IN THE MATTER OF	The Resource Management Act 1991
AND	
IN THE MATTER OF	applications for resource consents in relation to Te Ahu a Turanga; Manawatū Tararua Highway Project
BY	**NEW ZEALAND TRANSPORT AGENCY** Applicant

TE AHU A TURANGA: TECHNICAL ASSESSMENT C

WATER QUALITY

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1 INTRODUCTION

1. My full name is **Keith David Hamill**. I am an Environmental Scientist and Director at River Lake Limited. River Lake Limited is a consultancy that provides research and environmental science advice for understanding and managing rivers, lakes and estuaries. My technical speciality is in water quality and aquatic ecology.

Qualifications and experience

2. I hold a Bachelor of Science degree (Geography) from the University of Auckland (1992) and a Master of Science (1st Class Hons) in Ecology and Resource & Environmental Planning from the University of Waikato (1995).

3. I have 24 years' experience in the area of resource management and environmental science. I have previously worked as:

    (a) a Principal Environmental Scientist at Opus International Consultants Limited;

    (b) a Senior Environmental Scientist for Water Research Centre Ltd (WRc plc in the United Kingdom; and

    (c) an Environmental Scientist at Southland Regional Council.

4. Previous experience relevant to this assessment includes:

    (a) Mt Messenger SH3 Road Alignment where I led the assessment for freshwater ecology and water quality;

    (b) numerous ecological and water quality investigations contributing to the Best Practicable Option review for Palmerston North City Council ("**PNCC**") Totara Road Wastewater Treatment Plant; and

    (c) contributing to the single environmental indicators and dependable monitoring projects for the Ministry for the Environment.

Code of conduct

5. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2014. This assessment has been prepared in compliance with that Code, as if it were evidence being given in Environment Court proceedings. In particular, unless I state otherwise, this assessment is within my area of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

Purpose and scope of assessment

6. My role in the Te Ahu a Turanga: Manawatū Tararua Highway Project (the "**Project**") has been to assess the potential effects of the Project on water quality and to recommend measures to address those effects. This assessment:

   (a) describes the current state of water quality in streams affected by the Project;

   (b) describes the potential effects of the Project on these streams, with particular focus on the effects of stormwater on receiving waterbodies and potential water quality effects during the construction phase; and

   (c) sets out recommended mitigation and monitoring.

7. In preparing this assessment, I have relied on contributions Alex James (Ecologist, EOS) in the areas of current water quality conditions in catchments monitored during 2018 and 2019.

8. I am also a contributor to the natural character assessment, as I explain below under methodology.

Assumptions and exclusions in this assessment

9. This assessment focuses only on the effects of the Project on water quality. The effects of the water quality on aquatic ecology is covered in the Freshwater Ecology Technical Assessment by **Ms Justine Quinn** (Technical Assessment B). In practice, water quality is strongly interconnected with aquatic ecology and in this assessment.

10. This assessment relies on the input from other technical assessments undertaken for the Project, including:

    (a) the Design and Construction Report ("**DCR**"),

    (b) Technical Assessment A: Erosion and Sediment Control ("**ESC**") by **Mr Campbell Stewart**;

    (c) Technical Assessment B: Stormwater Management by **Mr David Hughes** as Appendix B.

    (d) Technical Assessment D: Hydrological Assessment by **Dr Jack McConchie**.

2 EXECUTIVE SUMMARY

11. The Project consists of approximately 11.5km of new State highway connecting Ashhurst and Woodville via a route over the Ruahine Ranges. I have undertaken an assessment of the Project's construction and operational effects on water quality.

12. The Project is within the main catchments of the Pohangina River and the Manawatū River and directly affects nine smaller catchments (referred to as "**C1 to C9**"), which all drain to the Manawatū River except C9. Most of the catchments are steep with the exception of C1, C8 and parts of C2 and C4.

13. Water quality across the catchments is varied; in general, the streams are characterised by:

    (a) relatively low water clarity;

    (b) high concentrations of nitrate in C1, C2, C7 and C8;

    (c) high concentrations of dissolved phosphorus in C5, C6 and C7;

    (d) occasionally high or very high concentrations of *E. coli* bacteria in all catchments, with the possible exception of C6 and upper C7;

    (e) high turbidity in C5;

    (f) high hardness in C7; and

    (g) concentrations of copper and/or zinc elevated above Australian and New Zealand Guidelines for Fresh and Marine Water Quality ("**ANZG**") Default Guideline Values ("**DGV**") in C4, C5, C6 and C7.

14. Assessing the effect of sedimentation during construction was informed by sediment yield calculations from the ESC Assessment. Assessing the effects of long-term stormwater discharges was informed by the Contaminant Load Model (version 2) ("**CLM**"). The key activities considered in assessing the potential effects of the Project on water quality were:

    (a) sedimentation effects from earthworks and potential effects of flocculants in erosion and sediment control devices;

    (b) potential water quality impacts from vegetation clearance;

    (c) potential water quality impacts from use of concrete; and

    (d) stormwater discharges from long-term operation of the road.

15. The bulk earthworks during construction will increase sediment loss and reduce water clarity. This will be more apparent during high flow events and in smaller sub-catchments. In some locations discharges during rain events may cause the water clarity to temporarily reduce by more than the 30% reduction set as a target in the One Plan. The effects on downstream water quality can be minimised and mitigated with the Project's ESC Management Plan, Site Specific Erosion and Sediment Control Plans ("**SSESCPs**"), and ESC Monitoring Plan.

16. The effect of vegetation clearance on stream water quality is expected to be negligible or small if good practice is followed to prevent leaching of wood chip residue to waterways or overland flow paths.

17. The risk of concrete pouring affecting stream water quality is expected to be low when good management practices are implemented.

18. In the long term, once the Project is operational, the high level of stormwater treatment provided by the Project will result in improved water quality in the Manawatū River, the Pohangina River and C1, C2, C4 and C9. No stormwater from the road will enter C5 and C6, so there will be no resulting stormwater effects in these catchments. There is potential for treated stormwater discharges to cause a decline in water quality in sub-catchment C2E and in C3, C7 and C8. However, for these catchments the effects will likely be small because:

    (a) stormwater discharges will be intermittent in nature;

    (b) the quality of the stormwater will be within relevant guidelines; and

    (c) for total suspended solids ("**TSS**"), the stormwater will have similar concentrations to that currently found in the streams during flood events.

3 PROJECT DESCRIPTION

19. The Project comprises the construction, operation, use, maintenance and improvement of approximately 11.5km of State highway connecting Ashhurst and Woodville via a route over the Ruahine Ranges. The purpose of the Project is to replace the indefinitely closed existing State Highway 3 ("**SH3**") through the Manawatū Gorge.

20. The Project comprises a median separated carriageway that includes two lanes in each direction over the majority of the route and will connect with State Highway 57 ("**SH57**") east of Ashhurst and SH3 west of Woodville (via proposed roundabouts). A shared use path for cyclists and pedestrian users is

proposed as well as a number of new bridge structures including a bridge crossing over the Manawatū River.

21. The design and detail of each of the elements of the Project is described in:

    (a) Section 3 of the Assessment of Environmental Effects (in Volume I);

    (b) the DCR (in Volume II); and

    (c) the Drawing Set (in Volume III).

22. The elements of the Project that are particularly relevant to this assessment are described in the Stormwater Management Design Report (Appendix B to the DCR).

4 BACKGROUND

23. The Transport Agency has separately given notices of its requirement for three designations for the Project ("**NoRs**"), and these NoRs are currently under appeal. I understand that the Transport Agency has asked the Environment Court, as part of those appeals, to modify the NoRs to provide for the Northern Alignment on which the Alliance's concept design is based.

24. I have familiarised myself with the technical assessments previously prepared by the Transport Agency in support of the NoRs that are relevant to water quality, including:

    (a) Boffa Miskell (2018a), Freshwater – Ecological Impact Assessment (particularly sections 4.1.3 and 4.1.4 relating to potential effects from erosion and stormwater discharges);

    (b) Boffa Miskell (2018b), Fish survey report; and

    (c) NoR Appendix 4.A: Natural character assessment (October 2018) (particularly section 6.6 "water quality methodology and results", prepared by O. Ausseil and M. Greer).

25. My assessment of effects has built upon the NoR work that was undertaken to assess water quality aspects of Natural Character. Ausseil and Greer (2018) compared modelled water quality (Larned et al 2017) against modelled baseline water quality (McDowell et al 2013), and assigned streams to a natural character state based on their River Environment Classification ("**REC**") class and statistical thresholds derived from a national dataset. We repeated this analysis to compare modelled water quality with the modelled baseline conditions for each sub-catchment. There are limitations to using modelled data, so this was augmented with baseline monitoring data collected

by EOS Ecology (2018), calculations of the percentage of the catchment in natural vegetation cover, and percentage of the riparian zone in natural vegetation cover.

5 EXISTING ENVIRONMENT

26. The Project is within the main catchments of the Pohangina River and the Manawatū River and directly affects nine smaller catchments (C1 to C9), which all drain to the Manawatū River except C9. With the exception of C9, these catchments enter the Manawatū Gorge from the ridge end and have pastural landuse in the headwaters with indigenous forest in the steep lower part of the catchment (**Figure C.1**). Most of the catchments are steep with the exception of C1, true left of C2, C8 and upper C4 (**Figure C.1**, stream numbering diagram is found in TAT-3 DG-E-4100-A (Waterways and Catchment Overview Plan in Volume III).

27. Catchment characteristics are described in **Table C.1** including the REC class and modelled flow estimates from the REC. A notable feature of the catchments affected is the variability in REC classes. Most of the affected catchments are small (with an estimated mean flow of less than 0.1 m^3/s) with the exception of the Manawatū River (83 m^3/s), Pohangina River (19 m^3/s) and Mangamanaia Stream (C2) (0.37 m^3/s). The existing road length contributing to stormwater is shown for each catchment and refers to existing roads taking traffic that is expected to mostly shift to the Project once constructed (e.g. Saddle Road).

28. Modelled median annual water quality for each catchment is shown in **Table C.2** based on national modelling by Larned et al (2017). Turbidity was calculated from the modelled clarity using the relationship: $TURB = 3.8046\ BDISC^{-1.096}$. TSS was calculated from turbidity using the relationship: $TSS = TURB / 0.61$. Both relationships were developed from data collected in the Manawatū River at Teachers College[1].

29. Horizons Regional Council ("**Horizons**") has regularly monitored standard water quality variables in the Manawatū River and Pohangina River (**Table C.3**), and undertaken short periods of intensive sampling for dissolved metals at some Manawatū River sites (**Table C.4**). The Pohangina River has clearer water with substantially lower concentrations of suspended sediment and nitrogen compared to the Manawatū River in the Gorge. Neither river site

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[1] These equations are only reliable when the TSS concentration is <1200 mg/L, probably because large floods with very high sediment concentrations mobilise larger particles with different light scattering characteristics.

meets the One Plan targets for clarity or dissolved reactive phosphorus ("**DRP**"), and the Manawatū River (upper Gorge) does not meet the One Plan target for soluble inorganic nitrogen ("**SIN**")[2] (**Table C.3**). **Table C.4** indicates that the lower Manawatū River (at Palmerston North) has average concentrations of dissolved metals within One Plan targets.

30. Baseline water quality was initiated in December 2018 in most sub-catchments affected by the Project. This included measuring water clarity, turbidity, TSS, aluminum and pH during wet and dry conditions; aquatic macroinvertebrate and deposited sediment were also monitored (EOS 2018). The results are described in EOS (2019) and summary water quality results for each catchment are shown in **Table C.5**. Most sites had relatively low visual clarity, moderately high turbidity and, with the exception of C7, a relatively high proportion of fine sediment on the stream bed. All sites had median water clarity less than the median clarity in the Manawatū River at upper Gorge, and all sites on all sample occasions had water clarity less than the One Plan target.

31. At a sub-set of sites additional water quality variables (nutrients and metals) were collected from October 2019 to November 2019 (**Table C.6**). The first two sample occasions (31 October and 7 November) were done during baseflow conditions. The third sample occasion was after rain but there appeared to be little change in stream flow. This sampling found:

    (a) high concentrations of nitrate in C2 and C7 compared to One Plan targets and modelled values. Modelling also shows high nitrate in C1 and C8;

    (b) DRP was high in C5, C6 and C7 (at the western end of the Alignment), but was particularly high in C6 and C7, where it was in excess of modelled estimates;

    (c) all catchments had occasions of high or very high concentrations of *E. coli* bacteria (in excess of guidelines and modelled medians), with the exception of C6 and the upper section of sub-catchment C7A, which had reasonable microbial water quality;

    (d) C5 had high turbidity relative to the other catchments and relative to modelled estimates;

    (e) C7 had high pH and high hardness;

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[2] SIN = nitrate nitrogen + nitrite nitrogen

(f) dissolved copper was occasionally elevated in C4 and C5 including to above One Plan target values[3] (before and after adjusting for hardness);

(g) total copper was occasionally elevated in C2, C4, C5, C6 and C7 to above the ANZG Default Guideline Values (DGVs) before adjusting for hardness, and in C4, C5 and C7 after adjusting for hardness; and

(h) total zinc was elevated above the ANZG DVG in C6 on one occasion (after adjusting for hardness).

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[3] The One Plan targets equate to the ANZECC (2000) 95 percent protection values and the ANZG (2018) Default Guideline Values (DGV).

