Appendix 15.A Grab Sample Water Quality Parameters

Test Group	Parameter	Test location
Trace Metals - dissolved and totals	Arsenic	Lab
	Chromium	Lab
	Copper	Lab
	Nickel	Lab
	Cadmium	Lab
	Lead	Lab
	Zinc	Lab
	Acid soluble aluminium	Lab
Organic compounds	Polycyclic aromatic hydrocarbons (PAH)	Lab
	Benzene, toluene, ethylbenzene, xylene (BTEX)	Lab
Nutrients	Total Nitrogen	Lab
	Total Ammoniacal Nitrogen	Lab
	Total Phosphorus (TP)	Lab
	Dissolved Inorganic Nitrogen (DIN)	Lab
	Total Kjeldahl Nitrogen	Lab
	Nitrite-nitrate Nitrogen	Lab
	Dissolved Reactive Phosphorus (DRP)	Lab
Physical tests	Dissolved oxygen saturation	Field
	Temperature	Field
	pH	Field
	Conductivity	Field
	Turbidity	Lab
	Total Suspended Solids	Lab
Field observations	Oil or grease films	Field
	Scums or foams	Field
	Floatable or suspended materials	Field
	Objectionable odour	Field
	Colour and visual clarity	Field – Munsell Colour and Black Disc Clarity

Appendix 15.B Water Quality Guidelines

Those guidelines relevant to baseline sampling and relevant to the parameters expected in stormwater discharges during the construction and operational phase are summarised in this section

Tables B.1 to B.6 give trigger values used in interpreting the baseline water quality data for parameters grouped by their potential effect. Parameters where there no relevant triggers exist are listed in **Table B.7**.

- **Table B.1 Trigger Levels for Toxicants Applied to Freshwater Streams in Transmission Gully Catchments**

Parameter	Trigger value	Source
Total and dissolved metals[f] (g/m^3)		
Arsenic (AsV)	0.013[c]	
Chromium (CrVI)	0.001[d]	
Copper	0.0014	
Nickel	0.011	ANZECC 2000 95% Ecological trigger value
Cadmium	0.0002	
Lead	0.0034	
Zinc	0.008	
Acid soluble aluminium	0.15[e]	Greater Wellington 1999
Aluminium	0.055[e]	ANZECC 2000 95% Ecological trigger value
C6-C9 Aromatic hydrocarbons (g/m^3)		
Benzene	0.95	
Toluene	0.18[a]	
Ethylbenzene	0.08[a]	ANZECC 2000 95% Ecological trigger value
m & p-Xylene	0.075[a]	
o - Xylene	0.35	
Polycyclic aromatic hydrocarbons (PAH's) (g/m^3)		
Anthracene	1×10^{-5}	ANZECC 2000 99% Ecological trigger value
Benzo[a]pyrene (BAP)	0.0008	
Chrysene	-	-
Fluoranthene	0.001	ANZECC 2000 99% Ecological trigger value
Fluorene	0.003	Canadian 2002
Naphthalene	0.05	ANZECC 2000 99% Ecological trigger value
Phenanthrene	6×10^{-4}	
Pyrene	2.5×10^{-5}	Canadian 2002

Notes:

[a] In general the 95% protection level has been used unless noted (to provide for protection of 95% of species in typical slightly-moderately disturbed systems).

[b] The ANZECC guidelines state that some polycyclic aromatic hydrocarbons (PAH's) have the potential to bioaccumulate. Where no bioaccumulation data is available it is recommended to apply 99% trigger level

[c] More conservative arsenic trigger value used (vs AsIII) as speciation is not determined in results

[d] More conservative chromium trigger value used as Cr speciation is not determined in results

[e] The Regional Freshwater Plan sets a limit that the concentration of acid soluble aluminium in discharges shall not exceed this value. It is used in this report for comparison of whether the background concentration already exceeds that limit only.

[f] Both total and dissolved metal concentrations have been measured. The dissolved fraction is more bioavailable and therefore gives a better indication of toxicity. Concentrations of total metals will therefore tend to overestimate the amount that is bioavailable. Both total and dissolved concentrations have been compared to the trigger levels.

[g] Aluminium limit in the ANZECC guidelines is for pH >6.5. Some sample results will be different pH's.

- **Table B.2 Trigger Levels for Physical and Chemical Stressors Applied to Freshwater Streams in Transmission Gully Catchments[a]**

Parameter	ANZECC 2000 risk based trigger values	Greater Wellington 1999
Nutrients (g/m^3 unless stated)		
Total Phosphorus	0.033	
Dissolved Reactive Phosphorus[b]	0.01	
Total Nitrogen	0.614	
Total Ammoniacal Nitrogen[c]	0.021	
Nitrogen Oxides[c]	0.444	
pH	Typical values between 6.5 - 9.0	No pH change shall be involved if it has an adverse effect on aquatic life[d]
Dissolved Oxygen	98-105%	Shall not fall below 80% saturation

Notes:

[a]Trigger values are applicable to slightly disturbed ecosystems in New Zealand. Where slightly disturbed ecosystems are defined as aquatic ecosystems that may have some experienced some adverse effects caused by human activity.

[b] The guidelines are for Filterable Reactive Phosphorous (FRP), this is the same as DRP as long as a suitable sized filter is used.

[c]Dissolved inorganic nitrogen (DIN) has also been measured. Because there is no trigger level for DIN, we have compared total ammoniacal nitrogen (NH_4^+) and nitrogen oxides (NO_x) to their respective trigger levels, where DIN = $NH_4^+ + NO_x$

[d]Level applies to streams managed for aquatic ecosystems only.

- **Table B.3 Trigger Levels for Other Measured Parameters Applied to Freshwater Streams in Transmission Gully Catchments**

Parameter	ANZECC 2000	Greater Wellington 1999	NZ specific guideline
Temperature (C°)		The natural temperature of the water should not be changed by more than 3°C	
Turbidity (NTU)			15[a] (upper limit)
Oil or grease films		Presence of conspicuous	
Scums or foams		Presence of conspicuous	
Floatable or suspended materials		Presence of conspicuous	
Objectionable odour		Presence of conspicuous	
Munsell colour (Munsell units)		Conspicuous change in colour	
Black disc clarity (m)	0.8[b] (lower limit)	Conspicuous change in clarity	

Notes:

[a]Upper limit defined by Boubee et al., 1997 which should be maintained in clear water streams to allow the migration of the most common New Zealand native freshwater fish species. If clarity measurements are not able to be obtained guidance for turbidity should be used instead. The turbidity should not be changed by more than 30% (Opus, 2008).

[b] Default trigger value for unmodified or slightly disturbed ecosystems in New Zealand

Table B.4 Trigger Levels for Parameters Relevant to Livestock Water Consumption

Parameter	ANZECC 2000 threshold (g/m^3)
Total Dissolved Solids	2000[a]
Aluminium	5
Total Arsenic	0.5
Total Cadmium	0.01
Total Copper	0.5
Total Chromium	1
Total Nickel	1
Total Zinc	20
Nitrate-Nitrogen	1772[b]
Nitrite-Nitrogen	5850[c]

Notes:

[a] Lower threshold for poultry used. Above this threshold animals may have initial reluctance to drink or there may be some scouring, but stock should be able to adapt without loss of production. Higher thresholds exist for beef cattle (4000), dairy cattle (2400), sheep (4000), horses (4000) and pigs (4000). Additional higher thresholds where a loss of production and decline in animal condition and health would be expected have not been used.

[b] Guideline values are given in terms of nitrate and nitrite, whereas data has been reported for nitrate-nitrogen and nitrite-nitrogen. The following conversions were used calculate appropriate thresholds:

1 g/m³ NO_3-N = 4.43 g/m³ NO_3

1 g/m³ NO_2-N = 3.29 g/m³ NO_2

- **Table B.5 Metal Water Quality Guidelines for Recreational Purposes (ANZECC, 2000)**

Parameter	Guideline (g/m³)
Zinc	5
Copper	1

- **Table B.6 Metal Water Quality Guidelines for Human Fish Consumption (ANZECC, 2000)**

Parameter	Guideline (g/m³)
Zinc	5
Copper	1

- **Table B.7 Parameters Analysed for Which No Relevant Trigger Levels Were Identified**

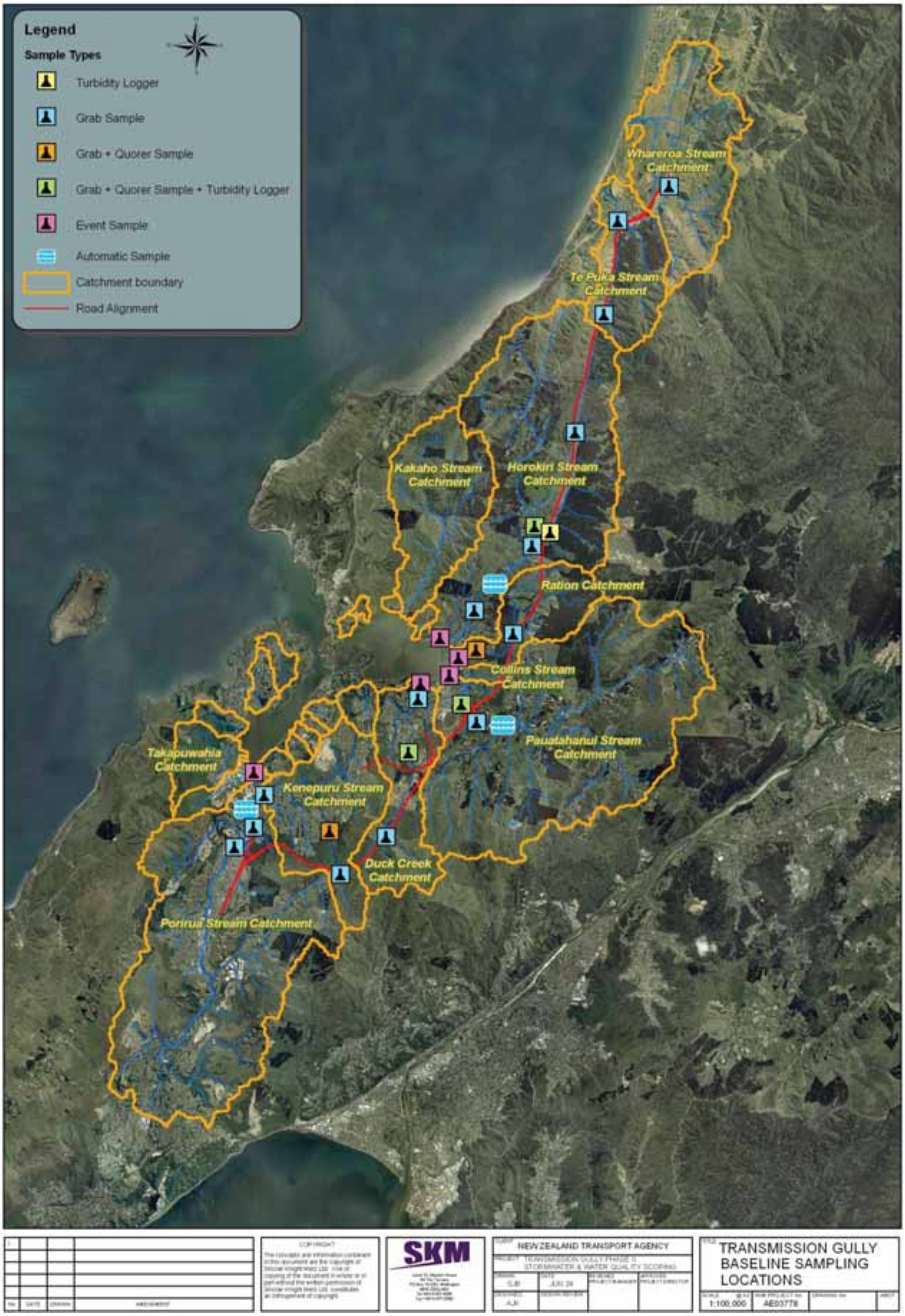
Parameter (g/m³ unless stated)
Total suspended solids[a]
Conductivity (µS/m)
Acenaphthene
Acenaphthylene
Benzo[a]anthracene
Benzo[a]fluoranthene + Benzo[j]fluoranthene
Benzo[g,h,i]perylene
Benzo[k]fluoranthene
Dibenzo[a,h]anthracene
Ideno (1,2,3, c,d) pyrene

Notes:

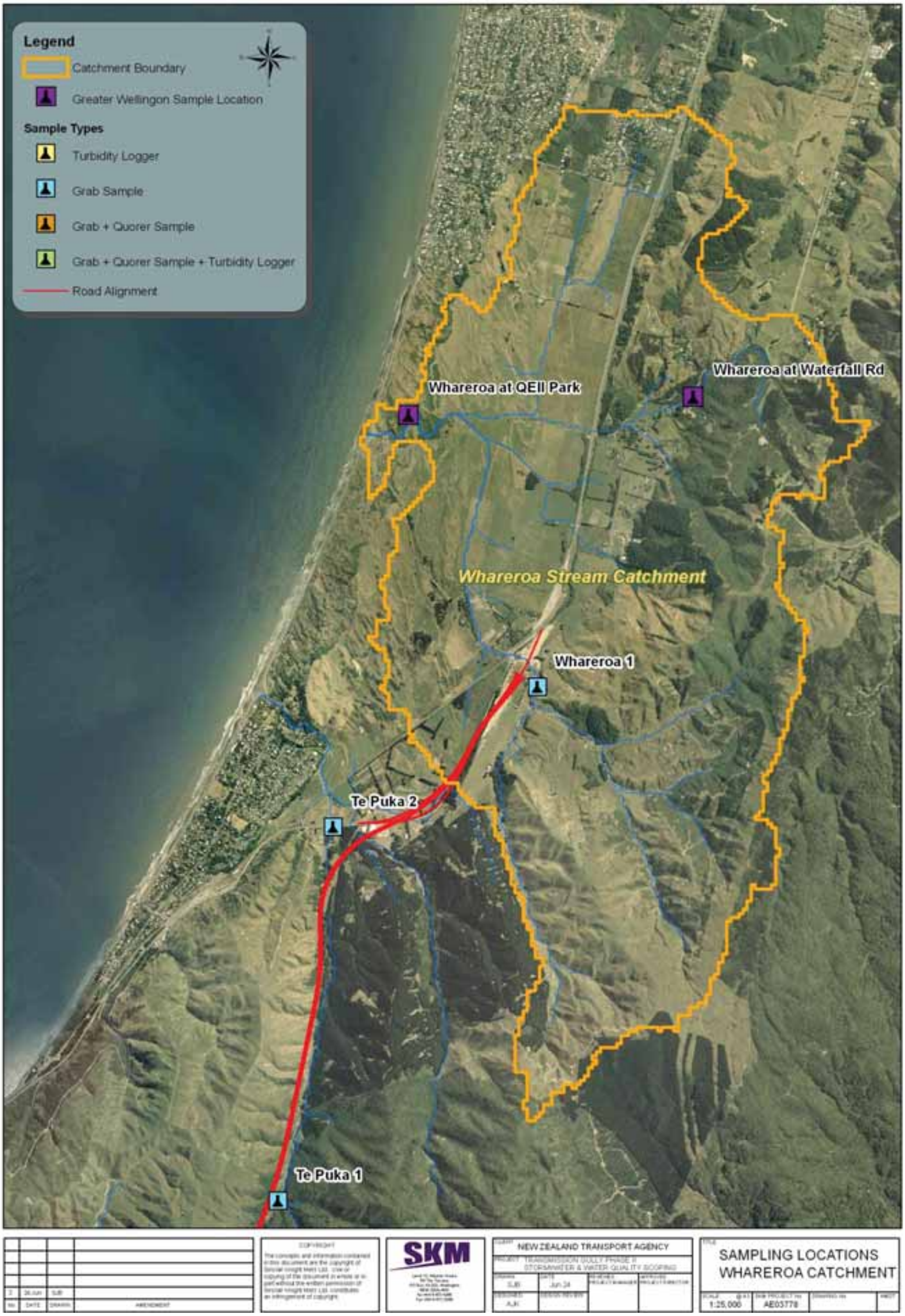
[a]No guideline for TSS has been provided. Refer to the NZ specific guideline for turbidity. The correlation between TSS and turbidity is strongly positively correlated. It can also vary in different streams. Relationships between these two variables were only calculated for selected streams. Therefore, we have not determined site specific TSS thresholds for different locations.

Appendix 15.C Maps of Sampling Locations

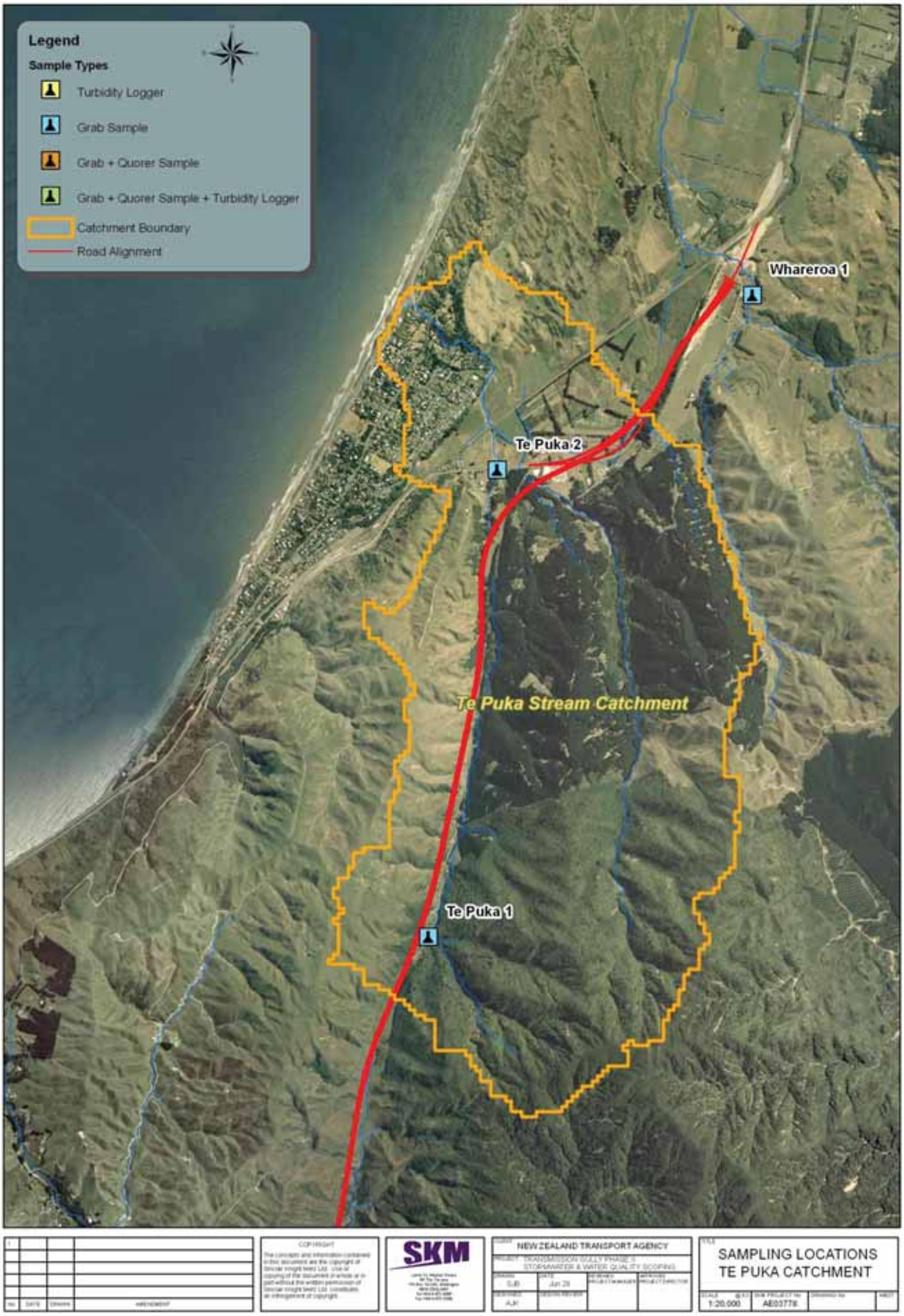
C1 - Overview of Sampling Locations



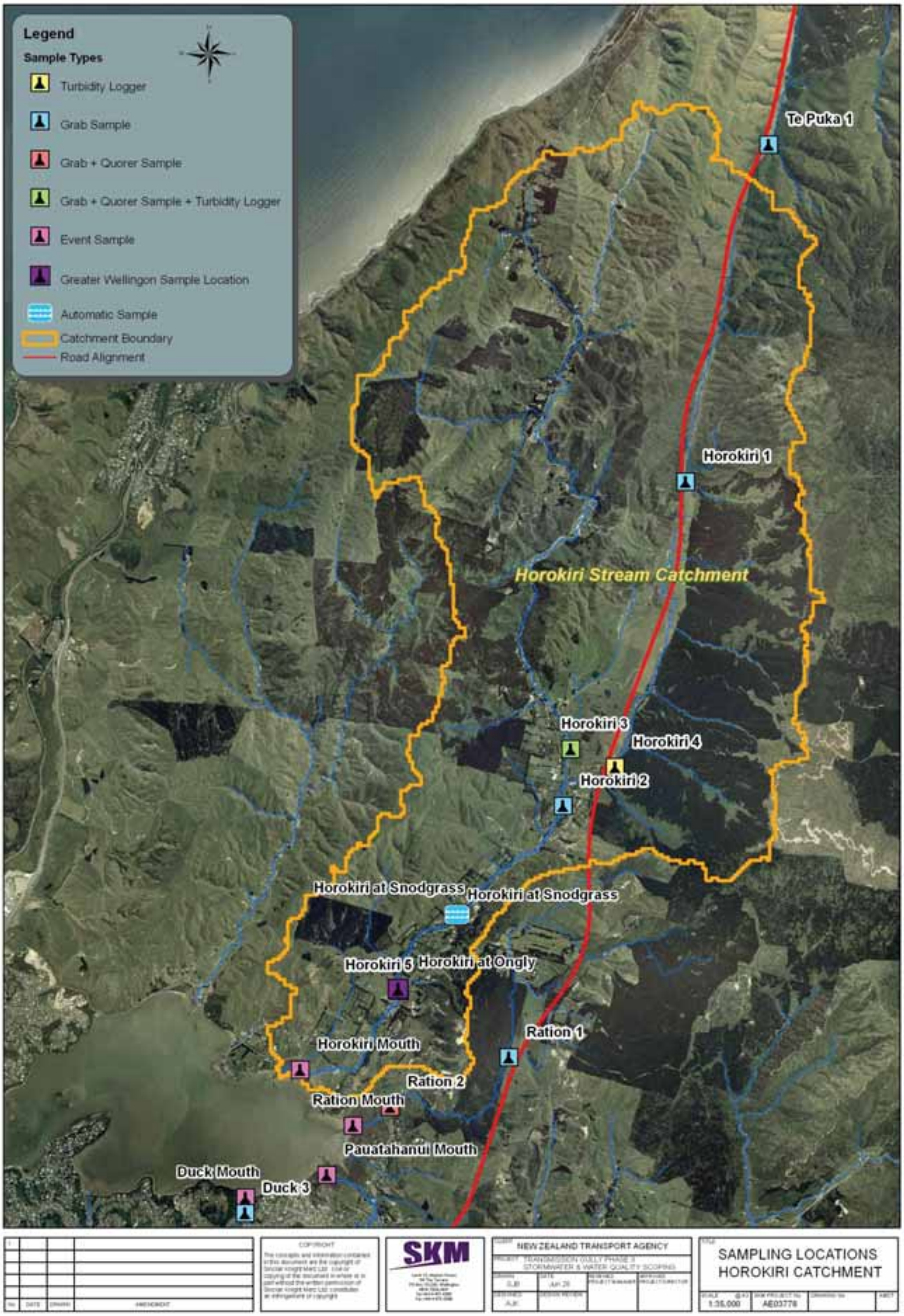
C2 - Catchment Sampling Locations – Whareroa Stream



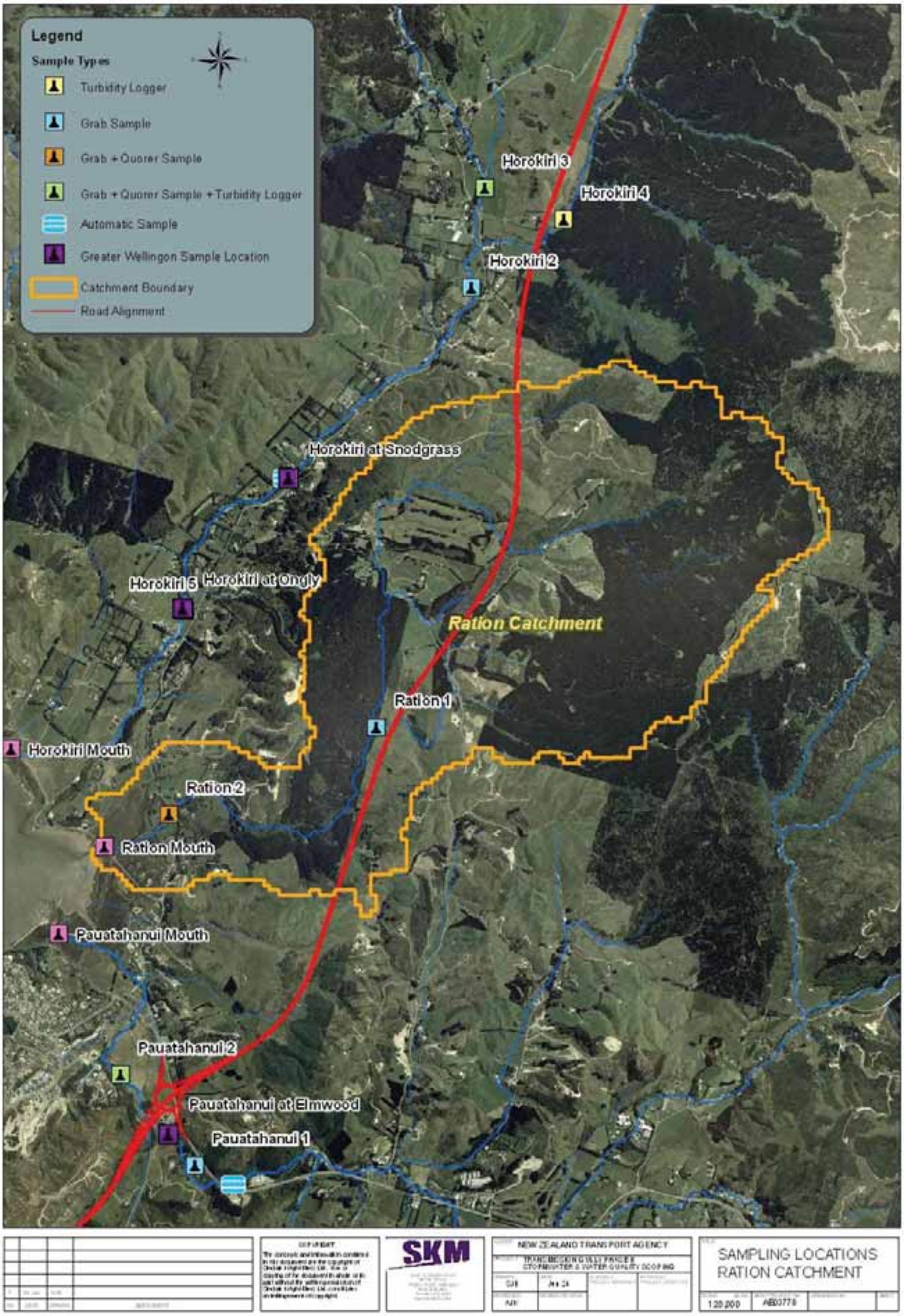
C3 - Catchment Sampling Locations – Wainui and Te Puka Streams



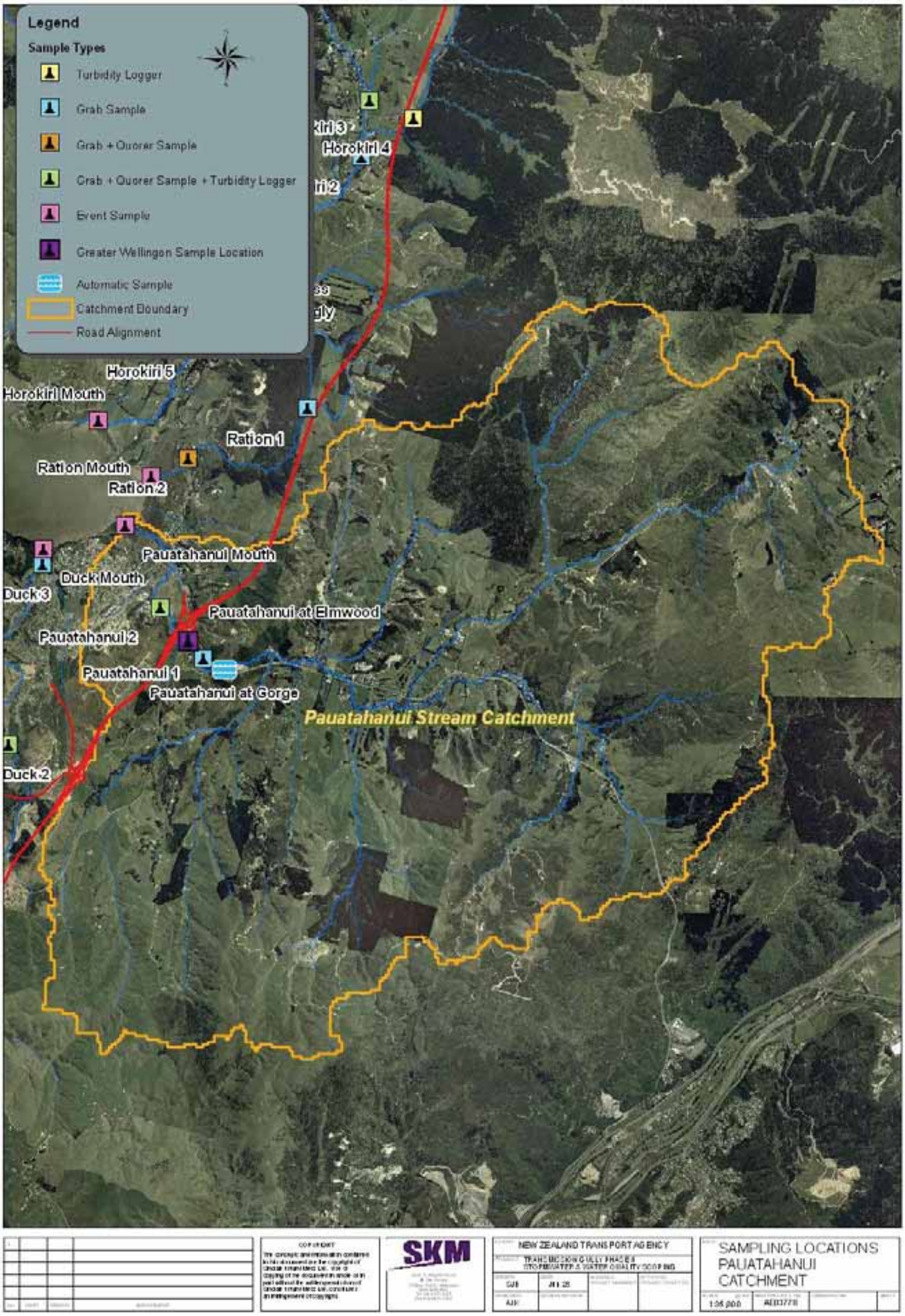
C4 - Catchment Sampling Locations – Horokiri Stream



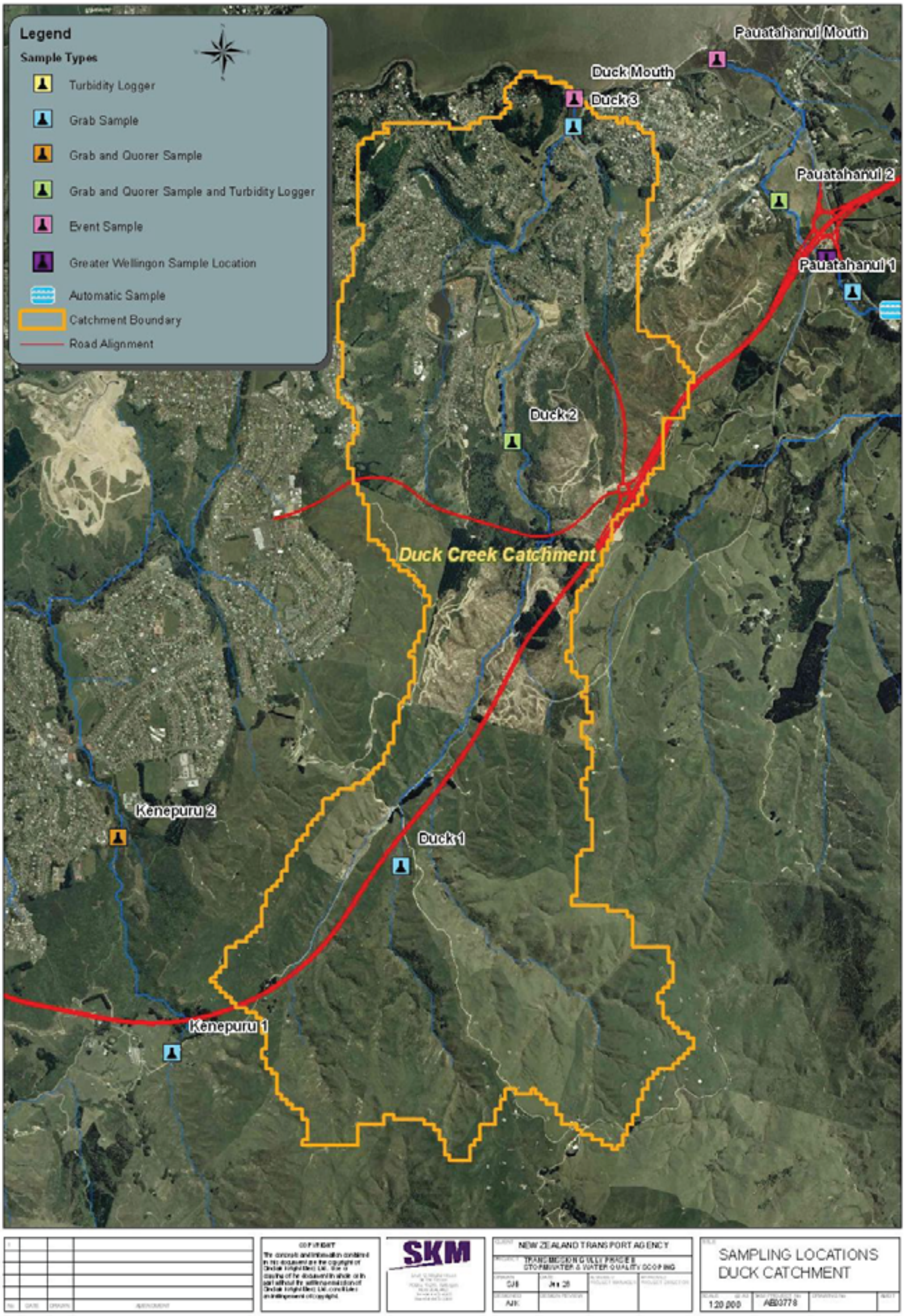
C5 - Catchment Sampling Locations – Ration Stream



