- The first output is the results of changing land-use across the likely construction period, which reflects the changing construction areas within the Indicative earthwork areas each year based upon the construction staging. The results of this are annual average sediment loads across each year of construction and peak daily event loads.
- The second output is a fixed land use which displayed the maximum extent of bare earth through the entire construction of the Project. The maximum open earthworks extent for:
    - the Mahurangi River is 43.3 ha;
    - the Hōteo River is 75 ha; and
    - the Oruawharo River is 25 ha.

The results of this are the daily event loads which show the largest potential change in sediment load within the receiving freshwater and saline water environments during various storm events.

These construction scenarios include the use of the recommended erosion and sediment controls (ESC) and these are considered inherent within the design. The erosion and sediment controls applied within the Project sediment model are based on a 6 year bulk earthwork programme with a further 1 year allowance for enabling and early works prior to that period. Key assumptions include:

- Reduction in winter work – it is assumed that throughout the winter the active earthworks area will be reduced (to approximately 20% of the summer works) of the previous summer active earthwork area, with mulching and stabilisation across the initial winter months;
- Super silt fences are assumed to be used on 10% of the active earthwork area;
- Decanting earth bunds are assumed to be used as the primary sediment treatment device in the steep catchment of the Waiteraire Stream (Hōteo Operation 2-4); and
- Sediment retention ponds are assumed to be used as the primary sediment treatment device for all other areas, however in the floodplain of the Hōteo River (Hōteo Operation 5) the ponds are assumed to have reduced capacity during a flood event.

Further details of the ESCs included in the model are contained in the Catchment Sediment Modelling technical report including the treatment efficiencies.

Sediment loads at river mouths

The following tables present a summary of the potential changes in sediment load, from the existing baseline to construction, estimated at the mouth of the freshwater catchments (Table 18 and Table 19) for the construction scenarios. The construction scenarios presented include erosion and sediment control treatment as inherent within the design.

Potential changes at reporting points in the freshwater environment are also shown in Table 19 below.

Table 18 - Modelled changes to mean annual sediment loads (T) at the mouths of the Mahurangi and Hōteo Rivers and the estuarine Oruawharo River for the changing land use construction output

Reporting point	Existing mean annual load (T)	Construction (treated) mean annual sediment load					
		A6 year average			Peak year		
		Load (T)	Increase (T)	Increase %	Load (T)	Increase (T)	Increase %
Mahurangi River mouth	12,193	12,306	113	0.9%	12,443 (years 1-3)	250	2.1%
Hōteo River mouth	25,600	25,809	208	0.8%	25,728 (years 1-2)	341	1.3%
Oruawharo River mouth	9,284	9,298	14	0.2%	9,302 (years 1-5)	18	0.2%

Table 19 - Modelled changes to daily sediment loads (T) at the mouths of the Mahurangi and Hōteo Rivers and the estuarine Oruawharo River for the peak active area construction output

Reporting point	ARI	Existing daily event loads (T)	Construction (treated) daily event load (T)		
			Event load (T)	Increase (T)	Increase %
Mahurangi River mouth	2-yr	2,502	2,558	56	2%
	10-yr	7,152	7,556	407	6%
	50-yr	18,304	20,202	1,911	10%
Hōteo River mouth	2-yr	3,715	3,854	139	4%
	10-yr	7,130	7.642	512	7%
	50-yr	10,912	12.776	1,864	17%
Oruawharo River mouth	2-yr	1,405	1,416	11	1%
	10-yr	2,860	2,914	54	2%
	50-yr	4,425	4,588	164	4%

The analysis of the Mahurangi sediment model estimates that across the indicative 6 year bulk earthworks programme there could be an increase in sediment yield of approximately 113 tonnes/year at the river mouth; representing an annual average increase of 0.9%. In the unlikely event of a 50 ARI storm occurring during peak active earthworks, an additional 1,911 tonnes could enter the estuary, representing an increase of 10% over background at the Mahurangi River mouth. The maximum active area of earthworks (43.3 ha) for the catchment occurs in the summer of years 1-3 of the peak earthworks. The likelihood of a 50 ARI storm occurring during a 3-year period is 6%, however this is less likely during the summer months.

There are a number of other rivers and streams that flow into the Mahurangi Harbour which will not be affected by the Project; the Mahurangi River contributes only 26% of the sediment entering the Mahurangi estuary and as such the increase in sediment to the harbour would be less than predicted by the model for the entire Mahurangi estuary. This is discussed further in Section 6.2.2 in relation to the Marine Sediment Modelling technical report.

The results of the southern Kaipara Harbour catchment sediment model at the Hō teo River mouth estimate that across the indicative construction programme there could be an increase in 1,459 tonnes of sediment (208 tonnes/year on average). This represents an increase of 0.8%. The maximum active area of earthworks for the Hōteo River catchment occurs in the summer of years 1-2 of construction. In the unlikely event that a 50 ARI storm occurs when the peak active area of earthworks (75 ha) is occurring an extra 1,864 tonnes of sediment could enter the harbour at the Hōteo River mouth, which would represent a 17% increase over the background daily load. This assumes full bare earthworks areas with no progressive stabilisation in place which is considered a conservative assumption due to the knowledge that progressive stabilisation will be occurring throughout.

At the mouth of the estuarine Oruawharo River the model estimates that an increase of 98 tonnes of sediment across the indicative construction programme (14 tonnes / year) could be added to the Kaipara Harbour at this location. This is approximately 0.2% increase in the background level of sediment load. In the unlikely event that a 50-year storm event occurs when the peak active area of earthworks (25 ha) is occurring there could be an additional 164 tonnes of sediment entering the Kaipara Harbour in a day, which represents a 4% increase over the background as a daily load.

The increases in sediment over the background do not include the additional sediment that would be entering the southern Kaipara Harbour from the rivers including the Kaipara River, the Kaukapakapa River, the Makarau River and the Araparera River, which the model has estimated contribute a combined annual average load of 29,126 tonnes/year. Our assessment also does not include the contribution from other small catchments around the harbour with this detailed within the Marine Sediment Modelling technical report. Therefore, the percentage change of sediment load entering the southern Kaipara Harbour is assessed as less than presented above.

Mahurangi River mouth

The Mahurangi River sediment loads are based on the existing P-WK GLEAMS model outputs. The Project earthworks are 43.3 ha, which is larger than the P-WK 'flats' earthworks area (37.5 ha), but smaller than the total P-WK earthworks within the Mahurangi catchment (89.9 ha). Therefore, the potential range of sediment yields at the Mahurangi River mouth associated with the Project is within these ranges.

Table 20 and Table 21 contain the results of the P-WK model, which represent the potential ranges associated with the sediment loads at the Mahurangi River mouth from the Project construction, alongside this high-level assessment of the Project earthworks.

Table 20 - Mean annual sediment load (T) for the Mahurangi River mouth corresponding to the 'P-WK project' changing land-cover (Harper et al, 2013) adopted for Project

Earthworks areas	Existing mean annual load (T)	Construction (treated) mean annual sediment load					
		Mean annual load			Peak year		
		Load (T)	Increase (T)	Increase %	Load (T)	Increase (T)	Increase %
P-WK "Flats" focus area (35.7 ha)	12,193	12,274	81	0.7%	12,318	125	1.0%
P-WK total earthworks (89.9ha)	12,193	13,072	879	7.2%	13,793	1,600	13.1%
WW2W earthworks assessment (43.3ha)	12,193	12,206	113	0.9%	12,443	250	2.1%

Table 21 - Daily sediment load (T) for the Mahurangi River mouth corresponding to the "P-Wk project" peak active earthworks area (Harper et al, 2013) adopted for Project

Earthworks areas	ARI	Existing daily event loads (T)	Construction (treated) daily event load (T)		
			Event load (T)	Increase (T)	Increase %
P-WK "Flats" focus area (35.7 ha)	2-yr	2,502	2,531	29	1%
	10-yr	7,152	7,354	202	3%
	50-yr	18,304	19,254	950	5%
P-WK total earthworks (89.9 ha)	2-yr	2,502	2,826	324	13%
	10-yr	7,152	8,249	1,097	15%
	50-yr	18,304	21,844	3,540	19%
WW2W earthworks assessment (43.3 ha)	2-yr	2,502	2,558	56	2%
	10-yr	7,152	7,556	407	6%
	50-yr	18,304	20,202	1,911	10%

The changes to sediment load in the Mahurangi River have been assessed at the Mahurangi River mouth (discussed above). The construction could result in elevated sediment loads and concentrations in minor receiving tributaries within the Mahurangi River catchment.

Hōteo River catchment

The Hōteo River was modelled for the Project with the estimated changes in sediment loads at a number of instream reporting points in the Hōteo River catchment as shown in Table 22 and Table 23. The reporting points in the following tables are identified on Figure 27 within the Catchment Sediment Modelling technical report.

Table 22 - Mean annual sediment load (T) for the Mahurangi River mouth corresponding to the "P-Wk project" peak active earthworks area (Harper et al, 2013) adopted for Project

Reporting point	Existing mean annual load (T)	Construction (treated) mean annual sediment load					
		6-year average			Peak year		
		Load (T)	Increase (T)	Increase %	Load (T)	Increase (T)	Increase %
Kourawhero Stream at Kaipara Flats Road	69	85	17	24%	43 (yrs 1-2)	112	63%
Waiteraire Stream headwaters	119	152	33	28%	183 (yrs 1-3)	65	55%
Waiteraire Stream at Hōteo confluence	678	848	170	25%	974 (yrs 1-2)	296	44%
Unnamed tributary (H2) at Rustybrook Road	78	83	5	6%	90 (yr 6)	12	15%
Waiteitei Stream at Sandersons	3,371	3,373	2	0.1%	3,377 (yr 6)	6	0.2%
Hōteo River upstream of SH1	12,308	12,325	17	0.1%	12,348 (yr 6)	40	0.3%
Hōteo River at Gubbs	18,449	18,640	191	1.0%	18,744 (yrs 1-2)	294	1.6%

Reporting point	Existing mean annual load (T)	Construction (treated) mean annual sediment load					
		6-year average			Peak year		
		Load (T)	Increase (T)	Increase %	Load (T)	Increase (T)	Increase %
Hōteo River at mouth	25,600	25,809	208	0.8%	25,941 (yrs 1-2)	341	1.3%

Table 23 - Modelled changes to daily sediment loads (T) in the Hōteo River for the peak active area construction scenario upstream of each reporting point (peak years shown in Table 10)

Reporting point	ARI	Existing daily event loads (T)	Construction (treated) daily event load (T)		
			Loads (T)	Increase (T)	Increase %
Kourawhero Stream at Kaipara Flats Road	2-yr	16	33	17	107%
	10-yr	30	115	85	284%
	50-yr	49	341	292	596%
Waiteraire Stream headwaters	2-yr	27	53	26	98%
	10-yr	51	151	100	197%
	50-yr	81	381	300	370%
Waiteraire Stream at Hōteo confluence	2-yr	140	262	122	87%
	10-yr	270	709	439	163%
	50-yr	421	1,779	1,358	323%
Unnamed tributary (H2) at Rustybrook Road	2-yr	14	19	5	34%
	10-yr	26	50	24	94%
	50-yr	37	137	100	270%
Waiteitei Stream at Sandersons	2-yr	449	452	3	1%
	10-yr	925	937	12	1%
	50-yr	1,144	1,492	51	4%
Hōteo River upstream of SH1	2-yr	1,643	1,660	17	1%
	10-yr	3,264	3,346	82	3%
	50-yr	5,554	5,497	303	6%
Hōteo River at Gubbs	2-yr	2,329	2,493	164	7%
	10-yr	4,578	5,020	442	10%
	50-yr	7,147	8,575	1,428	20%
Hōteo River at mouth	2-yr	3,715	3,854	139	4%
	10-yr	7,130	7,642	512	7%
	50-yr	10,912	12,776	1,864	17%

The Kourawhero Stream is a small tributary that has headwaters within the proposed designation boundary. As such the estimated mean annual sediment increase near the headwaters of the stream at Kaipara Flats road is 24%, and for the 50 year ARI event occurring during peak active earthworks could increase by up to 600%. This relative increase in sediment load decreases further downstream. However, the Kourawhero Stream headwaters flow through some natural wetlands. The predicted increase in sediment load in this stream could potentially result in measurable changes to the natural wetlands, such as a change in wetland substrate or a filling in of part of the wetlands with sediment. These wetlands are identified as of significance within the Ecology Assessment Report and as such avoidance and minimisation of discharges where practicable into this location will occur with the detailed management to be provided within the relevant CESCPs. Practices such as progressive stabilisation and weather forecasting for these locations (with associated actions) will also be emphasised through the CESCP process. These effects are discussed further in Section 6.3.

The Waiteraire Stream at Hōteo Confluence is estimated to have an average increase in mean annual sediment load of 170 tonnes/year (25% increase) over the background at the confluence of the stream with the Hōteo River (near SH1). For the 50-year ARI event to occur during the maximum open area, there could be an increase of over 300% over the background daily event load at that same location which is immediately downstream from the construction footprint. These changes are relatively large at that point in the catchment for such an event, however further downstream in the Hōteo River (at the Hōteo River at mouth) this only relates to a 17% increase over the existing daily event loads for the 50 ARI event due to the other catchment sediment sources contributing at that location.

The sediment load in the unnamed tributary (H2) of the Hōteo River could increase by a mean of 6% (5 tonnes) across a 6-year bulk earthworks period, and in the unlikely event of a 50 ARI storm occurring during the peak active area of earthworks an extra 100 tonnes of sediment could enter the H2 tributary.

The modelling location for the Hōteo River "Upstream of SH1" includes the discharge from the unnamed tributaries (H1, H2, H3 and W1). At this location the annual average increase is estimated as 0.1% (17 tonnes/year) over the background. This is similar in location to the Wellsford surface water abstraction. Further downstream along the Hōteo River at Gubbs, this modelling location is downstream of the majority of the Project footprint within the Hōteo catchment (excluding Kourawhero Stream construction zones). The increase in load due to the Project is larger however still minor, with an estimated average increase of 1.0% annually (191 tonnes/year).

The results of the sediment load model carried out in the Hōteo River indicate that there are some relatively large changes in sediment load predicted for some tributaries of the Hōteo River. However, these large changes are generally limited to small tributaries prior to flowing into the Hōteo River. The exceptions to this are in the Waiteraire Stream which is predicted to have a measurable increase in sediment load through the entire tributary, and in the Kourawhero Stream which could result in a measurable increase in sediment entering the natural wetlands.

Oruawharo River catchment

The Oruawharo River was modelled for the Project with the model estimated changes in sediment loads at a number of instream reporting points in the Oruawharo River catchment shown in Table 24 and Table 25 below.