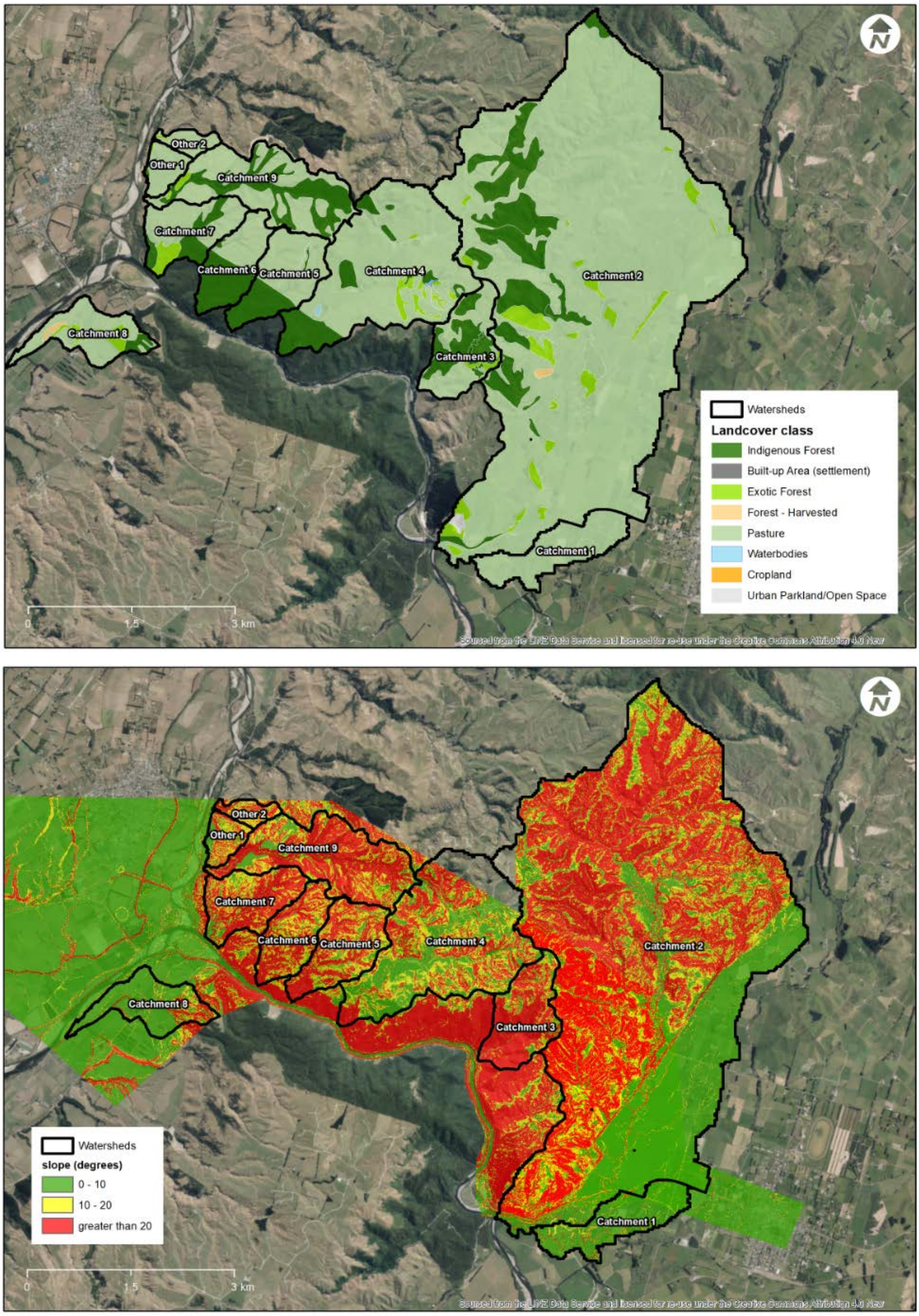

Figure C.1: Catchments affected by the Project showing landuse (top) and slope (bottom). Landuse is from the Land Cover Database version 4 (LCDB v4).

Table C.1: Features of catchments affected by the Project. Mean Annual Low Flow ("**MALF**"), Mean Flow, Stream Order and REC Code is from the River Environment Classification ("**REC**"). The length of road contributing to stormwater runoff in each catchment is shown separately for existing roads and the Project. The existing road length to stormwater ("**SW**") values refers primarily to stormwater from Saddle Road to Woodlands Road. Sub-catchments are in italics i.e. C2e, C2a downstream of confluence with 2e, and C4a at the new highway's route[4].

Catchment ID	**MALF (m^3/s)**	**Mean flow (m^3/s)**	**Catchment area (ha)**	**Stream Order**	**REC code**	**Existing road length to SW (m)**	**Project road length to SW (m)**
1	0.0054	0.020	114	1	WW/L/Al/P/LO/LG	1595	1,699
2e	*0.0018*	*0.009*	*53*	*1*	*WW/L/SS/P/LO/HG*	*0*	*1,449*
2a (ds 2e)	0.0757	0.370	1,658	3	CW/L/SS/P/MO/LG	5283	1,986
3	0.0044	0.027	123	1	CW/L/SS/P/LO/HG	0	1,214
4a at TAaT Highway	*0.0119*	*0.083*	*329*	*2*	*CW/L/SS/P/LO/LG*	*2043*	*2,782*
4	0.0136	0.095	412	2	CW/L/SS/P/LO/HG	0	2,782
5	0.0044	0.029	120	2	CW/L/SS/P/LO/HG	0	0
6	0.0023	0.019	95	2	CW/L/Al/P/LO/HG	0	0
7	0.0017	0.012	110	1	WD/L/M/P/LO/HG	0	3,035
8	0.0080	0.044	101	1	WD/L/SS/P/LO/HG	385	1,253
9	0.0065	0.042	220	1	CD/L/Al/P/LO/HG	850	0
Manawatū River Gorge	18.8	83.9	320,230	7	CW/L/SS/P/HO/LG	8921	15,743
Pohangina River	3.53	19.2	55,086	5	CW/H/HS/P/HO/LG	3785	0

Flow from River Environment Classification (REC)

Table C.2: Median annual water quality in catchments as modelled by Larned et al (2017) based on REC classes. Turbidity and TSS were estimated from clarity.

Catchment ID	**TSS (g/m^3)**	**Turbidity (NTU)**	**CLAR (m)**	**DRP (mg/m^3)**	**ECOLI (cfu/100 ml)**	**NH4N (mg/m^3)**	**NO3N (mg/m^3)**	**TN (mg/m^3)**	**TP (mg/m^3)**	**MCI**
1	9.1	5.6	0.71	24.8	347	44.9	1358	3391	121.1	90
2e	*6.8*	*4.2*	*0.92*	*18.8*	*224*	*16.7*	*472*	*1058*	*42.5*	*99*
2a (ds 2e)	6.1	3.7	1.02	14.7	327	15.4	420	762	40.4	100
3	4.9	3.0	1.24	13.9	182	13.5	160	356	25.5	114
4a at TAaT Highway	*4.6*	*2.8*	*1.31*	*14.5*	*220*	*20.1*	*537*	*1041*	*34.8*	*108*
4	4.4	2.7	1.38	14.7	187	19.6	279	653	35.9	106
5	6.0	3.6	1.04	14.8	198	14.6	252	570	35.1	111
6	6.0	3.6	1.04	12.7	191	14.8	217	443	34.4	111
7	6.1	3.7	1.02	15.0	131	14.1	186	439	36.8	107
8	8.4	5.1	0.76	17.8	178	23.8	414	1050	83.6	85
9	4.8	2.9	1.27	11.5	127	11.8	301	515	26.0	111
Manawatū River Gorge	6.8	4.1	0.93	12.5	199	12.4	521	880	35.6	100
Pohangina River	4.6	2.8	1.32	9.9	116	9.6	178	391	25.0	109

TSS = total suspended solids, CLAR = black disc clarity, DRP dissolved reactive phosphorus, ECOLI = *E. coli* bacteria, NH4-N = ammoniacal nitrogen, TN = total nitorgen, TP = total phosphorus, MCI = macroinvertebrate community index

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[4] The stream numbering diagram is found in TAT-3 DG-E-4100-A (Waterways and Catchment Overview Plan in Volume III.

Table C.3: Summary of water quality for Manawatū River at Upper Gorge (Ferry Reserve) and Pohangina River at Mais Reach for the period 2003 to 2013. Where available water quality targets from Schedule E of the One Plan are indicated. Values that do not meet these targets are shown in red.

Parameter	One Plan Target	Manawatu River at Upper Gorge				Pohangina River at Mais Reach			
		N	Median	Mean	Range	N	Median	Mean	Range
Water clarity (m)	2.5 *	99	0.8	1.31	0.04–8	94	1.26	1.87	0.01–8
DRP (g/m^3)	0.01	105	0.013	0.014	0.003–0.045	102	0.013	0.022	0.005–0.87
E. coli (MPN/100 ml)	260 /550 **	107	200	989	7–13,000	102	82.5	388	6–6,131
Ammoniacal-N (g/m^3)	0.4	100	0.011	0.019	0.005–0.094	101	0.01	0.011	0.005–0.090
Nitrate-N (g/m^3)	0.444 (for SIN)	105	0.61	0.608	0.022–1.44	100	0.062	0.111	0.0001–0.81
Suspended solids (g/m^3)		58	13	68	0.8–745	77	5	84	1–2,100
Total N (g/m^3)		89	0.88	0.874	0.204–1.69	90	0.18	0.245	0.03–1.84
Total P (g/m^3)		89	0.032	0.064	0.011–0.65	90	0.026	0.057	0.011–0.399

* for flows < median flow

** summer max of 260 cfu/100mL for flows < median, annual max of 550 cfu/100mL when < 20th percentile flow exceedance.

The two sites have the same One Plan Target values despite being in differing water management sub-zones.

Table C.4: Dissolved metal data from Manawatū River upstream of PNCC Sewage Treatment Plant (Waitoetoe Park) from period November 2011 to May 2012. Measurements below laboratory detection rates were given a value of half that rate for inclusion in statistical calculations.

Parameter	ANZG DGV*	N	Median	Mean	Range
Aluminium (g/m^3)	0.055**	30	0.021	0.036	0.0015–0.19
Boron (g/m^3)	0.37	30	0.022	0.021	0.012–0.029
Copper (g/m^3)	0.0014	30	0.00043	0.0005	0.00001–0.0013
Iron (g/m^3)	N.A.	30	0.062	0.08	0.0073–0.29
Nickel (g/m^3)	0.011	30	0.0003	0.0003	0.0001–0.00066
Zinc (g/m^3)	0.008	30	0.00015	0.0005	0.00015–0.0028

* 95% level protection. No hardness correction has been applied.

** Applies for water with pH <6

Table C.5: Baseline water quality for each catchment (December 2018 to September 2019) during dry weather (n=8) and wet weather (n=3 to 4) (in blue). Multiple sites in each catchment have been aggregated with medians and ranges shown (EOS 2019).

Catchment	No. of sites	Event	Visual clarity (cm)	Turbidity (NTU)	TSS (g/m^3)	Deposited fine sediment (%)
2	3	Dry	76 (36–100)	2.4 (0.4–6.7)	2 (1–10)	86.6 (33.1–94.5)
	3	Wet	9 (4–30)	80.2 (7.3–185)	58 (13–300)	
3	1	Dry	59 (44–73)	3.2 (2.3–7)	2.5 (1–6)	61.7 (48.8–77.8)
4	5	Dry	53 (18–78)	5.3 (3.2–32.2)	4 (1–40)	87.8 (39.5–98.5)
	5	Wet	22 (12–31)	22.6 (16.4–65.6)	19 (13–57)	
5	5	Dry	49 (25–74)	8.9 (2.7–19.3)	6 (1–19)	56.8 (13.8–82)
6	2	Dry	65 (40–100)	4.2 (0.7–9)	4.5 (1–18)	19.9 (12.1–72.5)
7	3	Dry	65 (45–100)	2.4 (0.5–10.4)	3.5 (1–49)	9.8 (1.8–52.5)
	3	Wet	32 (11–67)	12.5 (1.5–75.6)	25 (3–73)	

Table C.6: Baseline water quality for each catchment (Oct. – Nov. 2019). Values in red exceed the One Plan target and in red bold exceed the One Plan target after adjusting for hardness. Site locations described in EOS (2019).