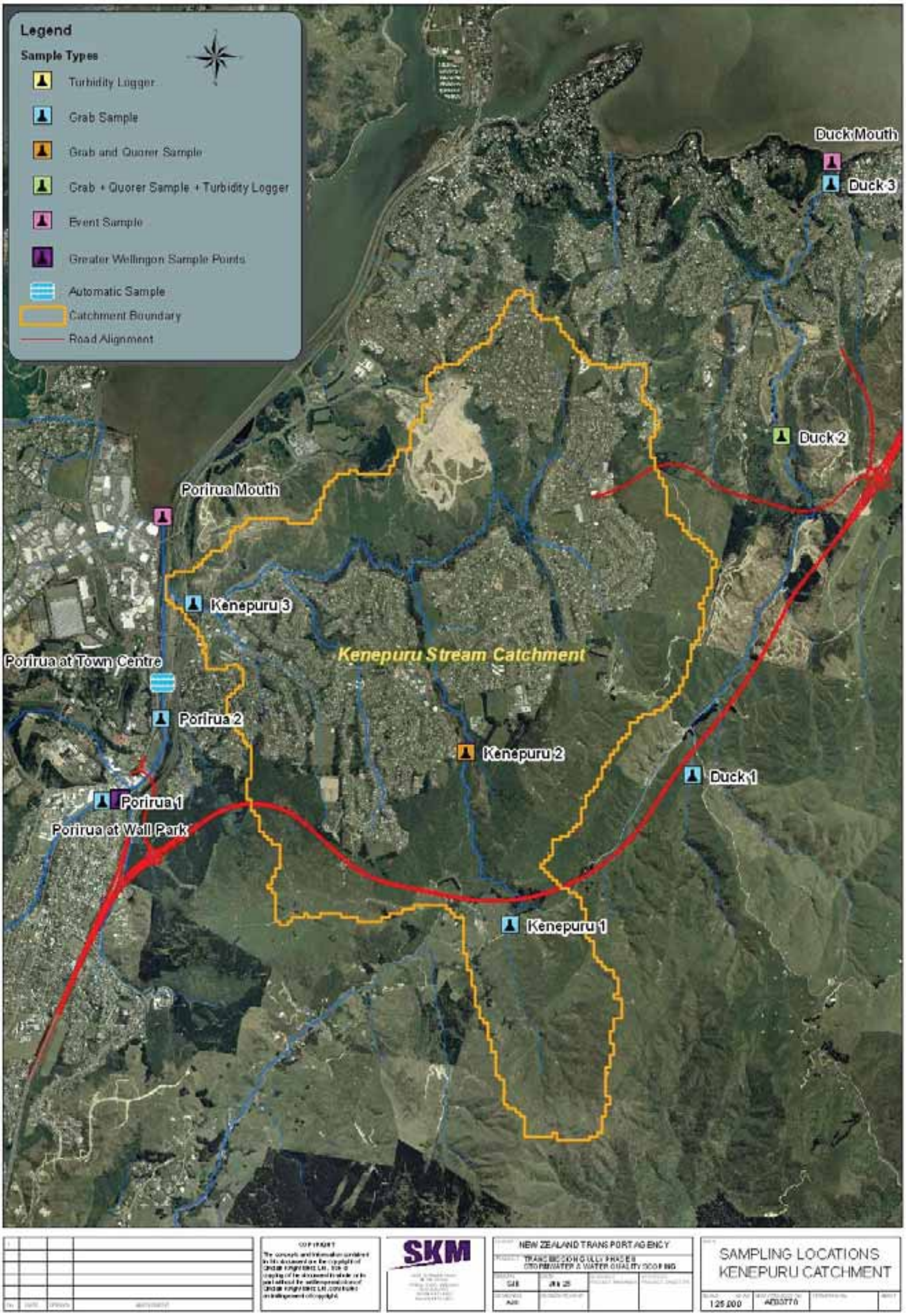
C6 - Catchment Sampling Locations – Pauatahanui Stream



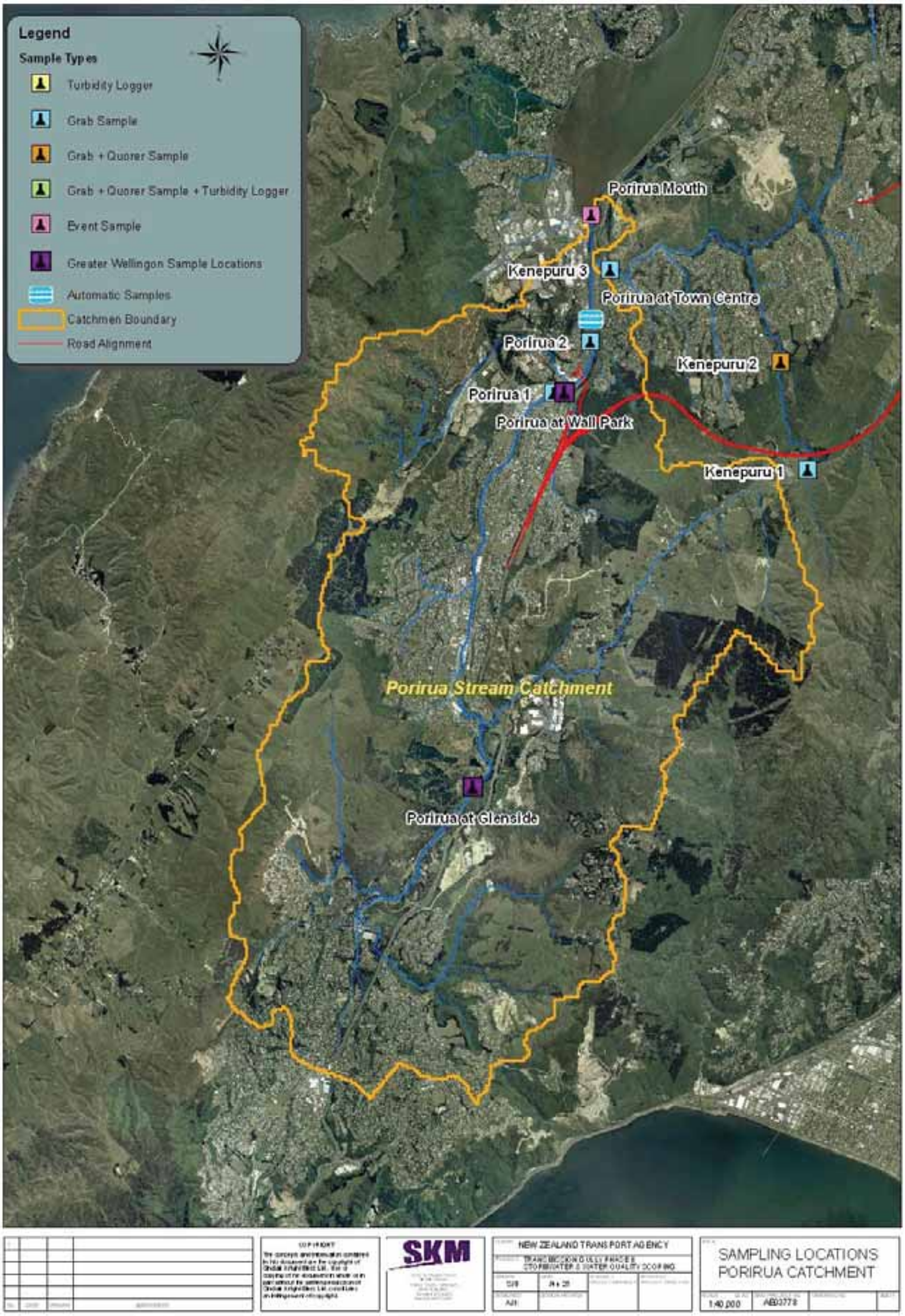
C7 - Catchment Sampling Locations – Duck Creek



C8 - Catchment Sampling Locations – Kenepuru Stream



C9 - Catchment Sampling Locations – Porirua Stream



Appendix 15.D Median Grab Sampling Results For All Catchments

D.1 Comparison to ecological and risk based guidelines

Parameter	Guideline value	Median																		
		Duck 1	Duck 2	Duck 3	Horokiri 1	Horokiri 2	Horokiri 3	Horokiri 5	Kenepuru 1	Kenepuru 2	Kenepuru 3	Pauatahanui 1	Pauatahanui 2	Porirua 1	Porirua 2	Ration 1	Ration 2	Te Puka 1	Te Puka 2	Whareroa 1
Temperature (C°)	3	12.4	14.2	14.3	13.3	13.0	12.5	13.1	12.1	12.1	14.7	12.6	12.9	13.1	13.9	11.6	12.0	11.2	12.7	14.3
pH	6.5-9.0	6.9	6.2	4.8	6.4	6.5	5.8	6.2	7.3	7.4	7.3	6.8	7.1	6.1	6.2	6.5	6.5	6.0	6.5	7.2
Conductivity (µS/m)	NA	236	256	276	171	202	258	228	238	249	254	182	173	218	212	210	214	174	250	257
Dissolved Oxygen % Saturation	98-105%	94.6	94.6	89.9	96.9	92.2	95.2	95.2	94.8	87.4	95.6	87.1	88.0	102.5	105.5	88.3	84.1	94.6	102.5	105.0
Dissolved Oxygen (g/m^3)	NA	10.2	9.4	9.2	9.3	10.1	10.3	9.7	10.0	10.9	9.3	9.2	9.5	11.3	9.9	9.3	9.1	10.0	11.2	10.3
Oil or Grease Films	Presence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scums or Foams	Presence	0	0	0	0	0	0	0	0	0	0	1	0	0.5	1	1	0	0	0	0
Floating/Suspended Material	Presence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Objectionable Odour	Presence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black disc clarity (m)	0.8	-	2.0	1.3	4.6	3.9	2.1	2.2	-	1.8	0.7	0.7	1.3	0.9	0.7	1.4	1.6	2.1	1.0	1.2
Munsell Colour	NA	-	5	10	5	7.5	5	7.5	7.5	10	10	5	6.25	5	7.5	5	5	5	6.25	10
Turbidity (NTU)	15	0.5	4.0	5.2	1.0	1.1	2.0	1.6	0.8	3.5	13.8	5.9	4.5	7.6	8.8	3.9	4.9	0.7	2.8	3.8
Total Suspended Solids (g/m^3)	NA	3.0	5.2	5.6	3.0	3.0	3.1	3.0	3.8	8.3	12.4	12.0	3.4	7.5	6.2	3.0	3.7	3.0	4.0	3.3
Hardness Total (g/m^3 as $CaCO^3$)	60	37	35	470	27	28	34	32	36	40	38	28	29	29	30	30	33	25	33	39
Aluminium Acid Soluble (g/m^3)	0.15	0.013	0.041	0.047	0.011	0.012	0.013	0.012	0.021	0.056	0.065	0.029	0.029	0.052	0.056	0.031	0.036	0.020	0.042	0.036
Dissolved Arsenic (g/m^3)	0.013	0.00050	0.00050	0.00064	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00063	0.00050	0.00050	0.00052	0.00054	0.00050	0.00050	0.00050	0.00050	0.00050
Total Arsenic (g/m^3)	0.013	0.00053	0.00053	0.00111	0.00053	0.00053	0.00053	0.00053	0.00060	0.00061	0.00117	0.00066	0.00057	0.00081	0.00077	0.00055	0.00058	0.00053	0.00053	0.00053
Dissolved Cadmium (g/m^3)	0.0002	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00003	0.00001	0.00001	0.00001	0.00001	0.00001
Total Cadmium (g/m^3)	0.0002	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00001	0.00001	0.00001	0.00001	0.00005	0.00007	0.00001	0.00001	0.00001	0.00001	0.00001
Dissolved Copper (g/m^3)	0.0014	0.00035	0.00044	0.00115	0.00025	0.00031	0.00054	0.00040	0.00021	0.00050	0.00215	0.00062	0.00058	0.00225	0.00255	0.00059	0.00062	0.00020	0.00042	0.00065
Total Copper (g/m^3)	0.0014	0.00040	0.00092	0.00172	0.00060	0.00051	0.00081	0.00063	0.00049	0.00078	0.00305	0.00079	0.00200	0.00410	0.00395	0.00067	0.00165	0.00031	0.00076	0.00110
Dissolved Chromium (g/m^3)	0.001	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00057	0.00081	0.00050	0.00050	0.00050	0.00050	0.00050
Total Chromium (g/m^3)	0.001	0.00053	0.00053	0.00097	0.00053	0.00053	0.00053	0.00053	0.00057	0.00058	0.00061	0.00053	0.00053	0.00128	0.00125	0.00053	0.00053	0.00053	0.00053	0.00053
Dissolved Lead (g/m^3)	0.0034	0.00005	0.00005	0.00012	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00021	0.00008	0.00008	0.00029	0.00029	0.00009	0.00012	0.00005	0.00005	0.00005
Total Lead (g/m^3)	0.0034	0.00006	0.00033	0.00045	0.00014	0.00009	0.00018	0.00010	0.00021	0.00027	0.00122	0.00025	0.00025	0.00136	0.00157	0.00018	0.00041	0.00013	0.00034	0.00057
Dissolved Nickel (g/m^3)	0.011	0.00030	0.00030	0.00040	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00039	0.00030	0.00030	0.00049	0.00061	0.00030	0.00030	0.00030	0.00030	0.00030
Total Nickel (g/m^3)	0.011	0.00032	0.00034	0.00075	0.00032	0.00032	0.00032	0.00032	0.00032	0.00037	0.00072	0.00034	0.00037	0.00066	0.00068	0.00039	0.00039	0.00032	0.00032	0.00032
Dissolved Zinc (g/m^3)	0.008	0.00050	0.00063	0.00455	0.00050	0.00106	0.00130	0.00135	0.00053	0.00081	0.00725	0.00115	0.00117	0.01400	0.01650	0.00145	0.00180	0.00068	0.00077	0.00091
Total Zinc (g/m^3)	0.008	0.00056	0.00179	0.00885	0.00143	0.00132	0.00235	0.00134	0.00103	0.00167	0.01900	0.00285	0.00345	0.03550	0.04450	0.00250	0.00330	0.00105	0.00194	0.00270
Dissolved Inorganic Nitrogen (g/m^3)	NA	1.12	0.67	0.18	0.1	0.28	0.1	0.275	0.3	0.55	0.43	0.011	0.011	0.261	0.25135	0.53	0.31	0.12	0.2	0.66
Total Ammoniacal Nitrogen (g/m^3)	0.021	0.01	0.01	0.0135	0.01	0.01	0.01	0.01	0.01	0.012	0.068	0.01	0.01	0.012	0.0115	0.01	0.01	0.01	0.01	0.01
Total Nitrogen (g/m^3)	0.614	1.33	1.2	0.84	0.36	0.535	0.78	0.705	0.745	0.97	1.185	0.635	0.575	1.5	1.55	1.26	1.165	0.215	0.37	1
Total Kjeldahl Nitrogen (g/m^3)	NA	0.21	0.28	0.3	0.125	0.115	0.195	0.166	0.1255	0.29	0.57	0.295	0.225	0.42	0.375	0.35	0.34	0.1	0.14	0.42

Parameter	Guideline value	Median																		
		Duck 1	Duck 2	Duck 3	Horokiri 1	Horokiri 2	Horokiri 3	Horokiri 5	Kenepuru 1	Kenepuru 2	Kenepuru 3	Pauatahanui 1	Pauatahanui 2	Porirua 1	Porirua 2	Ration 1	Ration 2	Te Puka 1	Te Puka 2	Whareroa 1
Nitrite-Nitrate Nitrogen (g/m³)	0.444	1.1	0.67	0.285	0.105	0.28	0.12	0.275	0.31	0.55	0.435	0.205	0.168	0.58	0.59	0.545	0.36	0.12	0.2	0.65
Total Phosphorus (g/m³)	0.033	0.034	0.044	0.035	0.009	0.0165	0.023	0.0175	0.0112	0.06	0.0855	0.0635	0.039	0.05	0.047	0.035	0.043	0.013	0.031	0.043
Dissolved Reactive Phosphorus (g/m³)	0.01	0.027	0.0385	0.024	0.0082	0.019	0.019	0.017	0.0108	0.033	0.023	0.025	0.022	0.025	0.023	0.022	0.023	0.0086	0.0245	0.026
Benzene (g/m³)	0.95	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Toluene (g/m³)	0.18	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ethylbenzene (g/m³)	0.08	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m&p-Xylene (g/m³)	0.075	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
o-Xylene (g/m³)	0.35	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Acenaphthene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Acenaphthylene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Anthracene (g/m³)	0.00005	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Benzo(a)anthracene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Benzo(a)pyrene (BAP) (g/m³)	0.0008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Benzo(b)fluoranthene + Benzo(j)fluoranthene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Benzo(g,h,i)perylene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Benzo(k)fluoranthene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Chrysene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Dibenzo(a,h)anthracene (g/m³)	NA	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Fluoranthene (g/m³)	0.001	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Fluorene (g/m³)	0.003	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Indeno(1,2,3-c,d)pyrene (g/m³)	NA	<0.000008	<0.000008	0.000014	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	0.000014	0.000014	<0.000008	<0.000008	0.000014	0.000014	<0.000008	<0.000008	<0.000008
Naphthalene (g/m³)	0.05	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
Phenanthrene (g/m³)	0.0006	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008
Pyrene (g/m³)	0.000025	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008	<0.000008

Note: Where result is outside guideline value, result is highlighted in **red**.

Medians have been compared to ecological, risk based and other guidelines as detailed in Appendix 15.B

D.2 Comparison to water quality guidelines for stock consumption

Parameter	Livestock Drinking Water Guideline	Median																		
		Duck 1	Duck 2	Duck 3	Horokiri 1	Horokiri 2	Horokiri 3	Horokiri 5	Kenepuru 1	Kenepuru 2	Kenepuru 3	Pauatahanui 1	Pauatahanui 2	Porirua 1	Porirua 2	Ration 1	Ration 2	Te Puka 1	Te Puka 2	Whareroa 1
Total Dissolved Solids (g/m³)	2000	158	172	185	114	135	173	152	159	167	170	122	116	146	142	141	143	117	167	172
Black disc clarity (m)	0.8	-	2.0	1.3	4.6	3.9	2.1	2.2	-	1.8	0.7	0.7	1.3	0.9	0.7	1.4	1.6	2.1	1.0	1.2
Munsell Colour	NA	-	5	10	5	7.5	5	7.5	7.5	10	10	5	6.25	5	7.5	5	5	5	6.25	10
Turbidity (NTU)	5.6	0.5	4.0	5.2	1.0	1.1	2.0	1.6	0.8	3.5	**13.8**	**5.9**	4.5	**7.6**	**8.8**	3.9	4.9	0.7	2.8	3.8
Total Suspended Solids (g/m³)	NA	3.0	5.2	5.6	3.0	3.0	3.1	3.0	3.8	8.3	12.4	12.0	3.4	7.5	6.2	3.0	3.7	3.0	4.0	3.3
Aluminium Acid Soluble (g/m³)	5	0.013	0.041	0.047	0.011	0.012	0.013	0.012	0.021	0.056	0.065	0.029	0.029	0.052	0.056	0.031	0.036	0.020	0.042	0.036
Total Arsenic (g/m³)	0.5	0.00053	0.00053	0.00111	0.00053	0.00053	0.00053	0.00053	0.00060	0.00061	0.00117	0.00066	0.00057	0.00081	0.00077	0.00055	0.00058	0.00053	0.00053	0.00053
Total Cadmium (g/m³)	0.01	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00001	0.00001	0.00001	0.00001	0.00005	0.00007	0.00001	0.00001	0.00001	0.00001	0.00001
Total Copper (g/m³)	0.5	0.00040	0.00092	0.00172	0.00060	0.00051	0.00081	0.00063	0.00049	0.00078	0.00305	0.00079	0.00200	0.00410	0.00395	0.00067	0.00165	0.00031	0.00076	0.00110
Total Chromium (g/m³)	1	0.00053	0.00053	0.00097	0.00053	0.00053	0.00053	0.00053	0.00057	0.00058	0.00061	0.00053	0.00053	0.00128	0.00125	0.00053	0.00053	0.00053	0.00053	0.00053
Total Nickel (g/m³)	1	0.00032	0.00034	0.00075	0.00032	0.00032	0.00032	0.00032	0.00032	0.00037	0.00072	0.00034	0.00037	0.00066	0.00068	0.00039	0.00039	0.00032	0.00032	0.00032
Total Zinc (g/m³)	20	0.00056	0.00179	0.00885	0.00143	0.00132	0.00235	0.00134	0.00103	0.00167	0.01900	0.00285	0.00345	0.03550	0.04450	0.00250	0.00330	0.00105	0.00194	0.00270

Appendix 15.E Event Sampling Results

E1 - Event Samples - Medians

Site name	Turbidity (g/m³)			TSS (g/m³)		
	Median	Min	Max	Median	Min	Max
Duck Mouth	18	3	430	18	5	490
Horokiri Mouth	15	1	66	20	3	68
Pauatahanui Mouth	20	3	240	28	7	220
Porirua Mouth	89	9	590	95	15	450
Ration Mouth	24	3	240	39	6	250

E2 - Event samples - all results

Site Name	Date/Time	Turbidity (NTU)	Total Suspended Solids (g/m³)	Flow (m³/s)	Flow gauge
Duck Mouth	9/10/2009 9:10	160	170	-	None on stream
Duck Mouth	16/10/2009 11:20	430	490	-	
Duck Mouth	29/12/2009 10:22	8	5	-	
Duck Mouth	16/01/2010 9:00	5	8	-	
Duck Mouth	28/04/2010 9:55	20	16	-	
Duck Mouth	15/05/2010 9:00	3	20	-	
Duck Mouth	25/05/2010 9:53	65	79	-	
Duck Mouth	26/05/2010 9:20	16	14	-	
Horokiri Mouth	9/10/2009 9:20	66	68	2.41	Horokiri Stream at Snodgrass
Horokiri Mouth	16/10/2009 15:20	45	58	3.30	
Horokiri Mouth	29/12/2009 9:50	5	21	1.39	
Horokiri Mouth	16/01/2010 9:30	1	3	0.32	
Horokiri Mouth	28/04/2010 10:10	13	10	0.58	
Horokiri Mouth	15/05/2010 9:20	2	5	0.18	
Horokiri Mouth	25/05/2010 10:20	22	65	1.12	
Horokiri Mouth	26/05/2010 9:50	17	19	1.69	
Pauatahanui Mouth	9/10/2009 9:20	240	220	6.83	Pauatahanui Stream at Gorge
Pauatahanui Mouth	16/10/2009 15:40	140	120	5.64	
Pauatahanui Mouth	29/12/2009 10:00	3	12	0.77	
Pauatahanui Mouth	16/01/2010 9:10	4	7	0.26	
Pauatahanui Mouth	28/04/2010 10:30	48	53	0.56	
Pauatahanui Mouth	15/05/2010 9:30	3	35	0.17	
Pauatahanui Mouth	25/05/2010 10:00	16	17	1.30	
Pauatahanui Mouth	26/05/2010 9:30	24	21	2.51	
Porirua Mouth	9/10/2009 9:00	140	140	3.59	Porirua Stream at Town Centre
Porirua Mouth	16/10/2009 12:30	590	450	9.15	
Porirua Mouth	29/12/2009 9:30	12	15	1.13	

Site Name	Date/Time	Turbidity (NTU)	Total Suspended Solids (g/m³)	Flow (m³/s)	Flow gauge
Porirua Mouth	16/01/2010 8:40	9	29	2.23	
Porirua Mouth	28/04/2010 9:40	95	100	0.29	
Porirua Mouth	15/05/2010 8:30	13	15	0.94	
Porirua Mouth	25/05/2010 9:40	82	160	6.68	
Porirua Mouth	26/05/2010 9:00	96	89	4.47	
Ration Mouth	9/10/2009 9:25	240	250	-	None on stream
Ration Mouth	16/10/2009 15:25	60	60	-	
Ration Mouth	29/12/2009 9:56	5	32	-	
Ration Mouth	16/01/2010 9:20	4	6	-	
Ration Mouth	28/04/2010 10:05	49	117	-	
Ration Mouth	15/05/2010 9:10	3	42	-	
Ration Mouth	25/05/2010 10:25	26	35	-	
Ration Mouth	26/05/2010 9:50	21	17	-	

Appendix 15.F Automatic Sampling Results

Site name	Date	"Beginning of Storm" sample								"Composite" sample						
		Time	Rainfall previous 24 hours (mm)	Turbidity (NTU)	Total Suspended Solids (g/m³)	Dissolved Zinc (g/m³)	Total Zinc (g/m³)	Dissolved Copper (g/m³)	Total Copper (g/m³)	Time	Turbidity (NTU)	Total Suspended Solids (g/m³)	Dissolved Zinc (g/m³)	Total Zinc (g/m³)	Dissolved Copper (g/m³)	Total Copper (g/m³)
Guideline value				6	NA	0.008	0.008	0.0014	0.0014		6	NA	0.008	0.008	0.0014	0.0014
Horokiri Stream at Snodgrass	13/04/2010	23:05:00	7.5	1	9	0.006	**0.009**	0.0007	0.0008	01:05:00	2	3	0.003	0.004	0.0007	0.0007
Horokiri Stream at Snodgrass	27/04/2010	17:50:00	20.0	**240**	370	0.005	**0.045**	**0.0038**	**0.0107**	19:50:00	**370**	610	0.002	**0.058**	**0.0018**	**0.0134**
Horokiri Stream at Snodgrass	25/05/2010	09:05:00	25.5	**21**	21	0.002	0.008	0.0011	**0.0018**	11:05:00	**42**	56	0.003	**0.011**	**0.0015**	**0.0029**
Horokiri Stream at Snodgrass	25/05/2010	18:20:00	37.0	**93**	124	0.003	0.006	**0.0016**	**0.0021**	20:20:00	**161**	200	0.003	**0.027**	**0.0016**	**0.0060**
Horokiri Stream at Snodgrass	6/06/2010	09:35:00	12.0	2	0	0.004	0.006	0.0005	0.0009	11:35:00	3	6	0.003	0.004	0.0007	0.0009
Horokiri Stream at Snodgrass	11/06/2010	03:20:00	8.5	**7**	4	0.002	0.004	0.0007	**0.0018**	05:20:00	**10**	11	0.002	0.003	0.0006	0.0009
Pauatahanui Stream at Gorge	24/03/2010	15:05:00	No data	1	5	0.006	**0.010**	0.0005	0.0006	17:05:00	1	3	0.006	**0.009**	0.0008	0.0011
Pauatahanui Stream at Gorge	13/04/2010	23:05:00	7.5	1	8	0.002	0.003	0.0006	0.0005	01:05:00	2	3	0.003	0.003	0.0005	0.0005
Pauatahanui Stream at Gorge	24/05/2010	22:05:00	14.5	**25**	22	0.004	**0.010**	0.0013	**0.0020**	02:05:00	**16**	18	**0.011**	**0.024**	**0.0034**	**0.0051**
Porirua Stream at Town Centre	24/03/2010	15:15:00	5.0	1	8	**0.023**	**0.033**	**0.0057**	**0.0081**	17:15:00	2	3	**0.021**	**0.032**	**0.0043**	**0.0066**
Porirua Stream at Town Centre	13/04/2010	22:05:00	2.5	**15**	25	**0.033**	**0.056**	**0.0040**	**0.0054**	00:05:00	**42**	73	**0.029**	**0.107**	**0.0052**	**0.0120**
Porirua Stream at Town Centre	27/04/2010	17:35:00	7.0	**240**	370	**0.016**	**0.210**	**0.0037**	**0.0240**	19:35:00	**193**	270	**0.027**	**0.280**	**0.0043**	**0.0280**
Porirua Stream at Town Centre	16/05/2010	17:05:00	5.5	**6**	15	**0.011**	**0.019**	**0.0022**	**0.0029**	19:05:00	**8**	4	**0.015**	**0.023**	**0.0030**	**0.0034**
Porirua Stream at Town Centre	25/05/2010	16:20:00	45.0	**310**	400	**0.012**	**0.163**	**0.0028**	**0.0186**	18:20:00	**980**	1360	**0.010**	**0.290**	**0.0033**	**0.0370**
Porirua Stream at Town Centre	28/05/2010	06:00:00	18.0	**8**	8	**0.023**	**0.026**	**0.0021**	**0.0020**	08:00:00	**8**	4	**0.019**	**0.020**	**0.0020**	**0.0020**
Porirua Stream at Town Centre	6/06/2010	08:35:00	6.0	**42**	45	**0.009**	**0.037**	**0.0017**	**0.0045**	10:35:00	**91**	138	**0.013**	**0.073**	**0.0022**	**0.0085**
Porirua Stream at Town Centre	14/06/2010	02:50:00	4.0	**7**	10	**0.008**	**0.011**	0.0013	**0.0014**	04:50:00	4	4	**0.012**	**0.015**	**0.0015**	**0.0017**

Note: Where result is outside guideline value, result is highlighted in **red**.

Appendix 15.G Quorer Sampling Results

Site name	Median Areal SIS (g/m²)	Volumetric SIS (g/m³)	Median Areal SOS (g/m²)	Volumetric SOS (g/m³)	Visual assessment % fine sediment
Duck 2	3661	5905	323	682	18.9
Horokiri 3	751	9217	81	1292	0.1
Kenepuru 2	2884	24451	357	3089	12.1
Pauatahanui 2	2649	8601	215	861	9.75
Porirua 2	2980	14005	287	2196	57.25
Ration 2	9628	14687	1237	1610	77.6

Appendix 15.H GWRC Median State of the Environment Water Quality Data

Parameter	Guideline value	Porirua Stream at Milk Depot (i.e., Wall Park)				Porirua Stream at Glenside Overhead Cables				Horokiri Stream at Snodgrass				Horokiri Stream at Ongly			
		Median	95th percentile	5th percentile	Count	Median	95th percentile	5th percentile	Count	Median	95th percentile	5th percentile	Count	Median	95th percentile	5th percentile	Count
Temperature (C°)	3	12.7	18.7	7.8	223	12.3	18.0	7.5	221	14.7	19.5	7.9	88	12.4	17.7	7.7	154
Dissolved Oxygen % Saturation	98-105%	105.0	127.3	95.6	148	104.0	129.7	93.3	148	100.5	116.0	92.8	88	101.0	116.4	93.0	74
Conductivity (µS/m)	N/A	253.0	281.5	183.5	211	252.0	285.2	177.2	209	183.5	205.7	155.2	88	181.0	201.0	149.0	143
pH	6.5-9.0	7.6	8.5	7.1	221	7.7	8.9	7.1	219	7.4	7.9	6.9	86	7.3	7.7	7.0	153
Turbidity (NTU)	15	2.9	38.4	1.4	223	2.5	48.0	0.9	221	1.2	8.7	0.4	88	0.9	11.7	0.4	154
Black Disc Clarity (m)	0.8	1.5	3.0	0.2	148	1.7	3.6	0.1	146	2.2	4.3	0.5	88	2.7	4.5	0.6	74
Munsell Colour	NA	5	10	2.5	74	5	10	2.5	74	5	10	2.5	74	-	-	-	-
Total Suspended Solids (g/m^3)	NA	4.3	77.7	2.4	10	3.2	130.0	2.1	11	3.6	20.4	2.4	7	-	-	-	-
Nitrite-Nitrate Nitrogen (g/m^3)	0.444	1.02	1.77	0.47	73	1.11	1.89	0.53	74	0.43	0.99	0.05	74	-	-	-	-
Total Ammoniacal Nitrogen (g/m^3)	0.021	0.04	0.24	0.01	68	0.03	0.17	0.01	49	0.01	0.05	0.01	29	0.08	0.08	0.08	1
Dissolved Inorganic Nitrogen (g/m^3)	NA	1.03	1.95	0.49	73	1.12	1.98	0.54	74	0.45	1.00	0.05	74	-	-	-	-
Total Kjeldahl Nitrogen (g/m^3)	NA	0.30	1.11	0.12	67	0.30	0.71	0.13	68	0.17	0.31	0.10	63	-	-	-	-
Total Nitrogen (g/m^3)	0.614	1.31	2.46	0.59	100	1.30	2.35	0.74	100	0.60	1.20	0.18	88	0.66	1.53	0.17	26
Dissolved Reactive Phosphorus (g/m^3)	0.01	0.02	0.04	0.01	141	0.02	0.04	0.01	150	0.01	0.02	0.01	79	0.01	0.02	0.01	44
Total Phosphorus (g/m^3)	0.033	0.04	0.11	0.01	98	0.03	0.11	0.01	98	0.02	0.05	0.01	87	0.01	0.13	0.01	17
Hardness Total (g/m^3 as $CaCO^3$)	60	41.0	47.5	34.8	12	37.5	47.6	33.0	12	28.0	31.5	23.1	12	-	-	-	-
Dissolved Arsenic (g/m^3)	0.013	<0.00100	<0.00100	<0.00100	18	0.002	0.002	0.002	1	<0.00100	<0.00100	<0.00100	12	-	-	-	-

Parameter	Guideline value	Pauatahanui Stream at Elmwood Bridge				Whareroa Stream at QE Park				Whareroa Stream at Waterfall Rd			
		Median	95th percentile	5th percentile	Count	Median	95th percentile	5th percentile	Count	Median	95th percentile	5th percentile	Count
Temperature (C°)	3	13.1	18.8	7.6	148	14.6	19.0	9.2	74	11.9	15.7	7.2	65
Dissolved Oxygen % Saturation	98-105%	95.3	111.0	82.4	148	71.7	94.3	50.4	74	96.7	108.0	86.2	65
Conductivity (µS/m)	N/A	178.0	204.0	151.4	137	273.0	317.9	211.9	74	237.0	268.2	176.8	65
pH	6.5-9.0	7.3	8.1	7.0	146	6.8	7.2	6.2	72	7.6	7.9	7.2	63
Turbidity (NTU)	15	2.6	17.6	1.1	148	8.9	20.3	3.8	74	4.8	48.5	2.5	65
Black Disc Clarity (m)	0.8	1.6	3.4	0.2	145	0.5	1.1	0.2	73	0.7	1.5	0.1	65
Munsell Colour	NA	5	10	2.5	74	5	10	2.5	73	7.5	10	2.5	65
Total Suspended Solids (g/m^3)	NA	3.2	70.0	2.1	7	4.3	13.0	2.6	21	3.3	24.0	2.5	16
Nitrite-Nitrate Nitrogen (g/m^3)	0.444	0.25	0.64	0.02	72	0.35	1.15	0.06	74	0.36	0.71	0.13	65
Total Ammoniacal Nitrogen (g/m^3)	0.021	0.02	0.07	0.01	51	0.11	0.27	0.03	71	0.02	0.08	0.01	19
Dissolved Inorganic Nitrogen (g/m^3)	NA	0.28	0.66	0.02	74	0.48	1.22	0.08	74	0.37	0.71	0.14	65
Total Kjeldahl Nitrogen (g/m^3)	NA	0.22	0.52	0.14	72	0.64	1.01	0.40	74	0.20	0.55	0.11	57
Total Nitrogen (g/m^3)	0.614	0.57	1.10	0.20	100	1.00	1.92	0.51	74	0.50	1.29	0.23	65
Dissolved Reactive Phosphorus (g/m^3)	0.01	0.02	0.03	0.01	97	0.04	0.06	0.02	74	0.03	0.05	0.02	65
Total Phosphorus (g/m^3)	0.033	0.03	0.08	0.01	99	0.09	0.14	0.05	74	0.05	0.12	0.03	65
Hardness Total (g/m^3 as $CaCO^3$)	60	27.5	34.5	20.7	12	60.5	80.5	46.2	12	38.0	46.9	27.6	12
Dissolved Arsenic (g/m^3)	0.013	<0.00100	<0.00100	<0.00100	12	0.0011	0.0011	0.0010	4	<0.00100	<0.00101	<0.00102	12

Note: Where result is outside guideline value, result is highlighted in red.

Appendix 15.I Turbidity Logger Data

I.1 Installation and Location of Loggers

The following details installation dates and the location of loggers installed on Duck Creek, the Horokiri Stream and the Pauatahanui Stream. Loggers were placed at or near freshwater sampling sites as detailed in Section 6.2.2. All loggers were installed between 19 October 2009 and 28 October 2009. All loggers were removed on 29 September 2010. Data was edited to remove erroneous sections of data, and an edited data set was used as part of the sediment yield analysis – as detailed in Section 10.