Table 24 - Modelled changes to mean annual sediment loads (T) in the estuarine Oruawharo River and tributaries for the changing land use construction scenario

Reporting point	Existing mean annual load (T)	Construction (treated) mean annual sediment load					
		6-year average			Peak year		
		Load (T)	Increase (T)	Increase %	Load (T)	Increase (T)	Increase %
Te Hana Creek tributary	67	70	4	6%	71 (yrs 1-5)	5	7%
Te Hana Creek at mouth	1,175	1,182	8	1%	1,184 (yrs 1-5)	10	1%
Maeneene Creek downstream of SH1	319	324	5	2%	325 (yrs 1-5)	7	1%
Maeneene Creek at mouth	537	542	5	1%	543 (yrs 1-5)	7	1%
Oruawharo River at mouth	9,284	9,298	14	0.2%	9,302 (yrs 1-5)	18	0.2%

Table 25 - Modelled changes to daily sediment loads (T) in the estuarine Oruawharo River and tributaries for the maximum active area construction scenario (peak years shown in

Reporting point	ARI	Existing daily event loads (T)	Construction (treated) daily event load (T)		
			Loads (T)	Increase (T)	Increase %
Te Hana Creek tributary	2-year	15	17	2	12%
	10-year	29	39	10	35%
	50-year	44	76	32	72%
Te Hana Creek at mouth	2-year	118	122	4	4%
	10-year	225	249	24	11%
	50-year	332	397	65	20%
Maeneene downstream of SH1	2-year	65	68	3	4%
	10-year	129	143	14	11%
	50-year	199	245	46	23%
Maeneene Creek at mouth	2-year	87	90	3	3%
	10-year	174	189	15	9%
	50-year	271	317	46	17%
Oruawharo River at mouth	2-year	1,405	1,416	11	1%
	10-year	2,860	2,914	54	2%
	50-year	4,425	4,588	164	4%

The results for the sediment model in a tributary of Te Hana Creek indicate that during construction the average sediment load could increase by 6% (4 tonnes/year) over background. However this reduces further downstream at the mouth of Te Hana Creek to less than 1% over background (increase of 8 tonnes/year). In the unlikely event of a 50-year ARI storm when the maximum active area of earthworks is occurring the daily load could increase by 72% in the upper tributaries and 20% at the mouth.

The results for the sediment model in Maeneene Creek indicate that during construction the average sediment load could increase by an average of 1% per year (6 tonnes/year). In the unlikely event of a 50-year ARI storm when the maximum active area of earthworks is occurring the daily load could increase by 23% downstream of SH1 and 17% at the mouth.

The results of the sediment load model carried out in Te Hana Creek and Maeneene Creek indicate that the changes to sediment load are most likely to be acute in the smaller tributaries. In the freshwater environment, deposition of sediment is likely to occur in smaller events, with this periodically being flushed into the marine environment. The effects of the sediment in the marine environment is discussed in Marine Ecology and Coastal Avifauna Assessment Report.

Sediment concentrations at river mouths

To assist with the assessment of the ecological effects in receiving water bodies, an understanding of suspended solid concentrations in streams and at catchment outlets within the Project area is necessary. At the mouths of rivers, the sediment concentration is a representation of the concentration in the freshwater entering the marine environment. Many of the river mouths are estuarine in nature, and as such have the influence of marine water and sediment interacting with the freshwater and terrestrial inputs, as well as tidal flushing.

In terms of an increase in sediment concentrations there is some relationship that can be established with the sediment loads as modelled. Effectively an increase in sediment loads will typically also result in an increase in sediment concentrations. On this basis the largest percentage increase in sediment loads is within the Kourawhero, Waiteraire and Tributary H2, and particularly for a 50 year ARI rain event. The specific nature of this sediment concentration is however not established. But based on previous water quality sampling results sediment concentrations of up to 2000 g/m^3 can occur at some periods during heavy rain events. Importantly, based on experience from other earthwork projects the sediment concentrations typically increases with flow rates and they often are for short periods of time and very quickly decrease back to lower levels. This can occur within less than 24 hours of the rain event.

It is also important to assess any increase in sediment concentrations in a risk management framework as per Section 6.1 of this report. The probability of a 50 year rain event occurring within the bulk earthworks period is 11%. In addition the sediment loads calculated are based on peak active areas of earthworks open at the same time as such a rain event occurring. The likelihood of this scenario is even less than the 11% due to:

- the earthworks will be staged with the peak earthworks area not exposed for the full period;
- the erosion and sediment controls to be established and in particular the 14 day stabilisation requirement; and
- the ability to forecast large rain events and therefore proactively manage risk with on site measures and maintenance provisions.

High risk locations

Based on the sediment modelling outcomes the higher risk catchments are identified as below. These need to be placed in the context of the previously identified risk of steep slopes and works in and adjacent to stream systems. This risk will be identified and confirmed through the CESCP process with associated risk management identified:

- The Kourawhero Stream due to the steep slopes and the natural wetlands within the catchments;
- The Waiteraire Stream due to the steep slopes and the large area of proposed earthworks;
- The unnamed tributaries (H1 and H2) to the north of the Hōteo River viaduct, due to the risk of flooding from the Hōteo River; and
- Te Hana Creek particularly during a large rain event due to the amount of earthworks occurring over the catchment area.

Figure 20 below illustrates this modelled sediment load risk over the Indicative Alignment and provides for quick identification and therefore assessment of these areas during the construction period.

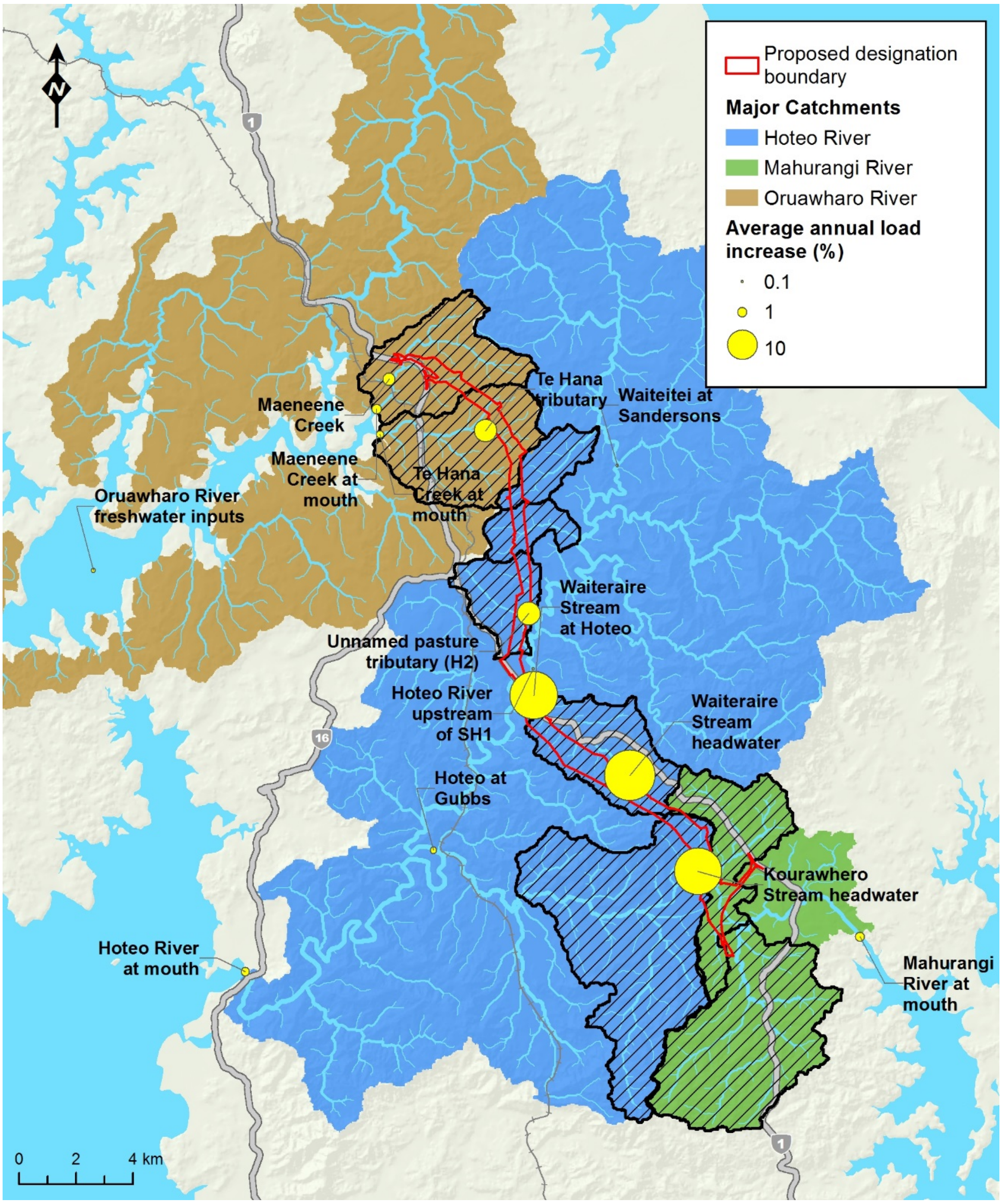

Figure 20 - Relative percentage increase in mean annual load over the background at Project reporting points for Hōteo River and Oruawharo River catchments

To address these effects the following measures will be implemented for all earthworks in those specific catchments and/or sub catchments:

- Consideration of winter close down of bulk earthworks with any such works subject to a risk review and assessment process prior to implementation. This is likely to include areas within floodplains and areas on slopes greater than 15º;
- Rain forecasting and more progressive stabilisation will be applied to reduce the likelihood of a large storm mobilising sediment. While this will occur over the full

Project location it will be focused and prioritised on these locations in an attempt to reduce such risk.

- A refinement of the construction sequencing and programme to minimise the duration of earthworks (and hence to minimise the risk profile) that will occur in areas of steep slopes and within floodplains.
- The discharge of sediment laden water to locations downstream of sensitive ecological features such as natural wetlands rather than through these features.

6.2.2 Harbour model results

The above modelled sediment loads were utilised within a Harbour Model and expert opinion process to determine the fate of sediment within these harbour environments. The harbour model outputs are detailed within the Marine Sediment Modelling technical report and Marine Ecology and Coastal Avifauna Assessment Report and are summarised below.

Mahurangi Harbour

For the Mahurangi Harbour no new modelling was undertaken for this Project, as the Harbour Model and outputs from the P-WK Project were able to be utilised. This comparative assessment confirms the ability to undertake earthworks within the Mahurangi catchment, within the same "constraints" as the P-WK Project. Consents granted for P-WK provided for an open area limit of up to 109 ha in the Flat Country in the Mahurangi catchment assuming there is no open area in the Hill Country at the same time. The proposed earthworks for this Project covers approximately 43 ha (of equivalent Flat Country) within the Mahurangi catchment, and therefore it follows that this is significantly less than the 109ha as currently consented for the P-WK project. From an open area extent perspective the Project can expose all 43.3ha within this catchment to remain within the open area envelope previously consented. The Catchment Sediment Report states that sediment release from this project is significantly less than that for P-Wk.

Hōteo River Coastal Modelling

Overall, the coastal modelling and interpretation shows that the additional sediment load delivered to the Kaipara Harbour by the Hōteo River during Project construction results in small increases above the baseline situation for both short-term and long-term timeframes. The coastal model simulations indicate the increase in sediment load from Project construction results in a few areas of additional sediment deposition short term within the Kaipara Harbour which are above that of the present-day situation, and above relevant ecological thresholds. This is detailed and assessed further within the Marine Ecology and Coastal Avifauna Assessment Report.

Oruawharo River

A literature review, site visit and interpretative assessment of likely depositional footprint was undertaken for the Oruawharo River, specifically including Maeneene Creek and Te Hana Creek.

The Oruawharo River is a depositional environment for sediment with a history of rapid infilling by fine sediments. Sediment-laden freshwater discharges into the headwaters of Maeneene and Te Hana Creeks will not be trapped solely within the upper sub-estuaries of each creek. During floods, the sub-tidal channels act to convey flood flows with high sediment loads downstream to be mixed into the broader body of the Oruawharo River estuary. Once here, tidal cycles, river currents and waves act to mix, flocculate, settle, resuspend, disperse and transport the sediment load around the wider estuary.

For the wider Oruawharo River estuary the proportional increase in sediment loads during a 50 year-ARI flood event is only a 3% increase above the baseline, with smaller increases during smaller rainfall events. This is assessed as barely perceptible at about 0.1 mm/year on average around the Oruawharo River estuary. The highest deposition rates are expected within the most sheltered mangrove stands.

Overall, the additional sediment load discharged into the headwaters of the Oruawharo River by the Project construction will have a negligible increase on sediment deposition rates within the estuary.

6.2.3 Sensitivity analysis

The assumptions used in the sediment modelling for the calculation of the sediment yields and loads during earthworks are outlined within the Catchment Sediment Modelling technical report. It is considered that these assumptions provide the necessary comparison for overall assessment and risk management purposes. The significant benefit of assessing sediment yield is using an onsite comparative analysis which allows high sediment areas to be identified, comparative analysis with pre construction yields and construction water management controls and monitoring to be targeted at specific areas. The assessment provides a 'closer' look at the site and begins to narrow the focus on what is expected to be the high sediment generating areas within the site. This comparative analysis with the background sediment loads has occurred and has allowed for such an analysis to occur.

It is confirmed that the assumptions that have been used within the modelling were based upon the best information available at the time of the modelling process. As the assessment, and Project design details, have matured some of these assumptions and factors are recognised as subject to potential change. In particular, change associated with soil types, slope angle, slope length and progressive stabilisation. It is concluded that any such amendments would not have a material effect on the modelling outcomes or conclusions with these discussed below in the context of sensitivity analysis.

Soil Types

This factor in the modelling is based on information available at the time from bore logs and geological information. No comprehensive soil particle size analysis has occurred and was not considered necessary to allow for an understanding of the soil characteristics. It is assessed that with more detailed soil information from deeper cuts and also alluvium material that a more accurate soil factor could be applied over time. This may result in a greater portion of finer soil particle size for some areas and a coarser particle size in others, with an associated change to the sediment yields. The soil factor applied within the model has undergone scrutiny within the Project team including reviewed by the geotechnical team, and a review of particle size distribution of boreholes within corresponding geological units for the P-WK Project. The geotechnical team have found that the soil particle size utilised within the model is comparable against borehole soil data.

Slope Angle and Slope Length

The slopes of the construction areas were modelled with the initial slope of the land as a reasonable representation of the slopes during construction. A comparison of initial and final slopes found that the slopes are generally similar for both cases, however the initial slope is steeper for the Waiteraire catchment and therefore this slope was used as a conservative assumption.

As construction progresses, these initial slope categories will change towards the final slope associated with the road platform. Typically this cut to fill process whereby slopes are quickly reduced and batter slope and cuts are stabilised will result in an overall reduction in sediment generation.

Progressive Stabilisation

Progressive stabilisation is not factored into the modelling process to the same level as what will be expected to occur on site. The model assumes that areas of earthworks, based on the peak active earthwork areas, remain exposed for the summer period. With a 14 day provision of progressive stabilisation and also proactive stabilisation of higher risk locations pre forecast rain events, it is expected, and has been experienced on other projects, that such peak active earthwork areas will not remain open for the long periods of time as modelled, and consequentially a reduction in sediment yields can be expected to occur from that modelled.

Stabilisation activity will occur not only at the end of the summer earthworks season but also through the summer season as batters come up to grade and as forecast weather events require high risk locations (steep areas and next to streams etc) to be stabilised.

The "on ground" construction process can be described as follows:

- Progressively open up earthwork areas;
- Stabilise once at grade, or not worked for a period of time. Stabilisation also to occur pre weather events as practicable and necessary;
- Continue to earthwork through summer period as above;
- Pre winter a full assessment will occur as to what will continue in winter months based on risk and programme; and
- Further stabilisation for winter months as necessary.

It is assessed that modelling a more realistic progressive stabilisation scenario as above will result in a further overall reduction in sediment yields in particular when stabilisation occurs in locations not worked for more than 14 days.