Site	**Date**	**SIN (mg/L)**	**DRP (mg/L)**	**NH4-N (mg/L)**	**TSS (mg/L)**	**Turbidity (FNU)**	***E. coli* (cfu/100ml)**	**pH**
One Plan targets		<0.444	<0.01	<0.4			<260	7-8.5
C2A-SW-A	31/10/2019	0.59	0.007	0.018	4.8	6.8	880	7.8
	7/11/2019	1.48	0.005	0.015	1	1.4	1112	7.6
	14/11/2019	0.74	0.014	0.010	1.6	2.6	1145	7.7
C2A-SW-B	31/10/2019	0.41	0.009	0.016	5	7.3	20	7.9
	7/11/2019	0.99	0.005	0.052	2.2	2.2	1467	7.5
	14/11/2019	0.63	0.015	0.021	3.5	3.7	1076	7.7
C4A-SW	31/10/2019	0.08	0.007	0.026	3.4	5.2	72	7.3
	7/11/2019	0.27	0.009	0.034	2.8	4.0	988	7.4
	14/11/2019	0.09	0.015	0.020	2.6	3.7	521	7.4
C4H-SW	31/10/2019	0.04	0.014	0.018	2.4	3.7	990	7.4
	7/11/2019	0.08	0.003	0.023	1.2	2.4	428	7.3
	14/11/2019	0.06	0.013	0.021	2.9	3.8	1153	7.5
C5A-SW-A	31/10/2019	0.09	0.007	0.020	5.8	11.0	455	7.3
	7/11/2019	0.04	0.009	0.022	5	11.4	31	7.4
	14/11/2019	0.04	0.015	0.017	7.1	12.4	1012	7.5
C5A-SW-B	31/10/2019	0.11	0.012	0.022	12.8	15.1	350	7.6
	7/11/2019	0.13	0.015	0.028	10	12.9	63	7.6
	14/11/2019	0.08	0.020	0.014	9.4	12.3	1296	7.7
C5B-SW	31/10/2019	0.09	0.011	0.020	13.6	15.5	404	7.5
	7/11/2019	0.07	0.013	0.028	10.4	11.4	529	7.6
	14/11/2019	0.26	0.021	0.047	8.1	17.9	3873	7.8
C6A-SW	31/10/2019	0.08	0.021	0.013	1.6	1.8	52	7.7
	7/11/2019	0.11	0.020	0.016	2	1.2	97	7.7
	14/11/2019	0.18	0.030	0.007	2.6	2.0	262	7.8
C7A-SW-A	31/10/2019	0.98	0.020	0.011	3.4	1.7	20	8.1
	7/11/2019	1.10	0.022	0.017	3.4	1.8	10	8.1
	14/11/2019	1.03	0.034	0.015	5.3	3.1	203	8.1
C7A-SW-B	31/10/2019	0.44	0.021	0.016	2	1.5	487	8.1
	7/11/2019	0.62	0.023	0.021	1.2	0.9	1401	8.1
	14/11/2019	0.56	0.034	0.020	2	1.8	410	8.1

Site	**Date**	**Chromium - Diss. (mg/L)**	**Copper - Diss. (mg/L)**	**Copper - Tot. (mg/L)**	**Lead - Diss. (mg/L)**	**Zinc - Diss. (mg/L)**	**Zinc - Tot. (mg/L)**	**Hardness Tot. (mg/L)**
One Plan targets *		<0.001 (Cr-VI)	<0.0014	<0.0014	<0.0034	<0.008	<0.008	
C2A-SW-A	31/10/2019	<0.00015	<0.001	0.0011	All below lab detection (<0.001)	<0.002	0.002	61
	7/11/2019	<0.00015	0.0014	0.0013		<0.002	0.002	82
	14/11/2019	<0.00015	<0.001	0.0012		<0.002	0.002	75
C2A-SW-B	31/10/2019	<0.00015	<0.001	0.0011		<0.002	0.002	65
	7/11/2019	<0.00015	<0.001	0.0024		<0.002	0.002	80
	14/11/2019	<0.00015	<0.001	0.0021		<0.002	0.002	77
C4A-SW	31/10/2019	<0.00015	<0.001	0.0015		<0.002	0.002	46
	7/11/2019	<0.00015	<0.001	0.0010		<0.002	0.002	56
	14/11/2019	<0.00015	<0.001	0.0014		<0.002	0.002	50
C4H-SW	31/10/2019	<0.00015	**0.0024**	0.0010		<0.002	0.002	49
	7/11/2019	<0.00015	**0.0030**	0.0018		<0.002	0.002	55
	14/11/2019	<0.00015	0.0012	**0.0042**		<0.002	0.002	51
C5A-SW-A	31/10/2019	0.00020	0.0015	0.0010		<0.002	0.002	30
	7/11/2019	0.00021	**0.0037**	0.0018		0.00257	0.0020	36
	14/11/2019	0.00020	<0.001	**0.0037**		0.00295	0.0023	28
C5A-SW-B	31/10/2019	0.00018	0.0033	0.0010		<0.002	0.002	51
	7/11/2019	0.00021	<0.001	0.0010		<0.002	0.002	59
	14/11/2019	0.00052	<0.001	0.0010		<0.002	0.002	56
C5B-SW	31/10/2019	0.00024	0.0014	0.0010		<0.002	0.002	29
	7/11/2019	0.00026	<0.001	**0.0034**		<0.002	0.002	28
	14/11/2019	0.00019	<0.001	0.0012		<0.002	0.002	32
C6A-SW	31/10/2019	<0.00015	<0.001	0.0010		<0.002	0.002	37
	7/11/2019	<0.00015	0.0010	0.0010		<0.002	0.002	55
	14/11/2019	<0.00015	<0.001	0.1769		<0.002	**0.0325**	40
C7A-SW-A	31/10/2019	0.000164	<0.001	0.0026		<0.002	0.002	125
	7/11/2019	<0.00015	<0.001	0.0014		<0.002	0.002	138
	14/11/2019	<0.00015	<0.001	0.0010		<0.002	0.002	125
C7A-SW-B	31/10/2019	<0.00015	<0.001	0.0010		<0.002	0.002	138
	7/11/2019	<0.00015	<0.001	0.0025		<0.002	0.002	145
	14/11/2019	<0.00015	<0.001	**0.0099**		<0.002	0.0053	140

OP target values for metals based on ANZECC (2000) 95% protection level. Quoted values assume a hardness of 30 mg/L

32. For most sites, there is insufficient information available to compare water quality with a strict assessment of One Plan targets. Nevertheless, a judgement can be made on the likelihood of streams meeting the One Plan targets based on the available information. This assessment is summarised in **Table C.7**. Based on available information, the existing water quality in the catchments is likely to meet One Plan targets for temperature, dissolved oxygen ("**DO**"), Particulate Organic Matter ("**POM**"), and total ammoniacal nitrogen ("**NH_4-N**"). However, the catchments are unlikely to meet the following One Plan targets:

(a) water clarity does not meet the One Plan target of 2.5m in any catchment;

(b) deposited sediment only meets One Plan targets in sections of C7;

(c) *E.coli* bacteria is unlikely to meet One Plan targets except in C6 and C7;

(d) SIN is unlikely to meet One Plan targets except in C3, C4, C5 and C6; and

(e) DRP is unlikely to meet One Plan targets except in C2, C3 and possibly C4.

Table C.7: Likelihood of streams meeting One Plan targets. Y = likely, N = unlikely, * = very high uncertainty on the assessment due to limited data.

Variable	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
pH range	Y*	Y	Y	Y	Y	Y	Y	Y*
Temp. <	Y*	Y	Y	Y	Y	Y	Y	Y*
DO	Y*	Y	Y	Y	Y	Y	Y	Y*
POM	Y	Y	Y	Y	Y	Y	Y	Y
DRP	N	Y	Y	Y*	N	N	N	N
SIN	N	N	Y	Y	Y	Y	N	N
NH4	Y	Y	Y	Y	Y	Y	Y	Y
Clarity >	N	N	N	N	N	N	N	N
E. coli	N	N	Y*	N	N	Y*	Y*	N
Deposited sediment	N	N	N*	N	N	N	Y	N

33. Detailed catchment descriptions are provided below:

Catchment 1 (C1)

34. C1 is a small (1.17 km^2), unnamed catchment at the eastern end of the Alignment on the plains near Woodville. It is a tributary of the Mangapapa Stream which itself merges with the Mangamanaia Stream (C2) approximately 900m upstream from the Manawatū River. The Landcover Database (“**LCDB**”) v4 describes the land use as 100% “high producing exotic grassland”. The

catchment currently receives untreated stormwater runoff from Napier Road (former SH3) and Woodlands Road (which leads to Saddle Road).

35. The Project will directly affect the upper part of the catchment where the channel has already been severely impacted by agricultural land use through channel straightening and stock access.

Mangamanaia Stream, Catchment 2 (C2)

36. C2, the Mangamanaia Stream, is the largest of the catchments directly affected by the Alignment (20.55 km^2) after the bridge crossing on the Manawatū River. It merges with the Mangapapa Stream some 900m from that stream's confluence with the Manawatū River. Its upper catchment drains an area of predominantly steep pastureland to the south of Wharite Peak. Based on the LCDB v4 the land use is 84% “high producing exotic grassland”, 6% “manuka and/or kanuka”, 5% “broadleaved indigenous hardwoods”, 4% “exotic forest”, and 1% “low producing grassland”.

37. The main direct effects of the Project include a crossing of the main stem (C2A), the loss of the headwaters for some tributaries, and the ongoing input of treated stormwater from the new highway.

38. Baseline monitoring in the main stem (C2A) upstream and downstream of the Alignment between December 2018 and September 2019 at three sites indicates very high deposited fine sediment cover of the stream bed with good to fair visual clarity during dry weather, and very poor visual clarity during wet weather. During dry weather turbidity and TSS were the lowest of six monitored catchments, however, were the highest during wet weather of the three catchments where wet weather sampling was undertaken. Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) values were generally indicative of “fair” conditions. During the baseline monitoring period riffles dried up at the most downstream monitoring site indicating that at times this stream loses surface water connectivity.

39. Additional water quality sampling between 31 October and 14 November 2019 at two sites indicate SIN and *E. coli* concentrations above One Plan targets and dissolved metals generally below laboratory detection limits. DRP was above the One Plan target on one of three sampling dates at each site, while NH_4-N was well below the target on all sampling dates.

Catchment 3 (C3)

40. C3 is a small (1.23 km^2), unnamed catchment draining a very steep catchment directly to the Manawatū River, with a mix of pasture and native vegetation. Based on the LCDB v4 the land use is 52% “high producing exotic grassland”, 27% “indigenous forest”, 10% “broadleaved indigenous hardwoods”, 9% “manuka and/or kanuka”, and 3% “exotic forest”.

41. Baseline monitoring from a single site downstream of the Alignment indicated moderate to high fine deposited sediment cover and fair visual water clarity during dry weather. Dry weather turbidity and TSS were slightly above values in ANZG (2018). MCI and QMCI values were among the highest of baseline monitoring sites and indicative of “good” to “excellent” conditions.

Catchment 4 (C4)

42. C4 is the second largest catchment directly affected by the Project (4.12 km^2). It is degraded by agriculture with much of the stream being unfenced from stock and actively eroding/slumping banks being commonplace. Based on the LCDB v4 the land use is 79% “high producing exotic grassland”, 12% “broadleaved indigenous hardwoods”, 4% “gorse and/or broom”, 3% “indigenous forest”, and 2% “low producing grassland”. The lower part of the catchment is within the Manawatū Gorge Scenic Reserve.

43. Catchment 4 differs from the other affected catchments in having some substantial artificial ponds/small lakes along its length, including a large one just upstream of the Scenic Reserve. This pond and its dam have had significant impacts on the stream within the Scenic Reserve through creating an armored bed of large substrate size through disrupting the natural downstream movement of cobbles and gravels, and a persistent cover of fine sediment on the bed resulting from the chronic high turbidity of the pond.

44. Baseline monitoring between December 2018 and September 2019 from five sites indicated very high levels of fine deposited sediment on the stream bed, with visual water clarity that is fair during dry weather and very poor during wet weather. Turbidity and TSS were the highest of all monitored sites during dry weather at the most downstream site within the Scenic Reserve. These parameters were also above values in ANZG (2018) at all sites during dry weather. During wet weather, turbidity and TSS were certainly elevated but were well below the levels seen in C2. MCI and QMCI values were among the lowest of baseline monitoring sites and indicative of “poor” and occasionally “fair” conditions. During the baseline monitoring period riffles dried up at the

most downstream monitoring site indicating that at times this stream loses surface water connectivity.

45. Additional water quality sampling between 31 October and 14 November 2019 at two sites indicated *E. coli* concentrations well above and SIN levels below One Plan targets. DRP was occasionally slightly above, while NH_4-N was always well below the target One Plan target. With the exception of dissolved copper at one site which at times was above the 95% level of protection (DGV) in ANZG, dissolved metals were below laboratory detection limits.

Catchment 5 (C5)

46. C5 is a small (1.2 km^2), unnamed catchment that discharges directly to the Manawatū River. The lower section of the catchment is within the Manawatū Gorge Scenic Reserve, and the upper part is adversely impacted by agriculture, being mostly unfenced with bank erosion caused by stock commonplace. Based on the LCDB v4 the land use is 65% “high producing exotic grassland”, 33% “broadleaved indigenous hardwoods”, and 2% “low producing grassland”.

47. Baseline monitoring from five sites between December 2018 and September 2019 indicated moderate fine deposited sediment on the stream bed, however, the most downstream site within the Scenic Reserve had much lower deposited sediment, indicating the thick forest cover has some regenerative effect on habitat quality. Visual water quality was poor and this catchment generally had the highest overall turbidity and TSS of all monitored catchments during dry weather. MCI and QMCI values were among the highest of all baseline monitoring sites and indicative of “good” and “excellent” conditions, with the most downstream site within the Scenic Reserve having the highest values.

48. Additional water quality sampling between 31 October and 14 November 2019 at three sites indicated SIN and NH_4-N consistently below, and DRP generally above, One Plan targets. *E. coli* concentrations were generally well above One Plan targets and cow faeces were regularly observed in the channel. With the exception of dissolved copper, which at times was above the 95% level of protection (DGV) in ANZG, and dissolved zinc at one site, dissolved metals were below laboratory detection limits.

Catchment 6 (C6)

49. C6 is a small (0.95 km^2), unnamed catchment that discharges directly to the Manawatū River. The lower section of the catchment is within the Manawatū Gorge Scenic Reserve, and the upper part is within farmland where a substantial part of the catchment has now been fenced to exclude stock. Based on the LCDB v4 the land use is 53% “high producing exotic grassland” and 47% “broadleaved indigenous hardwoods”, although a portion of that exotic grassland is now reverting to bush.