Horokiri 3

Horokiri 3 was installed on 28 October 2009. The original logger only recorded data to a maximum value of 400 NTU. It is likely that the logger was not recording higher turbidity values. Hence, a logger that records up to 1000 NTU was installed on 10 December 2009. We moved the logger further downstream (approximately 3 metres) on 21 December 2009 as the original location was producing erratic results. The flow at this site is not affected by an eddy and is more representative of the stream flow. We have therefore discounted data collected before 21 December 2009 (**Figure I.1**). The logger was removed from the Horokiri 3 site on 29 September 2010.

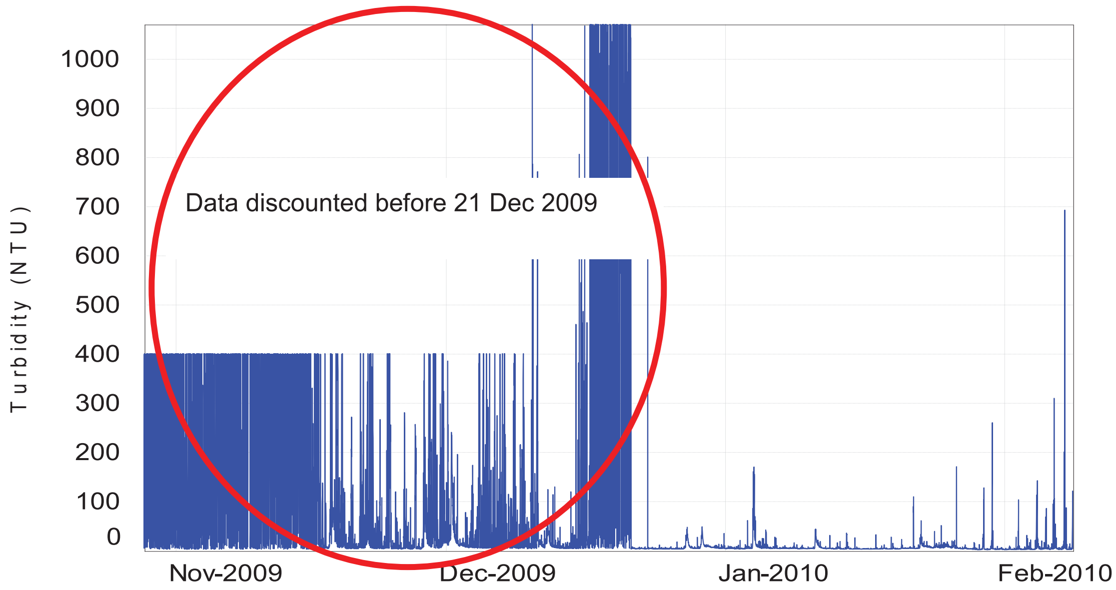


Figure I.1 Recorded Continuous Turbidity at Horokiri 3

Horokiri 4

A logger was installed at Horokiri 4 on 19 October 2009. Similarly to the Horokiri 3 site, this logger only recorded turbidity values up to 400 NTU. It is likely that the logger was not recording higher turbidity values. A new logger which records up to 1000 NTU was installed on 10 December 2009 (**Figure I.2**). The logger was removed from Horokiri 4 on 29 September 2010.

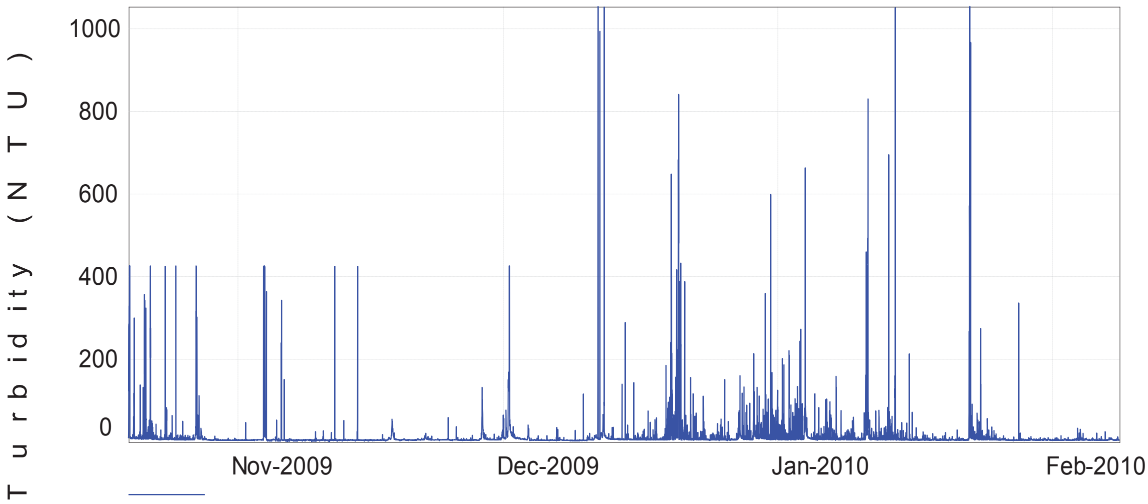


Figure I.2 Recorded Continuous Turbidity at Horokiri 4

Pauatahanui 2

A turbidity logger was installed at Pauatahanui 2 about 50 metres upstream of the sampling location on 28 October 2009. Erratic data was recorded in the first month of installation (**Figure I.3**). Turbidity data was compared to NIWA's gauged flow record which is recorded upstream of Pauatahanui 2. Some peaks in turbidity seem to be correlated with high flow. The erratic data recorded in the first month of recording did not seem to correlate with flow peaks, so this data was removed from the analysis. It should be noted that excavation to widen the streambed and reduce flooding on an adjacent property was being carried out upstream of the gauge for some of the time the logger was in place. It is understood this work started in January 2010 and took several months. These works may have had an impact on sediment loads further downstream (ie. At Pauatahanui 2).

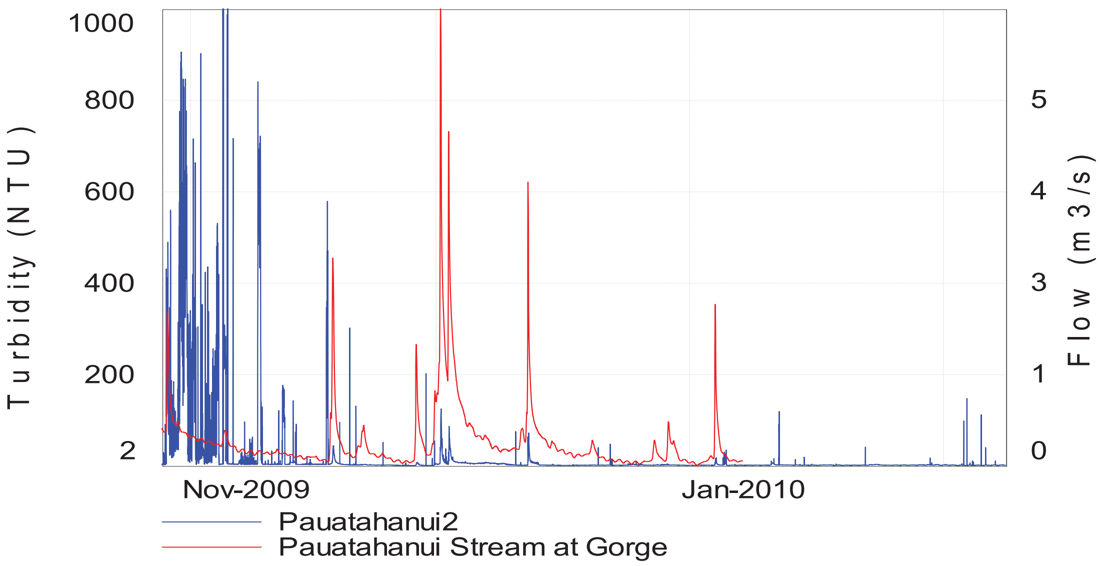


Figure I.3 Recorded Turbidity at Pauatahanui 2 and Flow at Pauatahanui at Gorge

Duck 2

The turbidity logger was installed at Duck 2 on 28 October 2009, about 20 metres upstream of the freshwater sampling location. The logger was removed on 29 September 2010. Data collected at this site was not edited significantly.

I.2 Turbidity Data

Table I.1 details calculated means and medians of turbidity data collected from the four loggers placed in Duck Creek, Horokiri Stream (two) and Pauatahanui Stream. Means and medians have been calculated from the beginning of reliable data collection to their removal from the streams on 29th September 2010.

Table I.1 Turbidity Mean and Median from Four Loggers

Site name	Data length	Turbidity (NTU)	
		Mean	Median
Duck 2	28/10/09 - 29/09/10	13.8	8.1
Horokiri 3	22/12/09 - 29/09/10	20.5	4.9
Horokiri 4	11/12/09 - 29/09/10	18.4	7.6
Pauatahanui 2	18/11/09 - 29/09/10	21.9	2.6

Appendix 15.J Methodology for Spot Flow Calculations

Flows also measured at un-gauged sample stream locations when simultaneous TSS and turbidity data was collected. The following methodology was employed to calculate spot discharge:

- A current meter was used to measure stream velocities at several points along a cross-section of the stream. This was at the same location where the grab samples were collected. The current meter observed revolutions of a small propeller for at least 60 seconds at each point. The revolutions and time were recorded, along with the water depth and distance from the stream bank at each location.
- At each site, cross sectional details including stream width and depth dimensions were recorded.
- The cross sectional area was calculated.
- The velocity was calculated using the following equation:

$$\text{Velocity} = k \times n + c$$

Where k = slope propeller

n = pulses (i.e. Revolutions per second)

c = propeller constant

- Discharge was calculated by multiplying the cross sectional area and velocity together

Appendix 15.K The Soil Moisture Water Balance Model

K.1 Introduction

The Transmission Gully Highway will be located between Paraparaumu and Wellington to:

- Improve regional network security;
- Assist in remedying safety concerns and projected capacity problems on the existing State Highway 1;
- Assist in enabling wider economic development by providing a route that improves through movement of freight and people; and
- Assist in the integration of the land transport system by enabling the existing State Highway 1 to be developed into a safe and multi-functional alternative to the proposed new strategic link.

Daily streamflow time series are required as input to hydraulic models that will be used to assess movement of sediment in the streams.

Four gauged catchments identified in are located in the project area, namely:

- Porirua Stream at Town Centre;
- Pauatahanui Stream at Gorge;
- Horokiri at Grenlo and Snodgrass; and
- Wainui Stream above Kapiti Coast District Council offtake.

The records for the Porirua and Pauatahanui gauges are 28 and 32 years long respectively, but contain significant periods of missing data. The Horokiri record is only 5 years long and the Wainui record only 5 months long. The gauges also only command part of the catchments where streamflow time series are required.

Rainfall-runoff models are available that can be calibrated to generate synthetic streamflow from catchment rainfall. Confidence in the synthetic streamflow time series depends on the length of period(s) with overlapping observed streamflow and rainfall data, accuracy of the observed flow record and representativeness of the rainfall data to catchment rainfall.

The spatial distribution of rainfall stations in the project area with suitable records is poor. However, the National Institute of Water and Atmospheric (NIWA) have developed a grid of historic rainfall time series for the whole of New Zealand at approximately 5 km grid spacing. These grid rainfall time series span the period 1960 to date and provide suitable daily rainfall data for input to a rainfall-runoff model.

This report describes generation of daily average streamflow time series for input to a sediment model using the Soil Moisture Water Balance Model (SMWBM).

K.2 SMWBM

The SMWBM is a conceptual lumped parameter soil moisture water balance model that is designed to simulate both surface runoff and groundwater discharge from catchments. It has four primary and eight secondary parameters that can be adjusted until simulated flows correspond acceptably with observed flows. These parameters are listed in Table K1 together with brief descriptions.

Table K1 SMWBM Parameters

Parameter	Description	Unit
Primary parameters		
ST	Soil moisture storage capacity	mm
FT	Maximum soil drainage rate	mm/day
Zmax	Maximum infiltration rate	mm/hr
PI	Interception storage capacity	mm
Secondary parameters		
AI	Impervious portion of the catchment	Ratio
Zmin	Minimum infiltration rate	mm/hr
R	Soil evaporation equation option	0, 1, 10
DIV	Proportion of infiltration excess to eventually infiltrate as groundwater rather than surface water	0 – 1
TL	Surface routing coefficient	days
GL	Groundwater recession parameter	days
LAG	Catchment flow lag	days
POW	Power in soil moisture percolation curve equation	1 - 2
SL	Soil moisture storage when soil drainage ceases	mm

Model parameters are determined for the gauged catchments taking physical attributes of the catchments into consideration. These parameters can then be transposed to the ungauged catchments on the basis of the similarity of these catchments to the gauged catchments.

The modelling methodology was as follows:

- Determine the area and primary characteristics (i.e. land use, slope, soils) for each gauged and ungauged catchment
- Identify representative rainfall time series for each catchment from available rainfall data

- Set up the SMWBM for the gauged catchments
- Adjust model parameters until the simulated streamflow corresponds suitably with the observed streamflow
- Transpose model parameters to the ungauged catchments
- Set up the SMWBM for the ungauged catchments
- Generate synthetic daily average streamflow time series for the period of rainfall data for all catchments.

K.3 Generation of Streamflow Time Series

This section describes the collection of data, set up and calibration of the SMWBM and generation of the required streamflow time series for input to the sediment model.

K.3.1 Catchment Definition

Data for four gauged catchments were used to calibrate the SMWBM to determine model parameters that were used as input to generate daily average streamflow time series for 25 catchments in the project area. These gauged catchments are listed in Table K2 and the ungauged catchments in Table K3 together with relevant attributes. The location of the catchments is shown in **Figure K.1**.

Table K.2 Summary of Gauged Catchments

Catchment	Area (km^2)	MAP (mm)	Period of Record	Primary Land Use	Catchment Slope
Porirua Stream at Town Centre	40.30	1215	Aug 1982 to Oct 2009	40% Agricultural 20% Forest 30% Urban 10% Scrub	Moderate
Pauatahanui Stream at Gorge	38.27	1251	Oct 1978 to Sep 2009	60% Agricultural 25% Forest 15% Scrub	Moderate
Horokiri Stream at Snodgrass	28.69	1313	Mar 2002 to Mar 2006	45% Agricultural 35% Forest 20% Scrub	Moderate
Wainui above KCDC Offtake	1.83	1348	Jan 1999 to May 1999	85% Forest 10% Agricultural 5% Scrub	Steep

Porirua Stream at Town Centre	40.30	1215	Aug 1982 to Oct 2009	40% Agricultural 20% Forest 30% Urban 10% Scrub	Moderate

Table K3 Summary of Ungauged Catchments

Catchment	Area (km²)	MAP (mm)	Primary Land Use	Catchment Slope
Browns Catchment	1.35	1097	25% Forest 5% Agricultural 60% Urban 10% Scrub	Moderate
Collins Stream Catchment	0.64	1192	5% Urban 95% Agricultural	Flat
Duck Creek Catchment	10.30	1164	20% Forest 15% Urban 10% Scrub 55% Agricultural	Moderate
Horokiri Stream Catchment	33.06	1303	50% Agricultural 15% Scrub 35% Forest	Moderate – Steep (upper catchment)
Kakaho Catchment	12.46	1208	15% Scrub 65% Agricultural 20% Forest	Moderate
Kenepuru Stream Catchment	12.66	1147	10% Forest 40% Urban 35% Agricultural 15% Scrub	Flat – moderate (upper catchment)
Pauatahanui Stream Catchment	41.68	1243	60% Agricultural 2% Urban 23% Forest 15% Scrub	Moderate
Porirua Stream Catchment	41.08	1211	30% Urban 20% Forest 40% Agricultural 10% Scrub	Flat – moderate (upper catchment)
Ration Stream Catchment	6.80	1295	4% Scrub 55% Forest 40% Agricultural 1% Urban	Moderate
Takapuwahia Catchment	3.47	1011	50% Forest	Moderate

Catchment	Area (km²)	MAP (mm)	Primary Land Use	Catchment Slope
			5% Scrub 25% Urban 20% Agricultural	
Wainui Stream Catchment	8.31	1306	65% Forest 3% Urban 2% Scrub 30% Agricultural	Steep
Whareroa Stream Catchment	15.72	1293	20% Forest 70% Agricultural 9% Scrub 1% Urban	Steep upper – flat lower
Catchment A	0.64	1076	20% Forest 10% Agricultural 70% Urban	Moderate
Catchment B	0.29	1072	3% Agricultural 90% Urban 7% forest	Moderate
Catchment C	0.41	1074	20% Forest 50% Urban 5% Scrub 25% Agricultural	Moderate
Catchment D	0.45	1074	10% Scrub 50% Agricultural 15% Forest 20% Urban	Moderate
Catchment E	0.58	1068	60% Agricultural 10% Urban 15% Forest 10% Scrub	Moderate
Catchment F	0.98	1035	30% Scrub 5% Forest 60% Agricultural 5% Urban	Flat

Catchment	Area (km^2)	MAP (mm)	Primary Land Use	Catchment Slope
Catchment G	1.11	1026	10% Agricultural 80% Urban 10% Forest	Flat
Catchment H	1.01	1003	10% Forest 10% Agricultural 35% Urban 45% Scrub	Moderate
Catchment I	1.60	1050	50% Forest 50% Urban	Moderate
Catchment J	0.41	1168	5% Forest 90% Agricultural 5% Urban	Moderate
Catchment K	0.25	1134	5% Forest 95% Agricultural	Moderate
Catchment L	0.25	1098	20% Scrub 65% Agricultural 5% Forest 10% Urban	Moderate
Catchment M	0.25	1084	20% Forest 80% Urban	Moderate

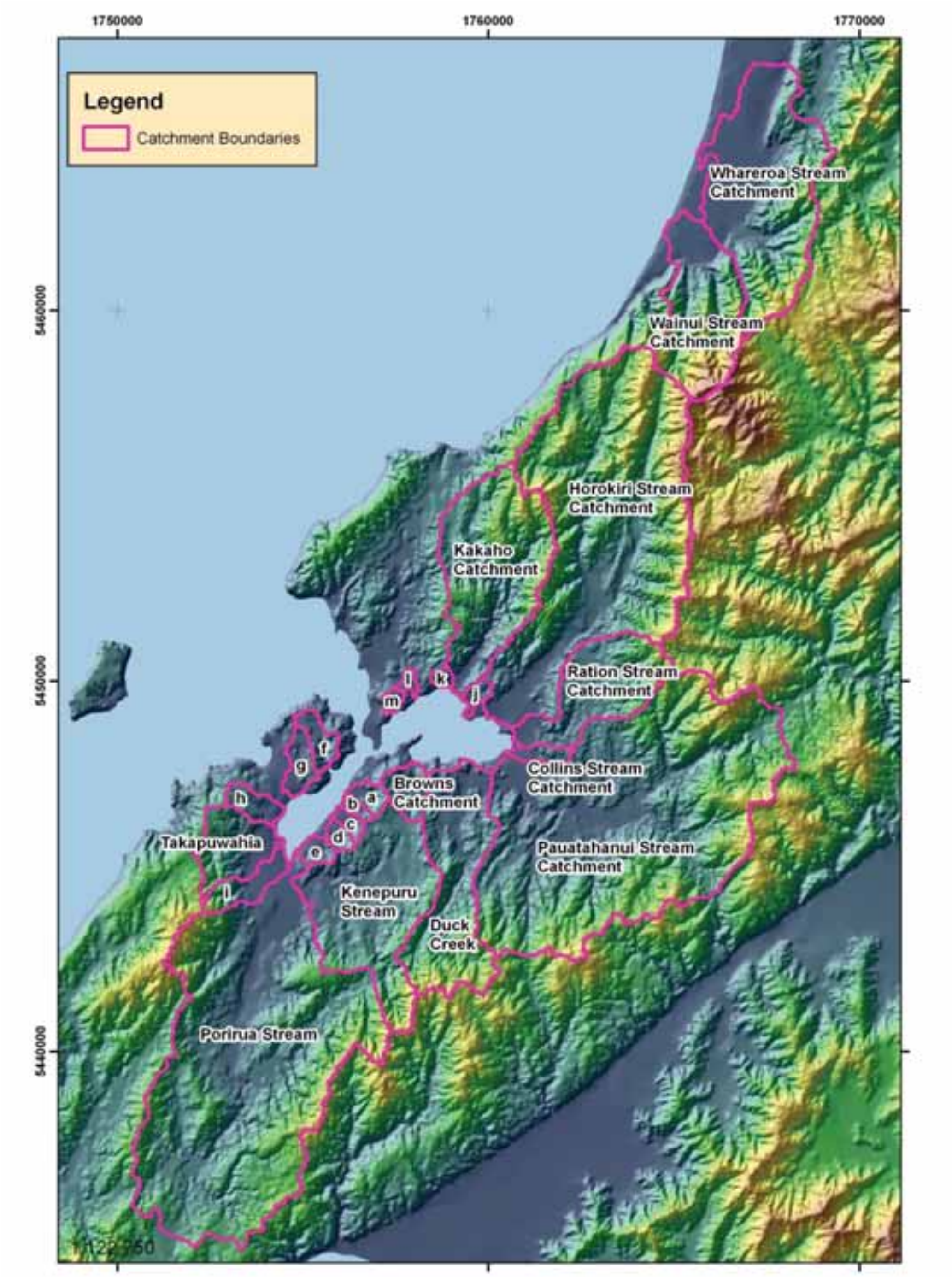


Figure K.1 Location of Catchments

K.3.2 Selection of Rainfall Time Series

Rainfall time series are the primary input to the SMWBM. The rainfall time series must be representative of average rainfall on the catchment to accurately simulate historic flows. Four rainfall stations were identified as potential candidates for representing rainfall over the gauged catchments. These stations are listed in **Table K.4** and their locations together with the gauged catchments are shown in **Figure K.2**.

Table K.4 Potential Rainfall Stations for Input to the SMWBM

Name	Period of Record
Putaputaweta at Whakatiki	1986-1992
Blue Gum Spur at Whakatiki	1981 to date
Moonshine at Pauatahanui	1975 to 1994
Whenua Tapu at Taupo	1991 to date
Putaputaweta at Whakatiki	1986-1992

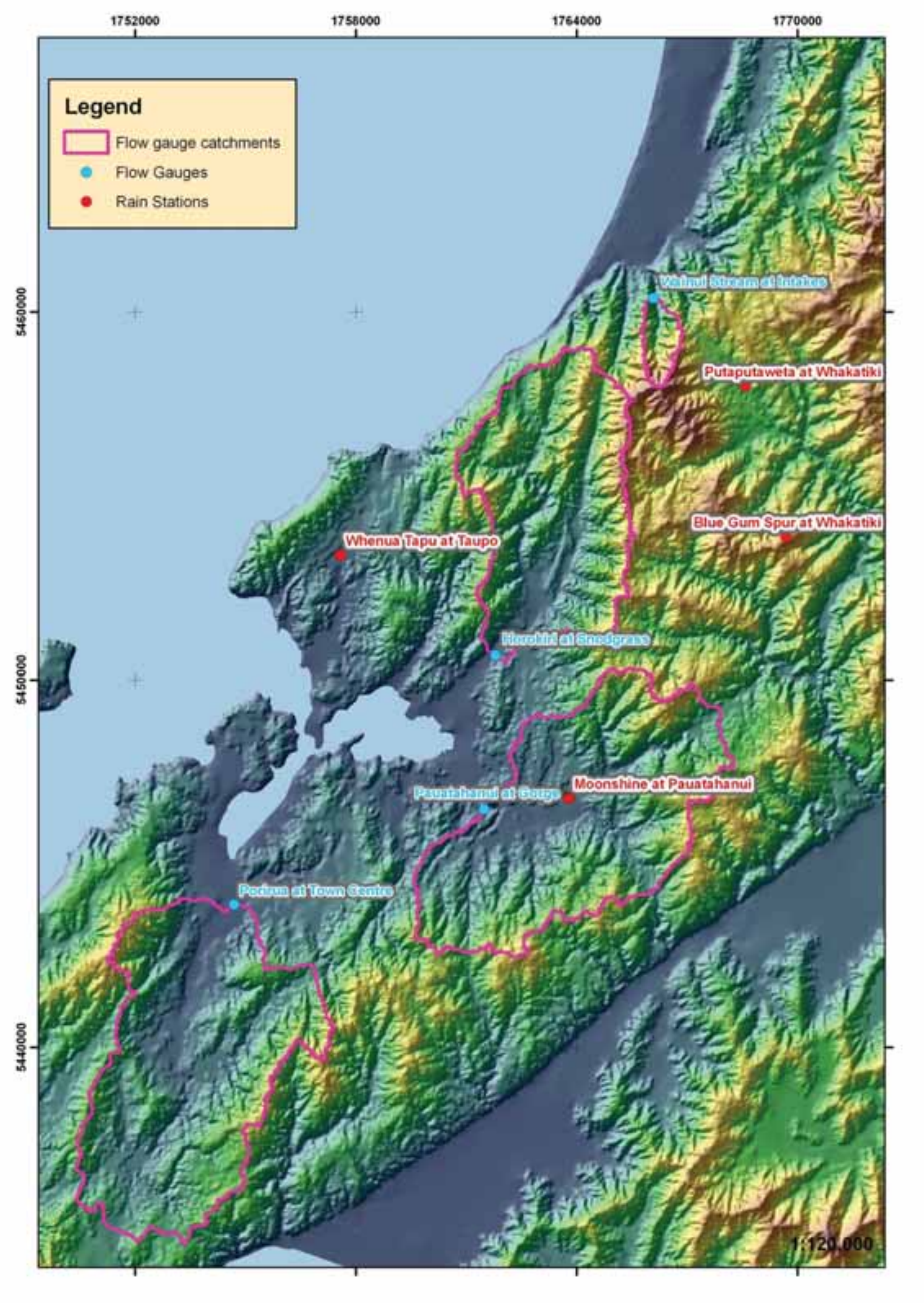


Figure K.2 Rainfall Stations and Gauged Catchments

Inspection of **Figure K.2** shows that, of the four gauged streams, only the Pauatahanui Stream has a rainfall station located within the catchment that could potentially be used to represent catchment rainfall in SMWBM.

NIWA have developed a model and used it to generate daily rainfall time series from 1960 to date at a 5 km grid spacing for the whole of New Zealand. These data for the study area were downloaded from the NIWA website. The grid point locations together with their reference numbers and mean annual precipitation (MAP) isohyets are shown in **Figure K.3** and are summarised in **Table K.4**.

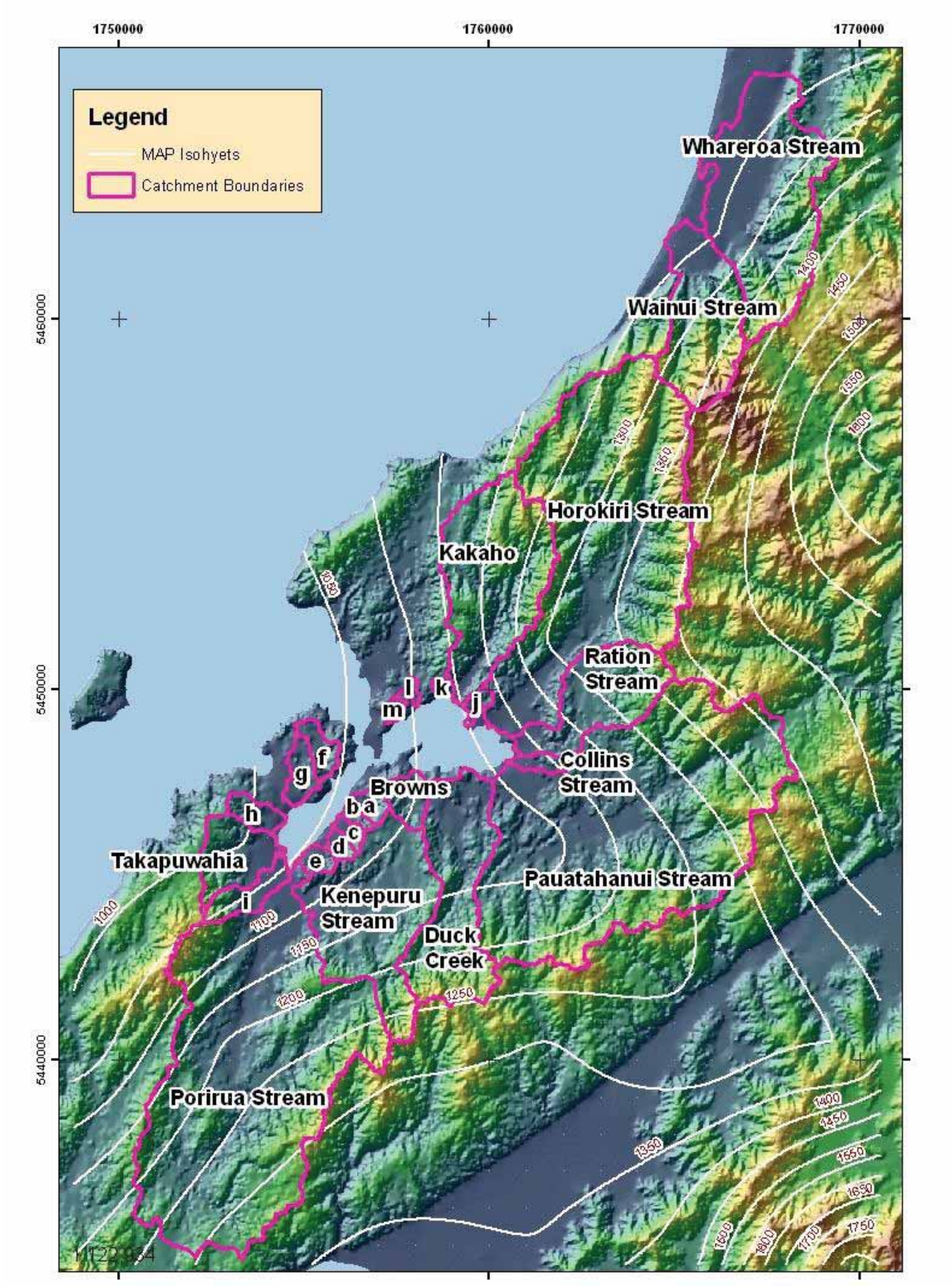


Figure K.3 Grid Rainfall Locations and MAP Isohyets with Study Catchments

Table K.4 Summary of Grid Rainfall Time Series in the Study Area

Grid reference	Location		Map
	Latitude	Longitude	
30212	-40.975	174.975	1250
28128	-41.025	174.925	1231
28632	-41.025	174.975	1379
27593	-41.075	174.875	1084
27059	-41.075	174.925	1311
30765	-41.075	174.975	1424
27590	-41.125	174.825	993
29144	-41.125	174.875	1102
27607	-41.125	174.925	1132
28134	-41.125	174.975	1266
29677	-41.175	174.825	1215
30196	-41.175	174.875	1283
29694	-41.175	174.925	1310
27069	-41.175	174.975	1268
27042	-41.225	174.825	1324
30195	-41.225	174.875	1361
30748	-41.225	174.925	1356
28133	-41.225	174.975	1440

A grid rainfall time series was allocated to represent the pattern of catchment rainfall for each of the catchments. Stations were selected on the basis of proximity and similarity of MAP. Interpolating rainfall for a catchment from the data for two or more grid time series was not carried out because this tends to generate a smoothed rainfall time series. Rather, the data from the selected grid time series was scaled according to the ratio of catchment and grid record MAP. **Table K.5** lists the catchments and selected grid time series together with their MAPs and factor used to adjust rainfall for input to the SMWBM.

Table K.5 Summary of Catchments and Grid Rainfall Stations

Catchment	MAP	Grid Ref. Time series	Grid MAP	Factor
Porirua Stream at Town Centre	1215	29677	1215	1.00
Pauatahanui Stream at Gorge	1251	28134	1266	0.99
Horokiri Stream at Grenlo	1313	27059	1311	1.00
Wainui above KCDC Offtake	1348	28632	1379	0.98
Browns Catchment	1097	29144	1102	1.00
Collins Stream Catchment	1192	27607	1132	1.05
Duck Creek Catchment	1164	27607	1132	1.03
Horokiri Stream Catchment	1303	27059	1311	0.99
Kakaho Catchment	1208	28128	1231	0.98
Kenepuru Stream Catchment	1147	29144	1102	1.04
Pauatahanui Stream Catchment	1243	28134	1266	0.98
Porirua Stream Catchment	1211	29677	1215	1.00
Ration Stream Catchment	1295	27059	1311	0.99
Takapuwahia Catchment	1011	27590	993	1.02
Wainui Stream Catchment	1306	28632	1379	0.95
Whareroa Stream Catchment	1293	30212	1250	1.03
Duck Creek 2	1170	27607	1132	1.03
Horokiri 3	1300	28128	1231	1.06
Horokiri 4	1350	28632	1379	0.98
Catchment A	1076	29144	1102	0.98
Catchment B	1072	29144	1102	0.97
Catchment C	1074	29144	1102	0.97
Catchment D	1074	29144	1102	0.97
Catchment E	1068	29144	1102	0.97
Catchment F	1035	27590	993	1.04
Catchment G	1026	27590	993	1.03
Catchment H	1003	27590	993	1.01

Catchment	MAP	Grid Ref. Time series	Grid MAP	Factor
Catchment I	1050	27590	993	1.06
Catchment J	1168	27593	1084	1.08
Catchment K	1134	27593	1084	1.05
Catchment L	1098	27593	1084	1.01
Catchment M	1084	27593	1084	1.00

K.3.3 Model Calibration

The SMWBM was set up and calibrated using the data for the four gauged catchments. Calibration was based on comparison of the daily observed and simulated hydrographs and flow duration curves. The comparison of the simulated and observed hydrographs as shown for the Horokiri gauge in **Figure K.4**, showed that for some events the simulated streamflow compared well with observed, but for many events the comparison was poor. This indicates that the selected rainfall time series do not accurately represent catchment rainfall for all events.

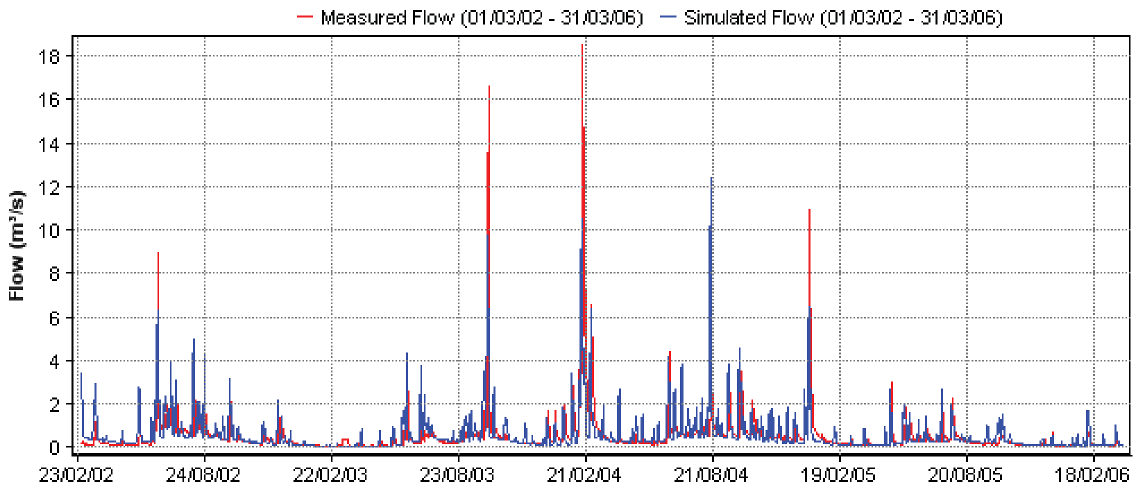


Figure K.4 Horokiri Stream: Observed and Simulated Hydrographs

Comparison of the flow duration curves generated from the observed and simulated flows showed good comparison for the Porirua, Pauatahanui and Horokiri catchments (**Figure K.5** to **Figure K.7** respectively) and poor result for the very short Wainui gauge (**Figure K.8**).