Overall it is assessed that a change to the sediment model input assumptions will generally have minimal effect overall on overall sediment yields and loads calculated. It is however important to recognise that the calculated yields are conservative and with, in particular, progressive stabilisation and risk management implementation it is assessed that a reduction in yield will result. The comparative analysis with background sediment loads remains relevant.

I further highlight my personal experience with sediment yield calculations (utilising Universal Soil Loss Equations) for the Long Bay development. For a particular season (2011/2012) of works these calculations estimated 43.8 tonnes of sediment yield from 20.2 ha of earthworks. The actual sediment yield was measured, including through automatic sampling, as 3.6 tonnes. These actual yields represent approximately 8% of that predicted through modelling. I consider this outcome to be a clear result of the innovation and onsite management for the associated earthworks and the over-prediction of sediment yield by USLE.

A further example is the Massey North Auckland Transport site on Fred Taylor Drive, Waitakere which involved earthworks over a site with one specific sub-catchment subject to an automatic flow and water quality sampling programme. This sub-catchment was 3.74 ha in area and had a slope of 10% and was subject to a standard cut-to-fill operation. Works were expected to be completed in a 6 month period and the USLE calculations to support this were also based on a 6 month period. Erosion and sediment control measures included a SRP with chemical treatment. The USLE calculations provided by the applicant were estimated to be 6.98 tonnes of sediment yield. Earthworks in fact occurred over a 10 month period from March 2013 to December 2013 with works occurring over the early winter months within this period

With best practice erosion and sediment controls, the actual sediment yields were lower than those modelled through USLE. I also note that during these earthworks, some issues were identified on the site with the operation of the chemical treatment system and pond performance over the early winter period below expectations. The actual yields were still only 66% of the USLE modelled yield.

The P-Wk project is still at a relatively early stage in terms of bulk earthworks activity however is also illustrating similar trends of lesser sediment yields than those predicted through modelling.

While therefore it is important that the modelling inputs reflect as close as possible to reality this is very difficult to assess with actions such as progressive stabilisation, slope reduction as earthworks progress, differing soil types and implementation of a proactive risk management framework. Our overall site experience and assessment is that these elements reduce overall sediment generation potential and yield and as a result the modelling outcomes can significantly overestimate sediment yields. This provides for conservatism within the modelling process utilised in this assessment.

In addition to the above, the sediment model outcomes will be monitored and verified during the implementation phase of the Project and will be confirmed or otherwise through a detailed continuous improvement monitoring programme. This monitoring allows for full control of the earthworks prior to effects occurring and has the ability to amend methodologies, specific controls, progressive stabilisation and open exposed areas dependent upon the outcomes of such a programme.

If the monitoring programme clearly illustrates, through a robust comparable analysis of earthworks programme, erosion and sediment controls and water quality outcomes, that actual sediment yields are less than that modelled then this may assist with justification of exposing a greater open area of earthworks than previously. This will need to be carefully assessed and supported by robust analysis.

In addition, any mitigation proposed for the marine environment based on sediment deposition can be determined by the actual yields that result, rather than the modelled yields. These actual yields can be extrapolated through the methodologies developed within the continuous monitoring programme.

6.2.4 Non-sediment contaminants

During the construction phase of the Project there is the potential for non-sediment contaminants to be discharged to the water environment. Other discharges during the construction works may include:

- Discharges of contaminants present in existing soils.
- Discharges of sediment pond treatment chemicals (flocculants) that may affect pH or have a direct effect (e.g. aluminium in alum);
- Clean water discharges from cut off drains and diversions;
- Dewatering water from deeper cut earthworks; and
- Accidental discharges such as spills of fuels, oils, cement etc.

Our method for assessing the potential effects of these contaminants is based on the experience of similar projects, including P-WK.

Discharges of sediment pond treatment chemicals (flocculants) if managed incorrectly may affect pH in receiving water dependent upon the flocculant type used. Prior to construction commencing, soil bench tests will be undertaken to identify the best flocculant for use based upon the soils encountered. As part of the continuous improvement monitoring programme (section 5.5), if the flocculant used has the potential to affect the pH of the water then the receiving environment will be monitored for changes and dosing would be adapted. This approach will mean that any changes to the pH of the receiving environment that would cause water to fall outside of the background range would be avoided.

In the event that clean water cut off drains and diversions divert water from one catchment to another, there is potential that there may be a change in water quality in the receiving catchment. Generally, any clean water cut off drains and diversions during construction will divert water into the nearest watercourse, and are unlikely to result in any significant change to hydrology or flooding, as discussed in the Construction Water Design technical report. In addition, the Water Quality technical report has found that the water quality across the study area is similar. Given this, it is unlikely that the diversion of clean water during construction would result in any change in water quality of the receiving environment.

There is the potential that dewatering operations could result in changes to water quality, generally associated with higher suspended sediment concentrations. As stated in Section 5 of this report and the Construction Water Design technical report, any discharges from dewatering will be monitored for sediment, and treatment will be provided for dewatered discharges if they have elevated sediment concentrations, compared with other discharges from the site.

Project works will include a wide variety of machinery that may require refuelling onsite, hence there may be fuel and oils stored onsite. In addition, building materials including cement and bitumen can have impacts if spilt into the freshwater environment. We consider the risk of accidental spills of hazardous substances and other contaminants can be managed through good site practices. The Construction Water Design technical report provides further detail on these aspects of site management.

6.2.5 Changes to hydrology during construction

There is the potential that during construction the Project could result in changes to hydrology within receiving watercourses associated with:

- Temporary and permanent culverts and stream diversions;
- Increased flows and a reduction in baseflows due to ground compaction, reduction of forestry and grassland and increased impervious areas;
- Increased hydrological connectivity through drainage resulting in increased peak flows downstream.

There is the potential that temporary and permanent culverts and stream diversions could result in increased flows within some streams and decreased flows within others. These types of changes have been assessed in the Hydrological Assessment technical report with a focus on the operational phase of the Project. This assessment has found that changes to catchment boundaries are generally small, and generally occur within small sub catchments. These effects are likely to be similar during the construction where temporary culverts and stream diversions will be implemented throughout the Project. The assessment confirms relatively large changes to flows in small tributaries including field drains (<1 km^2), however negligible changes to catchments within major streams. The effect of these changes to flow within the small tributaries will be negligible overall due to the small size of the tributaries in the context of the larger stream systems.

There is also the potential that there will be increases in peak flows due to reduction in infiltration/evapotranspiration associated with removal of vegetation, ground compaction and increased impervious areas. Peak flows could also increase due to increased hydrological connectivity through drainage. These effects will be reduced through the implementation of the sediment control devices which will provide some retention of flood water, although the primary function of these devices is a reduction in suspended sediment. Any residual changes to hydrology during construction are unlikely to be large, given that the Project will only account for a small percentage of the total stream and river catchments in the area. In addition, any changes would be short term and occur prior to the installation of the permanent drainage.

Harvesting of Matariki forest prior to Project commencement will increase peak flows from related catchments which will need to be addressed and accommodated at detailed design stage.

6.2.6 Changes to flooding

There is the potential that construction of the Project could result in changes to flooding beyond the proposed designation boundary. Generally, these are limited to:

- Temporary and permanent culverts and diversions; and
- Temporary construction activities within the floodplains.

All temporary and permanent culverts and diversions will be designed to accommodate the 1 in 20-year flood event where practicable and ensure flows greater than this can safely pass around the specific location. This confirms that for events up to the 1 in 20-year flood event there will be no change to flooding associated with the diversions and culverts. For larger storm events there may be some changes to the depth, duration and velocity of flood waters. However these are likely to be localised associated with the Project, any culverts and stream diversions will be designed to allow safe passage of larger flows and any change to depth, duration and velocity of flood waters are likely to be small.

There is the potential for construction within the floodplain to result in some changes to flooding outside of the proposed designation boundary. However these are temporary in nature only and would be equal to or less than the changes associated with the operational phase.

Construction yards will require careful consideration in terms of location to ensure they are not impacted by flood flows. This can be achieved by either avoiding these locations or by ensuring that they are constructed at a level (recommended to be above the 20 year flood level) and of material to minimise flood effects. This “policy” will ensure that any impacts on flooding is minimised. Where yards are required to be sited within the flood plain location they will be of a temporary nature only, will be constructed of such material (hardfill) that any flood flows will pass over these locations without contamination and overall will not result in any temporary or permanent effects on flooding.

Any planting within flood plain areas will need to be carried out in a manner that does not increase adverse effects.

6.2.7 Cumulative effect - forest harvesting

The Matariki Forest is located north of Warkworth and comprises an area of approximately 3,520 ha of exotic plantation pine forest. Approximately 99 ha of that is located within Hōteo Operation Area 2 and 3 (87 ha in the Waiteraire catchment and approximately 12 ha in the Kourawhero catchment).

Based upon a literature review carried out into sediment yields associated with forestry, sediment yields following harvesting activities vary highly and are dependent upon slope, geology, watercourse connectivity and harvesting activities (Croke & Hairsine, 2006) and can range between 80-500 tonnes/km^2/year during logging (Phillips et al., 2005). All of the studies assessed sediment yields following logging activities in New Zealand between 1974 and 2003 and did not take into account the provisions of the NESPF. It is important however to recognise that the practices utilised in accordance with the NESPF will not differ significantly from the practices likely to have been used during the period as above. While there has been a general trend of improvement overall and with the introduction of TP223 (as an Auckland Guideline) there are some practices that are now implemented to a higher standard. However, the general approach of hauler based logging practices or second rotation forestry utilising existing formed tracks continues. These methodologies are recognised as the key factor in reducing sediment yields from forestry operations.

In the absence of a sediment yield value available for the Matariki Forest logging, we have assumed a potential yield of 280 tonnes/km^2/year so that we could carry out a high level assessment of potential sediment yields associated with forest harvesting. This sediment yield is from a study into sediment yields pre and post harvesting of a very steep catchment in the Mahurangi River catchment (Hicks et al., 2009). Based upon the assumed

280 tonnes/km^2/year sediment yield, there is the potential that harvesting of the Matariki forest within the proposed designation boundary could result in an additional 244 tonnes of sediment entering the Waiteraire Stream and 33.6 tonnes of sediment entering the Kourawhero Stream during the harvesting period (assuming occurs in one year).

However, the potential sediment yield could reduce significantly if the ESC measures associated with forestry harvesting are significantly enhanced from that previously implemented (including through the study) with the adoption of best practice current guidelines. Due to forestry operations not typically utilising erosion and sediment control measures as would be expected for earthworks operations, the yield would be further reduced, if the harvesting also occurred as part of the Project, through implementation of the construction water quality treatment devices (such as SRPs) prior to commencement of the forest harvesting activities.

If the harvesting was undertaken as part of the Project and construction water management was implemented, then the sediment load from forest harvesting could be reduced by up to 90%. The Catchment Sediment Modelling technical report indicates that for forest harvesting within the proposed designation boundary, an estimated increase of approximately 25 tonnes/year of sediment in the Waiteraire Stream could result in an approximate 20% change in the average annual catchment sediment load, and a change of 3.5 tonnes in the Kourawhero could result in an increase of 5% in average annual catchment sediment load. The combined changes would result in a change at the mouth of the Hōteo River of less than 1% of average annual catchment sediment load.

The potential harvesting within the proposed designation boundary should be considered in the context of the wider Matariki Forest, which based on Matariki Forest's current harvesting programme, will be harvested before or at the same time as the Project. The area of the Matariki Forest within the proposed designation boundary is approximately 100 ha while the entire forest is approximately 3,520 ha. Therefore, less than 3% of the forest will be harvested as part of this Project.

This sediment load assessment, as detailed within the Catchment Sediment Modelling technical report indicates that harvesting of the Matariki Forest could result in an increase in sediment load within the Hōteo River annually by an average of 2.1%. The total increase in sediment load across harvesting is significantly larger than the modelled increase in sediment load to the Hōteo River mouth from the indicative construction programme for the Project. Overall if harvesting occurs prior to construction, as programmed, the effects of the Project will be reduced. Importantly the sediment modelling for the baseline is also based on current landuse and does not include such harvesting activity making the model outputs (comparative analysis) conservative.

From our assessment, the combined effect of changes in water quality associated with forest harvest within the proposed designation boundary and construction of the Project is significantly less than the potential change in sediment load associated with harvesting the wider Matariki Forest. If the Matariki harvesting occurs at the same time, the sediment loads and sediment deposition in freshwater and marine receiving environments will be cumulative, and higher instream concentrations and greater depths and extents of deposition would be likely to occur. Importantly, for that area that exists within the Project earthworks footprint a greater level of erosion and sediment control will be expected from the remaining forest harvesting activity. This will be determined and assessed through the continuous improvement monitoring programme.

6.3 Assessment of effects

This section sets out an assessment of effects associated with the construction water management aspects of the Project. The specific assessment criteria from the relevant statutory documents outlined in Section 3 have been used to inform the matters considered in this assessment.

The assessment considers the effects of construction related discharges and in particular those associated with sediment yields from land disturbing activities, including earthworks. In addition to the assessment provided in this section, the effects of construction-related water discharges from the Project are assessed in the Ecology and Marine Ecology and Coastal Avifauna Assessment Reports.

Design and methodologies adopted within this report are based on a best practicable option approach. While developed and tested processes and practices will be implemented during construction to achieve the necessary outcomes, these processes and practices must be supported by a monitoring programme linked to continuous improvement, as described above.

The assessment that follows has been informed by on site Project assessment, knowledge of earthworks projects and expert knowledge that has been gained in this regard, previous water quality sampling results and outcomes achieved with other earthworks projects, risk assessment and sensitivity analysis as described above and the sediment modelling work undertaken.

This section assesses the Project in the context of the assessment framework as detailed within Section 3.

6.3.1 Best Practicable Option

Criteria / consideration for the assessment

The construction water design described above has been designed to represent the best practicable option (BPO) for minimising the adverse effects on the environment from the construction discharges to the water environment.

The proposed Project design is considered to be the best practicable option and is assessed against the following RMA criteria:

i. the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and
ii. the financial implications, and the effects on the environment, of that option when compared with other options; and
iii. the current state of technical knowledge and the likelihood that the option can be successfully applied.

Policy E1.3(26) of the AUP(OP) seeks that construction related discharges must:

Prevent or minimise the adverse effects from construction, maintenance, investigation and other activities on the quality of freshwater and coastal water by:

(a) adopting best management practices and establishing minimum standards for the discharges; or

(b) where Policy E1.3(26)(a) is not practicable, have regard to the following:

- the nature, volume and concentration of the contaminants in the discharge;
- the sensitivity of the receiving environment to the contaminants in the discharge;
- other practicable options for the discharge, including reuse or discharge to the trade sewer; and
- practicable measures to reduce contaminant concentrations prior to discharge or otherwise mitigate adverse effects.

Best Practicable Option

Criterion (i)

The scale of the earthworks is significant with the bulk earthworks volume estimated to be 12 million m^3 and approximately 45% of the Project indicative earthwork footprint on slopes of greater than 10 degrees. The receiving environments include small streams, large rivers and the marine environments of the Mahurangi Harbour and Kaipara Harbour. Of these the most sensitive receiving environments are considered to be:

- the small streams, which relative to their catchments include large areas of disturbance; and
- the ultimate estuarine receiving environments, where the cumulative effect of earthworks in multiple freshwater sub-catchments is coincident and the sediment discharged from the Project is likely to deposit.