50. Baseline monitoring from two sites between December 2018 and September 2019 indicated moderate-low fine deposited sediment on the stream bed, however, the most downstream site within the Scenic Reserve had much lower deposited sediment, indicating the thick forest cover has some regenerative effect on habitat quality. Visual water quality was fair during dry weather and turbidity and TSS tended to be slightly above the DGVs in ANZG (2018). MCI and QMCI values were among the highest of all baseline monitoring sites and indicative of “good” and “excellent” conditions, with the most downstream site within the Scenic Reserve having higher values than the upstream site in the former farmland.

51. Additional water quality sampling between 31 October and 14 November 2019 at one site indicated SIN and NH_4-N consistently below, and DRP generally above, One Plan targets. *E. coli* concentrations were only slightly above or below One Plan targets. Dissolved metals were generally below laboratory detection limits.

Catchment 7 (C7)

52. C7 is a small (1.1 km^2), unnamed catchment that discharges directly to the Manawatū River. The upper section of the main stem (C7A) is within a thickly forested, steep gorge which has minimal stock access and is protected by a QEII covenant. Based on the LCDB v4 the land use is 62% “high producing exotic grassland” and 28% “broadleaved indigenous hardwoods”, and 10% “gorse and/or broom”.

53. Baseline monitoring from three sites between December 2018 and September 2019 indicated low fine deposited sediment cover of the stream bed, with visual water clarity that was fair to good during dry weather, and poor to very poor during wet weather. Turbidity and TSS tended to be below ANZG (2018) DGVs during dry weather. During wet weather turbidity and TSS was elevated at the mid and most downstream sites but was barely changed from dry

weather values at the most upstream site within the forested QEII covenanted reach. MCI and QMCI values were among the highest of all baseline monitoring sites and indicative of “good” and “excellent” conditions.

54. Additional water quality sampling between 31 October and 14 November 2019 at two sites indicated SIN and DRP above, and NH_4-N consistently below One Plan targets. *E. coli* concentrations were above One Plan targets at the downstream site but below at the upstream site which was located at the downstream end of a forested section from which stock were excluded. Stock (either sheep, cattle or both) were always present during visits to the area. Dissolved metals were generally below laboratory detection limits.

55. Water hardness was particularly high in Catchment 7 and pH was also relatively high, which suggests a distinct geology compared to other catchments. The high SIN (primarily nitrate-N) observed in the upper catchment, despite being forested and fenced, may be related to this geology.

Catchment 8 (C8)

56. C8 is a small (1.01 km^2), unnamed catchment at the western end of the Alignment, which discharges directly to the Manawatū River. Parts of the upper catchment appear to have been diverted and straightened where they flow alongside the former SH3. Based on the LCDB v4 the land use is 78% “high producing exotic grassland”, 11% “exotic forest”, 7% “indigenous forest”, 3% “exotic forest – harvested”, and 1% “deciduous hardwoods”. The catchment also receives untreated runoff from Napier Road (former SH3) and Fitzherbert East Road (SH57).

Catchment 9 (C9)

57. C9 is a small (2.2 km^2) tributary of the Pohangina River that is only affected by the Project by an encroachment into a relatively small area of ridgeline. There is no direct effect on the main stem (C9A), apart from a new culvert at the downstream end of the catchment associated with site access, which has been consented as an Enabling Work). Based on the LCDB v4 the land use is 57% “high producing exotic grassland”, 38% “indigenous forest”, 3% “low producing grassland”, and 1% “exotic forest”. One-off sampling at the downstream end of the catchment indicated high fine deposited sediment cover of the stream bed and good water clarity during dry weather conditions.

Manawatū River at Upper Gorge

58. The nearest Manawatū River Horizons water quality monitoring site to the Project is located at the upstream (eastern) end of the Gorge at Ferry Reserve. This is approximately 750 m downstream of the confluence with Mangapapa Stream (into which C1 and C2 flow into) and some 6,500 m upstream of the proposed Manawatū River Bridge (BR02) at the downstream (western) end of the Gorge.

59. Water quality of this site is representative of the Gorge section of the River. Mean, median, and MALF flow statistics are 83.8 m^3/s, 50.4 m^3/s, and 11.7 m^3/s, respectively (Henderson and Diettrich 2007). Based on data for the period 2003 to 2013 (mostly monthly sampling) median water clarity (0.8m) was below the One Plan target of 2.5 m and likely strongly related to the 13 g/m^3 median for TSS. Median DRP (0.013 g/m3) was slight above the target of 0.010 g/m^3. Median *E. coli* concentration (200 MPN/100 ml) was below the target of 260 MPN/100 ml, although there were occasions when levels could be very high (i.e., up to 13,000). Median NH_4-N (0.011 g/m^3) as well as the highest concentration recorded (0.094 g/m^3) were well below the One Plan target of 0.4 g/m^3. Nitrate-N was relatively high with a median of 0.61 g/m^3. Even though nitrite-N was not measured, this high nitrate-N concentration means the One Plan target for SIN (0.444 g/m^3) would not be met.

60. Metals were measured regularly for a short period (November 2011 to May 2012) in the Manawatū River in Palmerston North just upstream of the PNCC sewage treatment plant and provide some idea of existing background concentrations. Dissolved concentrations (median and maximum) for boron, copper, nickel, and zinc were well below the ANZG (2018) DGVs. Median dissolved aluminum was below the 95% level ANZG DGV, but did exceed it for six out of 30 measurements. However, note the ANZG DGVs for aluminum are considered to be of low reliability. Overall, the measured metals are not particularly elevated in the Manawatū River.

Pohangina River at Mais Reach

61. The Pohangina River at Mais Reach is some 7.5 km upstream of the Saddle Road bridge, 10 km upstream of the confluence with the Manawatū River, and representative of water quality in the lower Pohangina catchment. Mean, median, and MALF flow statistics are 17.21 m^3/s, 10.01 m^3/s, and 2.315 m^3/s, respectively. Water clarity with a median of 1.26 m is substantially greater than that observed at the Manawatū River at Upper Gorge site but still below the

One Plan target of 2.5 m. Median TSS was also relatively low at 5 g/m^3. Median DRP (0.013 g/m^3) was slightly above the target of 0.010 g/m^3. Median *E. coli* concentration (82.5 MPN/100 ml) was below the target 260 MPN/100 ml, although there were occasions when levels could be high (i.e., up to 6,131). Median NH_4-N (0.01 g/m^3) as well as the highest concentration recorded (0.09 g/m3) were well below the One Plan target of 0.4 g/m^3. Nitrate-N was low with a median of 0.062 g/m^3 and even though nitrite-N was not measured, it is highly likely One Plan target for SIN (0.110 g/m^3) would be met.

62. Overall, the Pohangina River is of higher water quality than the section of the Manawatū River into which it flows.

6 METHODOLOGY

Introduction

63. My assessment focuses on the potential water quality effects of the Project and makes comparisons with guideline values and targets in the One Plan. I have assessed the magnitude of potential water quality effects using the approach described in the Ecological Impact Assessment guidelines (EIANZ 2018) (**EcIA**). However, I have limited my assessment to describing the <u>magnitude</u> of effect only. I have not made an assessment of ecological values or of the overall level of effect, instead this is done in the Freshwater Ecological Assessment so as to ensure that the assessment is holistic.

64. The EcIA approach provides a structured, consistent and transparent method of assessing effects. However, it does not replace the need for sound ecological judgement. In simple terms, the EcIA uses a matrix to assess the overall level of effects of an activity based on the ecological values of the site affected and the magnitude of effect. Key components of the EcIA guidelines are:

    (a) Assess the ecological values of the environment;

    (b) Assess the magnitude of effects of the activities on the environment. This considers the intensity, spatial scale, duration, reversibility, and timing of the effects. Risk/uncertainty and confidence in predictions is also considered.

    (c) Assess the overall level of effect. This uses a matrix to combine the ‘ecological values’ and the ‘magnitude’ of effect in order to describe the ecological effect on a scale of ‘positive’ to ‘very high adverse’.

65. The assessment was applied to Project activities assuming standard mitigation proposed as part of the Project (e.g. the proposed stormwater treatment) but excluding any biodiversity offsets. A detailed description of how this approach is applied is provided in **Appendix C.A**.

Assessing the magnitude of water quality effects

66. The potential effects of the Project are assessed for construction activities and for the road stormwater during the long-term operation of the Project. The main risk to water quality during construction is the release of sediment during bulk earthworks. In addition, other water quality effects may result from vegetation clearance and concreting.

67. In assessing the magnitude of effects, I first describe the potential effects of the activity based on scientific literature, and then make a more detailed assessment of the potential effects of different Project activities on water quality and the likely changes relative to One Plan targets or the attribute criteria in the National Policy Statement for Freshwater Management ("**NPS-FM**").

68. The potential effects of erosion and sedimentation from the Project during construction was assessed for each waterway by:

    (a) Calculating the sediment yield likely to be discharged to each catchment from ESC devices described in the ESC Assessment (Technical Assessment A).

    (b) Comparing the predicted water quality of the stormwater after treatment with the appropriate guidelines and current water quality measured or estimated for each stream.

    (c) Comparing the relative increase in predicted sediment yield before and during construction.

    (d) Interpreting these results in the context of timing of flow events.

69. Sediment yields for catchments before earthworks were estimated using the Universal Soil Loss Equation (“**USLE**”) calculations applied to earthwork sites and scaled by catchment area (Erosion and Sediment Control Assessment). USLE calculations for ‘steep’ or ‘low’ gradient sites were weighted in accordance with the proportion of area as steep or low gradient in the relevant catchment. Sediment yields for catchments after earthworks were estimated by adding the additional sediment load from the earthworks to the estimated catchment load.

70. The potential effects of stormwater from the Project during long term operation were assessed for each stream by first comparing the relative change in stormwater contribution to each stream before and after the Project. For streams where the Project will result in a reduction or no increase in road stormwater, these were considered to have either no stormwater effect or a net benefit on the basis that all stormwater from the Project will be treated as compared to stormwater from the closed SH3 Manawatū Gorge section and Saddle Road, which is not treated.

71. For streams where the Project will result in additional road stormwater, we assessed the magnitude of effect by:

    (a) modelling the load of key road stormwater contaminants discharged to each sub-catchment from the Project. This was done using the Contaminant Load Model ("**CLM**") version 2 and assuming a traffic volume in 2041 of 13,335 vehicles per day (11,724 cars and 1611 heavy commercial vehicles) (as estimated in NoR Technical Report 1 - Transport);

    (b) modelling the load of road stormwater contaminants discharged to each sub-catchment from the existing roads (primarily Saddle Road) which will have reduced traffic after the Project;

    (c) estimating the net increase or decrease in road stormwater derived contaminant load after the Project (i.e. the load to each sub-catchment with the Project in place, after accounting for less traffic volume on Saddle Road as a result of the Project);

    (d) calculating the average concentration of contaminants discharged from stormwater devices during rain events for each sub-catchment. This assumed a net rainfall of 660mm per year falling within the catchment of each stormwater device[5]. This is the concentration in the discharge, during rain events, before any dilution with the receiving water. It was conservatively compared to acute toxicity guidelines (which are discussed further below);

    (e) estimating the water quality in the stream after dilution in comparison to One Plan targets and ANZG Default Guideline Values ("**DGVs**"). This was informed by a very conservative estimate of annual average water quality after full mixing with the stream, undertaken using a dilution

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[5] Based on NIWA rainfall data of 1160mm/year and evapotranspiration of 500mm/yr.

equation to add the modelled load upstream with the modelled load from the Project and dividing this amount by the annual flow in the stream near the point of discharge. This is a very conservative prediction and will over-estimate actual annual average concentrations because it does not account for stormwater discharges predominantly occurring for short periods of time during periods of high flow.

Contaminant Load Model

72. The CLM is a simple mathematical model to estimate the annual loads of TSS, total zinc ("**TZn**"), total copper ("**TCu**") and total petroleum hydrocarbons ("**TPH**") from stormwater networks. It was developed by Auckland Council but is widely used around New Zealand. The contaminant load of a particular source (e.g. roading) is calculated by multiplying the yield (kg/ha/yr) by the area (ha). Where the stormwater is treated, the source load is reduced by a load reduction factor (AC 2010). This load reduction factor is applied to the fraction of the area where the stormwater is being treated or managed. The results provide high level estimates and because of the model's simplicity, are not reliably predictive, instead the CLM should be viewed as a tool for understanding relative effects.

73. The CLM recognises that there will be a higher specific yield of contaminants in stormwater from roads with more traffic. Traffic volume is grouped into broad categories as shown in **Table C.7**. The Project is estimated to have traffic volume of 13,335 by 2041 (i.e. is in the 'vehicle per day' category of 5000 to 20,000). For the purpose of making a comparative assessment of contaminant load with and without the Project, we assumed that if the Project does not go ahead Saddle Road would have the same estimated traffic volume as the Project, and if the Project does go ahead the Saddle Road would have negligible traffic (as it did prior to the closure of SH3 through the Manawatū Gorge).

74. The load reduction factors ("**LRFs**") used in the CLM are based on Auckland Regional Council (2010a) and are set out in **Table C.8**. Vegetated conveyance channels were applied a LRF equivalent to vegetated filter strips[6]. Wetland swales were assigned a LRF midway between a constructed wetland and a swale, although they will likely perform more like a wetland than a

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[6] Vegetated filter strips have a wide range of treatment performance, often depending on design. The LRFs applied to vegetated filter strips in the CLM are low compared to estimates in NZTA (2010) Table 8.1 (i.e. 80%, 75%, 60% for TSS, Zn and Cu respectively) and considered appropriate to apply to vegetated conveyance channels.

swale. All LRFs assume correctly designed, implemented and maintained management options.