This shows that even though the simulations do not correlate well with all the historic events, overall the simulated time series are representative of flow at the gauges. Without more representative rainfall data for the catchments it is not possible to accurately simulate historic streamflow. Accordingly calibration of the soil moisture water balance mode concentrated on the comparison between observed and simulated flow duration curves.

The observed record for the Wainui gauge is only 5 months long. Over this very short period the simulated and observed flow duration curves do not correspond very well and the model parameters were selected on the basis of comparison of the hydrographs.

The adopted model parameters for the four catchments are listed in **Table K.6**.

Table K.6 SMWBM Calibration Parameters

Catchment	ST (mm)	FT (mm/day)	Zmax (mm/hr)	PI (mm)	AI	GL	POW
Porirua	250	1.2	5	2	0.16	1	1
Pauatahanui	200	1.2	5	2	0	1	1
Horokiri	250	1.5	5	1	0	1	2
Wainui	250	1.5	8	1	0	1	1

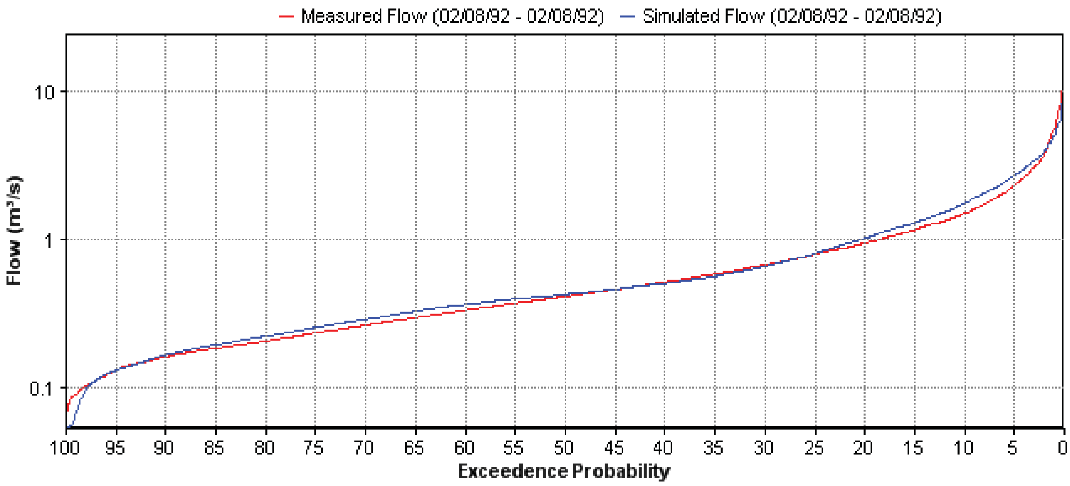


Figure K.5 Porirua Stream: Observed and Simulated Flow Duration Curves

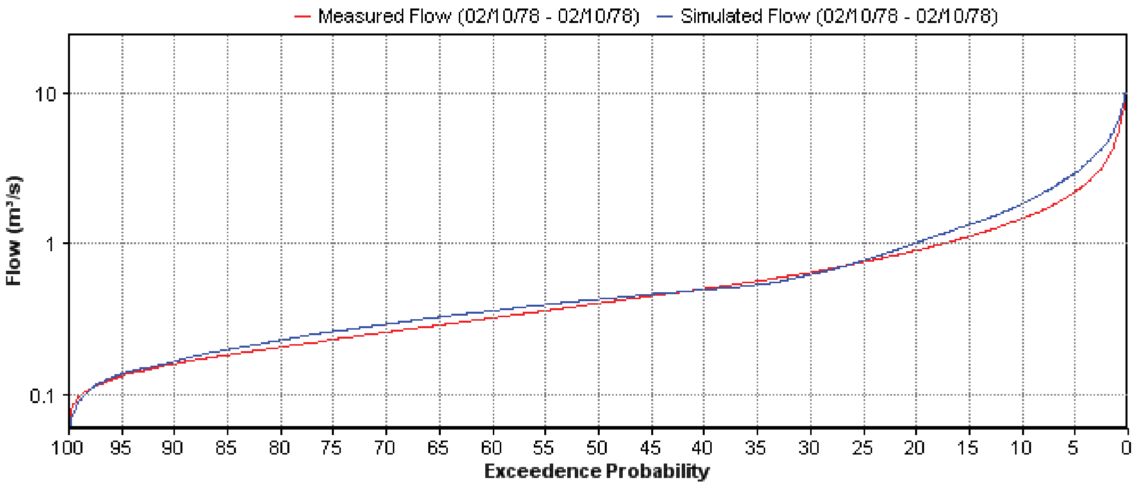


Figure K.6 Pauatahanui Stream: Observed and Simulated Flow Duration Curves

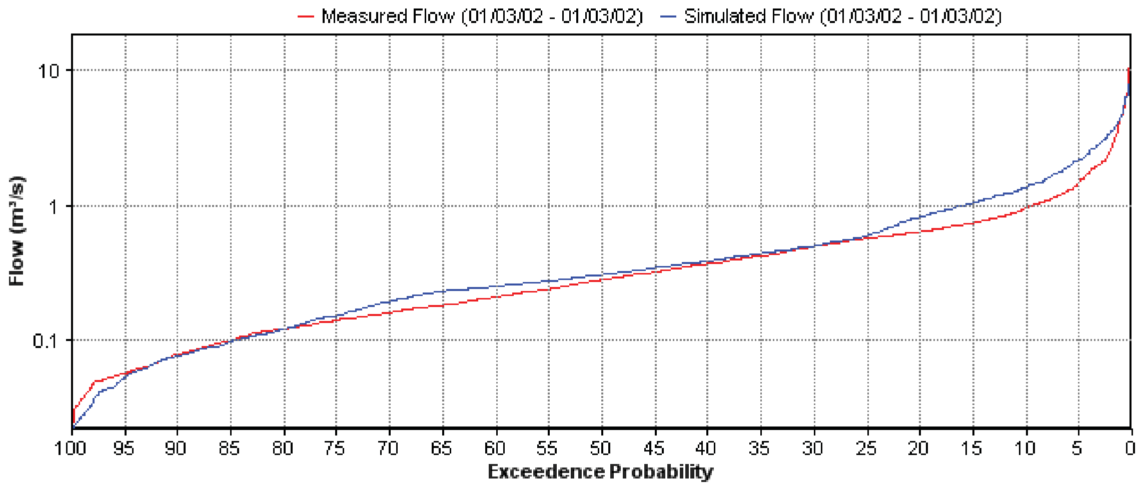


Figure K.7 Horokiri Stream: Observed and Simulated Flow Duration Curves

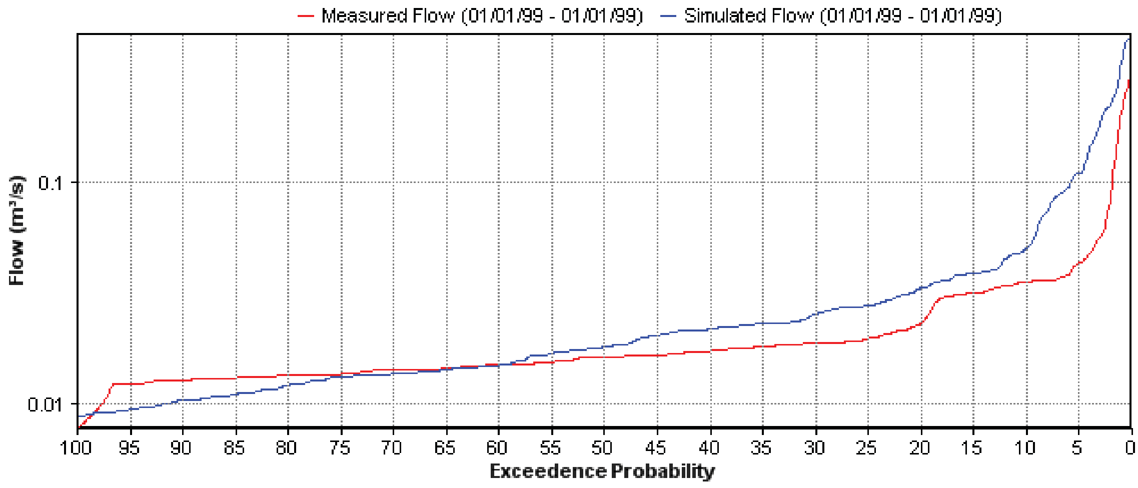


Figure K.8 Wainui Stream: Observed and Simulated Flow Duration Curves

K.3.4 Model Parameters for the Ungauged Catchments

SMWBM parameters were selected for the ungauged catchment on the basis of catchment similarity to gauged catchments. These parameters are listed in **Table K.7**.

Table K.7 SMWBM Parameters for Ungauged Catchments

Catchment	ST (mm)	FT (mm/day)	Zmax (mm/hr)	PI (mm)	AI	GL	POW

Catchment	ST (mm)	FT (mm/day)	Zmax (mm/hr)	PI (mm)	AI	GL	POW
Browns Catchment	250	1.2	5	1	0.3	1	1
Collins Catchment	200	1.2	5	2	0.3	1	1
Duck Creek Catchment	200	1.2	5	2	0.2	1	1
Horokiri Catchment	250	1.5	5	1	0	1	2
Kakaho Catchment	250	1.5	5	1	0	1	1
Kenepuru Catchment	250	1.2	5	1	0.27	1	1
Pauatahanui Catchment	200	1.2	5	2	0	1	1
Porirua Catchment	250	1.2	5	1	0.27	1	1
Ration Catchment	250	1.5	5	1	0	1	1
Takapuwahia Catchment	250	1.2	5	1	0.1	1	1
Wainui Catchment	250	1.5	8	1	0	1	1
Whareroa Catchment	250	1.2	5	1	0	1	1
Duck Creek 2	200	1.2	5	2	0	1	1
Horokiri 3	250	1.5	5	1	0	1	2
Horokiri 4	250	1.5	5	1	0	1	2
Catchment A	250	1.2	5	1	0.3	1	1
Catchment B	250	1.2	5	1	0.3	1	1
Catchment C	250	1.2	5	1	0.3	1	1
Catchment D	250	1.2	5	1	0.1	1	1
Catchment E	250	1.2	5	1	0	1	1
Catchment F	250	1.2	5	1	0	1	1

Catchment	ST (mm)	FT (mm/day)	Zmax (mm/hr)	PI (mm)	AI	GL	POW
Catchment G	250	1.2	5	1	0.3	1	1
Catchment H	250	1.2	5	1	0.2	1	1
Catchment I	250	1.2	5	1	0.1	1	1
Catchment J	250	1.5	5	1	0	1	1
Catchment K	250	1.5	5	1	0	1	1
Catchment L	250	1.5	5	1	0	1	1
Catchment M	250	1.5	5	1	0.3	1	1

The SMWBM was used to generate daily streamflow time series for the full period of the grid rainfall data (1 January 1960 to 22 March 2010). The catchment area together with average and maximum simulated daily flows are listed in **Table K.8** for each catchment.

Table K.8 Catchment Areas, Average and Maximum Daily Flows

Catchment	Area (km²)	Daily flow (m³/s)	
		Average	Maximum
Browns Catchment	1.35	0.026	0.517
Collins Catchment	0.64	0.014	0.322
Duck Creek Catchment	10.30	0.206	5.072
Horokiri Catchment	33.06	0.736	16.818
Kakaho Catchment	12.46	0.264	6.548
Kenepuru Catchment	12.66	0.259	5.881
Pauatahanui Catchment	41.68	0.876	22.638
Porirua Catchment	41.08	0.902	20.644
Ration Catchment	6.80	0.158	3.410
Takapuwahia Catchment	3.47	0.057	1.642
Wainui Catchment	8.31	0.181	5.810
Whareroa Catchment	15.72	0.352	8.991
Duck Creek 2	6.15	0.119	3.108
Horokiri 3	14.77	0.329	8.761

Catchment	Area (km^2)	Daily flow (m^3/s)	
Horokiri 4	10.60	0.247	6.421
Catchment A	0.64	0.012	0.223
Catchment B	0.29	0.005	0.100
Catchment C	0.41	0.008	0.142
Catchment D	0.45	0.008	0.198
Catchment E	0.58	0.010	0.253
Catchment F	0.98	0.016	0.481
Catchment G	1.11	0.020	0.439
Catchment H	1.01	0.017	0.423
Catchment I	1.60	0.028	0.798
Catchment J	0.41	0.008	0.220
Catchment K	0.25	0.005	0.128
Catchment L	0.25	0.005	0.117
Catchment M	0.25	0.005	0.085

The streamflow time series for the ungauged catchments were generated from the grid rainfall time series, which will preserve the temporal correlation of streamflow between the catchments.

K.4 Summary

The objective was to generate daily streamflow time series for the catchments that feed into the Porirua Harbour and that will be traversed by the proposed highway.

The approach followed was to calibrate the SMWBM using data for the four gauged catchments in the study area to form a basis for selecting model parameters for the ungauged catchments.

The grid daily rainfall time series, generated from observed rainfall data by NIWA, were selected to provide rainfall input to the SMWBM because inadequate observed rainfall data is available to represent rainfall on the catchments. The selected grid rainfall time series was factored according to the ratio of catchment MAP to grid MAP to generate a rainfall time series for each catchment.

The spatial and temporal correlation of rainfall between the grid time series helped preserve these correlations between the synthetic streamflow time series.

The synthetic streamflow time series are considered representative of runoff from each of the catchments and suitable for input to the hydraulic models that will be used in further analyses.

Appendix 15.L Construction - Draft Erosion and Sediment Control Monitoring

L.1 Introduction

This section describes a draft monitoring plan for the performance of the measures proposed and potential impacts on the streams water quality. It is intended to provide an outline to manage the performance of the erosion and sediment control devices and is considered key to the success of the Project.

L.2 Monitoring Plan Structure

The monitoring plan will need to detail who has responsibility for its control and ownership and the status of the document. Including:

- Covers the roles of the people who have actions to implement this plan and their responsibilities.
- Provides an overview of the proposed ESC measures for the road alignment.
- Documents the compliance monitoring required to ensure that the proposed ESC measures are operating and performing as designed.
- Inspections and Performance Monitoring
- Compliance Reporting
- Assess the impacts of construction of the Project on water quality are as anticipated and direct action to modify ESC Plans

L.3 Interaction with other Project Monitoring Documents

The Performance Monitoring Plan will need to cover how it interacts with:

- Construction Management Plan
- Incident Management Plan
- Health and Safety Plan
- Project Management Reporting and Personnel.

L.4 Document Control and Ownership

This draft plan has been produced for NZTA to support resource consent applications. Post consenting and pre construction this document will need further development. It is anticipated that ownership of the document will pass to the construction contractors. They will be responsible for its finalisation and implementation. It is however expected that the ESC measures will need to adapt and modify during construction. It is intended that this performance monitoring document should be adapted to reflect the operative ESC Plan.

L.5 Roles and Responsibilities

This section of the plan will outline who are the key contacts and their responsibilities and will be completed once a construction contractor is identified. It will include:

- Site management
- Training records and requirements
- Monitoring of weather patterns (predictions)
- Inspection parties involved, scheduling, records and reporting
- Sampling parties involved, scheduling, records and reporting
- Communications includes Media plan, CEMP changes, Project and site meeting actions and follow ups
- Reporting
- Incident and emergency response.

L.6 Emergency Contacts

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

L.7 Overview of Erosion and Sediment Control Activities

The ESC Philosophy outlines the principles to be applied in managing erosion and sediment release as part of this Project. The Project will be an extensive multi-linear construction project over approximately eight years. Site constraints change over the length of the alignment. The Project will require further specification on the application of these measures during construction and will need to be undertaken as part of the detailed design work. This includes the testing and development of measures to contain sediment in steep areas of the construction and matching the best treatment options to the catchment geology.

A similar approach has been taken to specifying the performance and water quality monitoring for the Project. It is not intended to specify monitoring for each of these individual devices in this plan. The general philosophy will be outlined.

The performance monitoring activities will focus on the ESC methods whose use and/or performance can be assessed as outlined in **Table L.1** to **Table L.3**.

As part of the construction of the Project, works will be required in water bodies. These will include stream crossings and stream diversions. Performance monitoring and compliance inspections of these work areas will be required.

L.8 Performance Monitoring Activities - Overview

The ESC activities proposed cover actions that are proposed to be undertaken on site as well as use of specific devices and methods. These will require a mix of monitoring types to ensure the performance of the ESC plan and compliance with consent conditions. Monitoring types can generally be grouped into inspection activities and physical monitoring activities. With all activities a management action is required should a specific trigger be exceeded. Reporting of inspections, monitoring and actions is also required. Erosion control measures and sediment control measures are considered separately in earlier sections. The GWRC guidelines have been used to develop these procedures.

L.9 Performance Monitoring Activities for Erosion Control Measures

Table L1 sets out the compliance monitoring activities, for each erosion control method identified in Table 15.11. These include the following activities:

- **Routine inspection** – Documents the inspection frequency that is required to ensure the devices are operative, performing as designed and ready for future rain events.
- **Incident inspection** – Details events that may trigger additional inspections to check the devices are operative
- **Wet weather inspections** – Documents the performance of erosion control measures in circumstances which test the design parameters.
- **Inspection criteria** –Specific factors to be considered and noted during the inspection.
- **Performance measures -** Performance specification identifying what trigger values (narrative and numeric) monitoring results should be compared against.
- **Maintenance / management actions** – Actions to be undertaken when trigger values are determined to be exceeded during inspection ; and
- **Reporting** – Notes what should be reported and who to.

Table L.1 Performance Monitoring Activities for Erosion Control Measures

Erosion Control Measure	Routine Inspection	Wet Weather and Incident Inspections	Inspect for	Performance measures	Management Action	Reporting
Control and retention of disturbed soil at earthwork sites (Improve Soil Health)	Weekly	During heavy rain (Q10 event) and after all rain	Soil loss Rill erosion Surface water flow pathways	Retention of soil	Rectify any erosion or channel formation Re-grade surface as required	Inspection, outcomes and managemen t action in site log
Provide Short Term Soil Cover	Weekly	When rainfall predicted through weather monitoring. After all rain	Surface water pathways / erosion	Design specifications	Undertake straw mulching Hydro seeding	Inspection, outcomes and managemen t action in site log
Provide Long Term Soil Cover	Weekly	During heavy rain (Q10 event) and after heavy rain (Q10 event)	Damage / erosion Growth of plantings (including gaps)	90% cover or stabilised.	Rectify and repair damage to blankets/netting Replant gaps/dieback	Inspection, outcomes and managemen t action in site log

Erosion Control Measure	Routine Inspection	Wet Weather and Incident Inspections	Inspect for	Performance measures	Management Action	Reporting
Steep Slope Techniques	Weekly till 90% stabilised (i.e. 90% gassed or equivalent)	During heavy rain (Q10 event) and after heavy rain (Q10 event)	Damage / erosion Growth of plantings (including gaps)	Design specifications	Rectify and repair damage to blankets/netting Replant gaps/dieback	Inspection, outcomes and managemen t action in site log

L.10 Performance Monitoring Activities for Surface Water Control Measures

Table L.2 sets out the compliance monitoring activities for each surface water control method. These include the following activities:

- **Routine inspection** – Documents the inspection frequency that is required to ensure the devices are operative, performing as designed and ready for future rain events.
- **Incident inspection** – Details events that may trigger additional inspections to check the devices are operative
- **Wet weather inspections –** Documents the performance of erosion control measures in circumstances which test the design parameters.
- **Inspection criteria** –Specific factors to be considered and noted during the inspection.
- **Performances measures** - Performance specification identifying what trigger values (narrative and numeric) monitoring results should be compared against.
- **Maintenance / management actions** – Actions to be undertaken when trigger values are determined to be exceeded during inspection ; and
- **Reporting** – Notes what should be reported and who to.

Table L.2 Compliance Monitoring Activities for Surface Water Control Measures

Surface Water Control Measure	Routine Inspection	Wet weather and incident inspections	Inspect for	Performance measures	Management Action	Reporting

Surface Water Control Measure	Routine Inspection	Wet weather and incident inspections	Inspect for	Performance measures	Management Action	Reporting
Clean water diversion bund	Weekly	During heavy rain (Q10 event) and after all rain	Damage / erosion Blockages Sediment build-up	Design specifications	Rectify any damage / erosion or blockages Remove accumulated sediment in diversion channel.	Inspection, outcomes and management action in site log
Rock check dam	Weekly	After all rain	Damage / erosion Blockages Sediment build-up	Design specifications	Rectify any damage / erosion or blockages Remove accumulated sediment behind dams when 50% full	Inspection, outcomes and management action in site log
Pipe drop structure/ flume	Weekly	After all rain	Damage / erosion Blockages	Design specifications	Rectify any damage / erosion or blockages	Inspection, outcomes and management action in site log
'Pinned' Silt socks or gravel check dams	Weekly	During heavy rain (Q10 event) and after heavy rain (Q10 event)	Damage / erosion Sediment build-up	Design specifications	Rectify and damage / erosion or blockages Replace/ repair gaps	Inspection, outcomes and management action in site log

L.11 Compliance Monitoring Activities for Sediment Control Measures

Table L.3 sets out an overview of the compliance monitoring activities for each sediment control method identified in **Table L.1**.

Table L.3 Overview of Compliance Monitoring Activities for Sediment Control Measures

Sediment Control measure	Inspection	Monitoring	Reporting

Sediment Control measure	Inspection	Monitoring	Reporting
Sediment Retention Pond	Daily and post incident	Performance audit check	Yes
Chemical Treatment System	Weekly and post incident	Performance audit check	Yes
Sediment Fence	Weekly and post incident	Performance audit check	Yes
Decanting Earth Bund	Weekly and post incident	Performance audit check	Yes
Stormwater Inlet Protection	Weekly and post incident	Performance audit check	Yes
Works in watercourses	Weekly and post incident	Performance audit check	Yes

For sediment control measures a greater range of compliance monitoring actions are required. These are further documented below in Table L4 and Table L5.

L.12 Performance Inspections

Table outlines the inspection required for each proposed sediment control measure. These include the following activities:

- **Routine inspection** – Documents the inspection frequency that is required to ensure the devices are operative, performing as designed and ready for future rain events.
- **Incident inspection** – Details events that may trigger additional inspections to check the devices are operative
- **Wet weather inspections** – Documents the performance of erosion control measures in circumstances which test the design parameters.
- **Inspection criteria** –Specific factors to be considered and noted during the inspection.
- **Performance measures** - Performance specification identifying what trigger values (narrative and numeric) monitoring results should be compared against.
- **Maintenance / management actions** – Actions to be undertaken when trigger values are determined to be exceeded during inspection ; and
- **Reporting** – Notes what should be reported and who to.

Table L4 Compliance Inspection Activities for Sediment Control Measures

Device	Routine Inspection	Incident Inspection	Inspect for	Performance Measures	Management Action	Reporting
Sediment Retention Pond	Daily	After all rain. During heavy rain (Q10)	Sediment build up	Measure depth of sediment versus pond volume	Remove sediment when 20% full	Inspection, outcomes and management action in site log
			Damage/ Function of the decants/ Level Spreaders / Fore bay	Design Specifications	Rectify any damage / blockages to fore bay	Inspection, outcomes and management action in site log Advise GWRC within 24hrs of significant damage and management actions
Chemical treatment System	Weekly	After all rain. During heavy rain (Q10)	Damage, low dosing supply	Design Specifications	Rectify any damage or blockages. Replace flocculent	Inspection, outcomes and management action in site log
Sediment Fence / Silt Socks	Weekly	After all storm events (Q2-Q10)	Sediment build-up	Measure depth of sediment versus fence height	Remove sediment when 20% of height occupied	Inspection, outcomes and management action in site log
			Damage/ erosion/ water bypass	Design Specifications	Rectify any damage / erosion. Relocate devices to deal with bypass	Inspection, outcomes and management action in site log

Device	Routine Inspection	Incident Inspection	Inspect for	Performance Measures	Management Action	Reporting
Decanting Earth Bund	Weekly	After all rain events During heavy rain (Q10)	Sediment build-up	Measure depth of sediment versus pond volume	Remove sediment when 20% full	Inspection, outcomes and management action in site log
			Damage/ erosion Blockages	Design Specifications	Rectify any damage / erosion or blockages	Inspection, outcomes and management action in site log Advise GWRC within 24hrs of significant damage and management actions
Stormwater Inlet Protection	Weekly	After all rain	Damage/ erosion Blockages	Design Specifications	Rectify any damage / erosion or blockages	Inspection, outcomes and management action in site log
Works in watercourses	Weekly	After all rain	Visual release of sediment into the water above that envisaged for works	Documented method for works	Investigate source of sediment and rectify works/modify method	Inspection, outcomes and management action in site log

L.13 Performance Monitoring

To ensure ESC measures function as intended it is proposed to monitor performance of sediment control devices at the beginning of each new construction phase (catchment section). Table L5 sets out the monitoring activities required for the sediment control devices to ensure that the designs are operating within their design performance specifications as discussed in section 3. This will allow update and modifications to the design should performance not be as planned. Following this and once compliance has been ascertained frequency for monitoring will drop back to a representative range of devices during a rain event. This section of monitoring assesses the performance of the devices versus their design standards, not the absolute effects on the receiving environment. It is noted that failure to meet the performance standard does not necessarily indicate that an impact will occur in the receiving environment as a result of the discharge. Monitoring proposed in section 4.6 is intended to understand the effect on the receiving environment water quality.

Table L5 Monitoring Activities for Sediment Control Measures

Device	Monitoring Required	Frequency	Parameters	Locations	Performances measures	Management Action and Reporting
Sediment Retention Pond	Audit check of device performance	All ponds constructed at the beginning of each new construction phase to enable performance to be ascertained during all rain events which generate a discharge. If devices are performing as intended then frequency should drop to one in every five ponds. Monitoring to occur at times during rain events that generate a discharge. Number of ponds is intended to encompass a representative sample of different soil characteristics in the construction area under the SEMP and as such could be adjusted accordingly.	Flow rates, Total Suspended Solids, calibrated turbidity, particle size analysis.	Inlet to pond and outlet from pond	Sediment retention devices up to Q2 event 90% removal particles >60 µm, 70% removal particles <60 µm	Consider whether discharge has downstream impact. Modify design to meet target and resample if required. Advise GWRC of failure. Report all samples in monthly report
Chemical Treatment System	Audit check of device performance	All ponds constructed at the beginning of each new construction phase to enable performance to be ascertained during all rain events which	Depends on chemical dosing method. Include Visual check of pond clarity, pH,	Inlet to pond and outlet from pond	System is not being over dosed; this will include limits for pH and Aluminium.	Modify dosing system if overdosing. Note Inspection, outcomes

		generate a discharge. If devices are performing as intended then frequency should drop to one in every five ponds. Monitoring to occur at times during rain events that generate a discharge. Number of ponds is intended to encompass a representative sample of different soil characteristics in the construction area under the SEMP and as such could be adjusted accordingly.	Flow rates, Total Suspended Solids, calibrated turbidity, particle size analysis and settling rates		(If required) Q2 event 90% removal particles >60 µm, 70% removal particles <60 µm	and management action in site log
Decanting Earth Bund	Audit check of device performance	All control devices at the beginning of each new construction phase to confirm operation as intended. If performing as designed then frequency should drop to one in every ten bunds checked once during operation during rain storm that creates discharge.	Include Visual check of pond clarity, calibrated turbidity, particle size analysis and settling rates	Inlet to bund and outlet from bund	Up to Q2 event, if 3% of catchment area, >30% TSS removal for particles <60microns 100% removal of >60microns. If less than 3% area ratio this down according to % catchment area/3%.	Consider whether discharge has downstream impact. Modify design to meet target and resample if required. Advise GWRC of failure. Report all samples in monthly report

L.14 Reporting

In addition to the outline for the reporting requirements for the inspection and maintenance activities in Table L4 and Table L5, it is considered that a monthly report to GWRC will be required. This would outline:

- Inspections undertaken where issues arose and action taken to rectify those issues
- Results of all monitoring undertaken
- Analysis of trends in monitoring data
- Non-conformances in monitoring results and actions undertaken.

L.15 Monitoring of Effects on Water Quality

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

L.16 Monitoring Philosophy

Within the Project alignment are a number of catchments. There will be many discharge points from sediment control devices within each catchment. The location of these discharges relate to the various sections of Project being worked on, the staging of works and topography.

It is not intended to monitor impacts at all sites throughout the entire development lifespan. Instead an approach of setting up long term catchment control sites and then short term smaller work area monitoring is proposed. The intent is that the catchment control sites create a long term dataset of upstream and downstream water quality. These can be used for monitoring both construction and operational stormwater discharges.

As work progresses through each area monitoring will assess the effect of each stage of work with sampling effort based on the risk the catchment poses from the ongoing activities. An indication of the monitoring required for a theoretical catchment is shown in **Figure L1**.

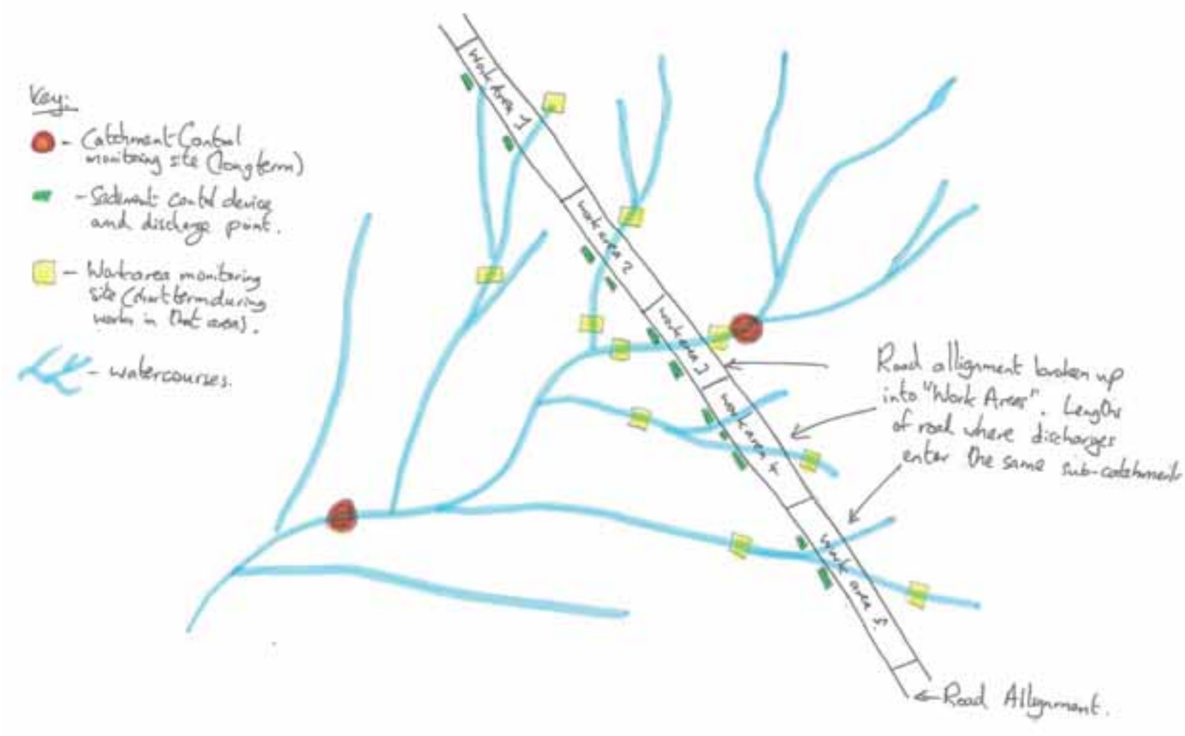


Figure L1 Indicative Monitoring Requirements for a Catchment

L.17 Proposed Monitoring and Reporting

The requirements for the catchment control and work area monitoring are shown in Table L6 and Table L7 These tables outline the following details:

- **Sample Point** – The locations at which monitoring is to be undertaken. For the Catchment Control sites these are a selection of the sites used in the scoping studies.
- **Frequency -** Required frequency of monitoring, this generally varies prior to, during and post construction. The intention is to sample pre construction to develop a baseline, then during and post construction until the catchment is stabilised to assess effects.
- **Parameters** – Recommended parameters to sample. These will be finalised after completion of the AEE. These are a subset of the monitoring undertaken for the scoping studies. For both the catchment control and work area monitoring sites key parameters are a visual assessment of percentage fine sediment, calibrated turbidity, particle size and total suspended solids as these relate to the primary construction contaminant risks. In addition field parameters including flow rates, pH, temp, streambed and macroinvertebrate assessments will be recorded. These are intended to give an early identification of where any changes in sediment load, movement and deposition are affecting basic water quality during works.
- At the catchment control sites additional monitoring will be undertaken for flow rates, turbidity, pH and temperature. These sites will also be used to monitor long term stream health indices by monitoring at regular intervals macro-invertebrate and fish communities.

- Compliance Limits – Proposed limits for certain monitored parameters. These will be finalised after completion of the AEE. These are only proposed for the key parameters of assessment as follows; percentage fine sediment, calibrated turbidity and total suspended solids. These will give the best indication of changes in sediment load and deposition in the catchments. Should these limits be exceeded it will trigger a management action to inspect and investigate the suitability of the ESC operations in that work area/catchment. The remaining parameters are intended to give a picture of longer term temporal changes in the catchments and would be analysed over the lifespan of the project. As such no compliance limits are finalised for this report and should be developed as part of the AEE.
- Reporting – An indication of how and when results should be reported. It is intended that all parameters are reported with analysis in monthly reports and collated with trend analysis in an annual report. Exceedance of compliance limits should be reported to GWRC within 5 working days of receipt of the results.

