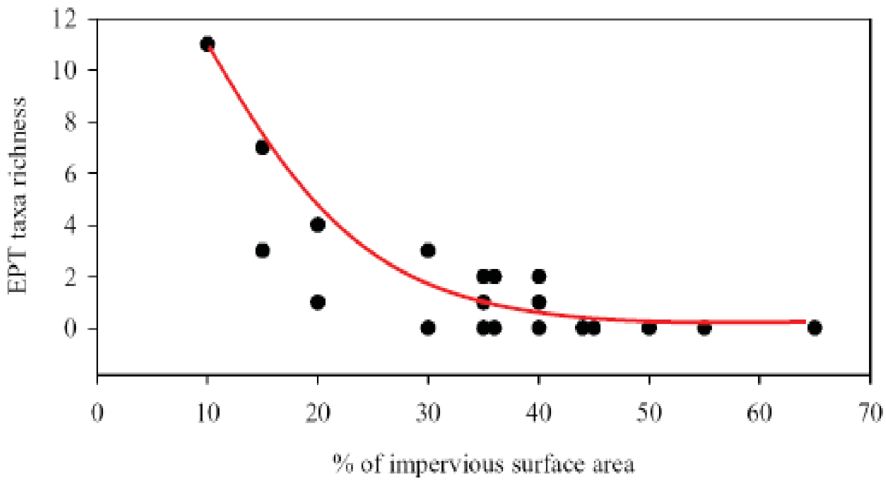
Figure 15.76 and **Figure 15.77** illustrate that in the scenario without the Transmission Gully Project the catchments that are predicted to exceed ANZECC ecological trigger levels for sediment quality are the Porirua for zinc (ISQG 'high') and copper (ISQG 'low'), the Kenepuru for zinc (ISQG 'high') and the Collins for zinc (ISQG 'low') These are also the only streams that are predicted to exceed the ecological trigger levels for sediment quality in the scenario with the Project. Of these the Porirua and the Collins are predicted to have decreased contaminant loads as a result of the Project. In the Kenepuru the predicted increase in zinc as a result of the road is 2%. In the Kenepuru the majority of sediment deposition occurs in the Cannons Creek lakes, limiting the effect of sediment deposition in this stream at locations downstream of the lakes.

For all other streams the predicted increased loads for zinc and copper are below the ISQG-low ecological trigger levels.

17.8. Catchment Imperviousness

Increased imperviousness in stream catchments can result in degradation of stream habitat due to changes in flow regime. This is due to the loss of natural evaporation, attenuation in soils and infiltration and the increased rate of runoff due to the reduction of friction.

Stream research generally indicates that certain zones of stream quality exist, most notably at about 10% impervious cover, where sensitive stream elements are lost from the system. A second threshold appears to exist at around 25 to 30% impervious cover, where most indicators of stream quality consistently shift to a poor condition, e.g., diminished aquatic diversity, water quality, and habitat scores (Tilburg and Merryl). This is evident in **Figure 15.83**, which compares the catchment impervious cover to sensitive species of macroinvertebrates (EPT - Ephermeroptera, Plecoptera and Trichoptera). As the impervious cover increases above 25 to 30%, the presence of sensitive macroinvertebrates diminishes (NZTA, 2010).



- **Figure 15.83 Catchment Impervious Cover compared to EPT (New Zealand Transport Agency, 2010)**

The Porirua and Kenepuru catchments have impervious areas at the higher threshold. The Duck catchment is close the lower threshold. The remaining catchments have low impervious cover areas, and are rural in nature. On an overall catchment basis, the Transmission Gully Project will have only a small impact on impervious area (**Table 15.64**).

- **Table 15.64 Connected Impervious Area with and without the Project**

Catchment	Existing % Connected Impervious Area	2031% Connected Impervious Area, Excluding Transmission Gully Project (% difference)	2031 % Connected Impervious Including Transmission Gully Project (% difference)
Collins	2	2 (<1%)	4 (<1%)

Kenepuru	23	26 (3)	26 (<1%)
Duck	9	11 (2)	12 (1)
Porirua	17	22 (5)	23 (1)
Ration	<1%	<1% (<1%)	1 (1)
Horokiri	<1%	0 (<1%)	1 (1)
Wainui/ Te Puka	1	1 (0)	3 (2)
Whareroa	<1%	2 (2)	3 (1)
Pauatahanui	1	1 (<1%)	1 (<1%)

According to the NZTA *Stormwater Treatment for State Highway Infrastructure* (May 2010), stream erosion control measures are applicable for rural catchments when the total imperviousness exceeds 3%. Considering the road and proposed development within the catchments at 2031, stream erosion control measures are required for Collins (4%), Wainui/Te Puka (3%), Whareroa (3%) and semi-rural catchment of Duck (12%).