75. Most stormwater from the Project will be treated by multiple treatment devices in series, providing greater benefit than individual devices (NZTA 2010). The CLM applies a simplified equation for total removal of a contaminant for two or more stormwater management practices as follows:

Total removal = A + B – [(A x B)/100]

Where: A and B are the removal rate of the first and second practice respectively.

76. All stormwater discharges from the Project will be treated with a treatment device. The road length and treatment train applying to each device is described in **Table C.9** (which comes from the Stormwater Management Design Report, Appendix B to the DCR). Saddle Road and other roads in the area have no stormwater treatment but we conservatively assumed a proportion of the current roads (20% to 50%) had stormwater treatment equivalent to a vegetative filter strip.

77. For the purpose of the CLM, the catchment area contributing to treatment devices was assumed to be the contributing road length multiplied by a 17m road width (which is consistent with the CLM approach). The actual catchment to wetland devices will be larger and includes batter slopes and the treatment devices. The contaminant load to treatment devices from non-road catchment area was assumed to be the same as prior to the Project. This is a conservative assumption as these areas will have stock excluded and batter slopes will be vegetated and have their own separate sediment treatment devices prior to the road stormwater treatment train.

78. Annual contaminant loads were estimated at the catchment and sub-catchment level. For calculating total catchment loads, I applied the slope classes and landuse categories in **Appendix C.B** and estimated the length of local roads in each catchment. The catchment sediment loads calculated using the CLM is higher than the catchment sediment load calculated using the USLE method before works, however the relative change in sediment load from changing landuse (e.g. farmed pasture to open construction site) and sediment management options (e.g. wet ponds with flocculation) are similar.

79. The CLM only covers a selection of the more relevant contaminants from road runoff, being sediment, copper, zinc and TPH. These are the most relevant

contaminants and it is reasonable to assume that if stormwater treatment adequately manages these contaminants then other contaminants will also be appropriately managed.

Table C.7: Contaminant load yields for selected land uses including roads at various traffic counts as applied in the CLM v2 (ARC 2010).

Landuse	**Sediment**	**Zinc**	**Copper**	**TPH**
	($g/m^2/yr$)	($g/m^2/yr$)	($g/m^2/yr$)	($g/m^2/yr$)
Roads (vehicles/day)				
<1,000	21.30	0.0044	0.0015	0.0335
1,000-5,000	27.81	0.0266	0.0089	0.201
5,000-20,000	52.56	0.1108	0.0369	0.839
20,000-50,000	95.60	0.2574	0.0858	1.947
50,000-100,000	158.4	0.471	0.157	3.56
>100,000	234.3	0.729	0.243	5.58
Farmed pasture <10^o	152	0.0053	0.0011	0
Farmed pasture 10-20^o	456	0.016	0.0032	0
Farmed pasture >20^o	923	0.032	0.0065	0
Retired pasture <10^o	21	0.0007	0.0001	0
Retired pasture 10-20^o	63	0.0022	0.0004	0
Retired pasture >20^o	125	0.0044	0.0009	0

Table C.8: Load reduction factor for road runoff for various treatment options (ARC 2010a). Highlighted cells show treatment options applied.

Treatment Option	**TSS**	**Zn**	**Cu**	**TPH**
Biomediafiltration	0.75	0.6	0.7	0.7
Catchpit filter	0.4	0.2	0.25	0.3
Catchpits	0.2	0.11	0.15	0.15
Constructed wetland	0.8	0.6	0.7	0.6
Dry pond	0.6	0.2	0.3	0.1
Sand-filter	0.75	0.3	0.4	0.7
Storm-filter	0.75	0.4	0.65	0.75
Swale	0.75	0.4	0.5	0.4
Vegetative filter strips*	0.3	0.1	0.2	0.3
Wet extended pond	0.8	0.4	0.5	0.2
Wet pond	0.75	0.3	0.4	0.15
Wet pond with flocculation	0.8	0.5	0.6	0.5

* Applied to planted conveyance channels.

Table C.9: Treatment devices' contributing catchment, road length, treatment train and catchment into which they discharge. TS = treatment swale, WS = wetland swale, W = wetland.

Device ID	Device Catchment Area (ha)	Contributing Road length (m)	Treatment Train Description	Receiving Stream ID
WS06	0.33	58	Road > catchpits > SW pipe > wetland swale	1A
WS07	0.93	275	Road > catchpits > SW pipe > wetland swale	1A
WS08	0.76	220.3	Road > catchpits > SW pipe > wetland swale	1A
WS09	0.57	156.7	Road > catchpits > SW pipe > wetland swale	1A
WS10	0.83	246	Road > catchpits > SW pipe > wetland swale	1A
TS06	0.25	72	Road > swale	1B
TS07	0.20	55	Road > swale	1B
WS04	0.60	167	Road > catchpits > SW pipe > wetland swale	1B
WS05	1.44	449	Road > planted conveyance channel > wetland swale	1B
W09 (Mangamanaia)	1.9	531	mixture of the following 1. road > planted conveyance channel > wetland (90%) 2. road > catchpit > SW pipes > wetland (10%)	2A
W08 (Bolton E)	5.3	1455	1. CP > SW pipes > sealed cut slope debris channel > wetland (75%) 2. sealed conveyance channel > wetland (25%)	2E
W07 (Pringle)	7.2	1214	1. CP > SW pipes > sealed cut slope debris channel > wetland (30%) 2. sealed conveyance channel > wetland (70%)	3B
W06 (Cook Rd)	2.69	455.7	planted conveyance channel > wetland	4A
WS01	2.97	954.1	planted conveyance channel > wetland swale	4A
WS02	4.61	429.3	CP > SW pipes > wetland swale 2	4A
WS03	3.33	943.2	planted conveyance channel > wetland swale	4A
TS05	1.40	324.8	Road > swale	7A
W05 (Bolton W)	3.4	1162.9	1. sealed cut slope debris channel > sediment basin > wetland 2. planted conveyance channel > wetland	7A
W04 (Hindmarsh)	1.6	1132.6	1. road > rocklined conveyance channel > wetland 2. road & embankment > sealed conveyance channel > rocklined conveyance channel > wetland	7B
W03 (Manawatū E)	3.7	414.4	Road > catchpits > SW pipe > wetland (with flow splitter)	7
TS01	0.22	101	Road > catchpits > SW pipe > swale	8A
TS02	0.35	184	Road > planted conveyance channel > swale	8A
TS03	0.35	98	Road > catchpits > SW pipe > swale	8A
TS04	0.67	280	Road > swale	8A
W01 (Napier Rd W)	2.2	589	mixture of the following 1. road > planted conveyance channel > wetland (50%) 2. road > catchpit > SW pipes > wetland (50%)	8A
W02 (Napier Rd E)	2.2	796.4	Road > catchpits > SW pipe > planted conveyance channel> wetland	Manawatu River

National standards, guidelines and One Plan targets

One Plan water quality targets

80. Schedule A of the One Plan identifies the Project as being located within the Middle Manawatū (Mana_10) and Upper Gorge Catchments (Mana_9) Water

Management Zone within the Parent Catchment: Manawatū. The streams affected by the Project fall within the following water management sub-zones:

(a) Middle Manawatū Mana_10a (Manawatū River in Gorge and catchments 3, 4, 5, 6, 7, 8, 9); and

(b) Upper Gorge Mana_9c (Mangaatua River and catchments 1, 2).

81. Some Enabling Works also fall within the sub-zone: Lower Pohangina Mana_10d (Pohangina River).

82. The targets for sub-zone Mana_10a and Mana_9c are the same (see **Table C.10**).

Table C.10: One Plan Schedule E surface water quality targets (excluding macroinvertebrate and periphyton targets).

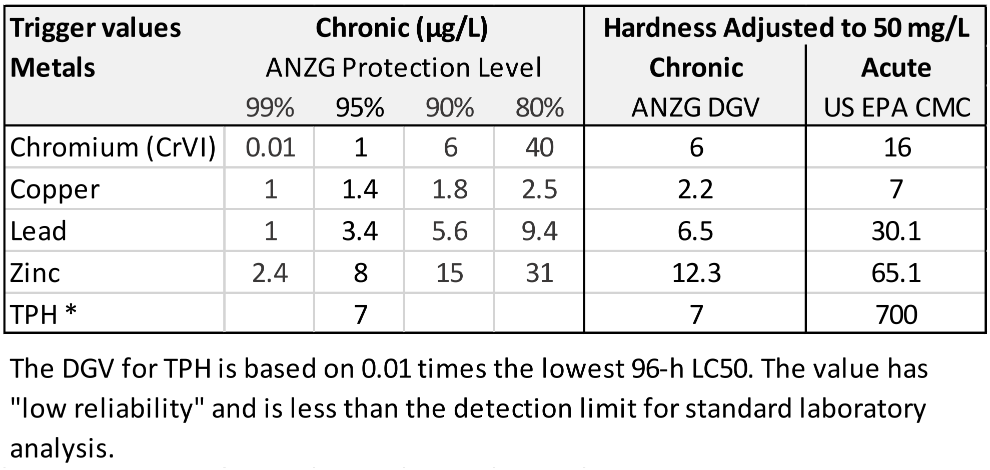
Variable	Units	Mana_10a, Mana_9c	Lower Pohangina Mana_10d	Condition criteria
pH range		7 to 8.5	7 to 8.5	within range
pH Δ		0.5	0.5	must not change by more than
Temp. <	^{o}C	22	22	must not exceed
Temp. Δ	^{o}C	3	3	must not change by more than
DO	% sat.	70	70	must exceed
POM	mg/L	5	5	average when flow < median
DRP	mg/L	0.01	0.01	annual average when <20th flow exceedance
SIN	mg/L	0.444	0.11	annual average when <20th flow exceedance
NH4	mg/L	0.4	0.4	average
NH4.Max	mg/L	2.1	2.1	Maximum
Clarity %Δ	%	30	30	must not be reduced by more than
Clarity >	mg/L	2.5	2.5	must exceed when river < median flow
Ecoli.Bathing	cfu/100mL	260	260	summer max. when flow < median flow
Ecoli.Year	cfu/100mL	550	550	annual max. when <20th flow exceedance
Tox. or Toxicants	%	95	95	Relevant protection level in ANZECC (2000) Table 3.4.1. For metals applies to dissolved fraction after hardness adjustment.
Deposited sediment	% cover	20	20	Maxium cover of fines on stream bed
MCI		100	100	

ANZECC guidelines for metals

83. The ANZECC (2000) and the updated ANZG (2018) guidelines set DGVs to protect freshwater systems. Stricter values are applied to waterways with higher ecological values; for ‘moderately disturbed ecosystems’ the 95 percent protection level is generally applied. For metals the ANZECC (2000) 95% protection level equates to the ANZG (2018) DGVs. These DGVs relate to chronic toxicity and for most variables are more suited to apply to baseflow monitoring or long-term averages rather than short-term intermittent discharges.

84. Stormwater discharges occur during rain events and are intermittent by nature. For sampling focused on short-term intermittent discharges it is more ecologically relevant to apply the USEPA (2006) Criteria Maximum Concentration ("**CMC**") which protects against acute effects (**Table C.11**). Chronic and acute guideline values for Copper (Cu), Lead (Pb) and Zinc (Zn) in Table C.11 have been adjusted for a water hardness of 50 mg/L. This equates to water hardness in catchments 4 and 8. Other catchments affected by stormwater from the Project have higher hardness (about 70 to 130 mg/L), which results in less stringent values for these elements. Note that the ANZG (2018) DVG for TPH has 'low reliability' and is less than the standard laboratory detection limit. The acute value is the lowest 96-hour LC50 from which the chronic value was derived.

Table C.11: Water quality trigger values for metals common in rural road stormwater (based on ANZG (2018) and USEPA (2006)). Discharge values based on the US-EPA acute (CMC) assuming a hardness of 50 g/m^3 and apply to dissolved metals.



Trigger values	Chronic (µg/L)				Hardness Adjusted to 50 mg/L	
Metals	ANZG Protection Level				Chronic	Acute
	99%	95%	90%	80%	ANZG DGV	US EPA CMC
Chromium (CrVI)	0.01	1	6	40	6	16
Copper	1	1.4	1.8	2.5	2.2	7
Lead	1	3.4	5.6	9.4	6.5	30.1
Zinc	2.4	8	15	31	12.3	65.1
TPH *		7			7	700

The DGV for TPH is based on 0.01 times the lowest 96-h LC50. The value has "low reliability" and is less than the detection limit for standard laboratory analysis.

National Policy Statement for Freshwater Management water quality attributes

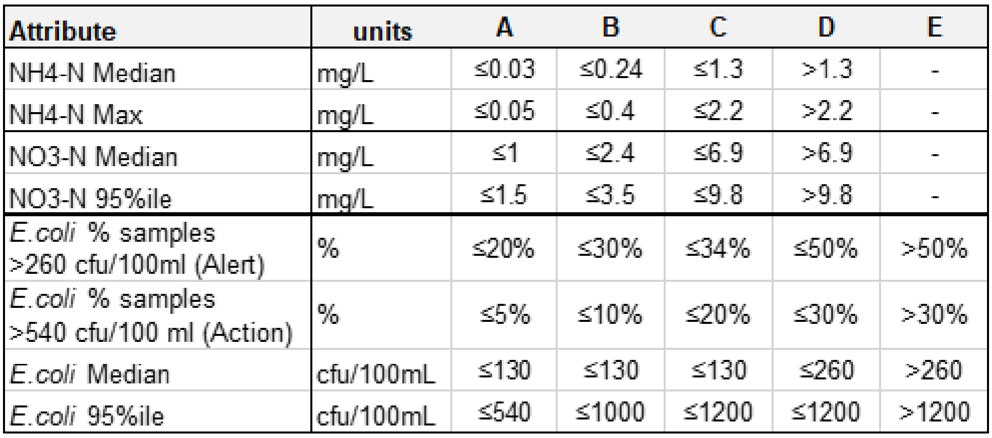
85. The NPS-FM includes a National Objectives Framework ("**NOF**") which sets compulsory national values for freshwater to protect 'human health for recreation' and 'ecosystem health'. The NOF ranks attributes into bands (A-D) to help communities make decisions on water quality. This includes setting minimum acceptable states called 'national bottom-lines'.