Table L6 Monitoring Requirement for Catchment Control Monitoring Sites

Sample point	Frequency	Parameters	Compliance Limits	Reporting
Whareroa – Whareroa 1 (U/S) and new D/S site. Wainui – Wainui 1 (U/S) and new D/S site. **Horokiri** -Horokiri 1 (U/S) and Horokiri 2 (D/S). [To confirm that 1 is upstream of all works – alternatively consider 3 as side control]. **Ration** – Establish new upstream and downstream sample points. **Pauatahanui** – Pauatahanui 1 (U/S) Pauatahanui 2 (D/S). **Duck Creek** – Duck 1 (U/S) Duck 2 (D/S). **Kenepuru** – Kenepuru 1 (U/S) and Kenepuru 3 (D/S). **Porirua** – Porirua 1 (U/S) and Porirua 2 (D/S).	Monthly starting at least 12 months prior to works starting in the catchment. Monthly during construction. For 6 months after opening of the road	Fine sediment percentage by particle size analysis (%)	Change by X% at D/S site compared to pre development	To GWRC within 5 working days of non compliance In monthly report
		Turbidity (NTU)	Change by X units vs. upstream site and/or X% outside the range of background data (If baseline data available)	In monthly report
		Total Suspended Solids (g/m^3)	Change by X units vs. upstream site and/or X% outside the range of background data (If baseline data available)	
		Temperature	Consultation with GWRC	
		pH	Consultation with GWRC	
		Macro-	Consultation with	To GWRC within

		Invertebrates	GWRC	5 working days of receipt of results In monthly report
		Fish community	Consultation with GWRC	To GWRC within 5 working days of receipt of results In monthly report
		Harbour Estuary assessment for cockle health and other benthic fauna parameters	Consultation with GWRC	To GWRC within 5 working days of receipt of results In monthly report

Table L7 Monitoring Requirement for Work Area Monitoring Sites

Sample point	Frequency	Parameters	Compliance Limits	Reporting
Upstream and downstream of works on each work area (to capture effect of all discharges from sediment control devices in work area sub-catchment)	Monthly starting at least 3 months prior to works starting in the catchment. Monthly during construction. Monthly after works completed in that catchment that result in all bare soils stabilised by non-vegetative means or until stabilisation of 90% of bare soils is achieved.	Fine sediment percentage by particle size analysis (%)	Change by X% at D/S site compared to pre development	Within 24 hrs of non compliance to GWRC In monthly report
		Turbidity (NTU)	Change by X% at D/S site compared to pre development	Within 24 hrs of non compliance to GWRC In monthly report
		Total Suspended Solids (g/m^3)	Change by X% at D/S site compared to pre development	
		Temperature	Change by X% at D/S site compared to pre development	
		pH	Change by X% at D/S site compared to pre development	
		Macro-Invertebrates	Change by X units vs. upstream site and/or X% outside the range of	Within 24 hrs of non compliance to GWRC In monthly report

			background data.	
		Streambed assessment	Change in bed matrix at downstream site by x% Visual assessment of re-suspension of suspended solids	Within 24 hrs of non compliance to GWRC In monthly report

Appendix 15.M Sediment Control Volumes

Catchment	Catchment Area (m²)	Required Pond Volume (m³)
1	5478	164
2	3651	110
3	5420	163
4	2258	68
5	6323	190
6	13003	390
7	3132	94
12	5185	156
13	2157	65
14	1568	47
16	1180	35
17	13787	414
19	2659	80
20	9236	277
22	1881	56
23	2303	69
24	3429	103
25	5493	165
26	3012	90
27	3194	96
28	2720	82
29	2895	87
30	2461	74
31	3642	109
33	3651	110
34	1040	31
35	3580	107

36	3150	95
37	6734	202
39	1658	50
41	6464	194
42	13173	395
43	7662	230
44	7632	229
46	5903	177
47	1362	41
48	2258	68
49	8907	267
50	2354	71
51	8218	247
52	4766	143
53	10105	303
54	6062	182
56	10744	322
57	8724	262
58	9551	287
59	5292	159
60	2822	85
61	3515	105
62	4046	121
64	4786	144
66	4472	134
67	6847	205
68	3803	114
70	4683	140
71	2791	84
72	2595	78
73	5405	162
74	3802	114

75	2560	77
76	839	25
77	3088	93
78	3340	100
83	10912	327
84	9468	284
86	2102	63
88	2772	83
89	1189	36
90	1297	39
91	949	28
93	4543	136
94	1629	49
96	4304	129
97	2116	63
98	998	30
99	1823	55
100	2363	71
102	2762	83
103	1049	31
105	3460	104
106	2151	65
107	2159	65
108	9397	282
109	4904	147
110	2775	83
112	1147	34
113	1353	41
114	1992	60
115	11031	331
116	11675	350
118	2350	70

119	2489	75
122	3534	106
123	2447	73
124	1950	58
125	2709	81
126	2512	75
127	2875	86
128	1409	42
129	7913	237
130	9661	290
131	800	24
132	1366	41
133	1705	51
134	613	18
135	2539	76
136	2113	63
137	2236	67
139	1570	47
140	5441	163
141	3169	95
142	1005	30
143	1929	58
144	2432	73
146	3703	111
147	1775	53
148	4391	132
149	3890	117
150	3928	118
151	1726	52
152	4088	123
153	649	19
154	716	21

155	3701	111
156	7158	215
157	939	28
158	1783	53
159	3197	96
160	1100	33
161	3285	99
162	3536	106
163	3625	109
164	889	27
165	1078	32
166	3053	92
167	1371	41
168	1134	34
169	3668	110
170	4216	126
173	857	26
175	909	27
176	2867	86
177	3585	108
181	1156	35
184	2711	81
185	2019	61
189	1919	58
190	4881	146
191	2234	67
192	12176	365
193	2321	70
194	12933	388
197	5147	154
198	4411	132
199	1603	48

200	1873	56
201	3700	111
202	11693	351
203	1439	43
204	2166	65
206	3126	94
207	3661	110
208	3523	106
209	1187	36
210	8047	241
211	2521	76
212	6916	207
216	6858	206
218	5181	155
219	5731	172
223	5629	169
227	5148	154
228	2708	81
229	4605	138
230	3281	98
231	3024	91
232	1556	47
233	2913	87
235	2178	65
236	3925	118
237	7350	220
238	5333	160
239	2160	65
242	5563	167
243	2903	87
244	6438	193
245	1861	56

246	2233	67
247	1481	44
248	2116	63
249	6803	204
250	6814	204
251	3712	111
252	6104	183
257	1739	52
258	7810	234
259	3230	97
260	11276	338
263	6036	181
264	5090	153
265	5370	161
266	6095	183
267	4181	125
268	4835	145
269	1737	52
270	2917	88
271	6496	195
272	4197	126
274	2091	63
277	8163	245
279	3906	117
281	3187	96
282	5227	157
283	4615	138
287	5210	156
293	2824	85
294	2788	84
295	4163	125
296	2736	82

297	1555	47
298	2071	62
300	1417	43
301	2613	78
302	2757	83
303	1073	32
304	1713	51
305	3056	92
306	2330	70
307	3498	105
308	4547	136
309	2245	67
310	2668	80
311	2029	61
312	3880	116
313	6633	199
314	3201	96
315	13952	419
316	3089	93
317	13956	419
318	3530	106
319	1865	56
320	3703	111
321	4009	120
322	2525	76
323	2373	71
324	2688	81
326	2554	77
327	3029	91
328	3758	113
329	4180	125
330	4206	126

331	1727	52
332	2701	81
333	2471	74
334	2013	60
335	3937	118
336	1120	34
337	2142	64
338	2160	65
339	1970	59
340	3082	92
341	3637	109
342	1032	31
344	3924	118
347	3812	114
348	6328	190
349	4727	142
350	11302	339
351	2837	85
352	2153	65
353	2598	78
354	2294	69
355	923	28
356	4841	145
357	1582	47
358	1637	49
359	4139	124
360	6936	208
361	7546	226
367	2759	83
370	2288	69
372	3230	97
373	1912	57

374	4305	129
376	2594	78
377	4248	127
378	8801	264
A - 400	3959	119
B - 401	3027	91
C - 402	3575	107
F - 405	3191	96
J - 408	2442	73
K1 - 409	11059	332
K2 - 410	7724	232
L - 411	2412	72
N - 413	21403	642
P - 415	1100	33
Q1 - 416	4107	123
Q2 - 417	3801	114
R - 418	3006	90
U - 421	10886	327
V - 422	11603	348
W - 423	5507	165
X - 424	7973	239
Y - 425	4838	145
Z - 426	5126	154

Appendix 15.N USLE calculation

N.1 Universal Soil Loss Equation

The universal soil loss equation (USLE) is an empirical model developed by the U.S. Department of Agriculture (USDA) to estimate sheet and rill erosion from agricultural lands (Goldman et al, 1986). The USLE was chosen as the preferred method of estimating the average annual sediment yield for the Transmission Gully Project.

The general form of the USLE is:

A = R x K x LS x C x P

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

N.2 USLE Additional Factors

The USLE provides a method of calculating a theoretical sediment yield, however it does not take account of the proportion of that sediment that is delivered to receiving environment, nor does it account for mitigation measures which are designed to intercept and remove sediment generated in the catchment prior to its delivery to receiving environments.

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

N.3 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.

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.

N.4 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 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. The factors assumed for calculation of the USLE are given in Table N1. Each factor is then discussed in the following sections.

Table N1 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	0.12

N.4.1 USLE Limitations

The USLE:

- Estimates erosion from sheet and rill erosion, not gully erosion, stream channel or land sliding
- Is an empirical equation based on US agricultural sites. There is limited research on its applicability to New Zealand, although it is widely used
- Estimates average annual sediment yield, rather than event based loads.

N.5 NIWA Suspended Sediment Tool

The NIWA Suspended-Sediment Yield Estimator Tool is a raster-based GIS layer of specific suspended-sediment yield (SSY, t/km2/y) from New Zealand's rivers and streams based on gauged sediment yields of over 200 river stations and an empirical model. The model relates sediment yield per unit area to mean annual rainfall and to an 'erosion terrain' classification, and has been calibrated off the river-gauging data. The erosion terrain was defined by Landcare Research on the basis of slope, rock type, soils, dominant erosion processes (using information in the NZLRI) and expert knowledge. The layer can be used to estimate suspended-sediment delivery to rivers and streams from within any defined catchment boundary and has been developed as a series of GRID files within the ARC GIS system.

The main limitation of this method is that it doesn't allow for a temporal frame for land use term, so it could not be used to predict changes in landuse such as the how the construction stage of Transmission Gully would affect sediment loads in the receiving environments. It also can't be used to predict event yields. Sediment yield estimates from Pauatahanui at Gorge were included in the calibration. The uncertainty level for this tool is order factor-of-two, but gets bigger for small catchments (< 10 km²).

Given these limitations, it was determined it would be more appropriate to use this method as a check to ensure the calculation of sediment yield using the USLE was in the correct order of magnitude.

N.6 Rainfall Erosivity (R) Factor

The 2 year 6 hour rainfall depth was used calculate R, as it is assumed that this would provide an estimate of the average annual rainfall erosivity. This is consist with published research: a paper *Potential Sources of Sediments and Nutrients: Sheet and Rill Erosion and Phosphorus Sources* published by C.J. Rosewell (1997) as part of the Australia: State of the Environment Technical Paper Series (Inland Waters) provides a relationship for R as a function of the 2 year 6 hour rainfall. It is also consistent with research in the US (Goldman et al, 1986), and is recommended by the Greater Wellington *Erosion and Sediment Control Guidelines* (2006) for pond design. The design assumes a 24 hour 2 year return period storm (50% AEP) of 90mm with a maximum intensity of 40mm/hour.

The equation from the *Erosion and Sediment Control Handbook* (Goldman et al, 1986) for the US west coast was used to calculate R from the 2 year 6 hour rainfall depth:

$$R=1.7 \times 0.00828p^{2.2}$$

where: R is the rainfall erosivity factor in J/ha and p is the 2 year 6 hour rainfall depth in mm.

Rainfall stations with continuous data were analysed and maximum 6-hour rainfall were extracted following a partial series analysis, which is appropriate for annual return intervals less than 10-years. In accordance with the paper by Rosewell (1997), the Log-Pearson 3 distribution was used to determine the 2-year 6-hour rainfall depths. Sensitivity analyses showed that for the 2-year events selecting the General Extreme Value or the Generalised Logistic distribution would have negligible impact on the rainfall depths. The results together with the rainfall erosivity factors calculated using the above formula are listed in Table N2.

Table N2 6-Hour Storm Rainfall and Erosivity Factors (R) for Local Rain Gauges

Rainfall Station	2-Year 6-Hour Rainfall Depth (mm)	Rainfall Erosivity Factor (R)
Kapakapanui	61.5	121
Mangaone	57.4	104
Taungata	75.5	191
Waikanae	47.8	70
Warwicks	68.5	154
Blue Gum Spur	65.4	139
Mill Creek Reservoir	40.3	48
Seton Nossiter Park	45.9	64
Whenua Tapu	44.1	58
Wellington Glenside	41.5	51
Wellington Karori	46.9	67

It should be noted that while the 2 year 6 hour rainfall is used, the USLE does not calculate the 2 year sediment load, rather it calculates the average annual sediment load. The average annual load can then be disaggregated using a rating curve to predict sediment loads at a range of return period events. The methodology for undertaking the development of the sediment rating curve is discussed in **Section Appendix 15.Q.**

N.7 Soil Erodibility (K) Factor

The K factor represents both susceptibility of soil to erosion and the amount and rate of runoff. Soil texture, organic matter, structure, and permeability determine the erodibility of a particular soil.

In the Wellington region, units of Quaternary marine grey-blue silt and sandy silt up to 30m thick are commonly perched on, or down-faulted between, greywacke blocks, or have accumulated in partly submerged valley systems. Both loess and the marine silts have high silt and clay contents (GWRC, 2006).

A value of K can be estimated using the published soil erodibility nomograph, adjusted for gravel content and organic content (ARC, 2009).

Appendix 15.Odescribes the method used to calculate K from test pits, which is a simplified version of the nomograph provided in the USLE text book (Goldman *et al*., 1986).

Two data sets were used to describe the soils: the NZLRI data set which provides soil information for the whole area, and test pit data which provided soil and gravel information at a greater detail for the Project alignment. The soil information from the test pits was considered to be more accurate and so, where appropriate, use was made of test pit data to describe soils.

The soils were analysed using the soil type polygons identified in the NZLRI and the hydrological catchments.

The following method was to ensure the best information available was used to describe the soils:

- For those soil polygons with test pits the average K of all the test pits in that polygon and the average of the gravel content in that soil polygon was used
- Where there was a test pit in a soil polygon classified by the NZLRI as the same particle size and/or name as another polygon elsewhere, the average K value calculated using the test pits and the NZLRI data was use. The average gravel content from the test pits within the hydrological catchment was used
- Where there was no test pit in a soil polygon classified by the NZLRI as the same particle size and/or name as another polygon elsewhere, the NZLRI name was used and it was assumed the soil was made up of 70% of the major soil component and 30% minor soil component. The average gravel content from the test pits within the hydrological catchment was used
- Where there was no test pit in a soil polygon classified by the NZLRI as the same particle size elsewhere, and the NZLRI data did not describe the soil using a name, the NZLRI particle size description was used and it was assumed the soil was made up of 80% of the major soil component and 10% the other two soil fractions. The average gravel content from the test pits within the hydrological catchment was used.

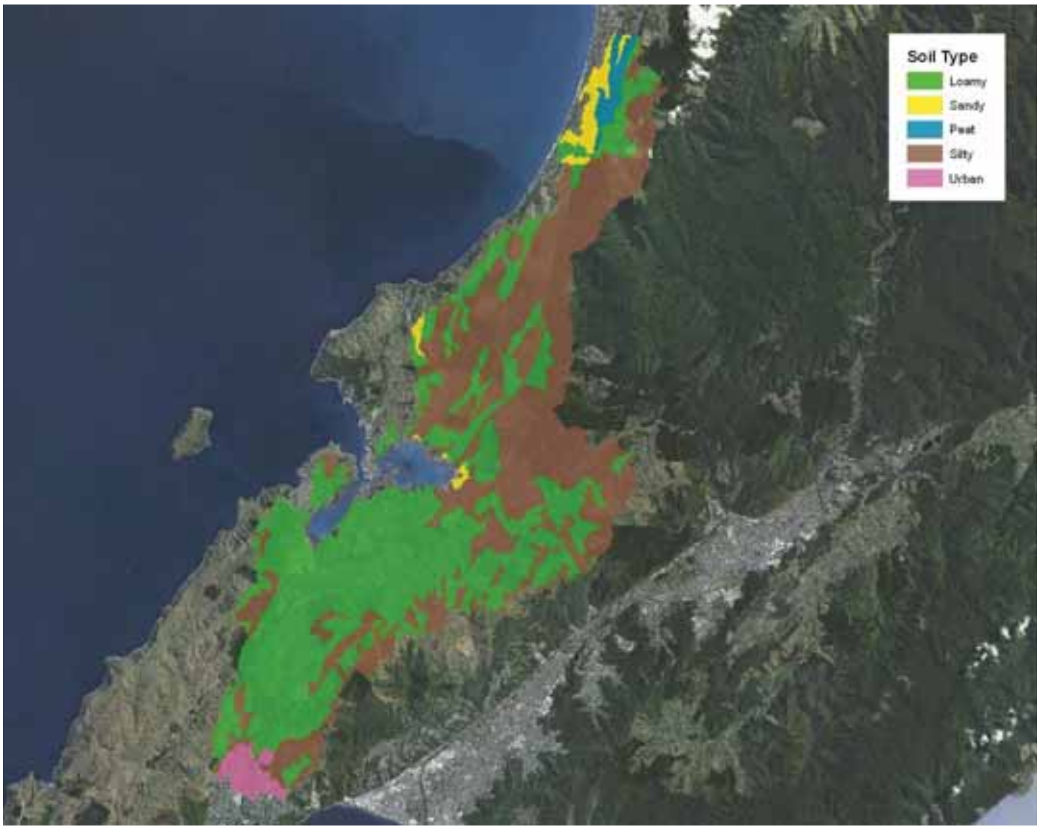
Soils

About half of the soils in the NZLRI have names and these adhere to the convention of major and minor e.g. Silt loam, where loam is major and silt is the minor. This is described in NZ Geotechnical Society (2005). All have a particle size described in the NZLRI and detailed in Table N3.

Table N3 Soil Particle Size and Description

Particle size	Description
K	Skeletal
S	Sandy
L	Loamy
Z	Silty
C	Clayey
Ts	Sandy peat or sandy litter, organic matter 30-50%, sand in mineral fraction >50%
Tl	Loamy peat or loamy litter, organic matter 30-50%, sand in mineral fraction <50%
Tp	Peat or litter, organic matter >50%

The soil types for the Project area were spatially resolved from the NZLRI database and used to calculate mean particle size distribution. **Figure N1** and **Figure N2** portray the soil types within the Project area.



- **Figure N1 Soil Types in Project Area**

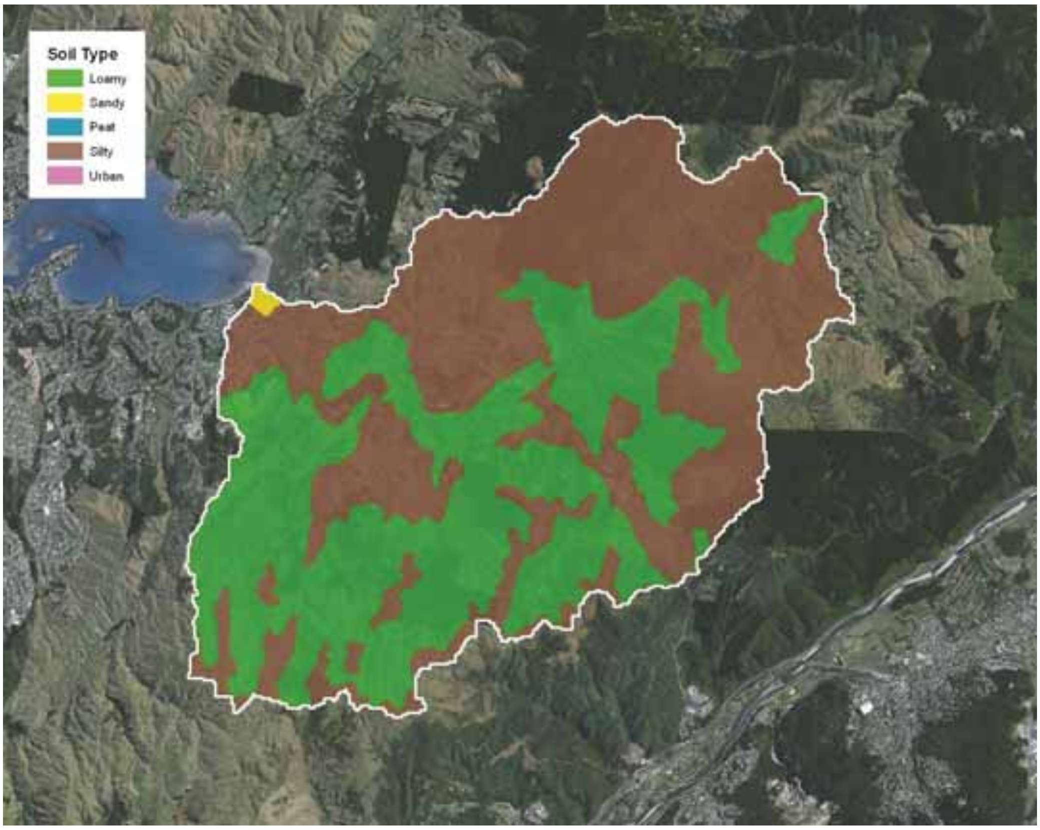


Figure N2 Soil Types in Pauatahanui Catchment

Gravel

The NZLRI gravel data, described in **Table N.4**, was assessed and was deemed not to be reliable for the Project area, with the vast majority of the area being described as having low gravel content.

The test pit analysis **Appendix 15.P** and from soil observation on site visits, indicated that the gravel content of soils, in particular in the Horokiri and Te Puka catchments was likely to be greater than described by the NZLRI.

Table N4 Gravel Content Classification

Gravel Class	Description	%
1	Non-gravelly to very slightly gravelly	0-4
2	Slightly gravelly	5-14
3	Moderately gravelly	15-34
4	Very gravelly	35-69
5	Extremely gravelly	70-100

Therefore, the test pit gravel data was deemed to be a more reliable dataset than the NZLRI and was used for describing the gravel content of all soils (**Figure N3**).

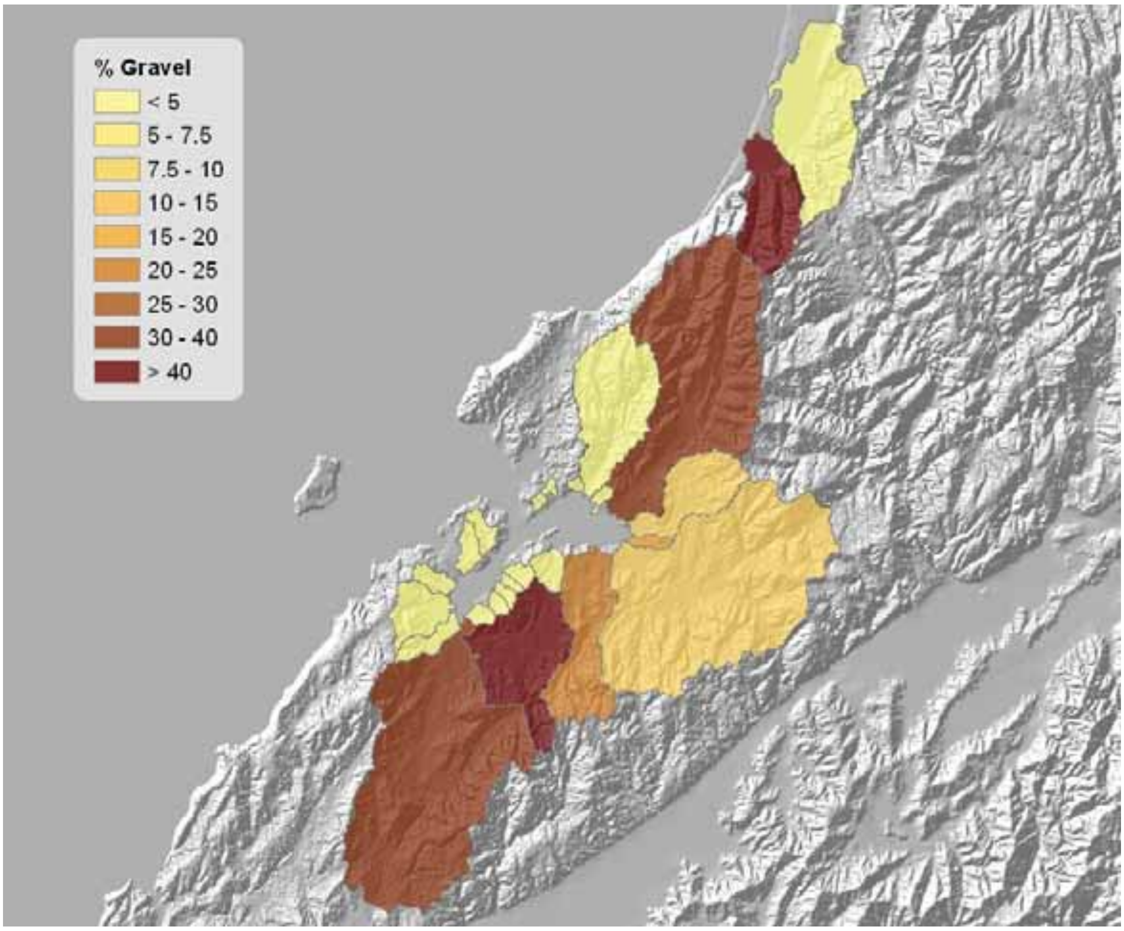


Figure N3 Average Gravel Content from Catchments Based on Test Pits

The average gravel content from the test pits was applied to the whole hydrological catchment, and then the K value was adjusted assuming that this was the percentage gravel for all soils within this catchment.

Particle Size

The particle size distribution for the catchments was selected by applying the most appropriate particle size based on the NZLRI information and test pits – as described in the method above then transformed to a spatial distribution based on the particle size classes in the NZS4404 (which covers requirements for earthworks and geotechnical needs, roads and stormwater). This allows for the prediction of a particle size distribution based on erosion and sediment loss in the catchment. This is an important attribute in calculating the distribution of particles in the harbour model. Particle size for each catchment is shown in **Table N4**. The sand, silt and clay fraction is given for each catchment.

Table N4 Particle Size by Catchment

Catchment Name	Sand Ratio [62- 2 millimetres]	Silt Ratio [2-62 microns]	Clay Ratio [0-2 microns]
Browns	40	40	20

Catchment Name	Sand Ratio [62- 2 millimetres]	Silt Ratio [2-62 microns]	Clay Ratio [0-2 microns]
Collins	37.16	50.14	12.7
Duck	34.82	47.13	18.05
Horokiri	22.53	64.28	13.19
Kakaho	19.57	68.56	11.87
Kenepuru	36.25	45.14	18.61
Pauatahanui	31.1	52.69	16.2
Porirua	33.08	49.46	17.47
Ration	22.34	65.34	12.32
Takapuwahia	36.68	44.43	18.89
Wainui	27.04	61.86	10.73
Whareroa	31.52	43.03	8.1
a	40	40	20
b	40	40	20
c	40	40	20
d	40	40	20
e	40	40	20
f	29.53	55.71	14.76
g	39.6	40.6	19.8
h	40	40	20
i	36.3	44.94	18.77
j	28	58	14
k	32.16	59.01	8.83

The calculated K values from the nomograph are portrayed in **Figure N4** and **Figure N5**, demonstrating the spatial resolution of the K factorial.

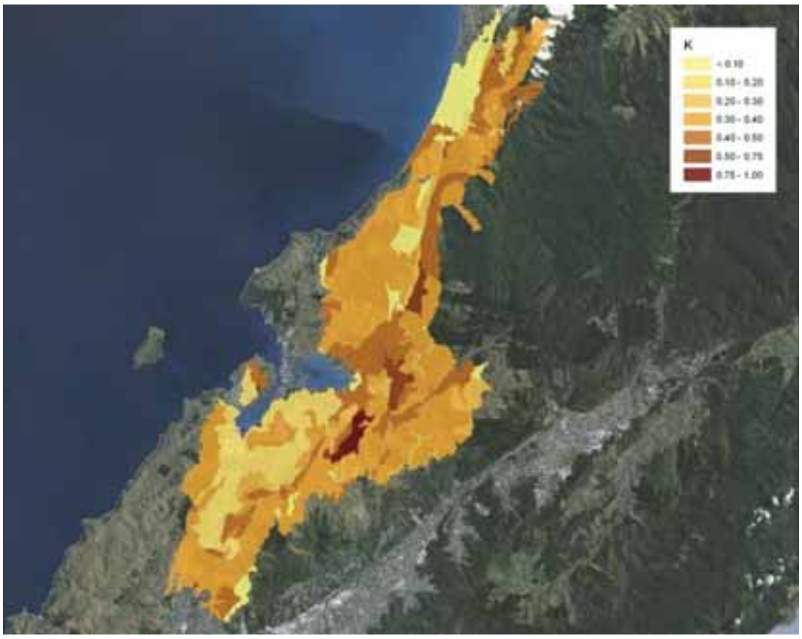


Figure N4 K Values for the Project Catchments

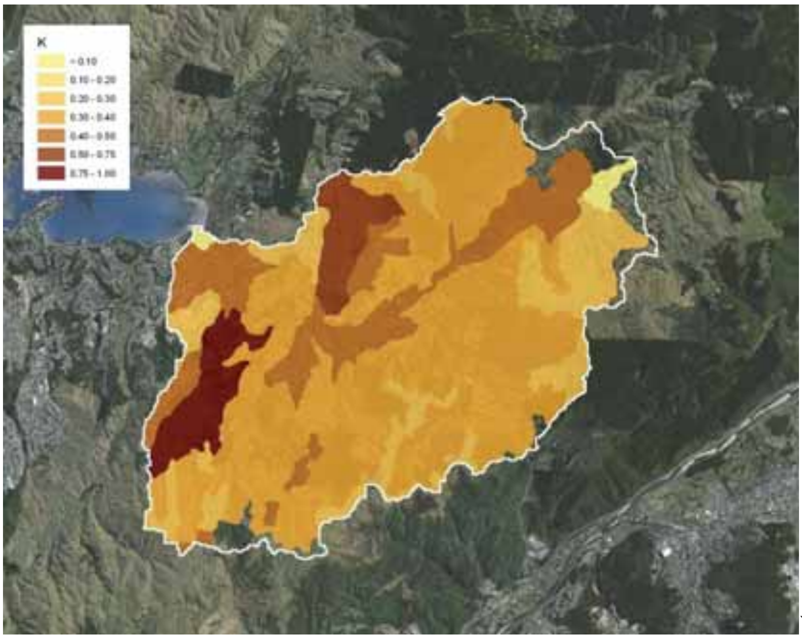


Figure N5 K Values for Pauatahanui Catchment

N.8 C Factor

Analysis of the aerial photographs was used to create a spatial distribution of land cover types which classified land into either:

- Impervious area
- Open space

- Bare soil.

This allowed the catchments to be modelled for changes in land cover over the course of the Project construction.

The C factors used were taken from ARC's *Erosion and Sediment Control Workshop Notes* (ARC, 2004) and were applied to all land Table N5.

Table N5 C Factors (ARC, 2004)

Description	C Factors
Bare soil	1
Native vegetation e.g. forest and scrub	0.01
Pasture or plantation forest	0.02
Temporary grass	0.1
Mulch on topsoil	0.05
Impervious/water	0

N.9 Impervious Area

Under the USLE method no sediment is calculated as being generated from impervious cover. However in practice impervious cover is a source of some sediment. Typical values for residential land, roads and roofs of 55g/m², taken from the Auckland Regional Council's Contaminant Load Model (ARC, 2006) were used to estimate sediment yields for all connected impervious land. These were calculated separately to the USLE and added to the final values. This contribution is considered as part of the conservative framework for the estimation of sediment yields within the Project catchments.

N.10 Bare Soil (Active Earthworks)

The bare soil that was identified through the aerial photographic analysis and as identified in the NZ Landcover database was given a C value of 1.0.

N.11 Open Space

The New Zealand Land Cover Database was used to classify open space land (**Table N6**).

Table N6 Classification of Open Space Land From the Land Use Database

Land Use Database Land Use Categories	USLE C Factor Land Use Categories
Parkland/gardens	Pasture or plantation forest
Water	Impervious/water
Crops	Pasture or plantation forest
Pasture/grassland	Pasture or plantation forest
Bush	Native vegetation

Land Use Database Land Use Categories	USLE C Factor Land Use Categories
Plantation forest	Pasture or plantation forest
Wetlands	Impervious/water
Transport infrastructure	Impervious/water
Fallow	Pasture or plantation forest
Bare	Bare soil

The following **Figure N6** and **Figure N7** portray the spatial and temporal resolution of the C factor.

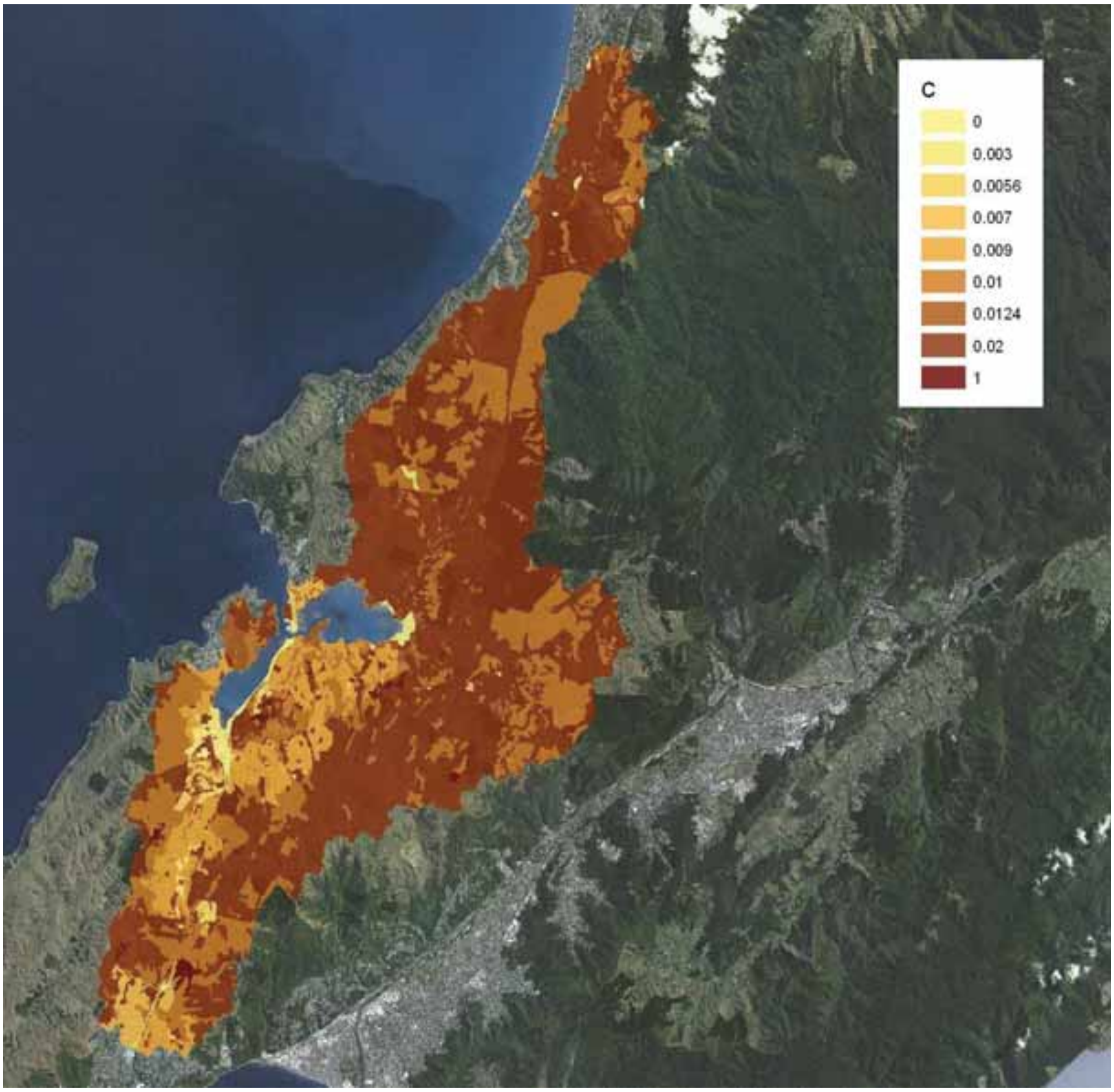


Figure N6 C Values for Project Area

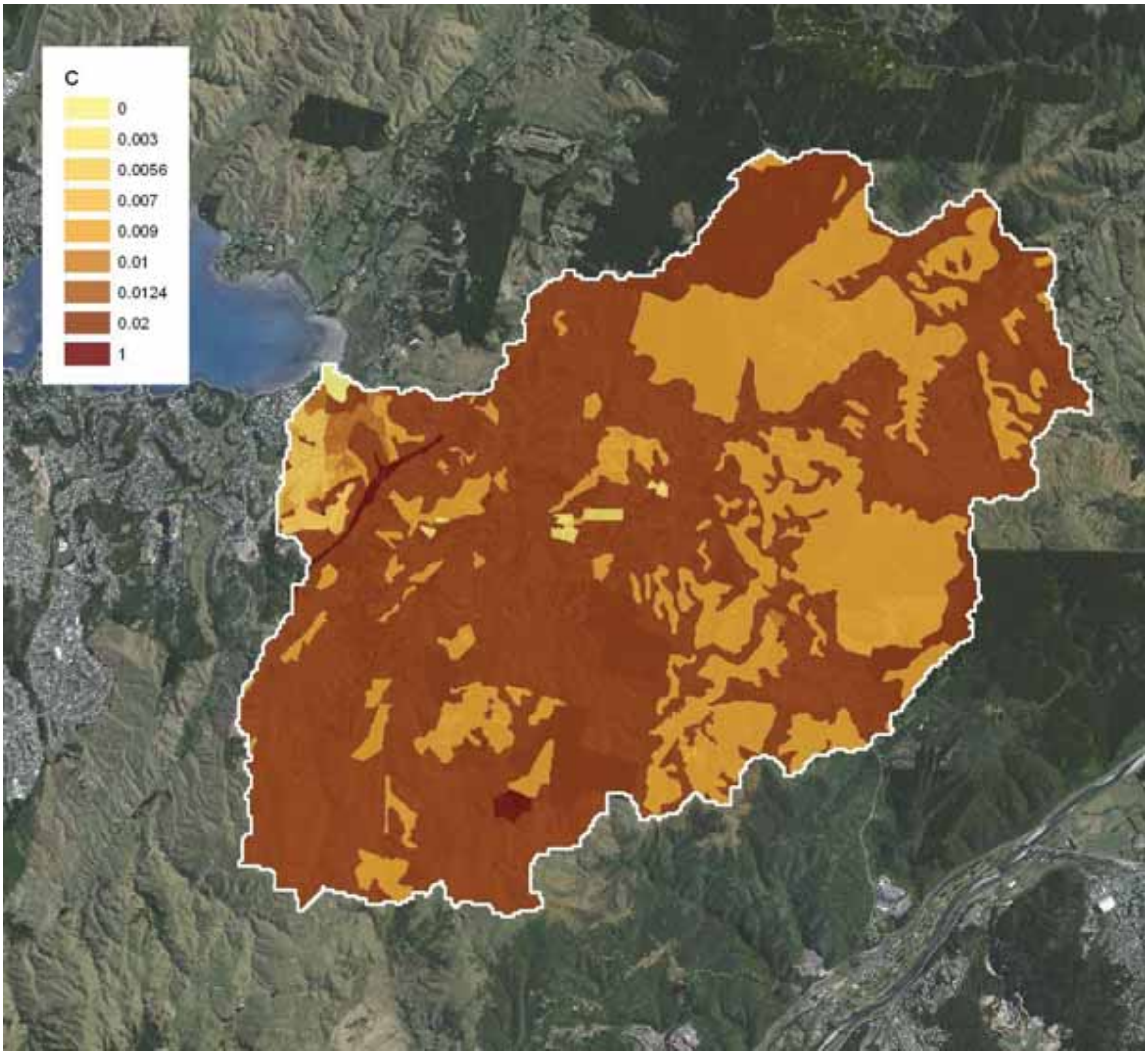


Figure N7 C Values for Pauatahanui Catchment

N.12 LS Factor

The Length-Slope factor (LS) describes the typical slope length and gradient within each catchment. Wischmeier's empirical equation as quoted by Goldman et al (1986) is used to calculate the LS factor. The LS was spatially projected from the two components slope length and steepness, then calculated to the relative proportions of each layer to give a sub-catchment and catchment value.