Despite the minimal impact of the project on impervious areas within the catchment we should still look to provide as much attenuation as practicable within the existing drainage solutions. In those catchments where wetlands are used, these will be designed to release an extended detention volume over a 24 hour period. Wetlands help to mimic natural processes and allow for evaporation, attenuation and infiltration.

However, due to site constraints, it will not be possible to use wetlands in all catchments. In those catchments served by kerb and channel and proprietary devices, no attenuation will be provided. **Table 15.65** identifies those catchments where wetlands and proprietary devices are proposed, and the percentage of the road catchment treated.

▪ Table 15.65 Proposed Treatment Approach by Catchment

Catchment	Treatment Type	Area (m²)	%
Collins Stream	Wetland	158,808	100%
	Proprietary	0	0%
Duck Creek	Wetland	0	0%
	Proprietary	1,599,919	100%
Horokiri Stream	Wetland	2,045,111	69%
	Proprietary	903,292	31%
Kenepuru Stream	Wetland	0	0%
	Proprietary	959,988	100%
Pauatahanui Stream	Wetland	536,864	44%
	Proprietary	689,994	56%
Porirua Stream	Wetland	0	0%

Catchment	Treatment Type	Area (m²)	%
	Proprietary	906,871	100%
Ration Stream	Wetland	64,115	5%
	Proprietary	1,229,816	95%
Te Puka Stream	Wetland	320,587	20%
	Proprietary	1,262,158	80%
Whareroa Stream	Wetland	528,420	100%
	Proprietary	0	0%

Maps in Appendix 15.AA show the connected imperviousness attributed to the Project on a catchment and subcatchment basis. There is only a minor increase of 1 – 2% on the imperviousness in all catchments, which will have very minimal impact on the natural flow regimes (in the 10% AEP flood peaks increase by less than 1% in the 2031 scenario). Where space is available as in Collins and Whareroa catchments, road runoff will be treated by wetlands, with extended detention to mitigate the effects of increase imperviousness in these catchments, so the mapped impervious area is assumed as zero. In the Wainui/Te Puka catchment, and the Duck catchment, attenuation is not possible due to space. Water quality will be treated by proprietary devices and the minor impact to the flow regime will be somewhat offset by planting within the catchment.

In addition, the impact of increased flows has been assessed in terms of flood risk in key catchments to ensure attenuation effects are avoided, or effectively mitigated. Stream erosion will be managed at the location of stream discharges through erosion protection. Details of proposed erosion protection at outlets are outlined in Technical Report 14: *Assessment of Hydrology and Stormwater Effects.*

17.9. Coastal Contaminant Load

To gain an understanding of regional impacts of the construction of the road on the Porirua Harbour and the coastal environment, catchments were spatially grouped and modelled. Catchments were grouped into three regions – these are displayed in **Table 15.66** and mapped in **Appendix 15.X**.

- **Table 15.66 Catchment Groupings for Contaminant Load Model**

Grouped name	Catchments	Receiving Environment
Te Puka - Whareroa	Te Puka, Whareroa	Coastal area to north of alignment
Harbour North East (NE) Catchments	Horokiri, Kakaho, Ration, Collins, Pauatahanui, Duck, Browns, Catchment J, Catchment K, Catchment L, Catchment M	Pauatahanui Inlet of Porirua Harbour
Harbour South West (SW) Catchments	Kenepuru, Porirua, Takapuwahia, Catchment A, Catchment B, Catchment C, Catchment D, Catchment E, Catchment F, Catchment G, Catchment H, Catchment I	Onepoto Arm and Pauatahanui Inlet of Porirua Harbour

The CLM was computed for 2031 without and with the road constructed and treatment devices applied (**Table 15.67**). This highlights the regional differences that are predicted to occur due to the operation of the Project.