The BPO for managing the quality of discharges recognised in the Auckland Unitary Plan is TP90. The design criteria proposed for the Project exceed some of the requirements in TP90 and incorporate some procedures and measures that exceed the design provided in GD05, Transport Agency ESC Guidelines and on site best practice. Some of these are detailed within Section 5.2.4 above. Through the design and construction phases of the Project, we recognise that there will be scope for innovation and alternative means of achieving the same environmental outcome as specified in consent conditions.

For managing effects on the freshwater environment, achieving the BPO for treatment of construction related runoff is the most important element. In addition, the active area of earthworks has been modelled which illustrates constructability and also management of effects. The assessment and the inclusion of a comprehensive monitoring programme further confirms that peak active earthwork areas can be potentially increased however this is subject to confirmation of effectiveness of the approach through the construction period.

When managing the effects in the marine receiving environment, the staging of the duration of the Project can influence the risk of large rainfall events coinciding with the peak active earthworks. The assessed indicative construction programme is 7-years, with a 6 year bulk earthworks period. Mitigation through peak active earthworks area limits are informed by the Catchment Sediment Modelling technical report and Marine Ecology and Coastal Avifauna Assessment Report.

Overall therefore the nature of the discharge during construction is predominantly sediment which increases with rainfall. This discharge (referred to as sediment yield) from the erosion and sediment control measures is minimised to the maximum extent possible and with full recognition of the sensitivities of the receiving environment.

Criterion (ii)

The peak area of active earthworks has an influence on the potential for effects at the river catchment scale and in the marine receiving environments. It also has an influence on the overall length of the construction programme and the subsequent cost of the Project.

To inform the assessment of marine effects, we have assumed that the earthworks required in the sub-catchments draining to the Mahurangi catchment could occur in one year, and that the earthworks in sub-catchments draining to mouths of the Hōteo River and Te Hana and Maeneene creeks could occur over two years.

This report summarises the probability of one or more ARI events occurring over different durations. The durations identified are representative of peak active earthworks durations and possible durations for the overall construction programme, (7 years). The analysis indicates that the longer the duration, the more likely it is that a large event will occur during the construction programme. The analysis highlights the importance of the performance of erosion and sediment control devices in the smaller events (2 year ARI and less), as these events are almost certain to occur during the construction programme, although they may not occur during the peak active earthworks stage.

The option of reducing the construction period has the effect of reducing the probability of large rainfall events however creates an earthworks programme that has constructability issues due to availability and physical capacity of resources. To increase the construction period has the opposite effect of increasing the probability of a higher intensity rain event occurring during that period with potential undesirable outcomes from an effects perspective.

The option of implementing the BPO approach remains and financial implications need to be considered as part of the BPO process. However, it is very clear that management of adverse effects is a critical component of all earthworks projects and it is assessed that staging, open area limitations and implementation of erosion and sediment controls are elements that must be applied to achieve an acceptable level of change in water quality.

Criterion (iii)

The Transport Agency has successfully implemented best practice construction water management on other similar projects, such as the Northern Gateway and P-WK (under construction). The construction water design proposed for this Project, follows Auckland Council and New Zealand Transport Agency guidance and is considered to represent the current state of technical knowledge. The Construction Water Management Design technical report summarises the details of the learnings and innovation from other projects and through the use of CESCPs for this Project further innovation and learning opportunities will be explored and implemented.

The successful application of the construction water management involves a continuous improvement management approach, informed by ongoing monitoring. We recommend monitoring conditions are developed to require this continuous improvement programme.

Overall the state of technical knowledge is robust and provides certainty and a very high likelihood that the construction water management measures as detailed can be successfully applied.

6.3.2 Land disturbance

Criteria / consideration for the assessment

The design of the construction water management plan was designed to take into account the AUP(OP) and ESC Design Guidance (GD05, TP90 and Transport Agency ESC guidance). The design criteria that the Project were assessed against include the following criteria:

i. The amount of land being disturbed at any one time is to be managed, particularly where the soil type, topography and location is likely to result in increased sediment runoff or discharge (AUP(OP) Policy E11.3(2))

ii. Design and implement earthworks with recognition of existing environmental site constraints and opportunities, specific engineering requirements, and implementation of integrated water principles (AUP(OP) Policy E11.3(5)

iii. Best practice erosion and sediment control measures must be implemented for the duration of the land disturbance. Those measures must be installed prior to the commencement of land disturbance and maintained until the site is stabilised against erosion (AUP(OP) E11)

iv. Whether the extent or impacts of adverse effects from the land disturbance can be mitigated by compliance with standards, the design and suitability of erosion and sediment control measures to be implemented, or by managing the proportion of the catchment which is exposed; staging of works and progressive stabilisation; and timing and duration of works (AUP(OP) E11/E12).

Land disturbance

Criterion (i)

The amount of land being disturbed at any one time (area and volume) has been accounted for in the indicative construction programme. This programme has been developed to understand the volumes and areas of earthworks to be undertaken each year. In addition to this the Project will include progressive stabilisation, which will further reduce the amount of area that will be exposed at any one time. Due predominantly to soil types, slope length and slope angle the earthworks to be undertaken are to be subject to an open area limit that provides for a maximum open exposed area at any one time. This open area limit results in a corresponding limit to the amount of potential sediment generation and hence assists with achieving a reduced sediment yield.

It is assessed that this criterion is achieved by the construction design, progressive stabilisation and overall open area limits.

Criterion (ii)

The earthworks methodologies associated with the Project have been designed with recognition of the site topography and geological constraints along the Indicative Alignment and providing for some flexibility within the proposed designation boundary. This has resulted in an Indicative Alignment that meets not only the design criteria but further addresses many of the environmental, including construction water management, principles. These principles are encompassed within the Construction Water Design technical report.

Integrated water management will occur on the Project with the construction phase utilising operational stormwater measures as a “polishing” device where appropriate.

Criteria (iii) and (iv)

The construction water design implements the most stringent of a number of recognised and accepted best practice guidelines. This includes measures from TP90, GD05 and Transport Agency ESC guidance to provide for good management practice. Best practice and lessons learnt from other projects have been incorporated into the Project erosion and sediment control measures to provide a further degree of certainty and effectiveness of such controls.

The process of undertaking the earthworks includes the future development of CESCPs prior to works commencing. The ESC design undertaken at this stage provide a high level assessment to provide confidence that the BPO measures can be implemented on this site taking into account specific issues such as flooding and terrain. The assessment of water quality changes includes assessing the proposed ESC device type for some specific identified activities and provides for a process with the CESCPs for further assessment of other activities. The predicted performance of the erosion and sediment control devices under a range of rainfall conditions is detailed within the catchment sediment modelling and includes the predicted duration, season and staging of construction.

We recommend conditions are developed that reflect the best practice methodology in this report to provide certainty that the performance assumptions inherent in the assessment of effects are reflected in the implementation phase.

As detailed within the assessment, and to be reinforced through the CESCPs, prior to any earthworks commencing the erosion and sediment controls will need to be installed and during earthworks these will require maintenance throughout. All erosion and sediment controls will remain in place until the contributing catchment areas are stabilised.

As part of this assessment we have identified risk locations including areas of steep terrain and also works within flood plains. The ESC design will consider these elements and confirm the use of specific control measures such as contour drains and progressive stabilisation to reduce this risk. Within the 20 year ARI flood extent, where possible devices will be located outside of the 20 year ARI flood extent. However, in the area of Wayby Valley Road, to the north of the Hōteo Viaduct, it is unlikely that all devices would be able to be sited outside of the floodplain, given the extensive area of the floodplain. In this area we have accounted for the flood risk and water quality effects of locating the ESC devices within the floodplain, as assessed in the Catchment Sediment Modelling technical report. If devices must remain in these locations the practice of bunding and regular maintenance has been emphasised.

Overall the provision of a continuous improvement monitoring programme is a key element of the earthworks programme. This allows for ongoing knowledge of water quality following a rain event, allows for issues and opportunities to be identified early in the process prior to any effects occurring and therefore allows for the ability to amend or improve such erosion and sediment control practices (structural and non-structural) to directly address such identified issues. This monitoring programme also will assist with confirming sediment yields and in that regard will assist with understanding any further mitigation that may be required as works progress.

The monitoring programme is designed as a critical element in ensuring that the design and suitability of erosion and sediment control measures remain.

6.3.3 Water quality

Criteria / consideration for the assessment

The potential effects of the Project on recreational uses were assessed against the following criteria. After reasonable mixing, the contaminant or water discharged shall not give rise to any of the following effects in the receiving waters:

i. Conspicuous oil or grease films, scums or foams, or floatable or suspended materials (RMA and AUP(OP) E11)
ii. Changes in colour and clarity than exceed ANZEEC guidelines for recreation guideline values (RMA and AUP(OP) E11)
iii. Any emission of objectionable odour (RMA and AUP(OP) E11)
iv. Excessive growth of aquatic plants (ANZECC).

Aesthetics and odour

Criterion (i) regarding discharges giving rise to oil and grease films

Oil and grease may be released in very small amounts due to accidental spills on the Project. Any conspicuous oil and grease films that develop would be temporary. We consider the risk can be identified within the CEMP and CESCPs with an associated management response. With this management in place we consider the effect to be minor.

Criterion (i) regarding discharges giving rise to foams and scums

During water quality sampling undertaken in the catchment, the Project team noted some films, scums or foams at the sample points on the Maeneene, Mahurangi and Hōteo River. The scums and foams observed appeared to be biofilms. Forest harvesting may have some impact on bio-films, but any change is likely to be very temporary in nature and to be minor.

The monitoring did not observe nuisance algal growth, although the monitoring occurred predominantly in winter months when algal growth is less likely to occur. Algal blooms are a potential cause of foams and scums. A number of factors contribute to algal blooms including light, water temperature, flow and nutrient concentrations.

We consider that the receiving environment is not likely to develop nuisance films and scums as a result of construction water discharges including from oil or chemical spills.

The release of small quantities of floatable materials (in particular litter) may occur during construction. Litter, in particular plastics and their persistence in the marine environment makes them problematic. We consider the risk of conspicuous floatable or suspended material can be managed through the CEMP and CESCPs.

Criterion (ii) regarding discharges giving rise to changes in colour and clarity.

The predicted increase in sediment yield during rain events is likely to result in temporary changes in water colour and clarity after storm events. The sediment yield from the construction areas will be made up of clays and fine silts and may contribute to changes in colour and clarity. (Hughes, 2014) found positive correlation between turbidity, total suspended sediment (TSS), and visual clarity, from water samples collected under event flow conditions in the Hōteo River.

The ANZECC guidelines (ANZECC/ARMACANZ, 2000) provides visual clarity and colour guidelines to protect the aesthetic quality of water bodies these include;

- The natural visual clarity should not be reduced by more than 20%; and
- The natural hue of the water should not be changed by more than 10 points on the Munsell Scale colour scale.

Panel studies undertaken by Davies-Colley, 1991 in New Zealand showed that almost all people can detect a change of 30% in visual clarity. For the smaller streams located close to the Project earthworks, the increases in visual clarity may exceed 30% in events and on an average annual basis, and in these watercourses, changes in clarity are likely to be noticeable and exceed the ANZECC guidelines. However, such changes will be temporary, restricted to during and after storms.

A study of the optical clarity of the Mahurangi Estuary (Davies-Colley et al., 2009), suggested an increase greater than 25% in TSS as a threshold for an unacceptable change in clarity in the Mahurangi Estuary. The flushing time for the Mahurangi Estuary has been estimated at approximately 2 days (Mead et al., 2007). The Kaipara Harbour has a similar catchment geology, land-use and flushing time as the Mahurangi. (Heath, 1976) estimated the residence time of water in the Kaipara as five tidal cycles or 2.6 days. For the purposes of this assessment we have considered it appropriate to assume the same TSS threshold for Kaipara as for the Mahurangi.

Based on sediment loads, in all of the modelled events (as per Tables 20 to 25 above), the post-treatment increases in TSS concentrations are varied with the largest percentage increase in sediment loads within the Kourawhero, Waiteraire and Tributary H2, and particularly for more significant rain events. When considering the risk management framework that will apply (including the low probability of a 50 year rain event occurring,) the staging of the earthworks, the 14 day progressive stabilisation requirement, open area limits and also the ability to forecast large rain events and therefore proactively manage risk with on site measures and maintenance provisions, it is assessed that any increase in sediment concentration will be short term and temporary only. The largest sediment concentration increases are expected to occur in the steeper smaller catchment locations with a large degree of earthworks proposed and with existing landuse in a vegetated state. These areas will be subject to an increased construction water management focus, and erosion and sediment control management, through the risk profile and management of the CESCP process.

New Zealand research has shown that people value blue and green hues in water but not yellows and reds (Smith and Davies Colley 1992). Davies-Colley (1991) recommends a change in hue of more than 10 points on the Munsell scale as a maximum increase, this is reflected in the ANZECC guidelines (ANZECC/ARMACANZ, 2000). In the Hōteo, Maeneene, Te Hana and Mahurangi the freshwater has yellow hues, related to the weathered clays in the catchments, with Munsell values ranging from 20 - 37.5 (Water Quality technical report). For all individual sites the range is equal to or less than 10 points. The monitored data was collected in wet and dry weather for a range of turbidity conditions. In most locations and for most events we expect changes of less than 10 points, although in tributary streams close to discharge locations colour changes greater than 10 points may occur temporarily during storms. However, any change in colour will be localised to the tributaries with the largest predicted increases in TSS. The changes will be temporary, restricted to the period during and after rainfall events.

Overall, we consider the effects on colour and clarity will be localised in extent and of a temporary duration only.

Criteria (iii) and (iv)

Algal blooms and eutrophic conditions can cause objectionable odours. We do not expect the predicted increases in nutrients associated with sediment to cause the conditions that would result in a noticeable change in odour in freshwater or marine environment.

Overall, we consider the effects of the Project will not give rise to effects on aesthetics and odour and the effects will be temporary.

Monitoring

The provision of a continuous improvement monitoring programme is a key element of the earthworks programme to assist with determination of the effects of the Project earthworks activity. This allows for ongoing knowledge of water quality following a rain event, allows for issues and opportunities to be identified early in the process prior to any effects occurring and therefore allows for the ability to amend or improve such erosion and sediment control practices (structural and non-structural) to directly address such identified issues. This monitoring programme in itself is a critical element in ensuring that the design and suitability of erosion and sediment control measures remain and allows mitigation for any residual sediment discharges to be determined based on sediment yields that are measured from the Project.

6.3.4 Human Impacts

Criteria / consideration for the assessment

The potential effects of the Project on recreational uses were assessed against the following criteria:

i. The extent to which the discharge would avoid contamination and avoid more than minor adverse effects on the health of people and communities as affected by their contact with fresh water (NPS-FW); and

ii. The extent to which significant adverse effects are avoided where there is high recreational use (AUP(OP) E11).

Recreational use

Criteria (i) and (ii)

Auckland Council freshwater data indicates that the current suitability of the Hōteo River (and catchments) and Mahurangi River for recreational use is 'fair' quality with some sections being classified as having poor or intermittent quality (http://www.mfe.govt.nz/fresh-water/about-freshwater/auckland). The river sites monitored by Auckland Council exceed E. coli indicators for swimming on some occasions. The Auckland Council data is consistent with the data we have collected, where all freshwater sites exceed E. coli on some occasions.