86. NPS-FM bottom-lines have been set for nitrate and total ammonia. The NOF bands set for nitrate (NO_3-N) and total ammoniacal nitrogen (NH_4-N) relate to their potential toxicity to aquatic life rather than their role as nutrients which influences algae growth and ecosystem health at much lower concentrations.

87. NOF bands have also been established for *E.coli* bacteria, but national bottom-lines have not been set; instead the Government has set targets of having >90% of freshwater bodies (streams fourth order or greater) suitable for swimming by 2040 and for this purpose defined suitability for swimming as Band C (yellow) or better (Clean Waters 2017).

88. The One Plan targets use different statistics compared to the NOF, but would roughly correspond to NOF bands C, A and A for the attributes of NH$_4$-N, NO$_3$-N and *E.coli* respectively (**Table C.12**). For the purpose of assessing water quality in this assessment I have focused on the One Plan targets.

Table C.12: NOF attribute criteria and state thresholds for NH4-N, NO3-N and *E.coli* bacteria.



Attribute	units	A	B	C	D	E
NH4-N Median	mg/L	≤0.03	≤0.24	≤1.3	>1.3	-
NH4-N Max	mg/L	≤0.05	≤0.4	≤2.2	>2.2	-
NO3-N Median	mg/L	≤1	≤2.4	≤6.9	>6.9	-
NO3-N 95%ile	mg/L	≤1.5	≤3.5	≤9.8	>9.8	-
E.coli % samples >260 cfu/100ml (Alert)	%	≤20%	≤30%	≤34%	≤50%	>50%
E.coli % samples >540 cfu/100 ml (Action)	%	≤5%	≤10%	≤20%	≤30%	>30%
E.coli Median	cfu/100mL	≤130	≤130	≤130	≤260	>260
E.coli 95%ile	cfu/100mL	≤540	≤1000	≤1200	≤1200	>1200

7 ASSESSMENT OF EFFECTS

Sedimentation from earthworks during construction

Potential effects of sediment in streams

89. Bulk earthworks associated with the Project's construction activities present a risk of erosion and sediment release. Sediment has a number of effects on stream water quality and aquatic life, including reducing water clarity, increasing turbidity and potential sediment deposition on the stream bed. Most fish species, with the exception of very sensitive species, such as banded kōkopu, are tolerant of high levels of suspended sediment, but many taxa are affected by a combination of other environmental changes associated with high loadings of suspended solids.

90. Banded kōkopu reduce feeding and show avoidance behaviour when water turbidity is over 25 Nephelometric Turbidity Units ("**NTU**") (Richardson et al. 2001), but numerous studies have shown that sublethal turbidity has little direct effect on most other fish species (Rowe et al.2002). Rowe et al. (2002) found that the supposedly 'sensitive' invertebrate and fish taxa were tolerant

of very high levels of turbidity (over 24 hours), and even repeated exposures to 1000 NTU had no adverse effects on their survival. They concluded that "*their absence from urbanised catchments and their relative scarcity in turbid rivers and streams is not caused by turbidity per se, but most likely reflects a combination of other environmental changes associated with high loadings of suspended solids*."

91. The main ways in which suspended sediment affects aquatic macroinvertebrate abundance and diversity is:

    (a) smothering and abrading;

    (b) deposition reducing their periphyton food supply or quality; and

    (c) deposition reducing available interstitial habitat.

92. Moreover, sediment deposition can alter substrate composition and change substrate suitability for some taxa (Wood and Armitage 1997). These effects persist long after a rain event has stopped.

Mitigation proposed by ESC Assessment

93. The ESC Assessment (Technical Report A) notes that ESC will include a hierarchy of measures including minimising sediment generation, and implementing sediment control for all sediment laden discharges (primarily by using chemically treated sediment retention ponds ("**SRPs**")). Detailed information is provided in the Project's ESC Management Plan and site-specific erosion and sediment control plans ("**SSESCPs**") that will be prepared prior to earthworks commencing. The ESC Monitoring Plan describes the ESC management and monitoring system that will be implemented for the duration of the earthworks period.

Predicted sediment loads and water quality

94. The ESC Assessment (Technical Report A) provides estimates of sediment loads resulting from the Project's earthworks. Load calculations were done using the USLE. The ESC Assessment notes that when compared to monitoring data this modelling approach can significantly over-estimates sediment yields. In part this will be due to a number of conservative assumptions.

Potential effects of sediment from the Project

95. Net sediment yields estimated for the earthworks by the USLE method are about 2 to 3 times higher than sediment yields estimated prior to the Project

from the land occupied by the earthworks (**Table C.13**). Most of this sediment load will be discharged over short durations during wet weather events, consequently, the wet weather suspended sediment concentrations are likely to increase by a similar amount. Median TSS during wet weather events were measured as 58 mg/L in C2, 19 mg/L in C4 and 25 mg/L in C7. Assuming this is representative and given the predicted increase in sediment loads from earthwork sites, the median TSS discharge from sediment treatment devices would be approximately in the range of 50 mg/L to 120 mg/L (C7 and C2 respectively). This range is consistent with the initial results of chemical treatment of soils from the sites using Polyaluminium Chloride ("**PAC"**) as reported in the Chemical Analysis and Reactivity Test ("**CART**") Report. Optimum PAC treatment doses reduced turbidity levels in soil slurries to between 29 NTU and 92 NTU (mudstone at chainage 9700 and weathered mudstone /sandstone overburden at chainage 6400 respectively). This range approximately corresponds to reducing TSS to be 48 mg/L to 153 mg/L.

96. The above discussion is for discharges from treatment devices before any mixing or dilution with the stream receiving environments. Sediment yields for catchments before and after earthworks as estimated using the USLE calculations are shown in **Table C.14**. The modelled percentage increase in whole catchment sediment loads ranged from 4.5% to 53% (C1 and C7 respectively), but the estimated percentage increase was higher in sub-catchments e.g. 87% in 3B, 80% in 5B and 59% in 7A downstream of the confluence with 7B. In general, the percentage increase in sediment load was higher in catchments where the earthwork area was a large proportion of the catchment area.

97. In contrast to the sub-catchments, the effects of sediment from construction phase of the Project on the mainstem of the Manawatū River will be negligible because the earthwork area represents less than 0.06% of the Manawatū River catchment (180ha/320,230 ha), and TSS concentrations in the Manawatū River are relatively high (Table C.3).

98. As discussed, the sediment load discharged from the earthwork sites will be skewed towards heavy rain events, when there will be more runoff from the site and less efficient treatment. Most of the additional load from the earthwork sites will be entering the stream during higher flows and flood events, while there is likely to be relatively little change in sediment loads during baseflow conditions. Median TSS during wet weather events were measured as 58 mg/L in C2, 19 mg/L in C4 and 25 mg/L in C7. Assuming this is representative

and given the predicted increase in sediment loads from earthwork sites, the median TSS discharge from sediment treatment devices would be approximately 63 mg/L in C2, 32 mg/L in C4 and 40 mg/L in C7. These increases in median values are all within the temporal range of wet weather TSS concentrations currently found at these sites (Table C.5).

99. For the purpose of comparing with water clarity, a 60% increase in TSS concentration at catchment 7 during rain events (i.e. from 25 to 40 mg/L) would correspond to a black disc water clarity change of about 29% (i.e. clarity reducing from 0.31m to 0.22m)[7]. This amount of change is borderline on the One Plan target of <30% change in clarity and the percent change in clarity in some sub-catchments (e.g. 3B, 5B) may be greater. However, the effect on clarity change will be primarily restricted to rain events and the percent change in clarity during baseflow conditions will be considerably less.

100. The above analysis is approximate and likely conservative because of assumptions in the USLE model. However, it highlights the need for appropriate ESC management, including the use of chemically treated SRPs, and robust monitoring.

101. For aquatic life, the deposition of sediment on the stream bed is more relevant than water column concentrations during flood events. The risk of sedimentation from discharges from treatment devices is reduced because appropriately designed treatment devices like SRPs with chemical treatment are particularly effective at removing the fraction of sediment most prone to settling.

102. Chemical treatment using flocculants like PAC can reduce the pH of the treated water as illustrated in the initial results in the CART report. Potential adverse effects of lowering pH in the receiving environment can be avoided by ensuring appropriate dosing rates as described in the Project’s ESC Management Plan and SSESCPs.

103. Overall, the bulk earthworks during construction will increase sediment loss. This will be particularly apparent during high flow events and in some of the smaller sub-catchments. In some sub-catchments the effect of earthworks on water clarity is likely moderate, but will be mostly restricted to high flow events during the period of earthworks. The effects on downstream water quality can

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[7] Formula described in section 5.

be minimised and mitigated with the Project's ESC Management Plan, SSESCPs, and ESC Monitoring Plan.

Table C.13: Sediment yields from earthwork sites after ESC measures as estimated using the USLE in Technical Report D. Fraction increase is the increase in sediment yield from existing during earth work stage.

Stream	Earthworks area total (ha)	Sediment load earthworks (t/yr)	Sediment load from existing land use (t/yr)	Sediment load difference: existing minus earthworks (t/yr)	Fraction increase
1A and 1B	2.98	0.45	0.15	0.3	2.0
2A/2B & 2C d/s of confluence*	43.21	62.93	20.98	41.95	2.0
3A & 3B d/s of confluence*	15.34	79.77	26.08	53.69	2.1
4A Totals*	42.24	84.49	21.12	58.14	2.8
5A & 5B d/s of confluence*	23.87	85.92	28.64	57.28	2.0
6A	11.97	43.11	14.37	28.74	2.0
7A & 7B d/s of confluence*	30.8	110.87	36.96	73.91	2.0
8A	9.93	1.49	0.5	0.99	2.0
Total (Manawatū River)	180.34	469.02	148.79	320.23	2.2

Table C.14: Sediment yields from catchments before and during earthworks as estimated using the USLE calculations.

Stream	Stream catchment area (ha)	Catchment sediment load Before works (t/yr)	Catchment sediment load During works (t/yr)	% increase catchment sediment load	Catchment sediment yield Before works (t/ha/yr)	Catchment sediment yield During works (t/ha/yr)	Earthworks area as % of catchment
Catchment 1	114	5.7	5.96	4.5%	0.05	0.052	2.2%
2A & 2C d/s of 2e	1658	758	812	7.1%	0.46	0.49	3.4%
Catchment 2 (d/s 2E)	1658	758	812	7.1%	0.46	0.49	3.4%
3A	47	80	103	29%	1.70	2.19	14%
3B	18	31	57	87%	1.70	3.19	42%
3A d/s of 3B confluence	65	110	160	45%	1.70	2.47	22%
Catchment 3	123	209	259	24%	1.70	2.10	12%
4A at TAaT Highway	329	265	332	26%	0.80	1.01	14%
Catchment 4	412	331	399	20%	0.80	0.97	11%
5A	52	62	78	26%	1.20	1.5	13%
5B	52	62	112	80%	1.20	2.2	40%
5A & 5B d/s of confluence	104	125	191	53%	1.20	1.8	26%
Catchment 5	120	144	210	46%	1.20	1.75	23%
6A d/s of 6B confluence	29	35	52	49%	1.20	1.79	24%
Catchment 6	95	114	131	15%	1.20	1.38	7%
7A d/s 7B/7C confluence	100	120	190	59%	1.20	1.9	29%
Catchment 7	110	132	202	53%	1.20	1.84	27%
Catchment 8	101	5.1	5.6	11%	0.05	0.055	5.3%
Catchment 9	220	264	283	7.1%	1.20	1.28	3.5%

Water quality effects from vegetation clearance

Potential effects of wood slash in streams

104. Vegetation clearance can have a number of potential effects on nearby streams. Felling and removal of trees can expose soil, make it more prone to erosion and cause sedimentation, the effects of which are discussed above. In addition, the accumulation or storage of sawdust, chip or mulch near or over waterways can cause serious water quality effects if it occurs.

105. The bulk storage of woodchip and wood residue can produce leachate with a high Biological Oxygen Demand ("**BOD**") as well as organic dissolved organic matter that promotes the growth of heterotrophic organisms (e.g. bacterial mats and ‘sewage fungus’). Both the BOD load and heterotrophic growths deplete dissolved oxygen from the water and sediments, with consequent adverse effects on aquatic life.

106. Leachate from storage of wood residue can also leach potentially toxic compounds in the form of tannins, phenols, and resin acids. The toxicity of these compounds tends to reduce with increasing pH (Samis et al. 1999).

107. The effect on streams of woodchip residue from vegetation clearance depends on the amount stored, proximity to waterways, size of the waterways

and mitigation. A moderate amount of woodchip beside a stream has negligible effects and is commonly used to positive effect as part of restoration. Similarly, small amounts of woodchip entering a stream will have negligible adverse effects. However, if situations occur where vegetation clearance causes piles of woodchip to cover a waterway, the effect on the aquatic life can be large, due to deoxygenation causing the loss of invertebrate and fish life downstream until sufficient reaeration or dilution occurs.