- **Table 15.67 Grouped Catchment Outputs - % Contaminant Load Change per Year**

Catchment	% Change Bottom of Grouped Catchment Loads (kg/yr)			
	TSS	Zn	Cu	TPH
2031 WITHOUT PROJECT to 2031 WITH PROJECT + TREATMENT OPTIONS				
Kapiti (Wainui/Te Puka – Whareroa)	-1	-4	-9	-14
Pauatahanui (NE catchments)	0	2	1	20
Onepoto (SW catchments)	-1	-6	-16	-44

17.9.1. Metals

The predicted concentrations for zinc and copper for all scenarios were well below the water quality guidelines for contact recreational purposes. See **Appendix 15.B** for guideline concentrations.

The majority of the modelled streams that discharge to the Onepoto Arm of the harbour are predicted to have either decreases or no change in predicted metal loads, resulting in an overall decrease in predicted metal loads. The exception is the Kenepuru stream which is predicted to have an increase in metal loads. When the predicted metal loads from the Kenepuru and Porirua Stream catchments are combined, this results in a very small increase in the total metal load at the outlet of the Porirua Stream.

Decreases in metal loads are expected on the Kapiti Coast the mouths of both the Wainui/Te Puka and the Whareroa streams.

A small overall increase in zinc (2%) and copper (1%) is expected in the Pauatahanui Inlet. In addition, the distribution of the contaminant load is predicted to change. Decreases or no change in metals loads are predicted at the mouths of the Browns and Kakaho streams and small watercourses draining to the Pauatahanui inlet of the harbour. Small increases in metal loads are expected at the mouths of the Duck, Pauatahanui, Ration and Horokiri streams.

The loads predicted by the CLM are very conservative and should not be directly used for ecological assessment. However, they are useful for considering relative changes. For example, the predicted increase in the metal load in the Ration Stream is similar to loads found in other small streams discharging the harbour in the scenario without the Project. The metal load is predicted to increase in the Horokiri Stream catchment. However, the load will still be less than the Duck catchment in the scenario without the Project. Metal loads are also predicted to increase in the Duck Creek catchment, but the load will still be less than that in the Porirua Stream catchment in the scenario without the Project.

It is appropriate to consider the quality of the sediment at the mouths of streams in the harbour at the current time and use this data to infer quality at other sites, based on the relative predictions from the CLM. However, consideration must be given harbour sediment transport processes, causing sediment accumulation in the deep basins in each arm. Harbour sediment transport is discussed in detail in **Section 10**.

17.9.2. TSS

Decreases or no change in TSS is expected in all coastal environments. This is due to the change in land use from the existing pastoral landuse to an increase in the paved road surface, which will generate less sediment.

17.9.3. TPH

Decreases in TPH loads are expected overall in the Onepoto Arm of the harbour. The majority of modelled streams that discharge to this arm of the harbour have decreased or no change in predicted TPH loads. The exception is the Kenepuru Stream where TPH is predicted to increase, however, when the predicted TPH load from the Kenepuru and Porirua Stream catchments is combined this results in a very small increase in the total TPH load at the outlet of the Porirua Stream.

Decreases in TPH loads are expected on the Kapiti Coast at both the mouths of Wainui/Te Puka and the Whareroa streams.

An overall increase in TPH of 20% is expected in the Pauatahanui Inlet. In addition, the distribution of the TPH load changes. Decreases or no change in TPH loads are predicted at the mouths of the Browns and Kakaho streams and small watercourses draining to the Pauatahanui Inlet. Increases in TPH loads are expected at the mouths of the Duck Creek and Pauatahanui, Ration and Horokiri Stream catchments

The large proportion of the increase is due to the low levels of TPH currently found in many of the streams. The loads predicted by the CLM are very conservative and should not be directly used for ecological assessment. However, they are useful for considering relative changes. For example, the predicted increase in the load in the Ration is similar to loads found in other small streams discharging the harbour in the scenario without the Project. The TPH load is predicted to increase in the Horokiri Stream catchment. This load is still lower than TPH loads predicted for the Duck and Pauatahanui catchments in the scenario without the Project.

It is appropriate to consider the quality of the sediment at the mouths of streams in the harbour at the current time and use this data to infer quality at other sites, based on the relative predictions from the CLM. However, consideration must be given harbour sediment transport processes, causing sediment accumulation in the deep basins in each arm. Harbour sediment transport is discussed in detail **Section 10**.