There are no major bacterial sources predicted in the construction phase. Sediment retention ponds are not habitat for wildfowl and we do not predict an increase in *E. coli* discharges as result of construction discharges and therefore we anticipate effects on human health will be negligible.

The river sites monitored by Auckland Council exceed clarity indicators for swimming on some occasions. The Auckland Council data is consistent with the data we have collected, where no sites meet the visual clarity standard for swimming

The Mahurangi Estuary, Kaipara Harbour and Oruawharo River are popular for secondary contact (boating), and for swimming in some locations. The mid to upper parts of the Mahurangi Estuary have poor clarity, generally less than 1.6m and do not meet the ANZECC contact recreation water quality guidelines for clarity (ANZECC 2000). The clarity of the lower Mahurangi Estuary is good and meets standards for contact recreation, with clarity generally greater than 1.6 m (Davies-Colley et al., 2009). The suspended sediment concentration at the Kaipara Harbour mouth is below guideline values indicating that the elevated sediments from the Hōteo and Oruawharo river mouths settle out prior to reaching the Kaipara Heads.

The increases in sediment load may result in changes in clarity that are noticeable, but we do not predict these temporary changes in clarity will alter the suitability of the freshwater or marine receiving environments for contact recreation. It is recognised that both the Mahurangi and Kaipara Harbours are popular for secondary contact (boating), but less popular for swimming.

We consider the temporary changes in colour and clarity associated with the Project will have minor effects on recreational values in the Mahurangi, Kaipara, freshwater and marine environments. Long term contamination is avoided through the provision of appropriate construction water management measures. Recreational use is not expected to be impacted in any way through the Project construction period.

Overall we consider the change in water quality associated with the construction runoff during the construction phase to have a negligible impact on health of people and communities as affected by their contact with fresh water and/or marine water.

6.3.5 Drinking Water

Criteria / consideration for the assessment

The potential effects of the Project on drinking water were assessed against the following criteria

i. After reasonable mixing, the contaminant or water discharged shall not introduce or increase the concentration of any aesthetic determinands in the drinking water so that, after existing treatment, it contains aesthetic determinands at values exceeding the guideline values. (NES for sources of human drinking water)

ii. After reasonable mixing, the contaminant or water discharged shall not have a significant adverse effect on the quality of the water at any abstraction point. (NES for sources of human drinking water)

Drinking water

Criterion (i)

Watercare currently takes water for Wellsford's potable water supply from a surface water take upstream of Wilson Road. Watercare has advised that if a groundwater supply can be confirmed, it will be several years before there would be a complete transition from the river supply to groundwater supply

Watercare has also recently surrendered its consent for a surface water take and replaced it with groundwater abstraction for Warkworth and have confirmed a change from surface water to groundwater abstraction occurring at the end of 2018

The water taken from the Hōteo and Mahurangi Rivers is treated to meet drinking water standards.

The Project construction is expected to increase the level of sediment within the Hōteo and Mahurangi Rivers, which can impact on the treatment of water. An increase in sediment will result in increased turbidity which has aesthetic effects. The release of sediment will result in the release of particulate nitrogen. Nitrate and Nitrite are nutrient compounds with human health significance.

The increase in nutrients as a consequence of increased sediment during the construction period is not expected to alter the quality of the source compared to NZ drinking water standard values (NZDWS 2008) for nitrite and nitrate, neither of which are elevated at the source in the monitoring data.

Our modelling predicts an increase in sediment load of less than 1% (mean annual sediment load increase) at both the Watercare water abstraction site on the Hōteo River.

The turbidity of surface water within the Hōteo and Mahurangi Rivers at the water take abstraction sites regularly exceeds the NZDWS 2008 values, but the water is treated by Watercare to meet the relevant NZDWS 2008 standards (less than 2.5NTU).

There may be instances where the turbidity in the Hōteo and Mahurangi Rivers exceeds the ability of the water treatment plant to meet NZ drinking water standard values (NZDWS 2008). This is typically due to land use and rainfall above the water treatment plant intake.

Our modelling indicates the construction water discharges would have only a small influence on whether increases in turbidity might occur. We expect that the background sediment load would be the main driver for determining when the raw water quality is approaching the treatment capability limits of the either water treatment plant.

We recommend a condition is developed that requires the Transport Agency to inform Watercare if a spill occurs or a larger rainfall event where large sediment loads are discharged from the site, so Watercare is able to determine what action, if any, is required. With this condition in place, we would assess the risk to the drinking water supply to be minor. We also recommend that Watercare be informed of, and sent any specific CESCPs, for works within the water supply catchment location to allow for awareness of pending works in such catchments.

Criterion (ii)

There is the potential for an accidental spill of contaminants (including sediment) entering the Hōteo or Mahurangi Rivers during construction, for example due to an accident involving a truck. If an accidental spill occurred, it is likely that a large proportion of contaminants would be intercepted by the sediment retention devices, but some residual contaminants may be discharged into the Hōteo or Mahurangi River. This is a temporary state only and after reasonable mixing it is assessed that there would be negligible impact on the quality of any water at any abstraction point.

6.3.6 Water users

Criteria / consideration for the assessment

The potential effects of the Project on other water users were assessed against the following criteria:

i. The rendering of freshwater unsuitable for consumption by farm animals must not occur; (RMA Section 107, E11); and

ii. the extent to which significant adverse effects are avoided where there is collection of fish and shellfish for consumption (AUP(OP) E11.3(7)).

Assessment of effects on water users

Criteria (i) and (ii)

The monitoring undertaken for the Project indicates that the freshwater meets guidelines for consumption by farm animals for the parameters that the Project may influence. The predicted increase in sediment and sediment bound nutrients is expected to have a negligible effect on the drinking water quality for stock.

Significant adverse effects will be avoided by the implementation of a robust erosion and sediment control programme that includes both structural and non-structural control measures. This is inclusive of progressive stabilisation and a comprehensive monitoring programme.

With the exception of the Watercare surface water abstraction on the Hōteo River, there are no consented surface water abstractions on watercourses within the Mahurangi, Hōteo or Oruawharo catchments that may be affected by the Project.

The permitted surface water abstraction rule in the Auckland Unitary Plan allows the taking and use of no more than 5m^3/day of water from a river, stream or spring, outside of the wetland management area overlay, subject to conditions. No information on permitted users is available from Auckland Council.

Freshwater consumption for farm animals will continue to be able to occur with only those that take water immediately downstream from a sediment discharge likely to have a temporary, moderate level of effect.

The collection of fish and/or shellfish within the marine environment is assessed as having no impact.

Overall we consider the potential effect on existing and foreseeable water users to be minor with potential moderate effects depending on the proximity of users to the Project discharges.

6.3.7 Flooding

Criteria / consideration for the assessment

The potential effects of the construction phase of the Project on flooding were assessed against the following criteria:

i. The diversion of water must not cause or worsen the flooding of any property in a range of flood events (AUP(OP) E7).

ii. Whether the earthworks and final ground levels will adversely affect overland flow paths or increase potential volume or frequency of flooding within the site or surrounding sites (AUP(OP) E12).

iii. Maintain the function of overland flow paths to convey stormwater runoff safely from a site to the receiving environment (AUP(OP) Policy E36.3(29)).

iv. Require changes to overland flow paths to retain their capacity to pass stormwater flows safely without causing damage to property or the environment (AUP(OP) Policy E36.3(30)).

v. Require earthworks within the 1 per cent annual exceedance probability (AEP) floodplain to do all of the following:

    a) remedy or mitigate where practicable or contribute to remedying or mitigating flood hazards in the floodplain;

    b) not exacerbate flooding experienced by other sites upstream or downstream of the works;

    c) not permanently reduce the conveyance function of the floodplain. AUP(OP) Policy E36.3(20)); and

vi. Require the storage and containment of hazardous substances in floodplains so that the integrity of the storage method will not be compromised in a flood event (AUP(OP) Policy E36.3(22)).

Assessment

Criteria (i) to (vi)

All temporary and permanent culverts and diversions will be designed to accommodate the 1 in 20-year flood event, and therefore there will be no change in flooding for events up to this size.

There is less than 30% chance of an event larger than the 1 in 20-year flood occurring across the 6-year bulk earthworks construction period however if such an event occurred during the construction period there might be some localised flooding associated with culverts and stream diversions. No changes to flooding depth, extent or hazard are anticipated outside of the proposed designation boundary, as diversions will be designed to accommodate and pass the 1 in 100 year flows through the works location. As such the effect is assessed to be negligible.

Some construction areas are within designated floodplain and overland flow paths, as such there is the potential for construction within these areas to result in changes to flooding outside of the proposed designation boundary. This flooding would be equal to or less than the changes associated with the operational phase.

Construction works within flood plain areas will be avoided as a first step and where works are required within flood plain areas such as those associated with culvert placement the risk profile is increased and the methodologies adapted for these areas. This includes ensuring that such works are undertaken during predicted fine weather windows and when weather conditions deteriorate ensuring that stabilised flow paths are available.

As such the effect of earthworks within floodplains during construction will be minor or less. Works within overland flow paths will also be avoided where possible to ensure the function of such overland flow paths is retained.

Storage of any hazardous substances, such as polyaluminium chloride, will not occur in flood plain locations and if required to be located in these areas on a temporary basis will be removed from the flood plain to higher ground before any significant rain event.

6.3.8 Streams

Criteria / consideration for the assessment

The potential effects of the construction of the Project on streams were assessed against the following criteria:

i. proposals to divert surface water required to demonstrate the diversion will to the extent practicable avoid significant adverse effects and remedy or mitigate other adverse effects including where relevant, effects on existing buildings, structures and services, existing flood hazards, river bank stability, people and communities and the life supporting capacity of freshwater (AUP(OP) Policy E2.3(22)).

ii. the effects on downstream lake, river or stream or wetland environments arising directly from the activity, and any effects arising from any permanent modification in stream state or function caused by the activity (AUP(OP E3)).

iii. the construction methodology, including the timing and duration of the activity and erosion and sediment controls, and location of mixing of construction materials and refuelling or maintenance of equipment and best site management practice must be used to avoid contaminants discharging into the water (AUP(OP) E3)).

iv. upstream or downstream flooding effects (AUP(OP) E3).

Assessment

Criteria (i) to (iv)

The Construction Water Design technical report outlines the design the will apply to all streamworks activities which is based on a best practicable option approach. This includes a robust methodology whereby works within stream systems will be minimised and if necessary and practicable will be undertaken in the "dry". This is achieved by methodologies such as creating formal stream diversions or pumping upstream flows past the works location. Duration of activity is also a key element with reducing during and extent of works a key non-structural element.

All stream works activities (including diversions) will be detailed in full within the applicable CESCP and this will confirm that no diversions of stream flows will impact on downstream buildings or structures.

We have considered the above criteria and conclude that subject to the imposition of the recommended consent conditions, overall the Project streamwork activities are consistent with them. We consider it to be of critical importance that the indicative methodology is appropriate in that all works are to be undertaken in a dry environment with full stream flows diverted around the works area where practicable. No refuelling activities will occur in these locations and all machinery will be serviced away from the flood plain location to ensure minimisation of spills. While these details are proposed within the methodologies, CESCPs will be established which will confirm the specific methodologies and approaches to be undertaken.

Overall, we assess the effects of the streamworks construction activity as minor.

6.4 Recommended management approach

The following section outlines the construction water management process and procedures that we recommend to provide for construction water design, maintenance and monitoring to address identified potential adverse effects. These recommendations build on the assessment that has occurred including the modelling outcomes and also the risk based assessment process undertaken.

6.4.1 ESC objectives

It is considered important that when managing earthworks and the potential for erosion, and sediment yields, during construction of the Project, that key construction water management objectives be detailed for achievement as follows. These objectives are recommended to be stated within each CESCP and to have associated commentary as to how that specific CESCP achieves these objectives:

- To minimise the volume and area of the proposed earthworks required for the Project through appropriate earthworks design which is closely linked to slope and expected soil types and geology; and
- To maximise the effectiveness of erosion and sediment control measures associated with earthworks by minimising potential for sediment generation and sediment yield.

6.4.2 Management Plans

A number of management plans will be required to be developed and submitted prior to construction activity associated with the Project. This includes;

- an overall Construction Environmental Management Plan to detail the overarching construction related activities;
- a Project wide Erosion and Sediment Control Plan that collates all the design details of water management measures and confirms the principles and practices that will apply;
- A Chemical Treatment Management Plan which outlines associated bench testing and analysis; and
- a Construction Erosion and Sediment Control Plan (CESCP) that specifies the detail of specific construction activities or locations and associated water management practices to be implemented.

CESCPs will provide the detailed design, specific ESC measure location, staging and sequencing of works for that location and will be developed prior to works commencing in these locations. The CESCPs will determine specific measures to be employed and will also consider any alternatives that exist.

The CESCPs will determine the most effective and appropriate form of construction water management devices and management practices required to manage discharges during the construction period with recognition of the environmental values for that location.

As part of the Project implementation, the CESCPs will follow the principles and approach outlined within this report and will also confirm specific design details.

The implementation of site specific CESCPs will further allow for innovation, flexibility and practicality of approach to construction related water management. They will enable the construction team to have ongoing input into the ESC measures and practices prior to and during construction. This CESCP process allows the construction water management measures utilised within the Project to continually adapt to changing construction, environmental and climatic conditions. While the exact form of the CESCP will be determined at the time of development, as a minimum these documents need to comment and provide details on all of the following items:

CESCPs will include:

- Contour information;
- ESC measures for the works being undertaken within a particular construction area;

- Chemical treatment design and details;
- Catchment boundaries;
- Location of the work;
- Details of construction methods;
- Design criteria, typical and site specific details of ESC measures including ensuring that all sediment retention ponds and decanting earth bunds have full access track provisions for maintenance at all times;
- Identification of risk and sensitive area locations and the details of management (including contingency measures) around these aspects;
- Details of open areas that exist for the project at the time of the CESCP and a programme for managing ongoing non-stabilised areas;
- The identification staff and resources who will manage and maintain all ESCs;
- The identification of staff who monitor compliance with conditions;
- Details of specific resources and responsibilities for managing environmental issues on site to ensure that any resultant conditions of consent are complied with;
- Methods and procedures for decommissioning measures; and
- Design details for managing the treatment, disposal and/or discharge of contaminants (e.g concrete wash water).

In addition, each CESCP must clearly illustrate on a plan the specific location and boundaries of the CESCP (in the context of the wider Project) and what activities are addressed within them.

6.4.3 Erosion and Sediment Control Design

Importantly the design criteria for all erosion and sediment control measures will be based on a best practice approach and includes details from TP90, GD05 and the Transport Agency Standards. It is recommended that some water management measures will exceed the design guidance provided in those documents through a more conservative design. These include:

1. All sediment retention ponds and decanting earth bunds are sized at 3% of the catchment area with full access track provisions for maintenance at all times;
2. The adopted silt fence design, follows the design provided in TP90 and Transport Agency ESC Guidelines with a return upslope to ensure robustness of the device;
3. The sizing of temporary diversions for clean and dirty water is for the 100 year ARI event; and
4. All sediment retention ponds with contributing catchments greater than 2ha will be required to have 2 flocculation sheds installed.

While the CESCP will finalise and confirm these provisions, Items 1, 2 and 4 must be implemented at all times.

6.4.4 Streamworks

It is recommended that prior to any streamworks commencing on the site, development of a final methodology for the streamworks (through a CESCP) needs to occur, with particular emphasis on timing, staging and sequencing of streamworks, to outline how effects on streams will be managed.