Equation 2

$$LS = \left(\frac{65.41\ x\ s^2}{s^2 + 10000} + \frac{4.56\ x\ s}{\sqrt{s^2 + 10000}} + 0.065\right)\left(\frac{l}{72.5}\right)^m$$

Where s is the slope steepness (%), l is the slope length (ft) and m is an exponent dependent on the slope steepness given in Table N7.

The typical slope length and gradient for each catchment was estimated using data used to calculate Time of Concentration for hydrological flows (see Technical Report 14: *Assessment of Hydrology and Stormwater Effects*) whereby the overland flow path for each catchment was used as the typical slope length. The typical slope gradients were found by averaging the gradient of all slopes within each catchment using a spatial analysis of the Digital Elevation Model at a resolution of 5 meters. This method of calculating gradients was used for simplicity and reflects typical slope gradients rather than the steepest slope gradient that is usually found in the overland flow path for Time of Concentration calculations.

Table N7 Slope Steepness Exponents

Slope Steepness (%)	m
<1	0.2
1-3	0.3
3-5	0.4
>5	0.5

Figure N8 and **Figure N9** portray the spatial distribution and resolution of the LS factor.

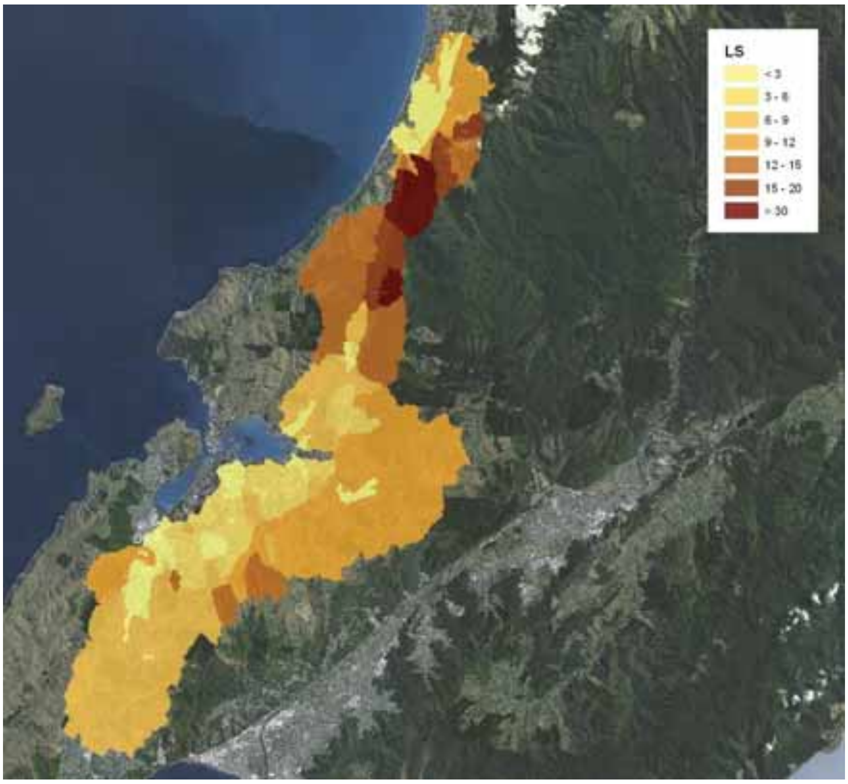


Figure N8 LS Values for Project Catchments

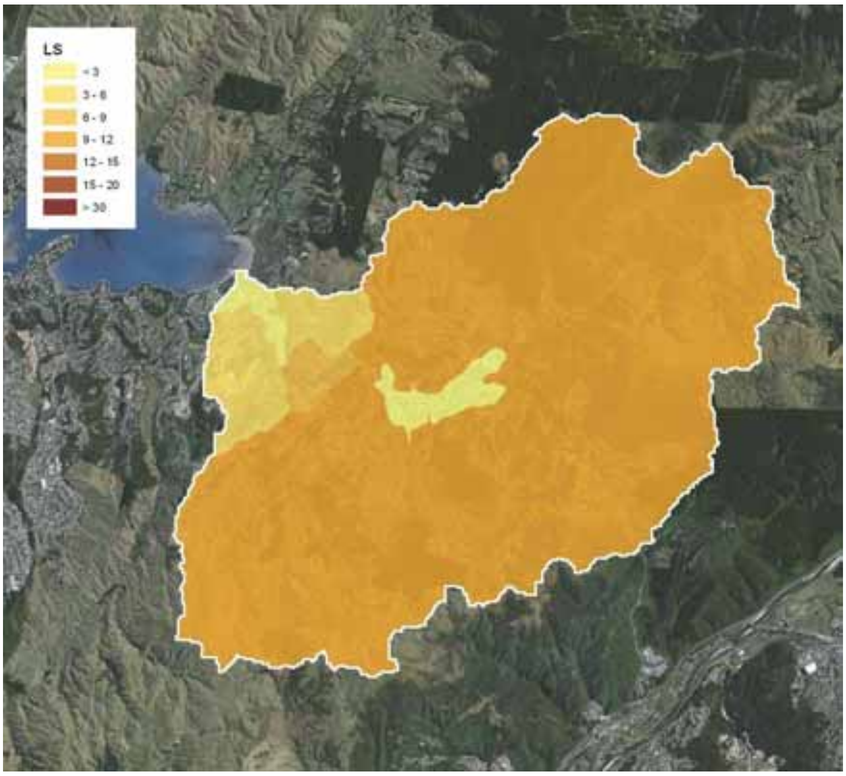


Figure N9 LS Values for Pauatahanui Catchment

N.13 P Factor

P describes the condition of bare soil and relates to how it is managed. For the development of sediment yields in the existing case a value of 1 was used for all land.

The value of P is adjusted to reflect the active earthworks stage of the Project construction (**Table N8**).

Table N8 Factors and Descriptions

Factor	Description
1.3	Bare Soil - compacted and smooth
1.2	Bare Soil – track walked on contour
0.9	Bare Soil – rough irregular surface
0.8	Bare Soil – disked to 250mm depth
1.0	Native vegetation/Pasture/Temporary grass/Mulch on topsoil

N.14 Sediment Removal Efficiency (SRE)

The SRE value describes the effectiveness of erosion control measures at preventing the release of sediment from earthworks areas. The factor allows a practice value for the proposed earthworks to be applied both for the construction erosion and sediment control methodology and sensitivity tests. These sensitivity tests can describe the magnitude of change in sediment release by altering the practice value for the proposed earthworks.

A factor 0.5 was applied to all land classified as bare soil in the aerial photographic analysis to reflect the requirements in the RFP for active earthworks sites to be managed with erosion and sediment control measures. It was applied as an average factor and verified through local knowledge and experience at well managed earthworks sites. This was considered to reflect the requirements in the RFP for active earthworks sites to be managed with erosion and sediment control measures.

There were exceptions within the catchment such as:

- The golf course development in the Duck Creek catchment is treated by sediment ponds with flocculation and therefore the sediment removal at this site is likely to be higher than 0.5
- The Silverwood development in the Pauatahanui catchment is classified as 'bare soil' using the aerial photography, but a site visit in February 2010, it was identified that the active earthworks phase was complete, but grass had not fully established.

No factor was applied to bare soil or cropping land as classified by the NZ Land Cover Data Base.

N.15 Sediment Delivery Ratio (SDR)

The best method to verify the proportion of the theoretical sediment that is actually delivered to receiving environment is to compare the USLE estimates with observed data.

While we had some observed data for the Project catchments, most of this data was collected in flows that were less than the events modelled for the average annual sediment yield. Therefore it was determined that the most appropriate method was to cross check the sediment yield estimates generated using the USLE with the NIWA Suspended-Sediment Yield Estimator Tool. The comparison was considered on the basis that within each model the other factors are equivalent in terms of catchment size, geology, land use and hydrology. Any comparison should present a linear relationship between the two models and allow an SDR to be used for all the sediment rating curves.

Following the data verification process an SDR of 0.17 was selected for all catchments. This was consistent with a correlation between the two models for all catchments with the exception of the Pauatahanui. The decision to use a single SDR factor was also consistent with the conservative approach used throughout the modelling and erosion and sediment control methodology.

N.16 Application of USLE in the Existing Situation

All of the catchments that either drain to the Porirua Harbour, or are crossed by the Project alignment, were described using the above USLE factors of rainfall, land cover, slope and soils (refer to Section N.4 for a detailed explanation of these factors). Table N9 describes the Geographical Information Systems (GIS) data sets that were used to describe these factors for the affected catchments:

Table N9 GIS Datasets Used to Describe Catchments

GIS Dataset	Application
Rainfall Gauge records	To calculate the 2 year 6 hour rainfall depths to calculate the rainfall erosivity (R) factor
NZ Land Resource Inventory (NZLRI)	To calculate the soil particle size and gravel content for the calculation of the soil erodibility (K) factor
New Zealand Land Cover Database Version 2	To calculate the land cover for the calculation of land cover (C) factor
Aerial Photography: Porirua City Council – Rural (.5m, 2009); Urban (scale 1:500, 2009) Kapiti Coast District Council - Rural (1m, 2006); Urban (scale 1:500, 2006) Wellington City Council - Rural (.5m, 2009); Urban (scale 1:500, 2009)	To calculate the impervious land area and the land that is in active earthworks (bare soil), for the calculation of land cover (C) factor
Contours - Digital elevation model Digital elevation model created to a resolution of 5 metres. Based on input contour data sources of differing accuracy levels.	To calculate the steepness and length of slopes, to calculate the length slope (LS) factor

N.17 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 N10.**

Table N10 Sediment Yield Estimates (tonnes/yr)

Large Catchments	NIWA Suspended Sediment Tool	USLE from This Study	Ministry of Works Study (Healy, 1980)	Difference USLE/Healy (%)	Difference USLE/NIWA (%)	Difference 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 N10, estimation of sediment yield calculated using the USLE, when 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 in 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), there are 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 N11.** 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 N11 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 km² (g/m²)	Comment
Duck	1144	11.6	99	Built
Horokiri	5296	33.1	160	Rural/agriculture
Kenepuru	826	12.7	65	Built
Pauatahanui	5889	41.7	141	Rural/agriculture
Porirua	3970	41.1	97	Built
Ration	793	6.8	117	Built
Te Puka/Wainui	1520	7.7	197	Rural/agriculture (steep)
Whareroa	2022	16.7	121	Rural/agriculture (flat)

Appendix 15.O Soil Erodibility Calculation Information

O.1 Introduction

An assessment of the environmental effects of the Transmission Gully roadway project is to be carried out. As part of the assessment, an estimate regarding volumes of material eroded from the landscape must be prepared. The general method to be used for estimating the volume of eroded material is to use the Universal Soil Loss Equation (Goldman et al., 1986). This equation requires the calculation of five main factors. This document describes the method used to estimate one of these five factors, the Soil Erodibility Factor, K. The method described by has been summarised and simplified in order to obtain a conservative and time-effective method for estimating K for a large number of soil samples where limited information is available.

O.2 Background

The preferred method for determining K is to use the nomograph method (Goldman et al., 1986). This method requires that an accurate particle size analysis be conducted to determine percentage of clay, silt, sand and very fine sand for exposed soil layers. With any two of the soil particle percentages (clay, silt and sand) the nomograph, shown in **Figure N1** can used to determine the K value.

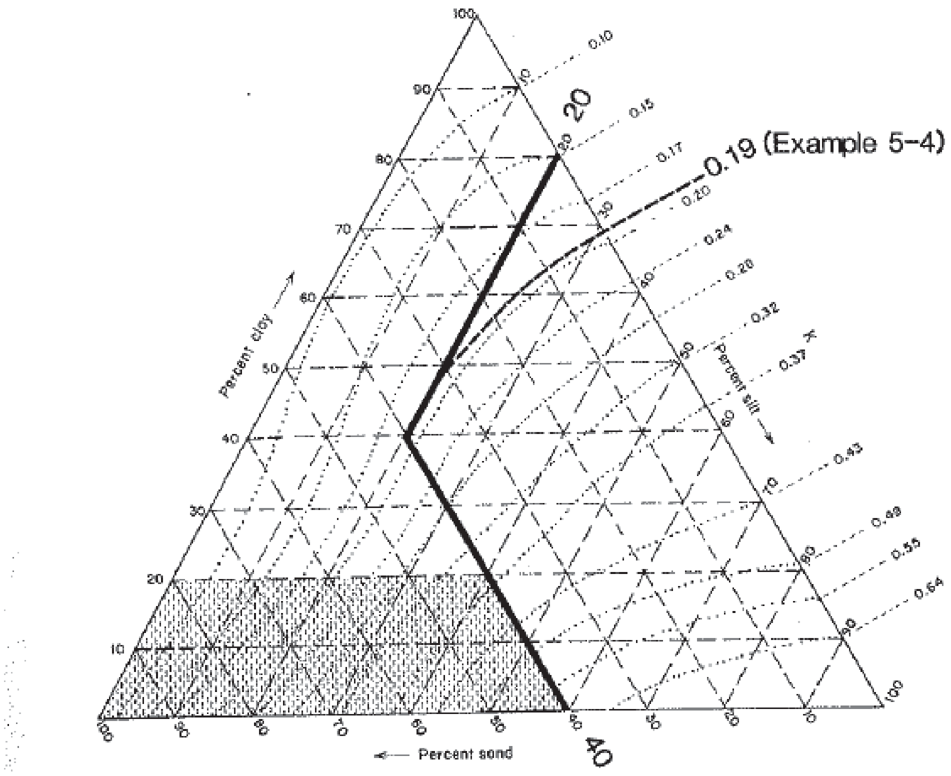


Figure O1 Nomograph presented by Goldman et al., 1986

The value determined can then be adjusted for organic matter and rock content, as the nomograph assumes 2% organic matter and 0-15% rock content. Tables of correction values are given by Goldman for this purpose.

Another nomograph method is used by the United States Department of Agriculture (USDA) and is the basis for the nomograph method provided by Goldman et al. This nomograph is slightly more complex and was originally determined by Wischmeier (1971).

A second method is to use the soil erodibility equation as presented by the USDA

Equation A

$$K = \frac{2.1\ x\ 10^{-4}\ x\ M^{1.14}\ x\ (12 - a) + 3.25(b - 2) + 2.5(c - 3)}{100}$$

Where M is the percentage of silt plus the percentage of very fine sand multiplied by the percentage of soil that is not clay, ‘a’ is the percentage of organic matter (rounded to the nearest whole number), ‘b’ is the soil structure code (1,2,3 or 4) and ‘c’ is the saturated hydraulic conductivity code (1,2,3,4,5 or 6).

The soil structure code is defined in the following way:

Table O1 Soil Structure Code

Soil Structure Code	Description
1	Very Fine Granular
2	Fine Granular
3	Medium or Course Granular
4	Blocky, Platy or Massive

Similarly the saturated hydraulic conductivity code is defined:

Table O2 Hydraulic Conductivity Code

Hydraulic Conductivity Code	Saturated Hydraulic Conductivity Range µm/sec	Saturated Hydraulic Conductivity Classes 1993
6	<0.30	very low to mod. low
5	0.30 to <1.20	mod. low
4	1.20 to <4.80	mod. high
3	4.80 to <15.00	mod. high to high
2	15.00 to <30.00	high
1	≥30.00	high to very high

In all of the above methods K is calculated in US Imperial Units of tons/acre per unit of rainfall erosion index (100ft.tons/acre x in/hr).

O.3 Limitations

The limitations to the two nomograph methods are that digital computation is not efficient for large numbers of soil samples. The simplification of the nomograph by Goldman et al. does not give good evidence of how hydraulic conductivity and soil structure have been accounted.

More generally Goldman et al. lists the limitations of the Universal Soil Loss Equation:

It is empirical, this means it does not represent the actual erosion process and has been created from specific sets of data. USDA notes that the nomograph and equation methods do not work for ‘certain Oxisols in Puerto Rico or the Hawaiian Islands, some soils with Andic properties, organic soil materials, low activity clays, and some calcareous or micaceous soils’.

It predicts average annual soil loss and is unlikely to accurately predict soil erosion if 'higher than normal' rainfall exists. Note rainfall data is primarily from US sources.

It estimates sheet and rill erosion NOT Gully erosion. (Concentrated flows).

Sediment deposition is not calculated.

O.4 Application

The particular situation in which the Soil Erodibility Factor is to be used has some limitations.

The soil samples which will be used to approximate the percentages of soil particles are large and do not distinguish between layers. Trial pit data with depths of up to 5m was averaged to obtain a bulk percentage of sand, silt clay and gravel (not very fine sand). Many of the soil samples contain very high rock/gravel content. Hydraulic conductivity data is not available for any of the soil samples.

It is desired that results obtained by a soil erosion calculation be order of magnitude correct and can be used as a relative indication of erosion potential over a large geographical area.

O.5 Method

In order to obtain sensible results for the Soil Erodibility Factor that will be appropriate to the application the following method shall be used.

Equation A shall be used as the primary calculation method.

In order for this equation to be used, the percentage of organic matter, a, must be determined as well as the soil structure code, b, and saturated hydraulic conductivity code, c.

The soil data that has been supplied only contains soil content percentages, so the two codes must be determined based on this data. The organic matter content can be estimated (assume 0-2%).

O.6 Soil Particle Percentages

The soil content has been characterised in terms of percentage sand, silt, clay and gravel. The percentages of fine material (sand, silt and clay) shall be adjusted to sum to 100%, the gravel content shall remain as an average bulk percentage.

O.7 Soil Structure Code

The soil structure code given in **Table O3** can be estimated based on gravel content and by eliminating code level 4, this assumes all soils are granular rather than massive. The estimation will be linear.

Table O3 - Soil Structure Code

Percentage of Gravel	Soil Structure Code
<34	1
34-67	2
>67	3

O.8 Saturated Hydraulic Conductivity Code

The USDA provides figures for estimating saturated hydraulic conductivity based on percentage of fines content, shown in Figure

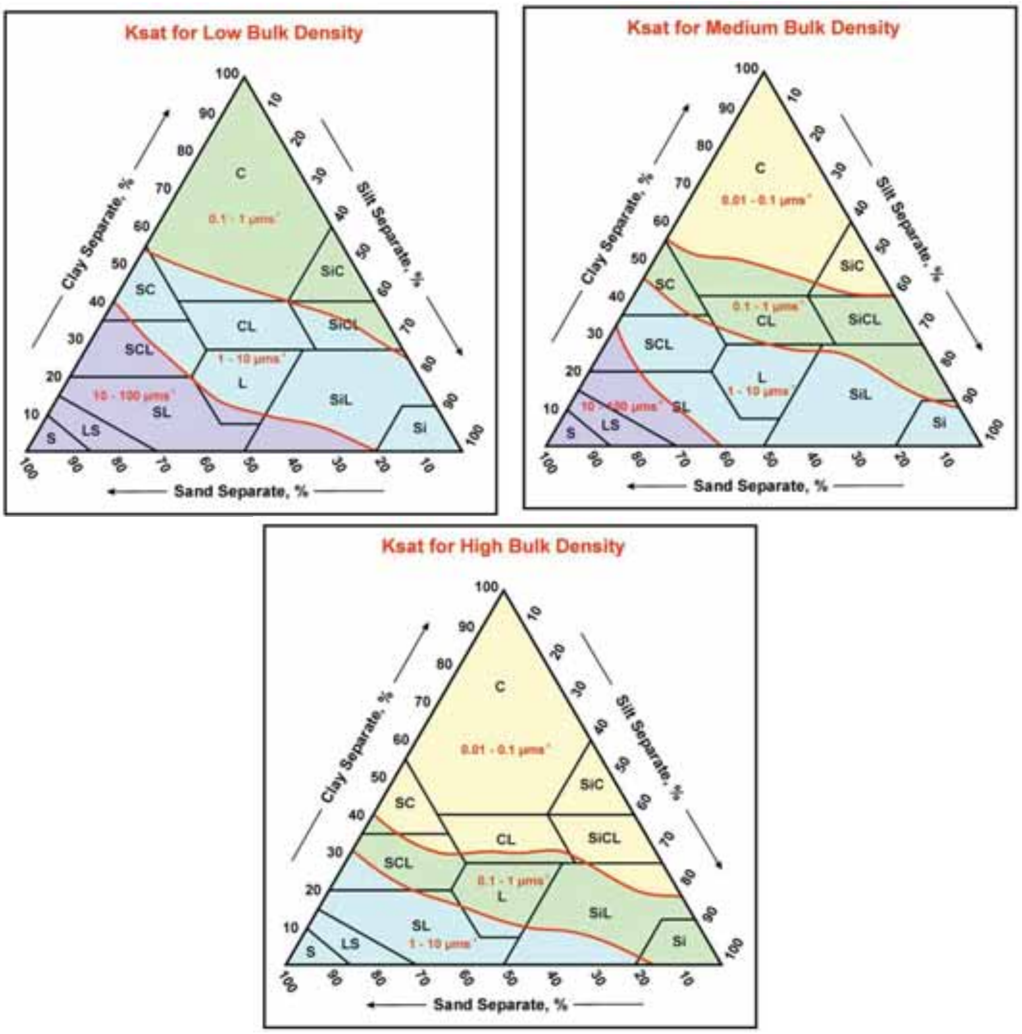


Figure O2 Saturated Hydraulic Conductivity

If it is assumed that all soils have a medium bulk density then a conservative approximation to the saturated hydraulic conductivity code is given in **Figure O3**.

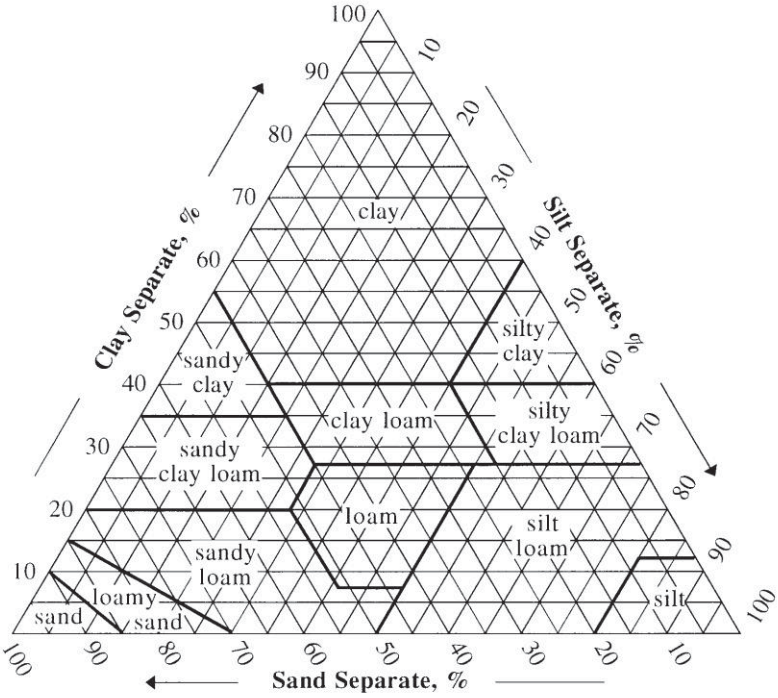


Figure O3 - Saturated Hydraulic Conductivity Code Approximation

When programmed into an excel spreadsheet:

c=IF(A>0.6,6,IF(B>0.6,2,IF(B<(-(5/9)*C+0.5),5,4)))

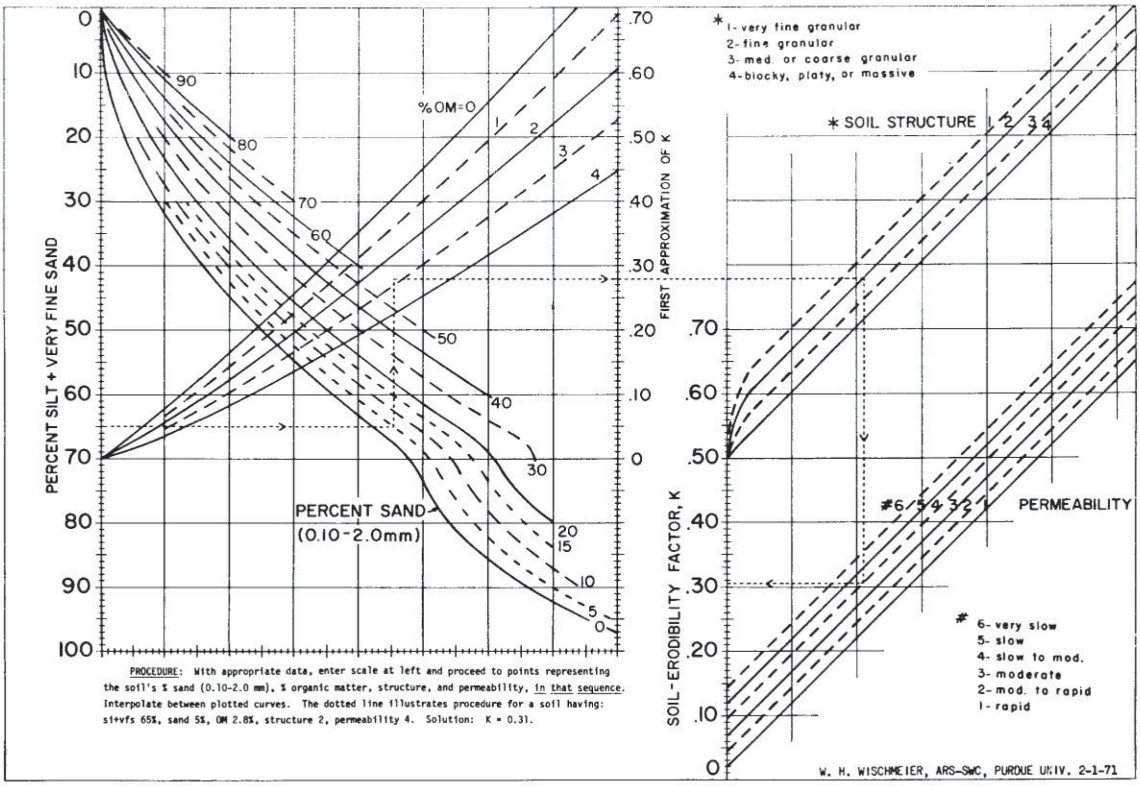
Where A is the proportion of clay, B is the proportion of sand and C is the proportion of silt and c is the saturated hydraulic conductivity code.

O.9 Rock Content

The soil erodibility factor, K, will then be adjusted for rock/gravel content based on the tables given by Goldman et al. (1986) shown in Table O4. Corrected factors replace the calculated K factor. This shall be carried out by using the closest match to the table factors rather than interpolating or extrapolating.

Table O4 Soil Erodibility Factor

Unadjusted *K* value from Fig. 5.6	*K* values adjusted for rock content as follows		
	15–35%	35–60%	60–75%
0.10	0.05	0.05	0.02
0.15	0.10	0.05	0.02
0.17	0.10	0.05	0.02
0.20	0.10	0.05	0.02
0.24	0.15	0.10	0.05
0.28	0.15	0.10	0.05
0.32	0.17	0.10	0.05
0.37	0.20	0.10	0.05
0.43	0.24	0.15	0.10
0.49	0.28	0.15	0.10
0.55	0.32	0.17	0.10
0.64	0.37	0.20	0.15



▪ **Figure O4 USDA Nomograph**

Appendix 15.P Soil Test Pits

	Top Layer 1					Middle Layer 2					Deep Layer 3					Total Depth	Average			
Hole No.	Depth	Clay	Sand	Silt	Gravel	Depth	Clay	Sand	Silt	Gravel	Depth	Clay	Sand	Silt	Gravel		Clay	Sand	Silt	Gravel
TP01	700			100%		500		16%		84%	1800		35%		65%	3000	0%	24%	23%	53%
TP02	1600	60%	5%	35%		1000		35%	65%		1200		5%	35%	60%	3800	25%	13%	43%	19%
TP03	1200			100%		2800		35%		65%						4000	0%	25%	30%	46%
TP04	2800	9%		91%												2800	9%	0%	91%	0%
TP05	600			84%	16%	700			65%	35%						1300	0%	0%	74%	26%
TP06	2900			100%		400			100%							3300	0%	0%	100%	0%
TP07	3100			65%	35%											3100	0%	0%	65%	35%
TP08	3000			100%												3000	0%	0%	100%	0%
TP09	200			100%		600		65%		35%						800	0%	49%	25%	26%
TP10	2900			100%												2900	0%	0%	100%	0%
TP11	550		35%	15%	50%											550	0%	35%	15%	50%
TP12	1100	100%				2500		95%		5%						3600	31%	66%	0%	3%
TP13	4000			100%												4000	0%	0%	100%	0%
TP14	1100			65%	35%	2500			35%	65%						3600	0%	0%	44%	56%
TP15	1800	35%		50%	15%	2100		35%	15%	50%						3900	16%	19%	31%	34%
TP16	2100	35%		50%	15%	1700		15%	35%	50%						3800	19%	7%	43%	31%
TP17	400			84%	16%	2200	15%		35%	50%	1500		35%	56%	9%	4100	8%	13%	47%	32%
TP18	900	15%		50%	35%	2000			35%	100%	1300		35%	15%	50%	4200	3%	11%	32%	71%
TP19	4400			35%	65%											4400	0%	0%	35%	65%
TP20	1600		35%	9%	56%											1600	0%	35%	9%	56%
TP21	2300			35%	65%											2300	0%	0%	35%	65%
TP22	1000		35%		65%	1000			35%	65%						2000	0%	18%	18%	65%
TP23	500			35%	65%	400	35%		50%	15%	2100		35%	15%	50%	3000	5%	25%	23%	48%
TP24	300			84%	16%											300	0%	0%	84%	16%
TP25	1000			100%		500			35%	65%	2000			100%		3500	0%	0%	91%	9%
TP26	1800	100%				1500				100%						3300	55%	0%	0%	45%
TP27	3100				100%											3100	0%	0%	0%	100%
TP28	500			84%	16%	2000				100%						2500	0%	0%	17%	83%
TP29	1100	35%		65%		300			35%	65%	1000				100%	2400	16%	0%	34%	50%
TP30	800			65%	35%	2000				100%						2800	0%	0%	19%	81%
TP31	500		35%	65%		2500			65%	35%						3000	0%	6%	65%	29%
TP32	1100			100%		2300			65%	35%						3400	0%	0%	76%	24%
TP33	500			35%	65%	3700		16%		84%						4200	0%	14%	4%	82%
TP34	500		15%	35%	50%	5000	50%	35%		15%						5500	45%	33%	3%	18%
TP35	1800	35%		65%		2000		16%		84%						3800	17%	8%	31%	44%
TP36	2100		15%	35%	50%	2100	35%	15%		50%						4200	18%	15%	18%	50%
TP37	300		15%	35%	50%	2200	50%	5%	15%	30%	2200	50%	25%		25%	4700	47%	15%	9%	29%
TP38	1900			65%	35%	1700			35%	65%						3600	0%	0%	51%	49%
TP39	2000			100%		1500				100%						3500	0%	0%	57%	43%