TPH can result in visual and odour effects and it can also cause water to become unsuitable for contact recreation. These effects are usually associated with high concentrations of untreated stormwater discharging to low energy environments where mixing is limited. It should be noted that in the baseline sampling no conspicuous oil or grease was noted and no objectionable odour associated with hydrocarbons at any of the stream locations. It is anticipated that the predicted increase in TPH in all streams will result in visual or odour effects that are no more than minor. Therefore we anticipate that any visual, odour and contact recreation effects associated with the predicted increase in TPH will be no more than minor.

18. Operational Assessment of Effects

The following summarises the assessed effect on the water quality in each stream as a result of the operation of the Transmission Gully Project. This assessment of effects does not address potential effects of stormwater discharge on aquatic ecosystems, which are separately addressed in Technical Report 11: *Ecological Impact Assessment*.

In each case the assessment criteria are based on permitted activity conditions and / or water quality guidelines from the RFP. Effects have been considered once ‘reasonable mixing’ has occurred; predictions from the contaminant load model have been compared with the average wet day flow to provide for reasonable mixing.

18.1. Porirua Stream

In the Porirua catchment, stormwater management devices will treat all runoff from the paved area of the Transmission Gully Project. The assessment assumes 100% is treated by StormFilters.

The Porirua Stream is not identified in the RFP as having any specific management objectives.

The assessment criteria below (**Table 15.68**) include the permitted standard conditions.

- **Table 15.68 Porirua Stream Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	Contaminant load is expected to decrease therefore no change expected as a result of the discharge. All treatment devices have gross pollutant traps thus no more than minor increase in floatable or suspended material is expected as a result of the discharge
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease therefore no change expected as a result of the discharge.
Any emission of objectionable odour.	TPH is predicted to decrease therefore no change expected as a result of the discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge.
Any significant adverse effects on aquatic life	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge. No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is 1%, no more than minor change in flow regime expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment*
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha	Stormwater discharge is from the paved road surface, not bulk earthworks and therefore no change expected as a result of the discharge
Concentrations of acid-soluble aluminium in the discharge shall be no more than	Aluminium is not a characteristic of road runoff and therefore no change is expected as a result of the discharge

0.15g/m³	
The discharge does not cause erosion at the point of discharge.	Point source erosion is provided at all outlets. No more than minor change is expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets, therefore a no more than minor change is expected as a result of the discharge. The increase in imperviousness is 1%, therefore a no more than minor change in flow regime expected as a result of the discharge

18.2. Kenepuru Stream

In the Kenepuru catchment, stormwater management devices will treat all runoff from the paved area of the Transmission Gully Project. The assessment assumes 100% is treated by StormFilters.

The Kenepuru Stream is not identified in the RFP as having any specific management objectives.

The assessment criteria below (**Table 15.69**) include the permitted standard conditions.

- **Table 15.69 Kenepuru Stream Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TPH is expected to increase, production of conspicuous oil or grease films considered no more than minor change expected as a result of discharge. No change to the level of scums and foams is expected as a result of the discharge. All treatment devices have gross pollutant traps so a no more than minor increase in floatable or suspended material is expected.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease as a result of the Project, so no change is expected as a result of the discharge.
Any emission of objectionable odour.	TPH is expected to increase as a result of the Project but this is expected to result in a no more than minor change to the production of odours as a result of the discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	Metals are predicted to increase but will still be below stock drinking water guidelines.
Any significant adverse effects on aquatic life.	Metals and TPH are expected to increase. No more than minor change in stream sediment deposition as a result of the discharge. The increase in imperviousness is 1% which will result in a no more than minor change in flow regime as a result of the discharge. See Technical Report 11 *Ecological Impact Assessment* for further details.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha.	Stormwater discharge is from the paved road surface, not bulk earthworks and so no change is expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change is expected as a result of the discharge.

The discharge does not cause erosion at the point of discharge.	Point source erosion control is provided at all outlets. No more than minor change expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than a minor change is expected as a result of the discharge. Increase in imperviousness is 1% so no more than a minor change in flow regime is expected as a result of the discharge.