6.4.5 Open Area Limits and Stabilisation

It is recommended that open area limits be imposed within the earthworks construction and that clear and robust criteria be established in conditions as to when and how open areas can be reviewed. These open areas will reflect the same areas as utilised within the Catchment Sediment Modelling technical report. It is recommended that the open earthwork area limits apply to match the sediment model inputs with the ability to amend these limits (on a catchment basis) based on the results and outputs of the monitoring programme. To achieve an amendment to the open area limits the following detail must be provided to allow for analysis:

- Through a robust comparable analysis of earthworks programme, erosion and sediment controls and water quality outcomes, confirm that actual sediment yields are less than that modelled;
- Provide a minimum of 12 months of monitoring data to support such an amendment which needs to include water quality results from the 4 automated sampling devices as detailed in Section 5.4.5; and
- Identification of areas for continuous improvement opportunities for future earthworks.

This information will need to be carefully assessed and supported by robust analysis including Project specific water quality outcomes.

It is further recommended there be the ability to assess open area increases on a month by month basis if required. This monthly review with conditions (including a formal review of open areas on a regular basis) could be supported through conditions of consent.

To ensure a risk based approach continues to be implemented it is recommended that progressive stabilisation within 14 days of completion of earthworks within an area of works. Where Project areas are not actively worked for more than 14 days the area will be stabilised. This will encourage and enforce the need to ensure that potentially erodible areas are not left exposed for long periods of time

The 14 day stabilisation period is further defined as below:

- Stabilised Area is defined as an area inherently resistant to erosion such as rock, or rendered resistant by the application of aggregate, geotextile, vegetation or mulch. Where vegetation is to be used on a surface that is not otherwise resistant to erosion, the surface is considered stabilised once an 80% vegetation cover has been established.

- The method of stabilisation is dependent upon site conditions and may include use of mulch and/or other woody organic matter, geotextile, the use of hard fill material and exposing rock.

- Actively worked means actively subject to earthworks production with cut and fill, stockpiling or topsoil removal.

- Areas of earthworks will be monitored on a weekly basis with ongoing field checks and understanding of production locations. A register of areas subject to earthworks, including timing, will assist in this process.

- The 14 day period (or otherwise agreed) will apply to all earthworks and will include parts of larger earthwork footprint locations. The overall intent is that if the Project is not working an area (or part of an area) then the stabilisation period provision applies.

6.4.6 Monitoring and continuous improvement

Incident reporting and applying incident procedures and requirements is recommended. Where a failure of a construction water control measure results in a discharge to a watercourse then reporting and remedial actions need to be actioned as necessary.

It is further recommended that implementation of a continuous improvement monitoring programme whereby the site and associated works are monitored using both qualitative and quantitative measures, sediment yields assessed on a selection of SRPs (4 SRPs recommended) and Project wide, and improvement opportunities identified for implementation. The monitoring programme should include ecological response as required and the ability to amend key items such as open area limitations imposed on the Project earthworks.

6.4.7 Training

Within the CEMP it is recommended that ongoing training to assist with environmental awareness and consent condition requirements should form part of the Project prior to the commencement of work in any stage.

6.4.8 Water users

To ensure effects on water users are managed appropriately it is recommended that the Project should:

- Make good any damage to water abstractions impacted by increased construction related discharges;

- Provide a temporary alternative supply of water if water is not suitable for existing use following the discharge of sediment from the Project; and

- To inform Watercare if a spill or large event occurs that releases large load of sediment upstream of the abstraction, so Watercare can take action to protect their surface water take.

- To ensure CESCPs within catchments that are subject to water takes from Watercare are developed with awareness of these water takes and that the final certified CESCPs are provided to Watercare.

6.5 Construction water management conclusion

Overall it is concluded that the state of technical knowledge associated with construction water management for this Project is robust and provides certainty and a very high likelihood that the construction water management measures as detailed within this report can be successfully applied. This includes a critical component referred to as a continuous improvement management approach which is informed by ongoing monitoring and allows for ongoing knowledge of water quality aspects. It also enables issues and opportunities to be identified early in the process prior to any effects occurring and therefore allowing for amendments or improvements to erosion and sediment control practices (structural and non-structural) to directly address such identified issues. This monitoring programme will also assist with confirming sediment yields during large rainfall events and in that regard will assist with understanding any further mitigation for marine effects that may be required as works progress through comparison with the thresholds set out in the Marine Ecology and Coastal Avifauna Assessment.

It is concluded that, with the recommended control measures in place, any change in water quality associated with the construction runoff during the construction phase will have a negligible impact on health of people and communities as affected by their contact with fresh water and/or marine water. There is the potential for an accidental spill of contaminants (including sediment) entering the Hōteo or Mahurangi Rivers during construction however this is a temporary state only and after reasonable mixing it is assessed that there would be negligible impact on the quality of any water at any abstraction point.

The effect of earthworks within floodplains during construction will be minor and storage of any hazardous substances, such as polyaluminium chloride, will not occur in flood plain locations and if required to be located in these areas on a temporary basis will be removed from the flood plain to higher ground before any significant rain event.

It is concluded that, provided the recommendations as detailed in Section 6.4 are implemented and any construction water discharges are subject to best practice management, then effects can be appropriately managed through the ability to monitor and adapt structural and non-structural controls as works proceed.

7 OPERATIONAL PHASE MITIGATION BY DESIGN

Section Summary

The stormwater design philosophy and requirements of the operational water system proposed for the Project are summarised from the Operational Water Design technical report.

The key features of the Indicative Design for operation water design are:

- Cut-off drains to separate "clean" water from the Project.
- The stormwater reticulation systems collect the stormwater from the road and adjacent areas and convey these to the stormwater treatment devices.
- Sediment traps in drains at the base of rock cut faces.
- Constructed stormwater wetlands as the primary stormwater treatment device. The Indicative design includes 34 stormwater treatment wetlands for the Project's impervious surfaces totalling approximately 198 ha.
- Conveyance of water runoff from local roads will be via vegetated or rock lined swales.
- Stream diversions are required where it is necessary to realign a natural stream channel including to connect an existing stream to a new culvert.
- Wetland and culvert outlets will incorporate energy dissipation structures and/or erosion protection measures to minimise stream bed scour and bank erosion in the receiving waterway.
- 85 culverts have been designed for the Indicative Alignment, which includes stream crossings under the road and land drains.
- 5 bridges and viaducts associated with river crossings.

7.1 Stormwater philosophy and requirements

Operational water management is primarily achieved by the provision of an effective stormwater management approach. This section sets out the philosophy and principles used to guide the design of this.

The design will integrate the stormwater collection and conveyance network, treatment systems and devices, culverts and watercourse diversions and consideration of the floodplain. The design will include a range of water sensitive design solutions including stormwater treatment wetlands to deliver stormwater hydrology (flow) and stormwater quality (treatment) mitigation. The design considers the operation and maintenance of stormwater systems through the design life of the asset. Also, the design considers the health and safety of road users and maintenance staff, which is an especially important consideration for a state highway with high speed vehicles. These health and safety considerations mean that lower maintenance stormwater systems are preferred and that these are ideally located outside of the road corridor (outside of barriers).

The proposed requirements for operational water management include:

- Stormwater will be treated in accordance with GD01;
- Removal of gross litter and floatables such as oil and volatile hydrocarbons;
- Hydrological mitigation for the increase in flows from new impervious areas by providing detention and controlled release over a 24-hour period for the 95th percentile rainfall event surfaces;
- Avoid or mitigate changes that may otherwise worsen existing flood issues and not significantly increase flood risk at existing properties outside the proposed designation boundary;
- Set the road level with a freeboard above the predicted 1 in 100 year climate change flood levels in accordance with NZTA standards;
- Stormwater runoff depths will be managed to provide safe serviceability of the road to NZTA standards;
- Overland flow paths will be provided to allow for flows up to and including the 100 year ARI storm inclusive of climate change;
- Outfalls will be assessed and where required will incorporate energy dissipation and erosion control measures to minimise stream erosion;
- Provide design outcomes to support replacement habitat in stream diversions to match the habitat lost in the diverted stream; and
- Provide design which enables fish passage in culverts for all permanent streams with upstream habitats, and for intermittent streams where there is potential for fish habitat upstream.

A number of design guidelines and standards have been used to inform the specific design criteria to be used in the design of the various operational stormwater features of the project, as detailed in the Operational Water Design technical report. Two fundamental guidance documents are:

- Auckland Council - Stormwater Management Devices in the Auckland Region; December 2017; Guideline Document 2017/001 Version 1 (GD01), as this provides the basis for designing stormwater treatment devices; and
- NZ Transport Agency: P46 Stormwater Specification; April 2016, as this documents the standards that NZTA require for stormwater management covering wider issues than environmental mitigation e.g. aquaplaning requirements and for culvert flood performance.

7.2 Operational water design

The Operational Water Design technical report provides an overview of the operational water systems for the Project. The key features of the operational water system are described in the sections below.

It is anticipated that further development of the Project design at future stages of the project and the stormwater treatment wetland locations and sizes will be further refined with consideration given to whole of life costs, landscape, constructability, maintenance and ecological values.

If forestry harvest occurs prior to project commencement and increased peak flows are predicted to occur during Project operation as a result, this will be addressed the during detailed design of the proposed stormwater management.

7.2.1 Cut-off drains

Clean water cut-off drains are provided above cut sections to divert “clean” stormwater runoff from the natural catchment that falls towards the Indicative Alignment. Cut-off drains are also provided along the toe of fill slopes to collect the clean runoff from these rehabilitated areas.

Cut-off drains have been designed to cater for the 100 year ARI rainfall event for the upstream catchment and will either discharge to existing streams, watercourses or to new culverts, or to the road edge conveyance system where this is not possible.

The cut-off drains will be grassed or rock lined channels to prevent erosion.

The location of the proposed cut off drains associated with the Indicative Alignment are shown on the SW series drawings and a typical detail of a cut-off drain is shown in the Project Drawing Set.

7.2.2 Stormwater reticulation

The stormwater reticulation systems collect the stormwater from the road and adjacent areas and convey these to the stormwater treatment devices. The stormwater reticulation has not been designed for this phase of the Project as it is not material to the consent applications. The discharge locations relate to the stormwater wetland locations that are outlined for the Indicative Alignment and management approaches (quality/quality/erosion) are detailed in the following sections.

An indicative stormwater reticulation has been included in the cross-section drawings in order to inform the Indicative Design of the state highway footprint.

Future stormwater reticulation may include the following types:

- Kerb/channel/catchpit/pipe;
- Drainage channels/swales;
- Rock trap drainage channels; and
- Inlet and outlet structures (i.e. inlets and outlets from wetlands, from state highway and/or streams).

7.2.3 Vegetated or rock lined roadside drains

A number of local roads will be modified as part of the Project as listed below:

- Carran Road;
- Woodcocks Road;
- Kaipara Flats Road;
- Phillips Road;
- Wayby Valley Road;
- Rustybrook Road;
- Farmers Lime Road;
- Silver Hill Road;
- Mangawhai Road;
- Vipond Road;
- Maeneene Road; and
- Waimanu Road.

Conveyance of water runoff from these local roads will be via vegetated or rock lined swales adjacent to the road. These swales will discharge to existing streams.

Roadside swales and open drains are commonly used around New Zealand and are generally "U" shape in profile. Their primary function is collection and conveyance of runoff. They are not a GD01 device. However, research[5] has shown that vegetated drainage channels are effective at TSS removal and achieve high removal rates of particulate and total copper and zinc.

These local roads have local space constraints (terrain, property boundaries), relatively low traffic volumes and we consider vegetated or rock lined roadside swales to be appropriate for the conveyance and treatment of stormwater runoff from these areas.

7.2.4 Sediment traps

Sediment traps are proposed for the Project in drains at the base of rock cut faces. These sediment traps are bespoke treatment devices that will assist in the capture of sediment generated from rock cuts.

We consider sediment traps are required based on the experiences and observations of the operational phase of the Northern Gateway Toll Road (NGTR) project, where cut faces have yielded larger sediment loads since becoming operational in 2009 than was

[5] Moores J, P Pattinson and C Hyde (2009) Enhancing the control of contaminants from New Zealand's roads: results of a road runoff sampling programme. New Zealand Transport Agency research report 395. 161pp

anticipated during the design of the NGTR project. This feedback was also considered for the P-Wk project and sediment traps are being designed and constructed for that project.

A typical detail for a sediment trap is shown in the drawings included in Volume 3: Drawing Set SW series.

7.2.5 Stormwater treatment

Constructed stormwater wetlands are proposed as the primary stormwater treatment device for the Project. The Indicative Design includes 34 stormwater treatment wetlands for the Project's impervious surfaces totalling 198.2 ha.

Stormwater runoff will be collected in the Project's stormwater reticulation and conveyed to the Stormwater treatment wetlands.

The stormwater treatment wetlands will provide water quality treatment in accordance with GD01. The wetlands will also provide hydrological mitigation by detention for the increases in runoff between the predevelopment and post-development runoff for the 95th percentile rainfall.

It is anticipated that with further design development of the Project that the wetland locations and sizes will be further refined with consideration given to landscape, constructability, maintenance and ecological values.

The stormwater treatment wetlands will be located off-line from existing streams and watercourses. Existing natural wetlands will not be used for the treatment of runoff from the Project.

The rationale for the indicative location of wetlands is as follows:

- Located to suit low points in the vertical alignment of the Indicative Alignment;
- Efficiently spaced to ensure consistent sizing and catchment sizes;
- Located close to the Indicative Alignment in order to minimise the overall Project footprint. Landscape fill along with soil disposal areas will be used as platforms for stormwater treatment wetlands for stormwater treatment. This reduces the overall footprint of the Project;
- Located out of the post-development 100 year ARI floodplain, wherever possible;
- Located close to the Indicative Alignment to provide convenient and safe access for maintenance; and
- Located to reduce conveyance of stormwater across bridges and viaducts.

A pipe or open channel will be provided to discharge treated stormwater from the stormwater treatment wetland to the nearest watercourse.

Wetland outfalls will incorporate erosion protection measures to minimise bed scour and bank erosion in the receiving waterway. Typically this protection would be through a culvert wingwall and/or energy dissipation device with rock aprons.

The indicative stormwater treatment wetland locations are shown in the drawings included in the Volume 3: Drawing Set SW series.

7.2.6 Stream diversions

Stream diversions are required where it is necessary to realign a natural stream channel including to connect an existing stream to a new culvert.

As culverts will normally be constructed offline in a dry environment and protected from flooding during construction, all new culverts require a minimum 10m of stream diversion upstream and downstream of the culvert to tie back into the existing stream. The offline construction methodology for culverts is described in the Construction Water - Design technical report.

All stream diversions should be designed to cater for a 100 year ARI rainfall event and will convey flows to/from a culvert, beneath a bridge or to another stream or water body.

The objective of the stream diversion design is to recreate streams and habitats that replicate, as much as is practically possible, the natural state and habitats of the streams that existed prior to the Project becoming operational.

Three stream diversion typologies are proposed as follows:

- Stream Diversion Type 1 – "Lowland Stream" that recreates habitats associated with a natural lowland stream.
- Stream Diversion Type 2 – "Steep Stream" that recreates habitats associated with a natural steep stream.
- Stream Diversion Type 3 – Flow Channel for flow conveyance only.