TP40	100	35%		65%		2700	50%	16%	30%	4%	500		16%		84%	3300	42%	16%	27%	16%
TP41	4550			100%												4550	0%	0%	100%	0%
TP42	1100			100%		2300			16%	84%						3400	0%	0%	43%	57%
TP43	1900			100%		2900			65%	35%						4800	0%	0%	79%	21%
TP44	1200			100%		800			65%	35%	1500			16%	84%	3500	0%	0%	56%	44%
TP45	1000			100%		1000	35%		50%	15%	500			16%	84%	2500	14%	0%	63%	23%
TP46	2800			65%	35%											2800	0%	0%	65%	35%
TP47	2500		35%	15%	50%	500		56%	35%	9%	500		35%		65%	3500	0%	38%	16%	46%
TP48	1500		35%	9%	56%	500		16%		84%						2000	0%	30%	7%	63%
TP49	3000			65%	35%	3500		35%	15%	50%	500	50%		35%	15%	7000	4%	18%	38%	41%
TP50	2000		35%	15%	50%	1600	50%	35%		15%	700		20%		80%	4300	19%	33%	7%	42%
TP51	850		15%	35%	50%	2200	9%	35%	56%		400		65%	35%		3450	6%	34%	48%	12%
TP52	100	35%			65%	500	35%		65%		2300		20%		80%	2900	7%	16%	11%	66%
TP53	700			100%		400			65%	35%	3300		5%		95%	4400	0%	4%	22%	74%
TP54	550			84%	16%	1350		20%		80%						1900	0%	14%	24%	61%
TP55	700	10%	10%	70%	10%	1500				100%	2400		16%		84%	4600	2%	10%	11%	78%
TP56	300		35%		65%	300			65%	35%	3100		10%	10%	80%	3700	0%	11%	14%	75%
TP57	600		35%		65%	600		16%		84%	1100				100%	2300	0%	13%	0%	87%
TP58	200		35%		65%	200	65%	35%			2200		15%		85%	2600	5%	18%	0%	77%
TP59	300			65%	35%	3000			25%	75%	700		16%		84%	4000	0%	3%	24%	74%
TP60	300			65%	35%	400		35%		65%	4300		16%		84%	5000	0%	17%	4%	80%
TP61	1000		25%	25%	50%	2100	15%	15%	20%	50%	500	100%				3600	23%	16%	19%	43%
TP62	1000		35%		65%	1600		16%		84%						2600	0%	23%	0%	77%
TP63	1500	35%	5%	60%		1100		35%		65%						2600	20%	18%	35%	28%
TP64	1300	35%	5%	60%		2500		35%	5%	60%						3800	12%	25%	24%	39%
TP65	1000	35%	5%	60%		3000	95%		5%							4000	80%	1%	19%	0%
TP66	1750	30%	10%	60%		1000			35%	65%	900		35%	65%		3650	14%	13%	54%	18%
TP67	300	35%	30%	35%		3200	50%		50%		500			95%	5%	4000	43%	2%	55%	1%
TP68	550		65%	35%		2500			35%	65%	450	100%				3500	13%	10%	31%	46%
TP69	300			100%		1000	100%				2300		35%		65%	3600	28%	22%	8%	42%
TP70	1100	35%	5%	60%		1000		16%		84%						2100	18%	10%	31%	40%
TP71	700	35%	5%	60%		200		60%	5%	35%	3550		35%		65%	4450	6%	31%	10%	53%
TP72	2100		35%	65%												2100	0%	35%	65%	0%
TP73	1400	35%		65%		700	15%		50%	35%	600		35%	5%	50%	2700	22%	8%	48%	20%
TP74	200		35%	50%	15%	1600		50%	50%		800		16%		84%	2600	0%	38%	35%	27%
TP75	3200		35%	65%		600		16%		84%						3800	0%	32%	55%	13%
TP76	600	5%	35%	60%		1800	5%		5%	90%						2400	5%	9%	19%	68%
TP77	1700		35%	56%	9%	2100	50%	9%	25%	16%	400		16%		84%	4200	25%	20%	35%	20%
TP78	200			65%	35%	700		50%	35%	15%	2600		35%		65%	3500	0%	36%	11%	53%
TP79	1800			35%	65%	400	35%		65%		1600		16%		84%	3800	4%	7%	23%	66%
TP80	500			35%	65%	3300			16%	84%						3800	0%	0%	19%	82%
TP81	400	35%		65%		1400		9%	75%	16%	2600		35%	15%	50%	4400	3%	24%	39%	35%
TP82	400			35%	65%	1700			16%	84%	1900	9%	25%	50%	16%	4000	4%	12%	34%	50%
TP83	600	35%		65%		3600	35%			65%						4200	35%	0%	9%	56%

TP84	500			65%	35%	3100			35%	65%	300	65%		35%		3900	5%	0%	39%	56%
TP85	1100		35%	65%		3100		40%	40%	20%						4200	0%	39%	47%	15%
TP86	1950		16%		84%											1950	0%	16%	0%	84%
TP87	1300			65%	35%	1300		25%	50%	25%	400			100%		3000	0%	11%	63%	26%
TP88	300			75%	25%	2200			35%	65%						2500	0%	0%	40%	60%
TP89	500			65%	35%	1000		16%		84%						1500	0%	11%	22%	68%
TP90	900		10%	70%	20%	300			16%	84%						1200	0%	8%	57%	36%
TP91	300		35%	65%		1700	10%		80%	10%	2200		35%	50%	15%	4200	4%	21%	63%	12%
TP92	900			84%	16%	3000			35%	65%						3900	0%	0%	46%	54%
TP93	1100			84%	16%	2600			16%	84%	300		16%		84%	4000	0%	1%	34%	65%
TP94	400	35%		50%	15%	4100			16%	84%						4500	3%	0%	19%	78%
TP95	250			84%	16%	1400			35%	65%						1650	0%	0%	42%	58%
TP96	1550			100%		2600		35%		65%						4150	0%	22%	37%	41%
TP97	1200		10%	80%	10%	550			65%	35%	2400		20%	20%	60%	4150	0%	14%	43%	42%
TP98	550		10%	80%	10%	1800		35%	50%	15%	600				100%	2950	0%	23%	45%	31%
TP99	2300		25%	50%	25%	2100	50%	15%	15%	20%						4400	24%	20%	33%	23%
TP100	500		15%	35%	50%	1700	15%	15%	50%	20%	100		35%		65%	2300	11%	16%	45%	28%
TP101	1000			65%	35%	1300			35%	65%						2300	0%	0%	48%	52%
TP102	800			35%	65%	2750			35%	65%						3550	0%	0%	35%	65%
TP103	700		35%	50%	15%	1400		65%	35%							2100	0%	55%	40%	5%
TP104	4200			35%	65%											4200	0%	0%	35%	65%
TP105	2200			100%		1200		16%		84%						3400	0%	6%	65%	30%
TP106	1200			35%	65%	1300				100%						2500	0%	0%	17%	83%
TP107	450			100%		200		65%	35%		1550		35%	9%	56%	2200	0%	31%	30%	39%
TP108	2650			100%		800		65%	35%							3450	0%	15%	85%	0%
TP109	1650	30%		70%		950		35%	65%		150		65%	35%		2750	18%	16%	66%	0%
TP110	400	9%		35%	56%	500				100%						900	4%	0%	16%	80%
TP111	500	35%		65%		1700			35%	65%						2200	8%	0%	42%	50%
TP112	1000	20%		80%		1500		65%	35%							2500	8%	39%	53%	0%
TP113	1100			100%		1100	10%	60%	20%	10%	900		50%	35%	15%	3100	4%	36%	53%	8%
TP114	3950		65%	35%												3950	0%	65%	35%	0%
TP115	900		35%	60%	5%	2700	50%		25%	25%						3600	38%	9%	34%	20%
TP116	3700		16%		84%											3700	0%	16%	0%	84%
TP117	600		65%	35%		3300		65%	35%							3900	0%	65%	35%	0%
TP118	400		65%	35%		3900		65%	35%							4300	0%	65%	35%	0%
TP119	3400		65%	35%												3400	0%	65%	35%	0%
TP120	750			100%		900		35%	65%							1650	0%	19%	81%	0%
TP121	2000	35%		65%		1600		16%	84%		600		65%	35%		4200	17%	15%	68%	0%
TP122	550	15%	15%	70%		1100		75%	16%	9%						1650	5%	55%	34%	6%
TP123	250	35%		65%		3800	65%		35%							4050	63%	0%	37%	0%
TP124	2850	35%		65%		1000	65%		35%		900	35%			65%	4750	41%	0%	46%	12%
TP125	750			100%		3200			35%	65%						3950	0%	0%	47%	53%
TP126	400			100%		1800			35%	65%						2200	0%	0%	47%	53%
TP127	300			100%		4000	35%		65%							4300	33%	0%	67%	0%

TP128	350			65%	35%	500			35%	65%	1650		15%	35%	50%	2500	0%	10%	39%	51%
TP129	450	35%		65%		2600	65%		35%		1400			100%		4450	42%	0%	58%	0%
TP130	1100			100%		400			80%	20%						1500	0%	0%	95%	5%
TP131	900		35%	15%	50%	200		35%		65%						1100	0%	35%	12%	53%
TP132	2800		35%	15%	50%	200				100%						3000	0%	33%	14%	53%
TP133	1500	35%		65%		1000		35%	65%		2100	65%		35%		4600	41%	8%	51%	0%
TP134	2400			35%	65%	900	65%		35%		400			20%	80%	3700	16%	0%	33%	51%
TP135	3150	60%		30%	10%	700	35%		65%							3850	55%	0%	36%	8%
TP136	1300		35%	65%		1500	65%		35%		500			16%	84%	3300	30%	14%	44%	13%
TP137	400		20%	20%	60%	1600		50%	50%		1900		84%	16%		3900	0%	63%	30%	6%
TP138	600		35%	65%		1600			65%	35%	800			16%	84%	3000	0%	7%	52%	41%
TP139	2100			65%	35%	900		15%	35%	50%	300			35%	65%	3300	0%	4%	54%	42%
TP140	3200		50%		50%	100				100%						3300	0%	48%	0%	52%
TP141	700		35%	15%	50%	1500		15%	35%	50%						2200	0%	21%	29%	50%
TP142	3450		35%		65%											3450	0%	35%	0%	65%
TP143	200			100%		2300			35%	65%	1500			16%	84%	4000	0%	0%	31%	69%
TP144	350		35%	65%		500		65%	35%		800		35%		65%	1650	0%	44%	24%	32%
TP145	1150	4%	61%	15%	20%											1150	4%	61%	15%	20%
TP146	600	35%		65%		400		35%		65%	600			16%	84%	1600	13%	9%	30%	48%
TP147	400			100%		800	65%		35%		1100		70%	15%	15%	2300	23%	33%	37%	7%
TP148	900	16%		84%		600	7%	25%	7%	61%						1500	12%	10%	53%	24%
TP149	800			100%		700	65%		35%		500	35%			65%	2000	32%	0%	52%	16%
TP150	400		35%	65%		500	35%		65%		450			35%	65%	1350	13%	10%	55%	22%
TP151	400		35%	15%	50%											400	0%	35%	15%	50%
TP152	1400			100%		1900	65%		35%		200	15%		15%	70%	3500	36%	0%	60%	4%
TP153	350			100%		3550		10%	20%	70%	200	65%		35%		4100	3%	9%	28%	61%
TP154	400			65%	35%	100	35%	9%	56%		3900		35%	15%	50%	4400	1%	31%	20%	48%
TP155	550			95%	5%	700			35%	65%	2150		16%		84%	3400	0%	10%	23%	67%
TP156	500			95%	5%	2450	65%		35%		1000			35%	65%	3950	40%	0%	43%	17%
TP157	500			84%	16%	600			35%	65%	3000		35%		65%	4100	0%	26%	15%	59%
TP158	1400			84%	16%	200			35%	65%						1600	0%	0%	78%	22%
TP159	3900		30%	15%	55%											3900	0%	30%	15%	55%
TP160	700		35%	65%		2900		16%	84%							3600	0%	20%	80%	0%
TP161	1800	35%		65%		1900				100%						3700	17%	0%	32%	51%
TP162	900	65%		35%		500			84%	16%						1400	42%	0%	53%	6%
TP163	750	65%		35%		750	35%		65%							1500	50%	0%	50%	0%
TP164	300		35%	15%	50%											300	0%	35%	15%	50%
TP165	4400	12%		88%												4400	12%	0%	88%	0%
TP166	150	35%		65%		3000			100%							3150	2%	0%	98%	0%
TP167	500	35%			65%	1200		35%		65%	2500	8%	20%		72%	4200	9%	22%	0%	69%
TP168	400	35%		65%		1300		75%		25%	1600	65%			35%	3300	36%	30%	8%	27%
TP169	1900	50%		50%		2400	30%			70%						4300	39%	0%	22%	39%
TP170	400	35%		65%		3100			35%	65%	500				100%	4000	4%	0%	34%	63%
TP171	300	35%		65%		3600			35%	65%						3900	3%	0%	37%	60%

TP172	600	35%			65%	2800	70%			30%	600		35%		65%	4000	54%	5%	0%	41%
TP173	900			35%	65%	200	100%				2600			35%	65%	3700	5%	0%	33%	61%
TP174	800	61%		35%	4%	950			35%	65%	1950			20%	80%	3700	13%	0%	27%	60%
TP175	2500			35%	65%	1900		20%	20%	60%	150	50%		35%	15%	4550	2%	8%	29%	61%
TP176	200			100%		1100	35%		60%	5%	3700		35%	15%	50%	5000	8%	26%	28%	38%
TP177	700		35%		65%	200			100%		3800		35%	15%	50%	4700	0%	34%	16%	50%
TP178	1400		20%	20%	60%	3600	10%	10%	10%	70%						5000	7%	13%	13%	67%
TP179	950		35%	65%		600	65%		35%		2300			100%		3850	10%	9%	81%	0%
TP180	1900		100%													1900	0%	100%	0%	0%
TP181	3500		100%													3500	0%	100%	0%	0%
TP182	3950		100%													3950	0%	100%	0%	0%
TP183	1200		15%	35%	50%											1200	0%	15%	35%	50%
TP184	200		35%	65%		800		15%	35%	50%						1000	0%	19%	41%	40%
TP185	600			100%		1700	4%	4%	92%		1600		35%	65%		3900	2%	16%	82%	0%
TP186	300		35%		65%	300		65%		35%	3900	50%	15%	15%	20%	4500	43%	20%	13%	24%
TP187	200		35%		65%	500		50%	15%	35%	2600		35%		65%	3300	0%	37%	2%	60%
TP188	300		35%		65%	400	4%	61%	35%		3100		35%		65%	3800	0%	38%	4%	58%
TP189	700	35%		65%		2900		35%		65%						3600	7%	28%	13%	52%
TP190	500		44%	12%	44%	2000		35%		65%						2500	0%	37%	2%	61%
HA191	950	35%		65%		200			84%	16%						1150	29%	0%	68%	3%

Appendix 15.Q Sediment Rating Curves

Q.1 Development of Sediment Rating Curves

Sediment rating curves were required for estimating sediment yields from various catchments within the Project area. These curves were used to predict sediment yields for catchments during the construction of the Project, based on a combination of observed and theoretical data. The curves for each catchment were adjusted to model future scenarios including sediment yields during the construction period and long-term when the Project is in operation.

These curves were developed using observed sediment (turbidity calibrated with observed TSS, as sediment) and flow data. Daily flow is generated by the Soil Moisture Water Balance Model (SMWBM), which is used to calculate sediment yields and peak flows.

The mathematical equation used to describe the relationship between sediment and peak flow is a power curve of the general form:

Equation 1

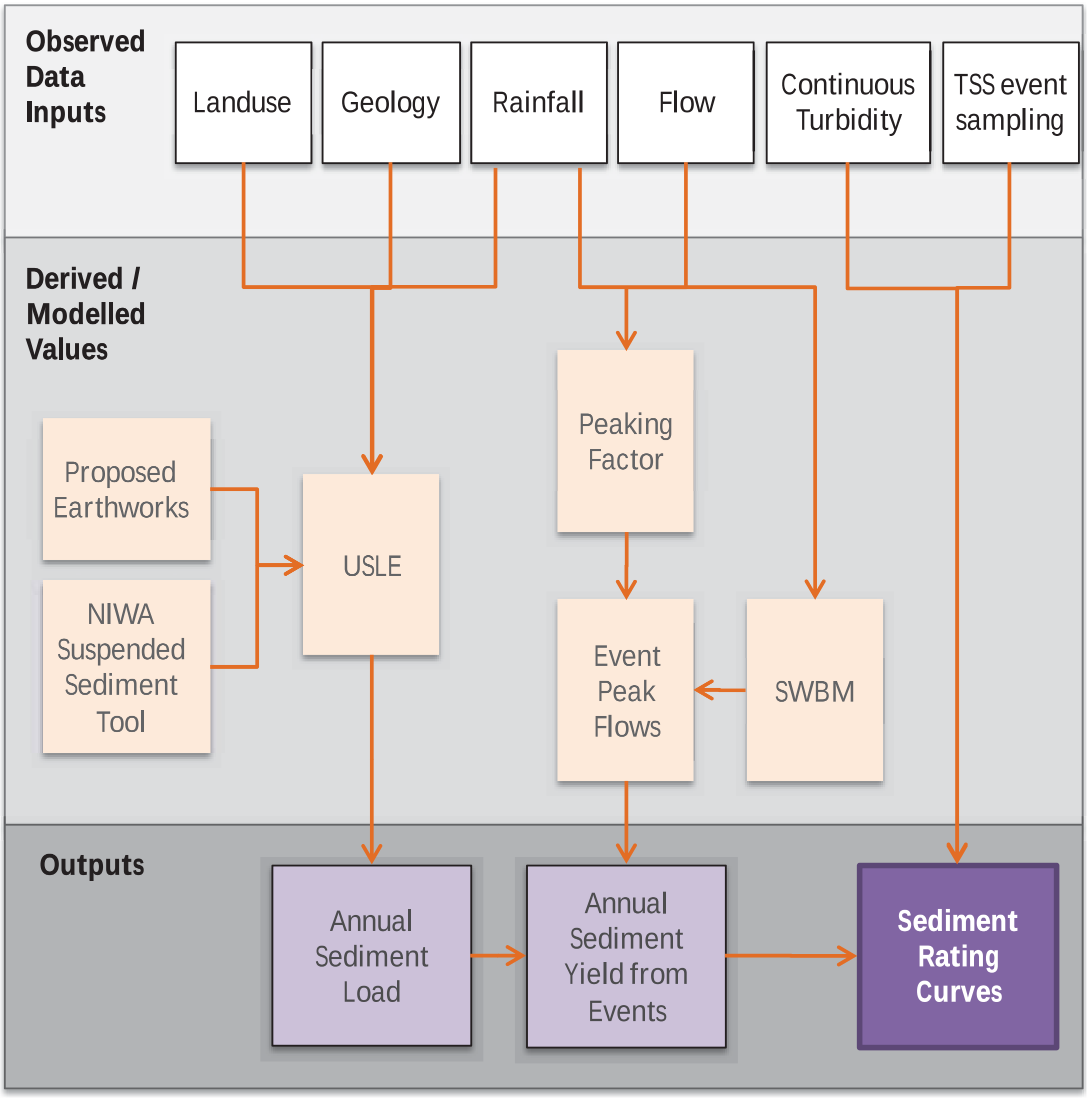
$$S = AQ_p{}^B$$

Where; S is the sediment yield in kg and Q_p is the event peak flow in m^3/sec.

This equation is commonly used for the development of sediment rating curves. The relationship is used by Hicks (1994) and a slightly modified version that includes a base flow factor is used by Sednet (Wilkinson, Henderson & Chen, 2005).

The observed data was used to adjust the sediment rating curve shape, this determined the exponent B. An exponent of 1.9 was used for all catchments. This relates well to exponents used by others (Hicks, 1996 and Wilkinson, 2004). The coefficient A factor was determined when the mean annual sediment yield calculated using the SMWBM simulated flow record matched the annual mean sediment yield calculated using the USLE for each catchment. **Appendix 15.R** lists A and B values used for each catchment. Table 15.88 provides a schematic of how sediment rating curves were developed.

▪ **Table 15.80 Sediment Rating Curves Calculation Method**



Q.2 Curves Shaped from Observed Data

Observed data from turbidity loggers in the Horokiri and Pauatahanui Streams was analysed and that which was deemed the most accurate selected for use in development of the sediment rating curves. An additional data point was also selected from literature data from the July 1976 storm event (Curry, 1981) in the Horokiri, Pauatahanui, Ration and Duck streams. The sediment values obtained for events with measured or calculated peak flow were plotted against the sediment curves. It has been found that sediment yield is best correlated with peak flow (Hicks, 1994) and on this basis individual curves were developed. Peak flow is also a useful value as it is easily observed and requires no transformation when calculating results from the curve.

Data supplied by the National Water and Soil Conservation Organisation (1981) has also been used for the four streams that drain to the Pauatahanui Inlet.

Q.3 Initial Curve Fitting Based on Observed Data

An initial curve was fitted to the data for each stream for where observed data was available using least squares regression. As a large proportion of the observed data was from low flow events, this approach was not considered to give the best estimation of the sediment peak flow relationship during larger events. To address this issue an estimate of the average annual sediment yield was calculated using the USLE and transformed to an annual yield estimate from the peak flow record generated using SMWBM to adjust the sediment rating curves (see **Section Q.4** below).

Q.4 Stream Flow from Soil Moisture Water Balance Model

The Soil Moisture Water Balance Model (SMWBM) was developed to generate daily streamflow time series for ungauged catchments and to extend observed records using rainfall data. The model uses representative rainfall to simulate surface runoff and groundwater discharge in these catchments. This is compared and verified against flow in gauged catchments. Details on the methodology to produce this model are further outlined in SKM's report "Generation of daily stream flow time series for selected catchments" (2010c).

The model produced mean and peak daily stream flow at the mouths of all catchments in the Transmission Gully area. Mean and peak daily flows were also simulated to the locations of the turbidity loggers.

The SMWBM model has three purposes:

- To estimate peak flows at the turbidity logger sites
- To provide inflows for the estuary model
- To provide a long term flow record for testing the estimate of average annual sediment yield derived from the sediment rating curves.

Q.5 Soil Moisture Water Balance Model

The driver of sediment yield from the catchments is rainfall. The nature of the stream beds are such that very little of the sediment load is from erosion of bed material. Thus days without rainfall should not be included in an assessment of long term sediment yield from the catchments.

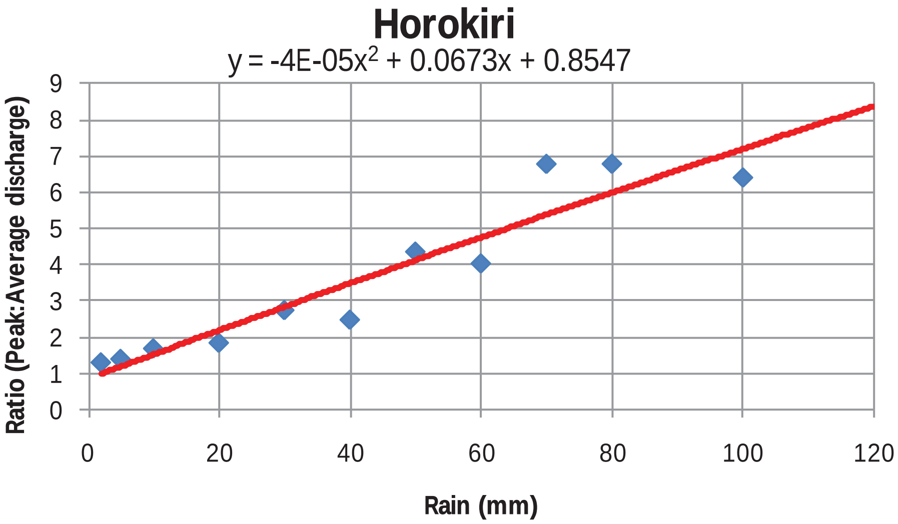
The SMWBM was used to generate daily peak flows for all catchments from 1960 to 2010. Sediment yield has been related to peak flows. Accordingly a time series of peak daily flows is required to estimate the long term sediment yield from the catchments.

Q.6 Peaking Factors

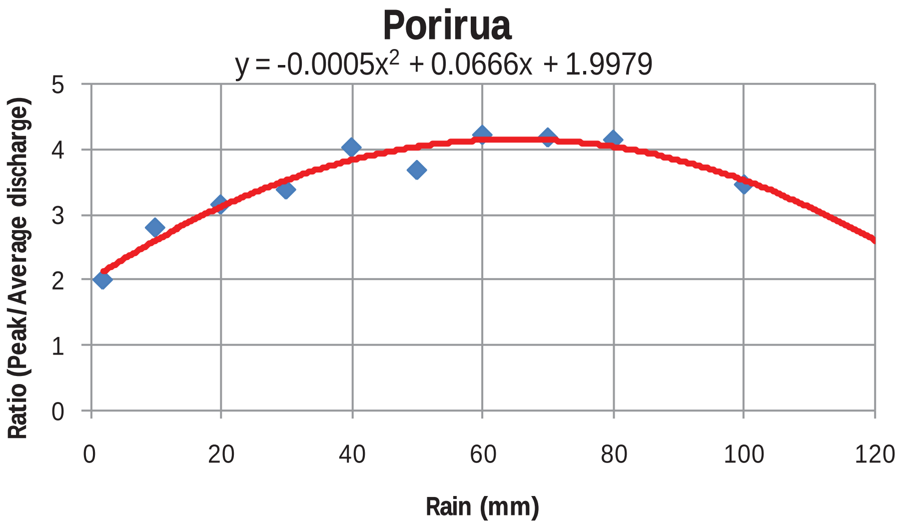
A relationship between daily rainfall and the corresponding ratio of peak to average flow was evaluated using the observed records for the Horokiri, Porirua and Pauatahanui streams. The results were grouped into rainfall depth categories and the peak/average flow ratio for was plotted against each category rainfall.

Functions relating daily rainfall to peak/average flow ratio were derived from the plotted data. Plots showing these relationships are included in **Figure 15.84** to **Figure 15.86**.

The data showed a decreased ratio between peak and average daily flows as rainfalls increased over a certain threshold. This is likely to be related to the increased base flow and slower receding limb in large events.



- **Figure 15.84 Horokiri Stream: Peak: Average Event Flow Versus Daily Rainfall**



- **Figure 15.85 Porirua Stream: Peak: Average Event Flow Versus Daily Rainfall**

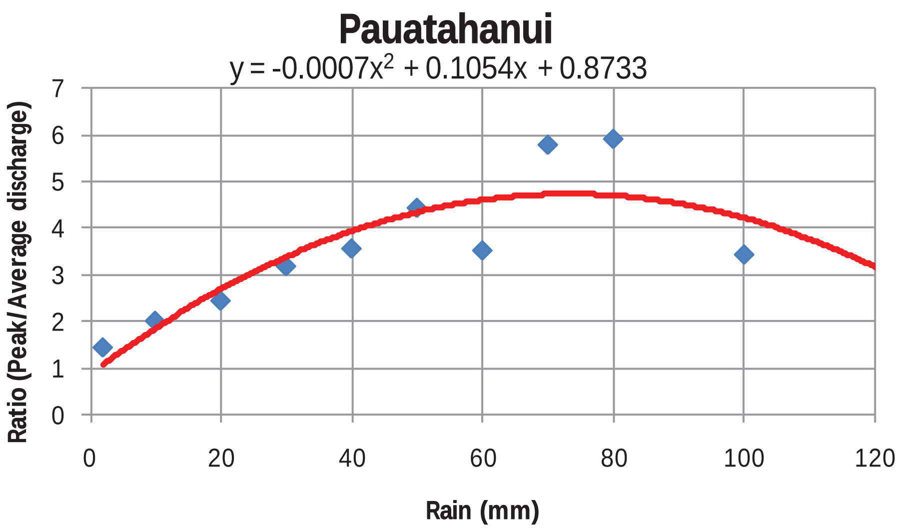


Figure 15.86 Pauatahanui Stream: Peak: Average Event Flow Versus Daily Rainfall

These relationships were allocated to the catchments feeding into the Porirua Harbour on the basis of catchment similarity to the gauged catchments. Factors to estimate peak daily flows from daily average flows were calculated using the appropriate relationship between daily rainfall and peak/average ratios. The factors for days without rainfall were set to zero because sediment yield without rain is negligible.

Q.7 Estimating Existing Sediment Yield – Observed Data

Both existing and observed data was collected and used in estimating existing sediment yields for each of eight catchments that are crossed by the proposed Project. This section describes the method for collection and use of this data.

Q.8 Existing Data

Existing data from GWRC and the NIWA has been collated and is detailed in **Table 15.81.**

Table 15.81 Existing Flow, Rainfall, Total Suspended Solids and Turbidity

Data Type	Station Name	Provider	Length of Record
Flow	Pauatahanui at Gorge Horokiri at Snodgrass Porirua at Town Centre	NIWA GWRC GWRC	34 years 8 years 44 years
Rainfall	Various stations – refer to SKM's 2010 report "Generation of daily streamflow time series for selected catchments"	NIWA and GWRC	Variable
Simultaneous total suspended solids and turbidity data	Horokiri at Snodgrass Pauatahanui at Gorge Porirua at Glenside Porirua at Milk Depot Porirua at Kenepuru	GWRC GWRC GWRC GWRC GWRC	Approximately 2 years

Q.9 Turbidity and Total Suspended Solids Field Data Collection

An assessment was made of the alignment catchments, and sites were selected for event based sampling and installation of turbidity meters for continuous logging of data (**Table 15.82**).

- **Table 15.82 TSS and Turbidity Field Data Collection**

Stream	Continuous Turbidity Loggers	Quarterly Grab Samples & Spot Discharges	Event Based Grab Samples
Horokiri Stream	Two sites	A total of 19 sites upstream and downstream of the proposed highway (see Appendix 15.C)	From stream mouth
Pauatahanui Stream	One site		From stream mouth
Ration Stream	-		From stream mouth
Porirua Stream	-		From stream mouth
Duck Creek	One site		From stream mouth
Wainui/Te Puka Stream	-		-
Whareroa Stream	-		-
Kenepuru Stream	-		-
Details of monitoring	These loggers were in place from mid October 2009 and logged turbidity every 15 minutes. Appendix 15.I outlines the turbidity logger installation at each site and how raw data was processed.	Samples were analysed for TSS and turbidity by Hills Laboratories. Samples were collected in the field using bottles supplied by the laboratory and stored on ice for transport. Spot discharge was simultaneously calculated (see Appendix 15.J) at grab sample locations.	Samples were analysed for TSS and turbidity by Hills Laboratories. Samples were collected in the field using bottles supplied by the laboratory and stored on ice for transport. Spot flows were not measured due to health and safety limitations.

All the samples collected in the field were sent by courier to Hill Laboratories in Hamilton for analysis (**Table 15.83**). The location of these sites can be seen in **Appendix 15.C**.

- **Table 15.83 TSS and Turbidity Analysis Methods by Hills Laboratories**

Data Type	Analytical method	Detection Limit (units)
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 3030 E 21st ed. 2005.	2 NTU's
Total suspended solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 – 1.5µm), gravimetric determination. APHA 2540 D 21st ed. 2005	3.0 g/m³

Q.10 Data Analysis

Q.10.1 Turbidity Used to Estimate Total Suspended Solids

Turbidity is a measure of the ability of water to transmit light. Turbidity is affected by water colour and the size, shape, composition and quantity of suspended particles (Packman, Comings and Booth, 1999; Ankcorn, 2003; Lewis, 1996). Higher turbidity values (observed in nephelometric turbidity units (NTU)) indicate higher concentrations of sediment suspended in the water column – since sediment particles can scatter light (Fink, 2005; Ankcorn, 2003). Suspended sediment is an important water quality measurement as it transports many contaminants such as nutrients and microbiological contaminants (Fink, 2005). An increase in turbidity and TSS has also been shown to have a cumulative negative impact on aquatic ecosystems (Packman et al., 1999; Lewis *et al.*, 2002).

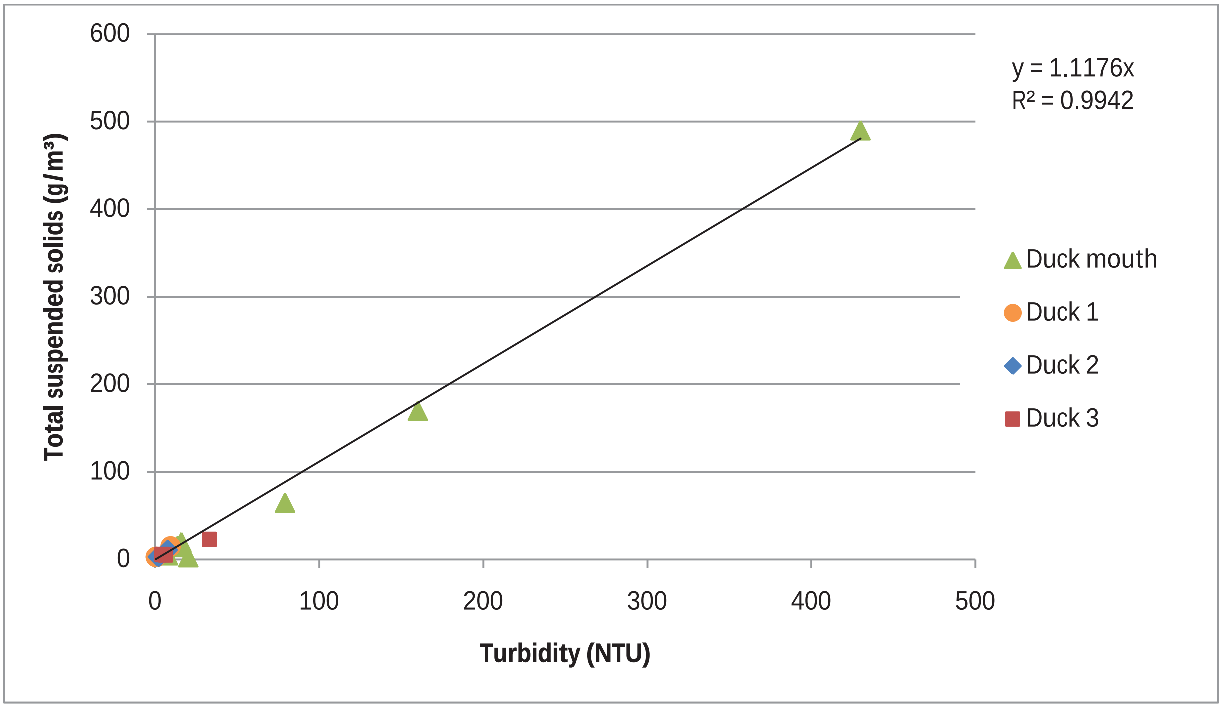
Strong positive relationships between turbidity and TSS have been found and documented in many ongoing studies including many by the US Geological Survey, with correlations often exceeding R^2=0.95 (Ankcorn, 2003; Lewis et al., 2002; Lewis, 1996; Randerson, et al, 2005; Packman et al., 1999; Fink, 2005). These relationships apply in both large events and low flows (Fink, 2005).

Several of these studies suggest that the collection of real-time turbidity data is an accurate and cost-effective way of estimating TSS. Continuous turbidity data can be calibrated by a small number of sediment samples to define a site specific relationship between turbidity and TSS (Fink, 2005). It should be noted that differences in the physical properties of sediment particles may give different turbidity readings for the same sediment quantity. For instance, organic material absorbs more light than inorganic particles, which means less light will reach the turbidity sensor, producing artificially low turbidity values (Ankcorn, 2003). Despite its limitations, long term turbidity data is still considered a reliable method of estimating TSS in streams. It is advised that relationships are determined on a site by site basis. This is due to differences in catchment geology, slope, aspect, soil, vegetation and landuse. These differences affect the type of sediment present in the stream (and therefore the ability of particles to scatter light), and the hydrologic response of the catchment (Fink, 2005; Lewis *et al.*, 2002).

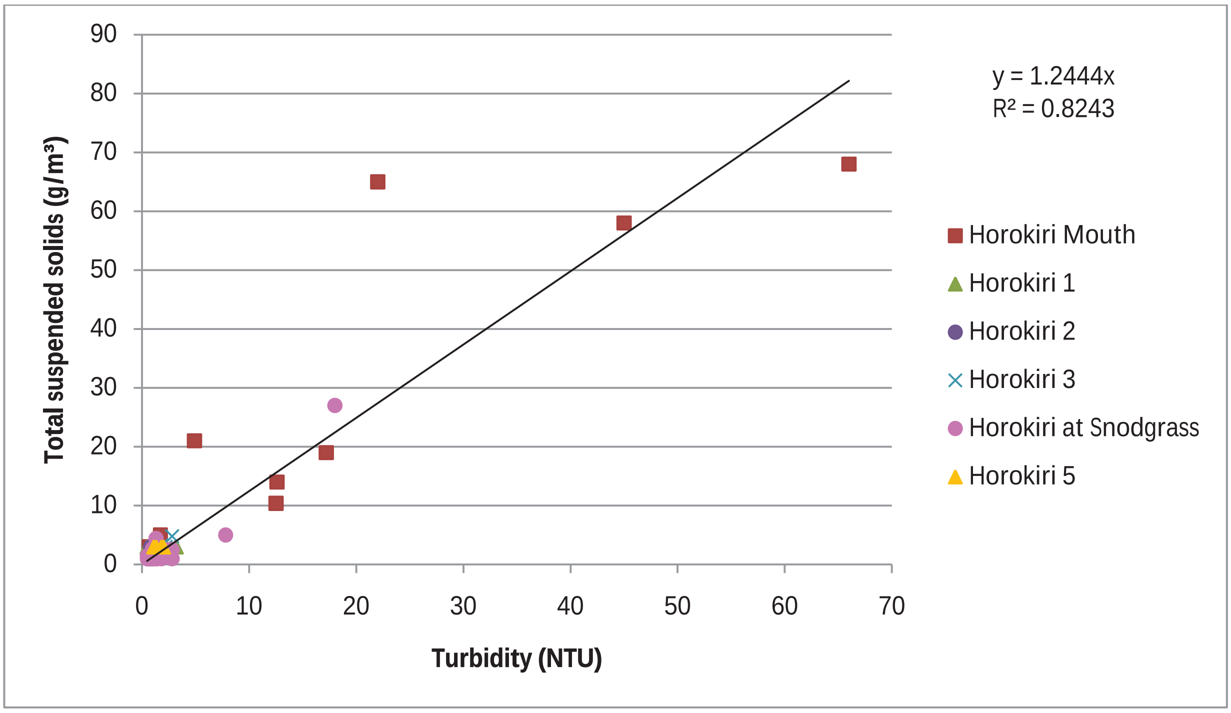
Q.10.2 Site Specific TSS and Turbidity Relationships

TSS and turbidity data from SKM's water quality characterisation stream grab samples and stream mouth event samples were collated for each stream. Data from GWRC's quarterly stream monitoring was also used where possible. Linear regression analysis was used to establish a relationship between turbidity and TSS for each stream. Using all available data, a strong positive relationship was produced for each stream catchment. Note as observed data has only been collected for smaller events, due to the limited period of monitoring has been occurring, this relationship reflects these smaller events.