18.3. Duck Creek

In the Duck Creek catchment, there are five stormwater management devices, which will treat all runoff from the paved area of the Transmission Gully Project. The assessment assumes that 100% of stormwater is treated by StormFilters.

The Duck Creek is identified in the RFP as being managed for nationally threatened indigenous fish.

The assessment criteria below include the permitted standard conditions and the water quality guidelines for aquatic ecosystem purposes from the RFP.

- **Table 15.70 Duck Creek Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TPH is expected to increase, but it is considered this will result in a no more than minor change as a result of discharge. All treatment devices have gross pollutant traps therefore no more than minor increase in floatable or suspended material as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease, no change expected as a result of the discharge
Any emission of objectionable odour.	TPH is expected to increase, production of odour considered no more than minor change expected as a result of discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	Metals are predicted to increase but will still be below stock drinking water guidelines.
Any significant adverse effects on aquatic life.	Metals and TPH are expected to increase. No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is 1% so no more than minor change in flow regime is expected. See Technical Report 11: *Ecological Impact Assessment*.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha.	Stormwater discharge is from the paved road surface, not bulk earthworks, so no change is expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change is expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge.

The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge. Increase in imperviousness is <1%, therefore no more than minor change in flow regime is expected as a result of the discharge.
The natural temperature of the water shall not be changed by more than 3° Celsius.	Temperature change >3 degrees is not predicted as a result of the discharge.
Any pH change.	No more than minor change in pH is predicted as a result of the discharge.
Any increase in the deposition of matter on the bed of the water body.	No more than minor change in stream sediment deposition as a result of the discharge.
The concentration of dissolved oxygen falls below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.
There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	No undesirable biological growths are expected as result of the discharge.

18.4. Pauatahanui Stream

In the Pauatahanui catchment, there are three stormwater management devices – two StormFilters and one wetland. Together they will treat all runoff from the paved area of the Transmission Gully Project. The assessment assumes 44% of the catchment is treated by wetlands and 56% is treated by StormFilters.

The Pauatahanui Stream is identified in the RFP as being managed for nationally threatened indigenous fish; it is also managed for aquatic ecosystems, due to its high degree of natural character.

The assessment criteria below include the permitted standard conditions and the water quality guidelines for aquatic ecosystem purposes from the RFP.

- **Table 15.71 Pauatahanui Stream Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TPH is expected to increase, but it is considered this will result in a no more than minor change as a result of discharge. All treatment devices have gross pollutant traps, no more than minor increase in floatable or suspended material as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease, no change expected as a result of the discharge.
Any emission of objectionable odour.	TPH is expected to increase, production of odour considered no more than minor change expected as a result of discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	Metals are predicted to increase but will still be below stock drinking water guidelines.
Any significant adverse effects on aquatic life	Metals and TP H are expected to increase. No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is <1% and extended detention is provided for 44% of catchment, therefore no more than minor change in flow

	regime expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment* for further details.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha.	Stormwater discharge is from the paved road surface, not bulk earthworks, no change expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge. Increase in imperviousness is <1% and extended detention is provided for 44% of catchment, therefore no more than minor change in flow regime expected as a result of the discharge.
The natural temperature of the water shall not be changed by more than 3° Celsius.	Temperature change >3 degrees is not predicted as a result of the discharge.
Any pH change.	No more than minor change in pH is predicted as a result of the discharge.
Any increase in the deposition of matter on the bed of the water body.	No more than minor change in stream sediment deposition as a result of the discharge.
The concentration of dissolved oxygen to fall below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.
There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	No undesirable biological growths are expected as result of the discharge.

18.5. Ration Stream

In the Ration catchment, there are four stormwater management devices, which will treat all runoff from the paved area of the Transmission Gully Project. The assessment assumes that 5% of the road runoff is treated by wetlands and 95% is treated by StormFilters.

The Ration stream is identified in the RFP as being managed for nationally threatened indigenous fish.

The criteria and assessment in **Table 15.72** includes the permitted standard conditions and the water quality guidelines for aquatic ecosystem purposes from the RFP.

▪ Table 15.72 Ration Stream Assessment of Effects

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TPH is expected to increase, but it is considered this will result in a no more than minor change as a result of discharge. All treatment devices have gross pollutant traps, thus no more than minor increase in floatable or suspended material is expected as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease, no change expected as a result of the discharge.