108. The Project requires some clearance of woody vegetation, particularly in sub-catchments C7A (*ca*. 0.9ha), C5B (*ca*. 1.3 ha), C4A (*ca*. 0.7ha) and catchment C3 (*ca*. 1.1 ha). In the absence of good practice there would be a potential risk of vegetation clearance causing adverse water quality effects on small waterways. Fortunately, the adverse effect of vegetation clearance and wood residue can be avoided and minimised by ensuring good management practice; in particular this requires that mulching is undertaken in a manner that prevents mulch entering small streams and waterways.

Mitigation proposed

109. The Ecology Management Plan includes measures to avoid and minimise adverse effects on vegetation during construction including mulching and storage of wood. Procedures for avoiding and minimising adverse effects of mulch on water quality include: minimising the area and duration of soil exposure from vegetation clearance, minimising the volume of vegetation to be mulched, locating wood residue piles with an appropriate separation distance from any waterways (i.e.10-20m), and managing potential leachate from these piles.

110. The Ecology Management Plan should seek to minimise the amount of wood that is mulched, leaving large wood in-situ where practical, and setting aside large wood for later use in rehabilitating the site and streams. A risk-based approach is appropriate for managing mulch taking into account the size of the stockpile, proximity to watercourses, topography and the duration of stockpiling. It should be noted that coarse woody debris is an important part of stream habitat, while it is excessive amounts of fine material like mulch that can cause adverse effects to watercourses.

Potential effects from the Project

111. The effect of vegetation clearance on stream water quality is expected to be negligible or small if good practice is followed to prevent leaching of wood chip

residue to waterways or overland flow paths as described in the draft Ecology Management Plan.

Water quality effects from concrete

Potential effects of concrete in streams

112. Water that comes in contact with unset concrete, concrete fines, concrete dust or concrete washings can become highly alkaline. If this runoff enters receiving waters untreated it can have adverse effects on aquatic life. There is a wide range of sensitivities of freshwater fish and invertebrates to pH, but most aquatic invertebrates and fish are tolerant to pH in the range of 6 – 9, and this range was proposed (but not adopted) as a possible national bottom line (Davies-Colley et al. 2013). Causing pH to extend outside this range has the potential to adversely affect aquatic ecosystems and is likely to change some geochemical processes. Many native fish species show avoidance of pH values below 6.5 (West et al. 1997). The ANZECC (2000) guidelines recommend that discharges causing unnatural pH changes of more than 0.5 units should be investigated.

Potential effects from the Project

113. The risk associated with concrete pouring will be avoided in some instances, where pre-cast concrete structures are being used across the Project, or works are to occur in dry conditions (i.e. not directly in water). However, where concrete pouring is to occur, for example near the bridge piles, the risk of concrete affecting stream water quality will be managed by minimising water on the works area, capturing any residual water associated with the concrete curing and either using the residual water for dust control (i.e. disposing to land) or treating separately prior to any discharge. A Hazardous Substances Procedure (**Appendix 7 of the ESCP, Volume VII**) has been developed which describes the processes to be implemented to minimise potential risks to aquatic life. Provided appropriate management practices are implemented, the risk of concrete pours causing adverse water quality effects on streams will be low.

Road stormwater runoff during long term operation

Potential effects of road stormwater runoff on streams

114. Stormwater discharges can have multiple levels of effects on streams by affecting stream hydrology and morphology, water quality and the water temperature regime (Storey et al. 2013, Walsh et al. 2005). The magnitude of

these effects is generally a function of the percentage of impervious surface in the catchment, type of landuse, amount of traffic on the road and how the stormwater is treated.

Hydrology and morphology

115. Stormwater discharges can alter stream hydrology. An increase in impervious surfaces from roads and urbanisation can increase flood peaks and volume causing them to be more ‘flashy’ than natural streams. As a result, urban streams are often deeper and wider than natural streams, become simpler and uniform, and have more fine sediment on the beds. This can result in less diversity and abundance of macroinvertebrates and fish in the stream (Storey et al. 2013, Walsh et al. 2005).

116. The potential effects of stormwater on hydrology can be minimised by reducing the amount of impermeable area, and by using treatment devices that enhance infiltration and flow detention (Storey et al. 2013).

Water quality

117. Stormwater runoff from roads can contain a wide range of contaminants including: TSS, chemical oxygen demand, BOD, oil and grease, TPH, polycyclic aromatic hydrocarbons (PAHs), heavy metals (most commonly cadmium (Cd), copper (Cu), lead (Pb), Nickel (Ni) and zinc (Zn)), faecal indicator bacteria (e.g. *E. coli*) and nutrients (nitrogen and phosphorus). However, the concentration of nutrients and faecal bacteria are typically less than that found in in runoff from agricultural land. Stormwater from rural road runoff typically has little microbiological contamination (e.g. *E. coli* bacteria) due to low loading and bacteria die-off between rain events (Fernandes and Barbosa 2018).

118. The contaminants most commonly monitored in road runoff is TSS, and heavy metals (e.g. Cu, Zn and Pb), and hydrocarbons (e.g. PAH or measured as TPH). Copper and zinc are important constituents in brake linings and tyres respectively. Braking and tyre wear results in the emission of brake pad and tyre debris, containing these metals, to the road surface. Hydrocarbon compounds are emitted to the road surface from oil, grease and fuel leakages and spills, and from exhaust emissions. Metals and hydrocarbons are strongly associated with sediment fractions, but some are also in a dissolved form (NZTA 2010, Fernandes and Barbosa 2018).

119. The CLM models TSS, Cu, Zn and TPH. Effectively treating for these contaminants is likely sufficient for protecting against a wider range of contamination. For example, road stormwater typically has lead concentrations less than that of copper but lead is much more strongly bound to sediment (typically 90% as particulate) and more easily treated (Cunningham et al. 2017, Fernandes and Barbosa 2018).

120. PAHs are sourced from vehicle fumes, lubricating oils, seal wear. They sorb strongly to sediments and are more persistent and in higher concentrations in colder climates. The concentration of PAHs in freshwater environments is typically below environmental thresholds. The amount of PAH emitted from vehicles has considerably reduced since vehicle emission standards were introduced in 2003 (Kennedy et al. 2016, Fernandes and Barbosa 2018).

121. TPHs are a common measure of hydrocarbons and a useful indicator of petroleum contamination. Analysis can divide TPH into fractions to give an indication or the likely source of contamination.

Thermal pollution

122. Water temperature has a strong influence on the distribution of aquatic biota. It directly affects metabolism and indirectly affects biota by influencing pH, dissolved oxygen and algae growth.

123. Runoff from treatment devices like wet ponds can still have high water temperatures. The frequency and severity of warm water discharges from ponds reduces with smaller surface area, increased shading and shorter retention periods. The quantity of runoff is dependent on the water level of the pond prior to a storm event. Elevated water temperatures from ponds can persist for several hundred metres downstream of ponds as water cools at a rate of about 1^{o}C per 100m (Maxted et al. 2005).

124. Some studies have found ponds to have little effect on the water temperature in small low volume streams. This was attributed to conveyance of water in underground pipes prior to discharge, good riparian vegetation and planting (e.g. Chung 2007). The heating effect of ponds and wetlands is limited to summer and late spring.

125. Thermal pollution from stormwater can be reduced by reducing the amount of impermeable area, maximizing infiltration (e.g. grass swales and infiltration trenches), using vegetated treatment wetlands and increasing shading (of the stream or treatment devices). Swale vegetation cools the first flush of

stormwater. Vegetated treatment wetlands can mitigate thermal pollution by providing shading, evapotranspiration and infiltration. Wetlands also mitigate the thermal load by capturing small rain events entirely (Young et al. 2013).

Stormwater treatment proposed

126. All stormwater discharges from the Project will be treated with one or more treatment devices. Most stormwater from the Project will be treated by multiple treatment devices in series – providing greater benefit than when they are used individually (NZTA 2010). The treatment train applying to each device is described in Table C.9The key stormwater treatment devices proposed by the project are as follows:

    (a) **Vegetated wetlands** – These are effective for detention and treatment of sediment, heavy metals, nutrients, hydrocarbons and thermal pollution (Cunningham et al. 2017).

    (b) **Wetland swales** – This provide a linear wetland system effective for detention and treatment of sediment, heavy metals, nutrients and hydrocarbons.

    (c) **Swales** – These are effective for sediment, temperature and partially effective for heavy metals, nutrients and hydrocarbons.

    (d) **Catch-pits and vegetated conveyance channels** – These are also used within a treatment train approach. Catch-pits are effective at treating sediment and associated contaminants. Vegetated conveyance channels provide very limited treatment for most contaminants but are effective for managing temperature effects.

127. Treatment wetlands and wetland swales can also provide ecological benefits in the landscape. These have not been considered in this assessment and are an additional benefit.

Potential effects of stormwater from the Project

128. Estimates from the CLM for each ‘whole of catchment’ load before the Project, after the Project and the net difference in load is shown in **Table C.15**. The percent change is shown in **Table C.16**. Estimates are provided for each catchment and for those sub-catchments which receive a relatively high proportion of stormwater compared to the overall catchment. Overall, the analysis shows a <u>net reduction</u> in the load of stormwater contaminants to the Manawatū River downstream of the Project; with TSS reducing by 9332 kg/yr, zinc reducing by 16.1 kg/yr, copper reducing by 5.87 kg/yr and TPH reducing

by 119 kg/yr. These reductions are very small in the context of loads in the Manawatū River, but they are still noteworthy. The load of stormwater contaminants will also reduce in the Pohangina River, and catchments C1, C2, C4 and C9. The reason for the load reductions is because the Project will result in traffic volume shifting to the new road which will have much better treatment of stormwater. No stormwater will be discharged to catchments C5 or C6 as is currently the case. One treatment device (Wetland 02) discharges treated stormwater directly to the Manawatū River.

129. There will be some catchments with a net increase in contaminants from stormwater. These are sub-catchments C2E, and catchments C3, C7 and C8. Using copper as an example, the CLM indicates the magnitude of increase in sub-catchment 2E and catchments C3, C7 and C8 as 13%, 6.5%, 19% and 2.8% respectively. The magnitude of increase in C7 is moderate but the effects of metals are moderated by the high hardness (*ca*. 135 mg/L) in the catchment.

130. CLM estimates of the total load of contaminants discharged to each catchment from stormwater treatment devices are shown in **Table C.17**. This total load was used to calculate an average concentration of contaminants in discharges from treatment devices (**Table C.18**) before any mixing with receiving waters. These discharges will be intermittent and will only occur for a short time follow rain events.

131. The estimated concentration of TSS in the stormwater discharge (**Table C.18**) is less than TSS measured in wet weather flows (**Table C.5**) and similar to long term median TSS in the Manawatū River (**Table C.3**). The estimated concentration of copper in the discharge is similar to occasional high values measured in catchments C4 and C7 (**Table C.6**). A large proportion of the estimated sediment load was from batter slopes (e.g. 61%, 73%, 70%, 67% for catchments C2, C3, C4 and C7 respectively).

132. The discharges to all catchments have estimated end of pipe concentrations of zinc, copper and TPH within the hardness adjusted acute toxicity guidelines, with exception of C8 which was borderline. Total copper in discharges to catchments C1 and C8 were close to the ANZG guideline values. The acute toxicity guidelines are for dissolved metals, so are conservative when compared with estimates of total metals as done by the CLM. Furthermore, there will be mixing and dilution with the receiving water.

133. Insufficient information is available on the stream flow regime to reliably estimate average concentrations in the streams after mixing. The analysis is complicated by the intermittent nature of stormwater discharges, skewed distribution of stream flows and contaminant concentrations and the co-correlation of stream flows, concentrations and stormwater discharges. Most of the time and during baseflow conditions the stormwater discharge can be expected to have negligible or minor impact on stream water quality. If the discharges were to result in deposition of sediments on the stream bed then there would be potential for impacts during baseflow conditions, but the risk of deposition is low given the high level of stormwater treatment provided by the Project.

134. Calculations indicate that to ensure ANZG DGVs are achieved during a stormwater discharge event the hydraulic dilution would need to be:

    (a) for zinc - between 1.4 times (C7) and 2.9 times (C1);

    (b) for copper - between 2 times (C7) and 4.2 times (C1); and

    (c) for TPH between 20 times (C3) and 38 times in C8 and 48 times in C7A d/s 7B.

135. The level of dilution required for Zn and Cu will very likely be exceeded during storm events, however it is possible that the level of dilution required for TPH will not be exceeded during storm events in some catchments. Nevertheless, the effect of TPH on the environment is expected to be small because intermittent stormwater discharges are more appropriately compared with the acute toxicity guidelines, which are met with no dilution.[8]

136. The effect of stormwater from the Project on thermal pollution is expected to be very small for two reasons. Firstly, the new road surface in each catchment is relatively small; the percentage of each catchment that will receive stormwater from impervious roading will be (in order): C7 (4.7%), C2E (4.7%), C1 (2.5%), C8 (2.1%), C3 (1.7%), C4 (1.1%), C2 (0.2%), C5 (0%) and C6 (0%). Secondly, the stormwater treatment devices proposed for use in the Project are effective at reducing temperature effects (e.g. vegetated wetlands, swales, and even grassed conveyance).