Typical details of these stream diversions are shown on Figure 22 to Figure 24 and the total lengths in the indicative operational stormwater design are summarised below:

- Stream Diversion Type 1 = 12,707 m
- Stream Diversion Type 2 = 5,554 m
- Stream Diversion Type 3 = 1,148 m

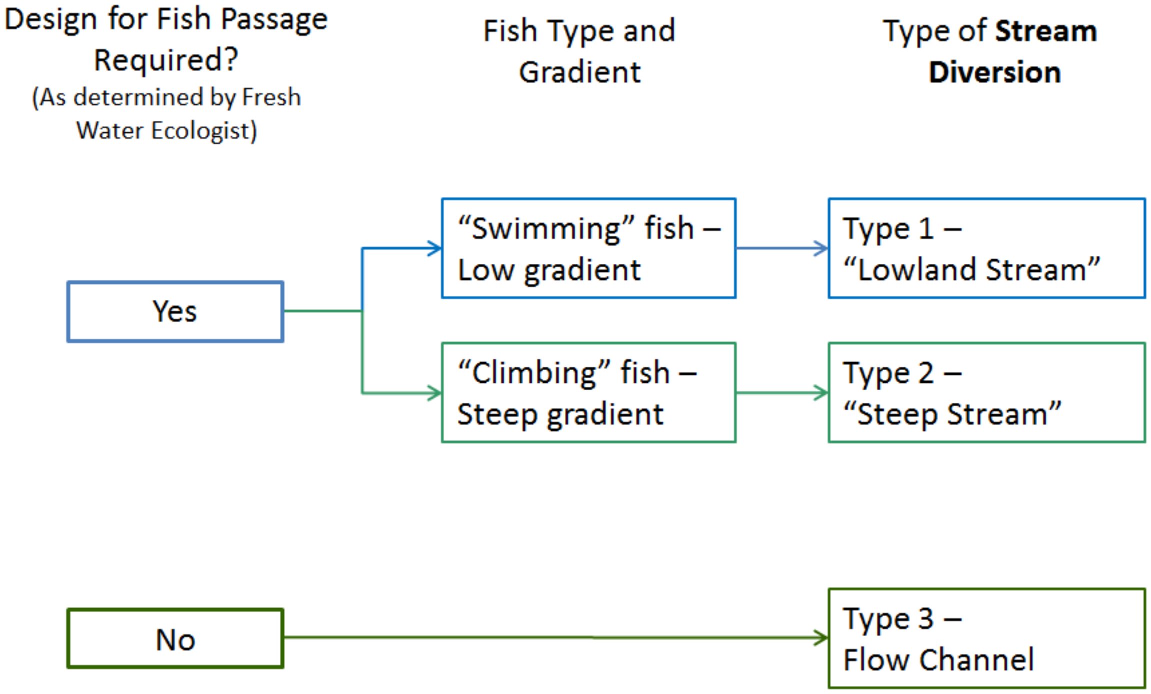

Figure 21 - Flow chart for stream diversion type

Fish passage will be required where there is currently fish habitat in or near the streams being affected, or where there is potential for future fish habitat. At this stage of the design, we have assumed that fish passage will be required in all these instances.

The stream diversion details below were developed for the P-Wk project in collaboration with that Project's freshwater ecologists together with input from Hōkai Nuku and we have adopted these in the design for this Project. These stream types are replicated the general stream typologies in the region and will be subject to further design refinement at detailed design stage.

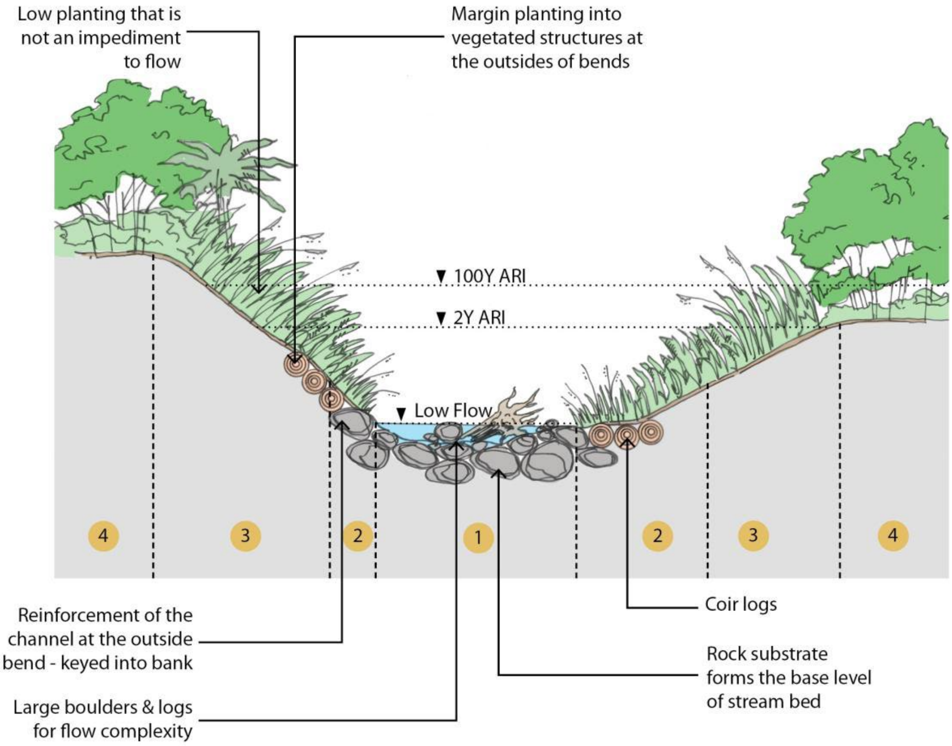

Figure 22 - Stream Diversion Type 1 – Lowland stream cross section

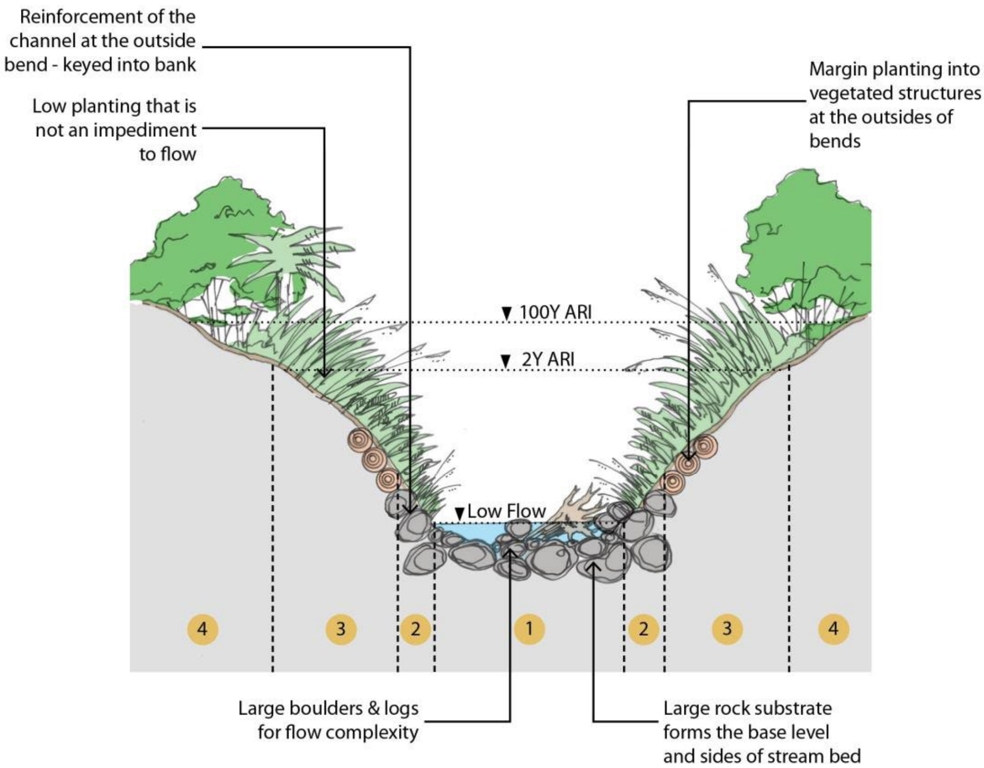

Figure 23 - Stream Diversion Type 2 – Steep stream cross section

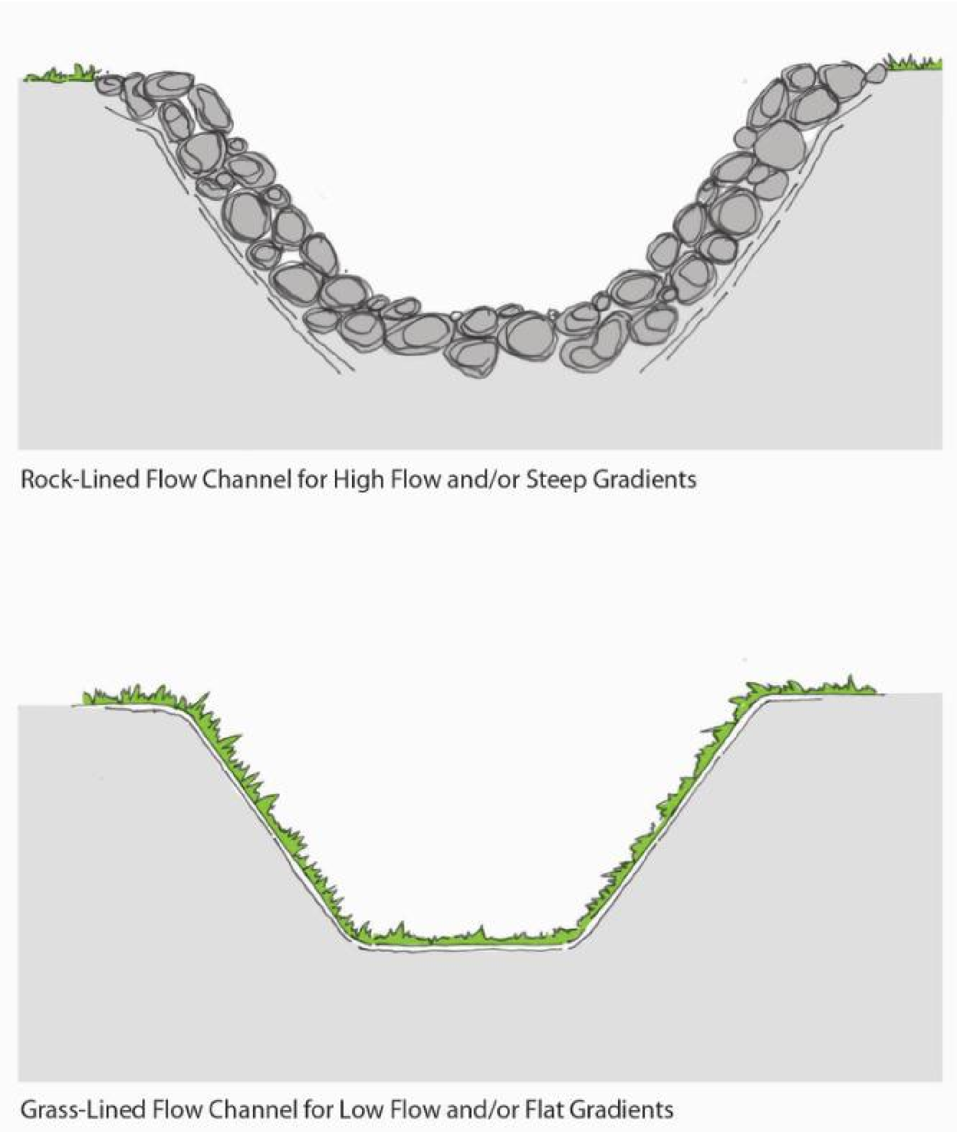

Figure 24 - Stream Diversion Type 3 – Flow channel cross section

7.2.7 Culverts

85 culverts have been designed for the Indicative Alignment for stream crossings under the road.

In general the culverts will likely be concrete pipes as they tend to be the most cost effective type of cross drainage. Culverts made from polyethalene have been used on the P-Wk project in several locations to meet specific requirements and are also possible for this Project.

The culvert sizes required for the Indicative Alignment were based on a range of requirements as detailed in Table 26 and are based on NZTA P46 Stormwater Specification and Austroads Guide to Road Design part 5 Drainage Design. The design methodologies are detailed in the Operational Water Design technical report.

Table 26 - Culvert Sizing Criteria

Culvert Sizing Criteria	
Aspect	**Criteria**
Hydraulic Capacity	• Pass a 10 year ARI without heading up • Minimum freeboard of 500mm to the edge of carriageway during a 1 in 100 year ARI event. • Headwater depth during a 100 year ARI event < 2 x culvert diameter
Debris Blockage	• In high risk catchments increase the culvert size to accommodate a 100 year ARI without heading up and provide debris rack upstream of inlet (Drawing SW-305) or alternative measures; and • In moderate risk catchments provide a relief inlet (Drawing SW-306).
Minimum diameter for safety and maintenance purposes	• Culvert < 30m length = Culvert to be 600mm minimum diameter; • Culvert 30 – 100m length = Culvert to be 1200mm minimum diameter; and • Culvert > 100m length = Culvert to be 1600mm minimum diameter.
Minimum cover	• Culverts to have not less than 1,200 of cover.
Energy dissipation	• Designed in accordance with Administration Hydraulic Engineering Circular No. 14: Hydraulic Design of Energy Dissipaters for Culverts and Channels

Culverts are typically provided in embankment sections where an existing watercourse intersects with the Indicative Alignment. The final location of the culverts will be determined at future stages of the Project and will be determined by the final road geometry for the Project.

The indicative location of culverts were determined following an analysis of the upstream catchments using land-use maps, aerial images, LiDAR contour information, and the nominated soil disposal sites identified for the Project.

We have assumed that all culverts will require some form of fish passage element to be incorporated into the design. The particular requirements and fish passage type required at each culvert will be confirmed at future stages of the design in conjunction with the Project ecologist.

We used a risk framework to assess the risk from debris to culvert blockage and determine mitigation measures for inclusion in the Project. Debris is carried by flood flows and by less frequent and more hazardous debris flows. The risk framework is detailed in the Operational Water Design technical report. Where the risk of blockage of a culvert by debris is moderate or high, this risk needs to be mitigated by incorporating debris control measures into the design. The following describes the mitigation measures we propose for the Project for different degrees of risk of blockage of a culvert by debris flow.

- For culverts with a high risk of debris blockage, our indicative mitigation measure is to construct a debris control structure. This structure comprises a steel rack at least 20 m upstream of the culvert to trap a proportion of large debris before it reaches the culvert. Alternative approaches are possible, such as debris fins at the culvert inlets as used by the P-Wk project, which arrest large floating debris (e.g logs) and push them up over the culvert or re-align smaller debris so that they can pass through the pipes. Further mitigation can be provided by sizing the culvert with additional capacity to accommodate 100 year ARI flow with the top water level not exceeding the culvert soffit level (the highest point on the inside of the culvert).

- For culverts with a moderate risk of blockage due to debris accumulation, our preferred mitigation measure is to install a relief inlet, which is a secondary intake with debris screen that is mounted on a vertical manhole over the culvert.

- For culverts within the Project that are at low risk of blockage due to debris accumulation, we do not consider any mitigation measures are necessary.

It is anticipated that further development of the Project design at future stages may result in changes to the number, location and design of the culverts following further refinement of the design.