Any emission of objectionable odour.	TPH is expected to increase, production of odour considered no more than minor change expected as a result of discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	Metals are predicted to increase but will still be below stock drinking water guidelines.
Any significant adverse effects on aquatic life	Metals and TPH are expected to increase. No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is 1%, therefore no more than minor change in flow regime expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment* for more detail.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha;	Stormwater discharge is from the paved road surface, not bulk earthworks, therefore no change expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge. Increase in imperviousness is 1%, no more than minor change in flow regime expected as a result of the discharge.
The natural temperature of the water shall not be changed by more than 3° Celsius.	Temperature change of >3 degrees is not predicted as a result of the discharge.
Any pH change.	No more than minor change in pH is predicted as a result of the discharge.
Any increase in the deposition of matter on the bed of the water body.	No more than minor change in stream sediment deposition as a result of the discharge.
The concentration of dissolved oxygen to fall below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.
There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	No undesirable biological growths are expected as result of the discharge.

18.6. Collins Stream

There are no stormwater management devices in the Collins Stream catchment. Road runoff is treated by a wetland in the Pauatahanui Stream catchment, which will treat all runoff from the paved area within the Collins Stream catchment. The assessment assumes 100% of this catchment is treated by this wetland.

The Collins Stream is not identified in the RFP as having any specific management objectives.

The assessment criteria in **Table 15.73** include the permitted standard conditions.

- **Table 15.73 Collins Stream Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	The contaminant load is expected to decrease therefore no change is expected as a result of the discharge. All treatment devices have gross pollutant traps therefore no more than minor increase in floatable or suspended material is expected.

Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease; therefore no change is expected as a result of the discharge.
Any emission of objectionable odour.	TPH is predicted to decrease, therefore no change is expected as a result of the discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge.
Any significant adverse effects on aquatic life	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge. No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is 1%, no more than minor change in flow regime expected.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha.	Stormwater discharge is from the paved road surface, not bulk earthworks; no change is expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change is expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge. Increase in imperviousness is 1% therefore no more than minor change in flow regime expected as a result of the discharge.

18.7. Horokiri Stream

In the Horokiri catchment, there are six stormwater management devices – three StormFilters and three wetlands. Together they will treat all runoff from the paved area of the Transmission Gully Project in this catchment. The assessment assumes 69% of the catchment is treated by wetlands and 31% is treated by StormFilters.

The Horokiri stream is identified in the RFP as being managed for nationally threatened indigenous fish. It is also managed for aquatic ecosystems, due to its high degree of natural character.

The criteria and assessment in **Table 15.74** includes the permitted standard conditions and the water quality guidelines for aquatic ecosystem purposes from the RFP.

- **Table 15.74 Horokiri Stream Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TPH is expected to increase, but it is considered this will result in a no more than minor change as a result of discharge. All treatment devices have gross pollutant traps therefore there will be no more than minor increases in floatable or suspended material as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease therefore no change expected as a result of the discharge.
Any emission of objectionable odour.	TPH is expected to increase, but is expected to result in a change in the production of odour at no more than minor levels.

The rendering of freshwater unsuitable for consumption by farm animals.	Metals are predicted to increase but will still be below stock drinking water guidelines.
Any significant adverse effects on aquatic life	Metals and TPH are expected to increase No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is 1% and extended detention is provided for in 69% of the catchment. Therefore, no more than minor change in flow regime is expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment* for further details.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha.	Stormwater discharge is from the paved road surface, not bulk earthworks, therefore no change expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change is expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge;	Point source erosion is provided at all outlets. No more than minor change is expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than minor change is expected as a result of the discharge. Increase in imperviousness is 1%, extended detention is provided for 69% of the catchment. No more than minor change in flow regime is expected as a result of the discharge.
The natural temperature of the water shall not be changed by more than 3° Celsius.	Temperature change >3 degrees is not predicted as a result of the discharge
Any pH change.	No more than minor change in pH is predicted as a result of the discharge.
Any increase in the deposition of matter on the bed of the water body.	No more than minor change in stream sediment deposition as a result of the discharge.
The concentration of dissolved oxygen to fall below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.
There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	No undesirable biological growths are expected as result of the discharge.