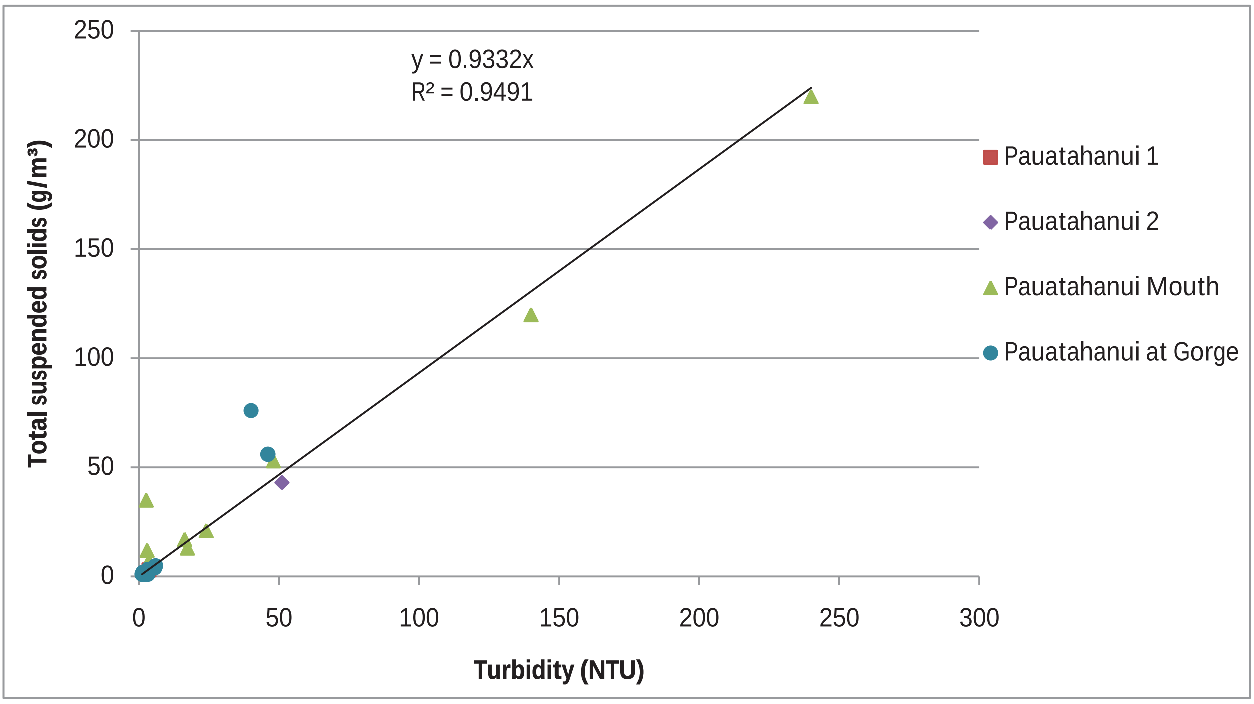
Figure 15.87, **Figure 15.88** and **Figure 15.89** display observed TSS and turbidity at Duck Creek, Horokiri Stream and Pauatahanui Stream respectively. Each graph shows data collected at each sampling location. This includes grab sample sites (which are labelled with the stream name and numbered – e.g. Duck 1, Duck 2, etc), and event sample sites at the each of the stream mouths, e.g. Duck Mouth. **Table 15.84** lists the equations for each stream to convert turbidity to TSS. The derived relationship for each stream was then applied to observed continuous turbidity data, thus converting it to continuous TSS data.



- **Figure 15.87 Observed TSS and Turbidity in Duck Creek – Duck Stream Mouth, and Grab Sample Sites – Duck 1, Duck 2 and Duck 3**



- **Figure 15.88 Observed TSS and turbidity in the Horokiri Stream – Horokiri Stream Mouth, Grab Sample Sites – Horokiri 1, Horokiri 2, Horokiri 3 and Horokiri 5 and the GWRC Site – Horokiri at Snodgrass**



- **Figure 15.89 Observed TSS and Turbidity in the Pauatahanui Stream – Pauatahanui Stream Mouth, Grab Sampling Sites – Pauatahanui 1 and Pauatahanui 2 and NIWA's Site – Pauatahanui at Gorge**

- **Table 15.84 TSS and Turbidity Relationships for Streams**

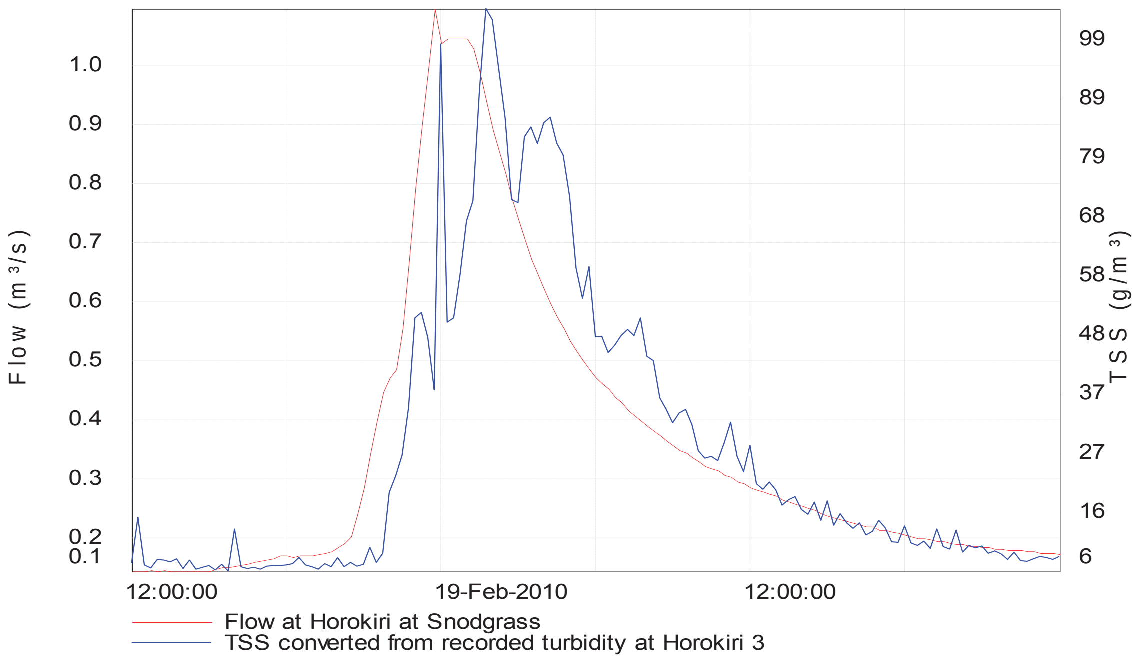
Stream	Equation (TSS = g/m³, Turbidity = NTU)
Duck Creek	TSS = 1.1176(Turbidity)
Pauatahanui Stream	TSS = 0.9332(Turbidity)
Horokiri Stream	TSS = 1.2444(Turbidity)

Q.10.3 TSS and Flow Relationships

There was a general relationship between the flow record at each site and the estimated TSS data. The relationships were strong but not 100% predictive - that is, increases in estimated TSS did not always occur simultaneously with flow increases. There are numerous interactions that preclude this from happening. Increases in observed turbidity and TSS may be related to other factors such as stock moving through the stream, antecedent soil moisture conditions, rainfall intensity, frequency and duration and the presence of algae in the stream (Hicks, 1994; Hicks et al., 1996).

There tended to be a stronger relationship between sediment loads and flow during higher flow events in our data. An example of one such event on the Horokiri Stream is shown in **Figure 15.90**. This is a well documented trend. Walling and Webb (1988) noted that relatively larger events (not necessarily floods) tend to transport most of the sediment load in a stream. In fact, in three study rivers approximately 75% of the total load was transported between 1% and 4% of the time. Hicks (1994) also found that while instantaneous sediment concentrations could vary greatly, most of this “noise” (present for reasons discussed above), would be averaged-out over the duration of a storm event. Furthermore, research on the development of sediment rating curves has shown that it is better to use event data to generate curves. Using the whole flow record to develop the curve would skew the data as base flows would be over represented, where only minor amounts of sediment are transported (Hicks, 1996).

Because of the fact that most sediment appears to be transported during larger events, a series of events were selected as input into the sediment rating curves. Events were selected when flow and sediment was significantly higher than the base flow. This typically occurred when the sediment concentration from a grab sample was greater than 10 g/m³.



- **Figure 15.90 Continuous TSS Data and Flow on the Horokiri Stream During a Rainfall Event on 18 and 19 February 2010**

Q.10.4 Load Calculations from Observed Data

For each of the streams, the peak sediment load was calculated for a range of different flow events. For each flow event, sediment loads were calculated using daily suspended sediment and flow data. **Table 15.85** shows the sources of sediment and flow data used to calculate these loads.

- **Table 15.85 TSS and Flow Data Sources Used**

TSS Data Source	Flow Data Source
GWRC TSS data	Daily peak flow data from corresponding gauge
SKM estimated TSS from turbidity loggers	Pauatahanui 2, Horokiri 3 and Horokiri 4 – estimated daily peak flow; Duck 2 – applied appropriate peaking factor to mean daily flow

TSS Data Source	Flow Data Source
SKM water quality characterisation grab samples	Peak flow data observed in field
SKM water quality characterisation event grab samples	Pauatahanui mouth, Horokiri mouth, Porirua mouth – estimated daily peak flow as detailed in Duck mouth and Ration mouth – applied appropriate peaking factor to mean daily flow

This data was used to calculate the sediment loads at peak flows for each catchment. These loads were used to develop the sediment rating curve.

Q.10.5 Threshold for Event Selection

Sediment runoff occurs during rain events that cause stream flows to increase. Low flows indicate no rainfall without sediment runoff whereas higher flows indicate rainfall producing sediment runoff. The exception is when works are undertaken in the bed of a stream and release sediment to the water column. The stream beds themselves are unlikely to be the source of increased sediment during construction. The operational effects on bed profiles are discussed in Technical Report 14: *Assessment of Hydrology and Stormwater Effects*.

During base flows, the sediment concentration in the streams is generally low. Concentrations are typically at or below the lowest detection limit for total suspended solids as observed by the laboratory, which is $1g/m^3$. Events were selected as input to the sediment rating curve when the flow exceeded the baseflow.

Q.10.6 Rating Curve Application

In order to create a curve that more accurately predicted sediment yield at higher flows and also produced accurate mean annual sediment when applied to the SMWBM the curve was adjusted by the scale coefficient 'A' in Equation 1. The A coefficient is determined by estimating an initial value and then using the 'goal seek' function within Microsoft Excel to converge on the correct solution. The solution is found by testing the USLE annual sediment yield value against a mean annual yield calculated by applying the curve equation to the SMWBM. The scale coefficient controls the yield magnitude of the sediment rating curve.

Due to observed data only being available in a selected number of catchments over a limited range of events, and for simplicity, all sediment rating curves were given the same exponent B consistent with that stated by Healy (1980). The exponent used for the rating curves is 1.9 this value was derived from the shape given by the observed data for peak flow and sediment. The curve exponent B controls the shape of the sediment rating curve where larger exponents would indicate lower catchment yields per unit area. A lower exponent indicates a more linear relationship between flow and sediment, hence higher yields per unit area.

Once the shape of the curves had been set by the exponent B and the magnitude set by 'A' they were adjusted through comparative changes in the USLE for the scenarios and used to calculate the predicted yields for the events during the Project construction. The result was sediment rating curves given in Equation 1.

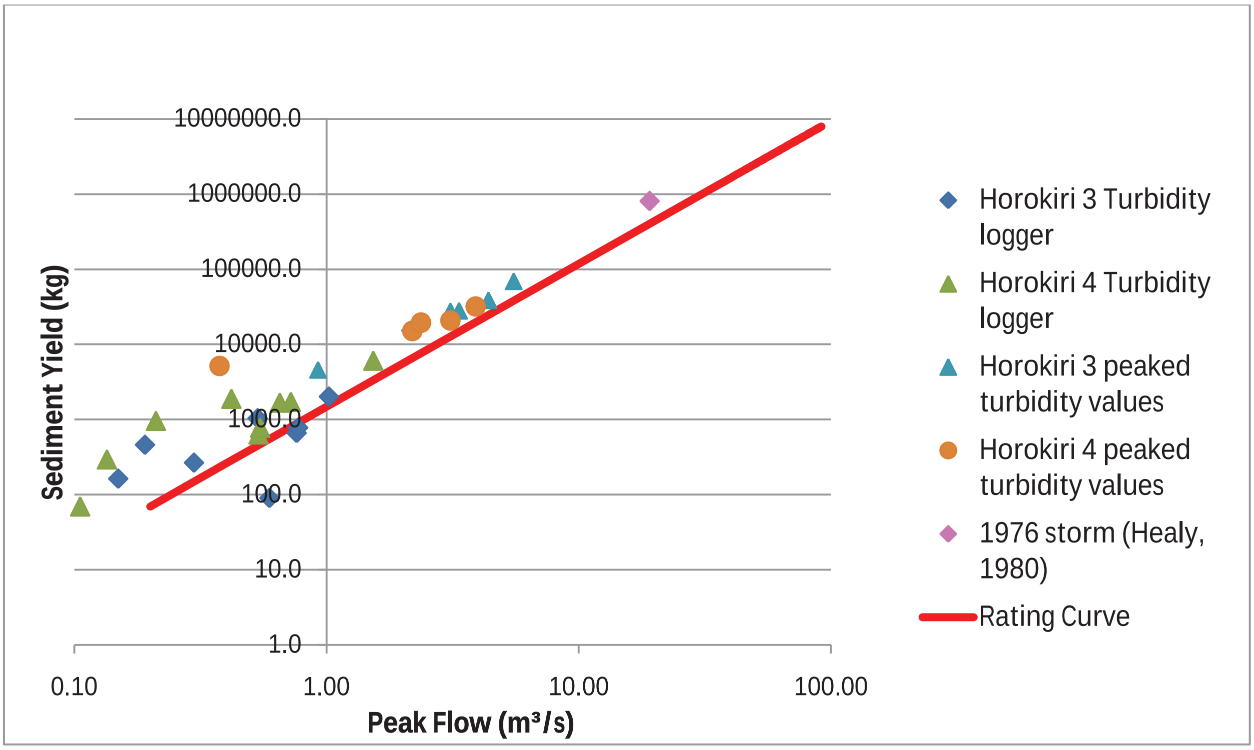
Q.10.7 Curve Application to Streams without Observed Data

The majority of the streams in the Project alignment are without observed data. The SMWBM was used to generate a stream flow time series for each of the catchments and the USLE to generate 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 Project 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.

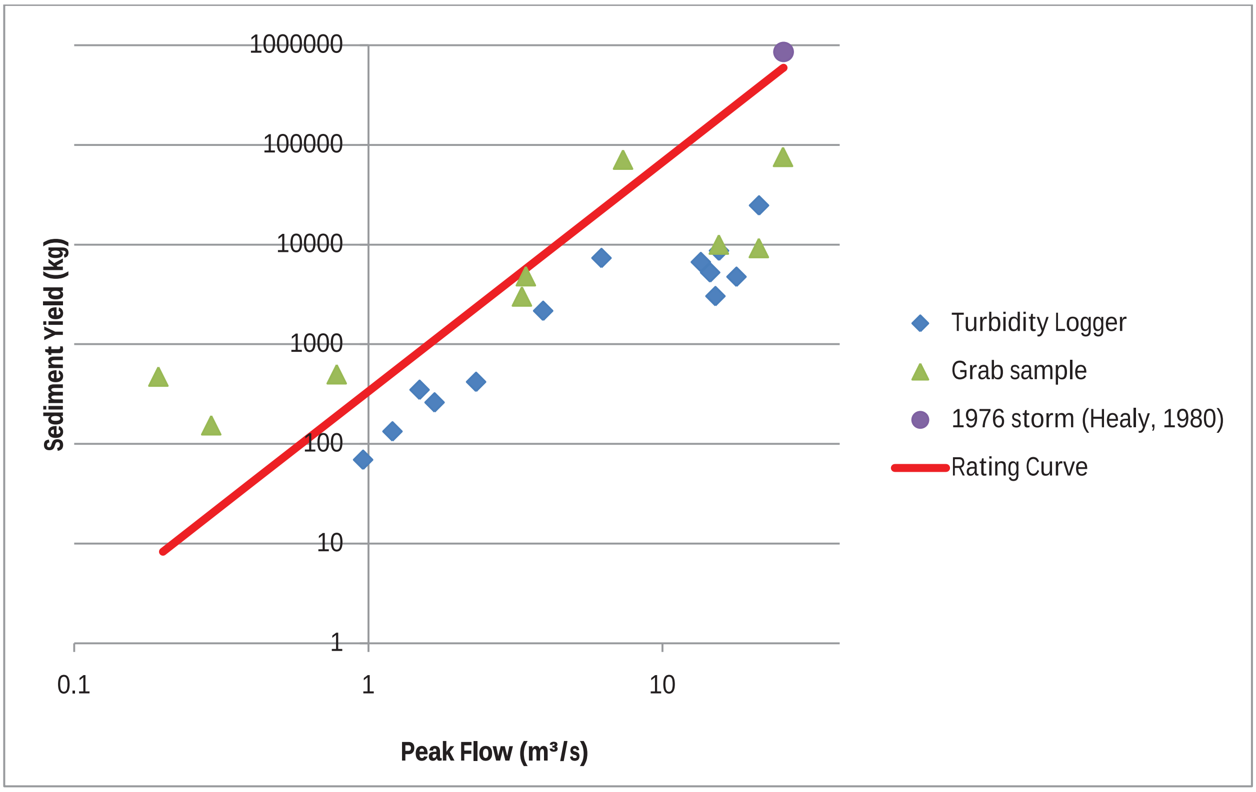
Once the curve had been applied to the overall stream catchments, individual sub-catchment curves were created by rescaling the overall sediment rating curve by dividing the coefficient A by the relative catchment proportion. The scaling factor used was the relative sediment yield from the sub-catchment 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.

Q.10.8 Sediment Rating Curves for Catchments with Observed Data

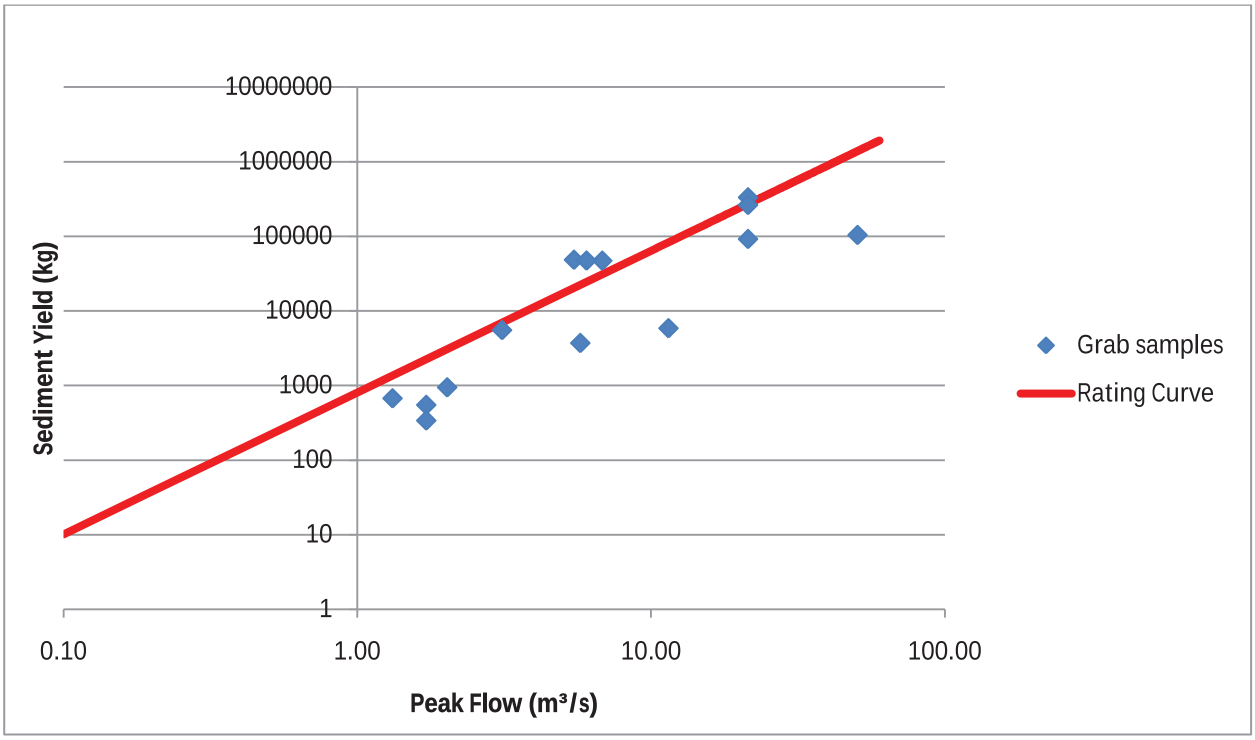
The calculated sediment-rating curves for three catchments with observed data are shown in **Figure 15.43** through **Figure 15.45**.



- **Figure 15.91 Sediment Yield and Peak Flow for Horokiri Catchment**



- **Figure 15.92 Sediment Yield and Peak Flow for Pauatahanui Catchment**



- **Figure 15.93 Sediment Yield and Peak Flow for Porirua Catchment**

Q.10.9 Rating Curve Analysis

The sediment rating curves developed for the catchments of the Horokiri, Pauatahanui, and Porirua streams are expected to approximate sediment yield well for both mean annual sediment and sediment loads in higher return period events. This is shown by the fit with observed data in **Figure 15.43** through **Figure 15.45**. The use of a single curve for each catchment means that peak flow variations are compressed giving lower correlation with low flow events and over-estimation at high flows. However, it is better to use a single curve and to be conservative for sediment yield during larger events which transport most of the sediment.

The method developed to apply sediment rating curves to stream catchments with no observed sediment data was consistent with those with observed data, with a B exponent of 1.9 being used, and the A coefficient being set using the estimate of average annual sediment load form the USLE and the long term simulated flow record created suing the SMWBM.

Q.10.10 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 the Project 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.

Appendix 15.R Existing Sediment Rating Curve Values ($S=AQ^B$)

Main Catchment	B	A
Duck	1.9	3746
Horokiri	1.9	1527
Kenepuru	1.9	1409
Pauatahanui	1.9	1182
Porirua	1.9	720
Ration	1.9	4564
Collins	1.9	10474
Wainui	1.9	13932
Whareroa	1.9	15389

Appendix 15.S Stream Sediment Transport Modelling – Suspended Sediment

- **Table S.1 – Total Suspended Sediment per Subcatchment**

Catchment	X Coordinate	Y Coordinate	Measured Baseline Median of 4 samples (g/m^3)	Flow m³/s	Modelled Baseline				Modelled 2021 without road				Modelled Worst Year (2021 hydrology)			
					1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)
Pori1HR	1753294	5441076			61	257	453	681	57	242	426	641	57	242	426	641
Pori3HR	1754338	5442279			48	185	313	461	60	230	390	574	70	268	455	764
Porirua 1	1754244	5443017	7.5	1.6												
Pori2HR	1754302	5443075			17	102	187	292	19	113	207	324	19	118	216	352
Pori5HR	1754432	5443147			216	792	1315	1920	219	799	1328	1939	219	799	1328	1939
Pori4HR	1754518	5442707			46	145	236	347	44	138	225	330	133	414	676	1653
Pori8HR	1754683	5445103			15	84	154	237	15	88	161	247	16	93	170	275
Porirua 2	1754674	5443626	6.2	0.4												
Pori6HR	1754778	5443443			40	148	251	378	40	146	248	373	96	352	599	1432
Kenepuru 3	1754908	5444471	12.4	0.4												
Kene14HR	1755090	5444350			93	447	741	1106	110	533	883	1318	110	533	883	1318
Kene15HR	1754750	5444661			71	350	591	901	95	465	787	1200	95	465	787	1200
Pori7HR	1755153	5442931			79	268	471	715	78	264	465	705	79	268	471	724
Kene13HR	1755584	5444674			85	453	769	1150	87	462	783	1171	92	490	831	1314
Kene12HR	1755635	5444706			126	555	923	1361	145	636	1059	1561	145	636	1059	1561
Kene11HR	1756084	5444898			474	2314	3978	6142	126	616	1059	1635	126	616	1059	1635
Kene10HR	1756121	5444905			88	490	841	1277	87	484	831	1261	87	484	831	1261
Kene9HR	1756490	5444747			117	587	998	1513	176	880	1495	2266	176	880	1495	2266
Kene5HR	1756504	5444682			64	326	551	829	63	318	538	809	63	318	538	809
Kene4HR	1756673	5443880			68	370	638	964	66	363	627	946	66	363	627	946
Kenepuru 2	1756916	5443374	8.3	0.1												
Kene2HR	1756959	5443458			187	598	939	1375	368	1181	1855	2716	682	2188	3436	7344
Kene3HR	1756964	5443458			142	442	719	1070	141	436	710	1056	141	436	710	1056

Catchment	X Coordinate	Y Coordinate	Measured Baseline Median of 4 samples (g/m^3)	Flow m³/s	Modelled Baseline				Modelled 2021 without road				Modelled Worst Year (2021 hydrology)			
					1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)
Kene6HR	1756978	5444344			66	408	736	1147	64	396	714	1113	64	396	714	1113
Kene8HR	1757123	5445300			90	485	840	1287	101	543	941	1440	101	543	941	1440
Kene7HR	1757165	5445282			111	527	878	1304	114	541	902	1339	114	541	902	1339
Kenepuru 1	1757236	5442104	3.8	0.1												
Kene1HR	1757313	5442249			320	1327	2300	3600	316	1311	2271	3554	335	1389	2408	3981
Duck 1	1758585	5443207	3.0	0.02												
Duck2HR	1758594	5443534			384	1505	3037	4655	384	1505	3036	4655	538	2108	4251	8380
Duck3HR	1758757	5443712			381	1464	2980	4585	381	1464	2980	4585	430	1651	3362	5760
Duck7HR	1758845	5446283			104	618	1383	2044	104	618	1383	2044	104	618	1383	2044
Duck4HR	1758971	5444007			290	1112	2291	3512	290	1112	2290	3511	290	1112	2290	3511
Duck8HR	1759002	5446888			35	303	803	1238	35	303	803	1238	35	303	803	1238
Duck6HR	1759096	5446838			68	503	1234	1893	58	434	1065	1633	58	434	1065	1633
Duck 2	1759241	5445707	5.2	0.4												
Duck5HR	1759251	5444608			373	1393	2836	4273	373	1393	2836	4272	373	1393	2836	4272
Duck1HR	1759439	5445148			372	1438	2918	4436	372	1438	2917	4436	584	2260	4586	9510
Duck 3	1759600	5447569	5.6	0.2												
Duck10HR	1759610	5447476			197	1360	3300	5005	68	471	1142	1731	68	471	1142	1731
Duck9HR	1759635	5447728			30	259	689	1071	36	304	810	1259	36	304	810	1259
Horo7HR	1760064	5449043			60	465	1112	1621	60	465	1112	1621	61	474	1135	1688
Paua6HR	1760441	5447932			5	66	205	308	5	66	205	308	5	66	205	308
Pauatahanui 2	1760814	5447129	3.4	1.3												
Rati6HR	1760714	5448493			103	823	1801	2586	103	823	1801	2586	188	1506	3293	6872
Paua5HR	1760947	5447709			26	203	535	796	26	203	535	796	31	246	649	1135
Paua4HR	1760953	5447542			47	715	2340	3547	14	211	689	1044	31	468	1531	3597
Paua3HR	1760959	5446685			68	520	1370	2045	68	520	1370	2044	86	659	1736	3135
Paua2HR	1761048	5446824			51	412	1079	1596	51	412	1078	1596	51	412	1078	1596

Catchment	X Coordinate	Y Coordinate	Measured Baseline Median of 4 samples (g/m^3)	Flow m³/s	Modelled Baseline				Modelled 2021 without road				Modelled Worst Year (2021 hydrology)			
					1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)
Ration 2	1761101	5448667	3.7	0.2												
Horokiri 5	1761192	5449870	3.0	0.8												
Pauatahanui 1	1761252	5446595	12.0	1.0												
Paua1HR	1762047	5446637			78	598	1584	2355	78	598	1584	2356	78	598	1585	2357
Rati2HR	1762322	5449235			84	720	1621	2346	84	720	1621	2346	140	1203	2707	5487
Ration 1	1762326	5449179	3.0	0.1												
Rati5HR	1762357	5449206			116	984	2222	3252	116	984	2222	3252	194	1653	3732	7672
Horokiri 2	1762888	5451776	3.0	0.1												
Horo6HR	1762891	5452045			12	98	241	361	12	98	241	361	12	98	241	361
Rati4HR	1762942	5449955			142	1205	2691	3950	142	1205	2691	3950	230	1959	4374	8893
Horo1HR	1762950	5452443			68	555	1352	2001	68	555	1352	2001	68	555	1352	2001
Horokiri 3	1762966	5452361	3.1	0.2												
Horo4HR	1763047	5452977			39	313	779	1170	39	313	779	1170	39	313	779	1172
Rati3HR	1763100	5450266			186	1619	3653	5376	186	1619	3653	5376	206	1793	4046	6531
Rati1HR	1763166	5450993			184	1540	3468	5108	184	1540	3468	5108	224	1869	4208	7290
Horo5HR	1763309	5452064			106	861	2116	3147	106	861	2116	3147	155	1255	3085	6028
Horo2HR	1763950	5454328			90	700	1702	2504	90	700	1702	2504	99	764	1859	2964
Horokiri 1	1764158	5455125	3.0	0.1												
Horo3HR	1764252	5455241			142	1075	2635	3858	142	1075	2635	3858	142	1075	2635	3858
Te Puka 1	1765016	5458606	3.0	0.2												
Te Puka 2	1765423	5461361	4.0	0.6												
Whareroa 1	1766929	5462394	3.3	0.2												
Wain10HR	1765573	5461548			52	459	1065	1556	65	567	1317	1924	67	589	1366	2067
Wain11HR	1764912	5462408			75	1132	2983	4368	77	1158	3051	4466	77	1161	3059	4489
Wain1HR	1765090	5458560			732	6184	13971	20785	732	6184	13971	20785	732	6184	13971	20785
Wain2HR	1765664	5461287			922	8432	31980	29428	922	8432	31980	29428	963	8807	33400	32042

Catchment	X Coordinate	Y Coordinate	Measured Baseline Median of 4 samples (g/m^3)	Flow m³/s	Modelled Baseline				Modelled 2021 without road				Modelled Worst Year (2021 hydrology)			
					1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)	1/3 of Q2 Sed (g/m^3)	Q2 Sed (g/m^3)	Q10 Sed (g/m^3)	Q50 Sed (g/m^3)
Wain3HR	1765087	5458592			870	7347	16597	24892	870	7347	16597	24892	870	7347	16597	24892
Wain4HR	1765387	5460579			851	7684	17809	26946	851	7684	17809	26946	1381	12468	28895	60492
Wain7HR	1765344	5461625			272	3111	7651	11247	272	3111	7651	11247	272	3111	7651	11247
Wain8HR	1765387	5461613			410	3498	7980	11901	410	3498	7980	11901	1107	9437	21527	52309
Wain9HR	1765560	5461416			512	4465	10178	15219	512	4465	10178	15219	965	8416	19183	42153
Whar1HR	1766903	5462245			2213	17024	39381	58313	834	6416	14842	21976	834	6416	14842	21976
Whar2HR	1767411	5461951			2039	15615	35662	52659	769	5885	13440	19845	769	5885	13440	19845
Whar3HR	1767434	5461970			2046	14802	33233	48044	771	5578	12525	18106	771	5578	12525	18106
Whar4HR	1766871	5462569			1286	9684	22091	32129	485	3650	8326	12109	783	5898	13455	27028
Whar5HR	1766572	5464185			16	109	239	334	13	87	191	267	14	95	208	315
Whar6HR	1766396	5464409			564	4558	10503	15279	241	1946	4484	6523	241	1946	4484	6523
Whar7HR	1765673	5464316			1	6	12	16	0	1	3	3	0	2	3	5

Table S.2 – Percentage Change in TSS between No Road and Peak Construction

Catchment	Event	Sediment Yield (kg)		Volume (m^3/s)	Total Suspended Sediment (g/m^3)		Percentage Change
		No Road	Peak Construction		No Road	Peak Construction	
Duck	1/3 of Q2	10793	13670	57046	189	240	27%
	Q2	342821	434196	329425	1041	1318	27%
	Q10	1581875	2003508	703380	2249	2848	27%
	Q50	3617255	5545538	1074540	3366	5161	53%
Horokiri	1/3 of Q2	10572	12055	126987	83	95	14%
	Q2	688690	785323	1062829	648	739	14%
	Q10	3754028	4280771	2465820	1522	1736	14%
	Q50	8288985	10615110	3698400	2241	2870	28%
Kenepuru	1/3 of Q2	18243	20079	110245	165	182	10%
	Q2	375466	413243	507219	740	815	10%
	Q10	1050597	1156302	860220	1221	1344	10%
	Q50	2345704	2817725	1294560	1812	2177	20%
Pauatahanui	1/3 of Q2	10675	10917	136868	78	80	2%
	Q2	695481	711242	1148265	606	619	2%
	Q10	4425800	4526101	2873520	1540	1575	2%
	Q50	10117500	10576084	4390140	2305	2409	5%
Porirua	1/3 of Q2	22817	23277	305474	75	76	2%
	Q2	480840	490536	1460295	329	336	2%
	Q10	1417250	1445827	2549760	556	567	2%
	Q50	3193641	3322436	3875580	824	857	4%
Ration	1/3 of Q2	4049	5779	29235	139	198	43%
	Q2	271448	387367	242240	1121	1599	43%
	Q10	1352966	1930742	541440	2499	3566	43%
	Q50	2941754	5454267	808380	3639	6747	85%
Wainui	1/3 of Q2	23588	30510	32368	729	943	29%
	Q2	1709800	2211592	268740	6362	8229	29%
	Q10	8687664	11237318	599330	14496	18750	29%
	Q50	19431041	30836279	905941	21448	34038	59%
Whareroa	1/3 of Q2	33405	34991	69249	482	505	5%
	Q2	1948361	2040840	540726	3603	3774	5%
	Q10	9594996	10050423	1179982	8131	8517	5%
	Q50	20496760	22442520	1739778	11781	12900	9%
Collins	1/3 of Q2	376	673	3050	123	221	79%
	Q2	21201	37908	22955	924	1651	79%
	Q10	107131	191555	50460	2123	3796	79%
	Q50	221820	571425	75419	2941	7577	158%