137. Overall, the Project will improve water quality in the Manawatū River, the Pohangina River and catchments C1, C2, C4 and C9. This is because the

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[8] Also, the catchment where highest dilution is required is C1, and the Project will result in an overall improvement in water quality in this catchment. The catchment requiring the next highest dilution for stormwater discharges to achieve ANZG DGVs is: C8 which requires 2.5 times dilution for Zn, 3.6 times dilution for Cu and 38 times dilution for TPH.

new road will have high level of stormwater treatment compared to the existing roads. No stormwater from the road will enter catchments C5 and C6, so there will be no resulting stormwater effects in these catchments. There is potential for stormwater to cause a decline in water quality in sub-catchment C2E and in catchments C3, C7 and C8. However, for these catchments the effects will likely be small because of the intermittent nature of stormwater discharges, the quality of the stormwater is within relevant guidelines after adjusting for hardness, and for TSS, the stormwater has similar concentrations to that found in the streams during flood events.

Table C.15: Whole of catchment load Before the Project, After the Project and the difference (after – before) for each catchment as estimated using the CLM.

Catchment	TSS load (g/yr)	Zn load (g/yr)	Cu load (g/yr)	TPH load (g/yr)
C1	230,581,374	11,041	2,560	20,591
C2E	264,064,986	9,242	1,848	0
C2 (d/s C2E)	7,826,019,608	285,256	58,415	83,995
C3	481,989,049	16,870	3,374	0
C4 (at alignment)	1,314,969,760	51,770	10,937	40,142
C7A d/s 7B	447,994,480	15,680	3,136	0
C7	492,793,928	17,248	3,450	0
C8	188,769,647	7,309	1,545	4,853
C9	229,550,140	9,616	2,122	11,484

Catchment	TSS load (g/yr)	Zn load (g/yr)	Cu load (g/yr)	TPH load (g/yr)
C1	-931,056	-1,458	-546	-10,060
C2E	221,013	1,006	243	7,365
C2 (d/s C2E)	-4,148,864	-8,390	-2,862	-61,275
C3	203,930	885	218	6,612
C4 (at alignment)	-1,263,879	-1,628	-685	-13,287
C7A d/s 7B	420,967	2,141	549	14,229
C7	495,763	2,484	639	16,433
C8	-102,184	347	44	1,938
C9	-691,140	-1,554	-502	-11,029
Pohangina Rv	-3,077,604	-6,918	-2,235	-49,109
Manawatū Lower	**-9,332,483**	**-16,098**	**-5,870**	**-119,013**

Table C.16: Percent change in whole of catchment load After the Project compared to Before the Project as estimated using the CLM.

Catchment	TSS	Zn	Cu	TPH
C1	-0.40%	-13.2%	-21.3%	-49%
C2E	0.08%	11%	13%	
C2 (d/s C2E)	-0.05%	-2.9%	-4.9%	-73%
C3	0.04%	5.2%	6.5%	
C4 (at alignment)	-0.10%	-3.1%	-6.3%	-33%
C7A d/s 7B	0.09%	14%	18%	
C7	0.10%	14%	19%	
C8	-0.05%	4.7%	2.8%	40%
C9	-0.30%	-16%	-24%	-96%

Table C.17: Total load of contaminants discharged from stormwater treatment devices to each catchment (grey cells are sub-catchments).

Catchment	TSS load (g/yr)	Zn load (g/yr)	Cu load (g/yr)	TPH load (g/yr)	Catchment area (ha)
C1	349,083	1,399	356	9,270	117
C2E	579,155	1,019	246	7,365	56
C2 (d/s C2E)	740,777	1,382	327	9,530	1,658
C3	764,782	904	222	6,612	123
C4 (at alignment)	1,294,214	2,138	528	13,220	329
C7A d/s 7B	1,446,103	2,177	556	14,229	100
C7	1,533,734	2,520	646	16,433	110
C8	254,800	1,038	262	6,604	101
Manawatū direct	130,363	483	102	2,703	320,230

Table C.18: Average concentration of contaminants from treatment devices to each catchment before any mixing with receiving waters (assuming annual rainfall of 660mm/yr).

Catchment	TSS (g/m^3)	Zn (g/m^3)	Cu (g/m^3)	TPH (g/m^3)	SW device catchment (ha)
C1	8.96	0.036	0.0091	0.24	5.90
C2E	16.56	0.029	0.0070	0.21	5.30
C2 (d/s C2E)	15.61	0.029	0.0069	0.20	7.19
C3	16.09	0.019	0.0047	0.14	7.20
C4 (d/s alignment)	14.42	0.024	0.0059	0.15	13.60
C7A d/s 7B	34.45	0.052	0.0132	0.34	6.36
C7	23.10	0.038	0.0097	0.25	10.06
C8	10.19	0.042	0.0105	0.26	3.79
Manawatū direct	8.98	0.033	0.0071	0.19	2.20

8 CONCLUSION AND RECOMMENDATIONS

138. The bulk earthworks during the construction phase of the Project have potential to increase sediment loss and reduce water clarity. This will be more apparent during high flow events and in smaller sub-catchments. The effects on downstream water quality can be minimised and mitigated with the Project’s ESC Management Plan, SSESCPs, and ESC Monitoring Plan.

139. During the operational phase, well treated stormwater from the Project will result in overall better water quality in the Manawatū River. Some catchments will have worse water quality but the overall impact of road stormwater on these catchments will be small.

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APPENDIX C.1: ECOLOGICAL IMPACT ASSESSMENT APPROACH

The method applied to this assessment of ecological effects broadly follows the Ecological Impact Assessment Guidelines (EcIA). The framework for assessment provides structure but needs to incorporate sound ecological judgement to be meaningful. Deviations or adaptions from the methodology are identified within each of the following sections as appropriate.

- Outlined in the following sections, the guidelines have been used to ascertain the following:

- The level of ecological value of the environment (Step 1);
- The magnitude of ecological effect from the proposed activity on the environment (Step 2);
- The overall level of effect to determine if mitigation is required (Step 3), and
- The magnitude and overall level of effect following implementation of measures to avoid, remedy, mitigate the effects (repeating Step 2 and 3).

Step one: Assigning ecological value

Ecological values are assigned on a scale of 'Low' to 'Very High' based on species, communities, and habitats, using criteria in the EcIAG. These criteria can be readily applied to terrestrial environments.

There is no unifying set of attributes used to assign value to freshwater systems as there is for terrestrial ecosystems. There are however numerous metrics and measures that are used in the assessment of freshwater systems.

Table 1: Ecological values assigned to species and habitats (adapted from Roper-Lindsay *et al*., 2018).

Value	Species values	Habitat values
Very high	Nationally Threatened - Endangered, Critical or Vulnerable.	Supporting more than one national priority type. Nationally Threatened species found or likely to occur there, either permanently or occasionally.
High	Nationally At Risk – Declining.	Supporting one national priority type or naturally uncommon ecosystem and/or a designated significant ecological area in a regional or district Plan. At Risk - Declining species found or likely to occur there, either permanently or occasionally.
Moderate-high	Nationally At Risk - Recovering, Relict or Naturally Uncommon.	A site that meets ecological significance criteria as set out in the relevant regional or district policies and plans.
Moderate	Not Nationally Threatened or At Risk,	A site that does not meet ecological significance criteria but that contributes to

Value	Species values	Habitat values
	but locally uncommon or rare	local ecosystem services (e.g. water quality or erosion control).
Low	Not Threatened Nationally, common locally	Nationally or locally common with a low or negligible contribution to local ecosystem services.

Step two: Assess magnitude of effect

Magnitude of effect is a measure of the extent or scale of the effect of an activity and the degree of change that it will cause. The magnitude of an effect is scored on a scale of 'Negligible' to 'Very High' (Table 2) and is assessed in terms of:

- Level of confidence in understanding the expected effect;
- Spatial scale of the effect;
- Duration and timescale of the effect (Table 3);
- The relative permanence of the effect; and
- Timing of the effect in respect of key ecological factors.

The spatial scale for effects are considered in the context of the local and landscape scale effects as appropriate.

Table 2: Criteria for describing magnitude of effect (Roper-Lindsay *et al*., 2018).

Magnitude	Description
Very high	Total loss of, or very major alteration to, key elements/features/ of the existing baseline[1] conditions, such that the post-development character, composition and/or attributes will be fundamentally changed and may be lost from the site altogether; AND/OR Loss of a very high proportion of the known population or range of the element/feature
High	Major loss or major alteration to key elements/features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed; AND/OR Loss of a high proportion of the known population or range of the element/feature
Moderate	Loss or alteration to one or more key elements/features of the existing baseline conditions, such that the post-development character, composition and/or attributes will be partially changed; AND/OR Loss of a moderate proportion of the known population or range of the element/feature
Low	Minor shift away from existing baseline conditions. Change arising from the loss/alteration will be discernible, but underlying character, composition and/or attributes of the existing baseline condition will be similar to pre-development circumstances or patterns; AND/OR Having a minor effect on the known population or range of the element/feature
Negligible	Very slight change from the existing baseline condition. Change barely distinguishable, approximating the 'no change' situation; AND/OR Having negligible effect on the known population or range of the element/feature

[1] Baseline conditions are defined as ‘the conditions that would pertain in the absence of a proposed action’ (Roper-Lindsay *et al*., 2018).

Table 3: Timescale for duration of effects (Roper-Lindsay *et al*., 2018).

Timescale	Description
Permanent	Effects continuing for an undefined time beyond the span of one human generation (taken as approximately 25 years)
Long-term	Where there is likely to be substantial improvement after a 25 year period (e.g. the replacement of mature trees by young trees that need > 25 years to reach maturity, or restoration of ground after removal of a development) the effect can be termed ‘long term’
Temporary[1]	Long term (15-25 years or longer – see above) Medium term (5-15 years) Short term (up to 5 years) Construction phase (days or months)

[1] Note that in the context of some planning documents, ‘temporary’ can have a defined timeframe.

Step three: Assessment of the level of effects

An overall level of effects is identified for each activity or habitat/fauna type using a matrix approach that combines the ecological values with the magnitude of effects resulting from the activity (Table 4).

The matrix describes an overall level of effect on a scale of ‘Negligible’ to ‘Very High’. Positive effects are also accounted for within the matrix.

The level of effect is then used to guide the extent and nature of the ecological management response required, which may include remediation, mitigation, offsetting or compensation.

The overall level of effects on each value (habitat or species) is assessed before and after recommendations to avoid, remedy or mitigate effects. As such, the need for and extent to which recommendations to reduce effects, if implemented, is clearly understood.

Table 4: Criteria for describing overall levels of ecological effects (Roper-Lindsay *et al*., 2018).

Ecological value (Table) Magnitude (Table)	Very high	High	Moderate	Low	Negligible
Very high	Very high	Very high	High	Moderate	Low
High	Very high	Very high	Moderate	Low	Very low
Moderate	High	High	Moderate	Low	Very low
Low	Moderate	Low	Low	Very low	Very low
Negligible	Low	Very low	Very low	Very low	Very low
Positive	Net gain	Net gain	Net gain	Net gain	Net gain

APPENDIX C.2: CATCHMENT LANDUSE AND SLOPE

Percentage landuse in each catchment used in the Contaminant Load Model based on LCDB4.

Landuse categories	**C 1**	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**	**C 8**	**C 9**
1	Slope 0 to 10 degrees								
Broadleaved Indigenous Hardwoods		0.3%	0.5%	5.5%	3.7%	4.4%	3.1%		
Deciduous Hardwoods		0.2%		0.1%				0.8%	
Exotic Forest	0.2%	0.5%	0.2%	0.1%				4.1%	0.0%
Forest - Harvested		0.0%		0.0%				2.7%	
Indigenous Forest		0.0%	0.7%	0.5%			0.0%	0.7%	2.8%
Manuka and/or Kanuka		0.2%	0.5%	0.0%					
Gorse and/or Broom				0.6%			2.0%		
High Producing Exotic Grassland	88.7%	31.2%	10.0%	30.9%	10.0%	6.5%	7.0%	67.3%	10.9%
Low Producing Grassland		0.1%		0.2%	0.2%				0.2%
Lake or Pond				0.4%					
River								0.0%	
Surface Mine or Dump		0.0%							
2	Slope 10 to 20 degrees								
Broadleaved Indigenous Hardwoods		0.7%	0.9%	3.4%	9.0%	17.5%	5.7%		
Deciduous Hardwoods		0.0%		0.1%				0.1%	
Exotic Forest	0.0%	0.7%	0.7%	0.1%				2.8%	0.1%
Forest - Harvested		0.0%		0.0%				0.3%	0.0%
Indigenous Forest		0.0%	1.8%	1.1%			0.0%	2.3%	6.6%
Manuka and/or Kanuka		0.6%	2.0%						
Gorse and/or Broom				1.2%			2.2%		
High Producing Exotic Grassland	8.0%	17.2%	10.5%	24.1%	23.4%	16.4%	21.1%	7.6%	16.8%
Low Producing Grassland		0.1%		0.6%	0.4%				0.8%
Lake or Pond				0.0%					
River								0.0%	
Surface Mine or Dump		0.1%							
3	Slope greater 20 degrees								
Broadleaved Indigenous Hardwoods		3.8%	8.3%	5.1%	20.5%	31.5%	18.9%		
Deciduous Hardwoods		0.0%		0.1%				0.1%	
Exotic Forest		2.4%	2.3%	0.01%				3.7%	1.3%
Forest - Harvested		0.1%						0.0%	
Indigenous Forest		0.4%	24.0%	1.7%			0.0%	4.0%	28.7%
Manuka and/or Kanuka		5.0%	6.4%	0.0%					
Gorse and/or Broom				2.4%			6.1%		
Low Producing Grassland		0.3%		0.9%	1.5%				2.1%
High Producing Exotic Grassland	3.1%	35.8%	31.2%	20.9%	31.4%	23.8%	33.8%	3.4%	29.7%
River								0.0%	
Lake or Pond									
Surface Mine or Dump		0.1%							
Grand Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**