18.8. Wainui /Te Puka

In the Wainui / Te Puka catchment, there are six stormwater management devices – five StormFilters and one wetland. Together they will treat all runoff from the paved area of the Transmission Gully Project in this catchment. The assessment assumes 20% of the catchment is treated by wetlands and 80% is treated by StormFilters.

The Wainui / Te Puka stream is identified in the RFP as being managed for nationally threatened indigenous fish, aquatic ecosystems purposes and fish spawning. The Wainui stream is also managed for water supply purpose, but the Transmission Gully Project is downstream of the water supply intake and therefore will not impact on water supply quality.

The criteria and assessment in **Table 15.75** includes the permitted standard conditions and the water quality guidelines for aquatic ecosystem purposes from the RFP.

Table 15.75 Wainui /Te Puka Stream Assessment of Effects

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	Contaminant load is expected to decrease therefore no change is expected as a result of the discharge. All treatment devices have gross pollutant traps therefore no more than minor increase in floatable or suspended material is expected.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease therefore no change is expected as a result of the discharge.
Any emission of objectionable odour.	TPH is predicted to decrease therefore no change is expected as a result of the discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge.
Any significant adverse effects on aquatic life.	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge. No more than minor change in stream sediment deposition as a result of the discharge. Increase in imperviousness is 2% and extended detention is provided for 20% of the catchment, therefore no more than minor change in flow regime expected. See Technical Report 11: *Ecological Impact Assessment* for further details.
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha.	Stormwater discharge is from the paved road surface, not bulk earthworks therefore no change is expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³.	Aluminium is not a characteristic of road runoff. No change expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge.	Point source erosion is provided at all outlets. No more than minor change expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No more than minor change is expected as a result of the discharge. Increase in imperviousness is 2% and extended detention is provided for 20% of the catchment therefore no more than minor change in flow regime expected.
The natural temperature of the water shall not be changed by more than 3° Celsius.	Temperature change >3 degrees is not predicted as a result of the discharge.
Any pH change.	No more than minor change in pH is predicted as a result of the discharge.
Any increase in the deposition of matter on the bed of the water body.	No more than minor change in stream sediment deposition is expected as a result of the discharge.
The concentration of dissolved oxygen to fall below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.
There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	No undesirable biological growths are expected as result of the discharge.

The natural temperature of the water no to exceed 25 degrees	Temperature change >25degrees is not predicted as a result of the discharge.
Fish not to be rendered unsuitable for human consumptions by the presence of contaminants	See Technical Report 11: *Ecological Impact Assessment* for further details.

18.9. Whareroa

In the Whareroa catchment, stormwater management devices will treat all runoff from the paved area of the Transmission Gully Project in this catchment. The assessment assumes 100% of the catchment is treated by wetlands.

The Whareroa stream is identified in the RFP as being managed for nationally threatened indigenous fish (aquatic ecosystems purposes).

The criteria and assessment in **Table 15.76** include the permitted standard conditions and the water quality guidelines for aquatic ecosystem purposes from the RFP.

- **Table 15.76 Whareroa Stream Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	Contaminant load is expected to decrease therefore no change is expected as a result of the discharge. All treatment devices have gross pollutant traps, no more than minor increase in floatable or suspended material expected as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to therefore no change is expected as a result of the discharge.
Any emission of objectionable odour.	TPH is predicted to decrease therefore no change is expected as a result of the discharge.
The rendering of freshwater unsuitable for consumption by farm animals.	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge.
Any significant adverse effects on aquatic life.	TSS and metals are predicted to decrease therefore no change is expected as a result of the discharge. No more than minor change in stream sediment deposition is expected as a result of the discharge. Increase in imperviousness is 1% and extended detention is provided for 100% of the catchment therefore no more than minor change in flow regime is expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment*
The discharge does not originate from an area of bulk earthworks greater than 0.3 ha;	Stormwater discharge is from the paved road surface, not bulk earthworks, therefore no change is expected as a result of the discharge.
Concentrations of acid-soluble aluminium in the discharge shall be no more than 0.15g/m³;	Aluminium is not a characteristic of road runoff. No change is expected as a result of the discharge.
The discharge does not cause erosion at the point of discharge;	Point source erosion is provided at all outlets. No change is expected as a result of the discharge.
The discharge does not alter the natural course of the river or stream.	Point source erosion is provided at all outlets. No change is expected as a result of the discharge. Increase in imperviousness is 1%, extended detention is provided for

	100% of the catchment, no more than minor change in flow regime expected as a result of the discharge.
The natural temperature of the water shall not be changed by more than 3° Celsius.	A temperature change >3 degrees is not predicted as a result of the discharge.
Any pH change.	No more than minor change in pH is predicted as a result of the discharge.
Any increase in the deposition of matter on the bed of the water body.	No more than minor change in stream sediment deposition as a result of the discharge.
The concentration of dissolved oxygen to fall below 80% of saturation concentration.	DO is not expected to drop below 80% as a result of the discharge.
There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.	No undesirable biological growths are expected as result of the discharge.

19. Operational Coastal Assessment of Effects

The following summarises the assessed effect on the water quality on the Porirua Harbour and Kapiti Coast as a result of the operation of the Transmission Gully Project. This assessment of effects does not address potential effect of stormwater discharge on aquatic ecosystems, which are separately addressed in Technical Report 11: *Ecological Impact Assessment*.

In each case the assessment criteria are based on permitted activity conditions from the Regional Coastal Plan (GWRC, 2000). Effects have been considered once 'reasonable mixing' has occurred; predictions from the contaminant load model have been compared with the average wet day flow to provide for reasonable mixing.

19.1. Onepoto Arm

The CLM was used to model stormwater inputs from 12 water courses into the Onepoto Arm. Of these two will receive discharge from the Transmission Gully Project. **Table 15.77** summarises the assessed effect of the Project on water quality in the Onepoto Arm.

Table 15.77 Onepoto Arm Assessment of Effects

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge All treatment devices have gross pollutant traps therefore no more than a minor increase in floatable or suspended material is expected as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.
Any emission of objectionable odour.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.
Any significant adverse effects on aquatic life.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment* for further information.
The rendering of water unsuitable for bathing by the presence of contaminants.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.
Undesirable biological growths.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.

19.2. Pauatahanui Inlet

The CLM was used to model stormwater inputs from 11 water courses into the Pauatahanui Inlet. Of these 5 will receive discharge from the Transmission Gully Project. **Table 15.78** summarises the assessed effect of the Project on water quality in the Pauatahanui Inlet.

Table 15.78 Pauatahanui Inlet Assessment of Effects

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TPH is expected to increase, production of conspicuous oil or grease films considered no more than minor change expected as a result of discharge. All treatment devices have gross pollutant traps, no more than minor

	increase in floatable or suspended material expected as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS is predicted to decrease, no change expected as a result of the discharge.
Any emission of objectionable odour.	TPH is expected to increase, but the production of odour is considered to be no more than minor change expected as a result of discharge.
Any significant adverse effects on aquatic life.	TPH and metals expected to increase. Sediment discharged in stormwater is expected to accumulate in the central basin. See Technical Report 11: *Ecological Impact Assessment* for further information.
The rendering of water unsuitable for bathing by the presence of contaminants.	TPH and metals expected to increase. Zinc and copper concentrations are predicted to be well below the contact recreation guidelines. The effects on contact recreation as a result of TPH are predicted to be not more than minor.
Undesirable biological growths.	No change in nutrients predicted. No change expected as a result of the discharge.

19.3. Kapiti Coast

The CLM has been used to model stormwater inputs from the Whareroa and Wainui/Te Puka Stream; both catchments receive discharge from the Transmission Gully Project. **Table 15.79** summarises the assessed effect of the Project on water quality on the Kapiti Coast.

- **Table 15.79 Kapiti Coast Assessment of Effects**

Assessment Criteria	Assessed Effect
The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge. All treatment devices have gross pollutant traps, no more than minor increase in floatable or suspended material expected as a result of the discharge.
Any conspicuous change in the colour or visual clarity.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.
Any emission of objectionable odour.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.
Any significant adverse effects on aquatic life.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge. See Technical Report 11: *Ecological Impact Assessment*
The rendering of water unsuitable for bathing by the presence of contaminants.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.
Undesirable biological growths.	TSS, metals and TPH are predicted to decrease therefore no change is expected as a result of the discharge.

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