7.2.8 Erosion control at outlets

Wetland and culvert outlets will incorporate energy dissipation structures and/or erosion protection measures to minimise stream bed scour and bank erosion in the receiving waterway. Typically this protection from erosion will be through an energy dissipation device and/or rock aprons.

Energy dissipation structures are used to reduce high velocity and energy at the outlet of culverts prior to discharge back into the natural stream. Energy dissipation structures include stilling basins, impact basins and a range of other US Army Corps of Engineers (USACE) and Federal Highway Administration Hydraulic Engineering Circular No. 14 Hydraulic Design of Energy Dissipaters for Culverts and Channels (HEC-14) structures to suit different applications.

Energy dissipation structures have not been designed at this stage of the Project as it is not considered to be material to the consent applications. The requirement for energy dissipation and erosion protection at outlets can be a consent condition.

The design of energy dissipation structures will be developed during future stages of the design of the Project and the options to be considered for energy dissipation and erosion control for culvert outlets are outlined below. Other options may also be viable.

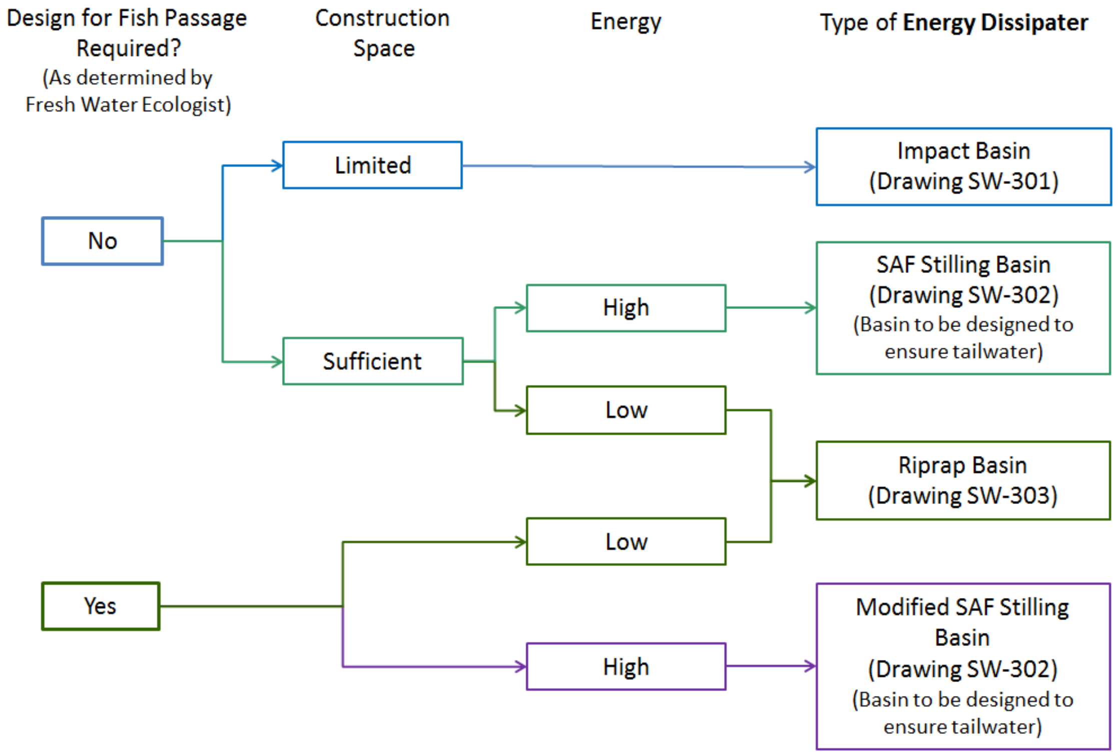

Figure 25 - Flow chart for energy dissipation

Details, advantages and disadvantages of each type of energy dissipation structure are given in the Operational Water Design technical report. An example of an impact basin is shown in Photo 1 for the Otanerua wetland outfall on NGTR. An example of a riprap basin is shown in Photo 2 for the NGTR Nukumea culverts on NGTR.

Photo 1 - Impact basin on NGTR Otanerua Wetland outfall

Photo 2 - Riprap basin for NGTR Nukumea culverts.

7.2.9 Proposed bridges and viaducts

Bridges are typically proposed where there are road crossings, where a major/large body of water has to be crossed or to minimise effects on valuable ecological features. The Indicative Alignment includes 22 bridges and viaducts, including those associated with slip roads. Of these, 6 are associated with river crossings. It is anticipated that further development and refinement of the Project design at future stages may result in changes to bridge locations and design. For example the bridge lengths and spans in the Indicative Alignment are influenced by a number of factors including hydraulic requirements for flood flows, ecological mitigation and road geometric design, and will be refined at the detailed design stage.

The summary of the bridges and viaducts crossing rivers and streams is contained in Table 27. The designs of representative bridges and viaducts are available in Drawing Set at Volume 3 of the AEE.

Table 27 - Summary of bridges in the Indicative Alignment that are relevant to the Operational Water Design

Catchment	Structure name	Description	Length (m)
Mahurangi River	Bridge 5	Warkworth Interchange - northbound off-ramp spanning over Mahurangi River	65
	Bridge 6	Warkworth Interchange - southbound off-ramp spanning over Mahurangi River	120
	Bridge 21	Warkworth Interchange northbound on-ramp spanning over the Mahurangi River and mainline	555
Hōteo – Kourawhero Stream	Bridge 22	Kaipara Flats bridge – mainline crosses the Kourawhero Stream natural wetlands	96
Hōteo River	Bridge 11	Hōteo River Viaduct - crosses the Hōteo River and Waiteraire Stream as well as the existing SH1 and indigenous forest area	485
Maeneene Creek	Bridge 20	Overpass - spans over Maeneene Road and Maeneene Stream	104

7.2.10 Kraak Road Tunnel

The Kraak Road Tunnel will have a water management system to collect water from the tunnel fire detection and suppression system, washdown water from cleaning and groundwater inflows. This system has not been designed, so this section describes the typical considerations and the aspects of the system that are relevant to the resource consent process.

The drainage for the tunnel is a specialised system of inlets and conveyance pipes that is primarily designed to intercept and collect the fire-fighting water. It includes drainage zones to intercept the fire-fighting water, as well as firetraps in the drainage system, both of which prevent flaming oils from flowing along the tunnel. The fire-fighting water is delivered by a deluge system comprising of a deluge tank/ pumps and sprinkler systems. The washdown water from tunnel cleaning will use the same system. The groundwater inflow to the tunnel, which will be minor, will also connect into the tunnel water management system.

The Indicative Alignment has a highpoint in the vertical alignment that is within the Kraak Road Tunnel, which means the tunnel drainage will be to the nearest stormwater treatment wetlands to the north and south of the tunnel.

To manage potential environmental effects the stormwater management associated with the tunnel will include:

- All normal tunnel drainage, such as tracked rainfall and groundwater, shall be treated in stormwater treatment wetland or alternative approved GD01 treatment device;
- Water collected from the tunnels that is not suitable for treatment, such as washdown water and contaminated firefighting water, shall be collected and transferred for treatment and disposal off-site. This is recommended as a condition of consent.

To achieve these management approaches the stormwater system will need some additional components that will be determined at the detailed design stage but may comprise of:

- An inline tank to collect washdown water from tunnel cleaning. This approach was used for the Johnstones Hill Tunnel where an inline tank was formed from oversized stormwater pipes with a valve at the downstream end in the stormwater network. When the tunnel is washed the valve is closed and the washdown water is collected in the inline tank. The washdown water is pumped out of the inline tank and disposed to an off-site facility that has any necessary council approvals or consents.
- Containment of the fire-fighting water in the stormwater treatment wetlands. This approach was used for the Johnstones Hill Tunnel where the stormwater treatment wetlands have extra baffle height to contain any floatable materials (eg oils, petrol) and a shut-off valve for the low flow outlet from the wetland. In the event of a fire the procedure is to close the shut-off valve to contain the full volume of the fire-fighting water in the stormwater treatment wetlands. Subject to the water quality: it is discharged if of similar quality to treated stormwater; or pumped out and disposed off-site if it contains contaminants from the fire.

8 ASSESSMENT OF OPERATIONAL EFFECTS

Section Summary

This section assesses the magnitude of effects of the operational phase of the Project on the freshwater and marine receiving environment. The ecological assessments described in the Ecology Assessment Report are informed in part, by the predicted changes in water quality and hydrology described in this section.

The section assesses the operational water design of Project against integrated stormwater management and Best Practicable Option criteria. Then the section assesses the effects and impacts of the operational phase of the Project on water quality, water quantity and flooding, as supported by technical reports, modelling and assessments.

The assessment has found that the Project has incorporated the required integrated stormwater management, and that the design of the Project has applied the Best Practicable Option to comply with the RMA and AUP(OP).

The water quality effects assessment includes an estimation of change to contaminants and changes to other water quality factors, as supported by the Operational Water – Road Runoff technical report. The water quality impacts to humans, including recreational use, drinking water and water users, has also been assessed. An assessment of the effects of the Project has found, with the proposed management approaches and mitigations in place, that the effect of the Project on water quality, including human health impacts, is minor or less.

The assessment of water quantity (hydrological) effects, as supported by the Hydrological Assessment technical report, includes an assessment of the magnitude of effects of the operational phase of the Project on hydrology in streams (including erosion) and in wetlands. An assessment of the effects of the Project has found, with the proposed management approaches and mitigations in place, that the effect of the Project on hydrology and streams is minor or less. The effect on wetlands has been assessed as moderate.

The flood effects assessment is based upon the modelling results from the Flood Modelling technical report, and assesses the vulnerability of the Project to flooding, as well as the effects to other properties upstream or downstream of the Project. An assessment of the effects of the Project have found that the effect of the Project on flooding is generally minor or less.

This section recommends mitigation relating to the operational water design, as well as recommendations for controls/monitoring, to ensure that the Project fulfils the criteria in relation to stormwater management, BPO, water quality, water quantity (hydrology) and flooding. The key mitigation is summarised below:

- Stormwater systems – incorporate sediment traps (or alternatives) for rock cuts and vegetated roadside drains for ancillary roads.

- Stormwater treatment wetlands – based on GD01 for water quality and hydrological mitigation. The stormwater treatment wetlands should include wetland vegetation, deeper zones, forebays, submerged or baffled low flows outlets, and valves on low-flow outlets. They should be located outside of natural wetlands and streams.
- Stormwater discharges/outfalls – designed to minimise erosion through energy dissipation and erosion protection
- Stream diversions – designed to convey 100 year ARI rainfall event including blockage risk and to include natural stream forms; monitoring and remediation post-construction of erosion prone streams.
- Culverts and bridges - designed to convey the 100 year ARI event, provided fish passage where necessary, consider debris blockage risk, incorporate erosion control and provide bridges across main rivers (Mahurangi, Hōteo and Maeneene) as well as across the Kourawhero for ecological mitigation.
- Flooding – flood effects of the final design are assessed to ensure flood effects are no worse than outlined in this assessment.
- Spills – Transport Agency to inform Watercare if a spill occurs upstream of Warkworth or Wellford water treatment plants.

8.1 Introduction

This section assesses the magnitude of effects of the operational phase on the water environment based upon the assessment matters and associated criteria contained in Section 3 Table 3. These assessment matters are from the AUP(OP) and other environmental regulations.

This chapter has the following structure based on the assessment matters:

- Assessment of the integrated stormwater management approach.
- Assessment of the application of Best Practicable Option.
- Assessment of the magnitude of effects to water quality, including changes to contaminants (as modelled in the Operational Water – Road Runoff technical report), other water quality effects (temperature, colour, odour, oil and grease, scums and foams, aquatic plant growths), and human impacts (recreational use, drinking water, and water users).
- Assessment of magnitude of changes and effects to water quantity taking into account changes to hydrology, effects on streams (including erosion) and effects to wetlands, as assessed within the Hydrological Assessment technical report.
- Assessment of the magnitude of effects associated with flooding, and an assessment of the impact of the changes identified in the Flood Modelling technical report.

This assessment then includes recommended mitigation relating to the operational water design as well as recommendations for controls/monitoring.

8.2 Integrated stormwater management approach

This section assesses against the requirements for an integrated stormwater management approach. This section includes an assessment of effects against the criteria identified in Section 3 Table 3, which are detailed below.

8.2.1 Criteria / consideration for the assessment

i. The AUP(OP) E1.3.8 (a) seeks that development is to avoid as far as practicable, or otherwise minimise or mitigate, adverse effects of stormwater runoff from greenfield development on freshwater systems, freshwater and coastal water by:

   a) taking an integrated stormwater management approach (refer to Policy E1.3.10).

ii. The AUP(OP) E1.3.10 seeks that in taking an integrated stormwater management approach regard be had to all of the following:

   a) the nature and scale of the development and practical and cost considerations;

   b) the location, design, capacity, intensity and integration of sites/development and infrastructure, including roads and reserves, to protect significant site features and hydrology and minimise adverse effects on receiving environments;

   c) the nature and sensitivity of receiving environments to the adverse effects of development, including fragmentation and loss of connectivity of rivers and streams, hydrological effects and contaminant discharges and how these can be minimised and mitigated, including opportunities to enhance degraded environments;

   d) reducing stormwater flows and contaminants at source prior to the consideration of mitigation measures and the optimisation of on-site and larger communal devices where these are required; and

   e) the use and enhancement of natural hydrological features and green infrastructure for stormwater management where practicable.

8.2.2 Assessment of Integrated Stormwater Management Approach

Criteria (i) and (ii)

The Indicative Design for operational water has incorporated an Integrated Stormwater Management Approach, as identified in the Operational Water Design technical report.

Section 7.2 sets out how the Project will integrate the stormwater system collection and conveyance network, treatment systems and devices, culverts and watercourse diversions and give consideration to the floodplain. The design will include a range of water sensitive design solutions including treatment swales and stormwater treatment wetlands to deliver stormwater quality treatment and hydrological mitigation. The Indicative Design has considered the operation and maintenance of stormwater systems through the life of the asset. Also the design considers the health and safety of road uses and maintenance staff, which is an especially important consideration for a state highways with vehicles travelling at high speeds. These health and safety considerations mean that lower maintenance stormwater systems are preferred that are ideally located outside of the road (outside of barriers).

In summary the sub-criterion of criterion (ii) are fulfilled as follows:

a) The nature and scale of the development has been considered in the Operational Water Design technical report and within this assessment. The nature and scale of the Project are determined by the need for the state highway upgrade and the design requirements for state highways. The practical considerations of the state highway and the associated stormwater are set out in Transport Agency Stormwater Specification (P46, 2016). The practices to achieve these requirements are well established from NZTA's programme and locally from the Northern Gateway Toll Road and P-Wk sections of SH1.

b) The Project and the operational water management have been designed to protect significant site features and minimise adverse effects on receiving environments. Firstly, a preferred route was selected from multiple options to best meet the Project objectives and including minimising environmental effects. Subsequently, within the proposed designation boundary, the Indicative Design was developed to minimise adverse effects as detailed in the following sections.

c) As per criterion (ii),b the selection of a preferred route, a proposed designation and development of an Indicative Design have had regard to the nature and sensitivity of receiving water environments, adverse effects and minimisation and mitigation of these effects. The assessment is detailed in the Sections 8.3 - 8.6.

d) The reduction of stormwater flows and contaminants at source has been undertaken through the use of stormwater treatment wetlands, as detailed in Section 7.3.5.

e) The use and enhancement of natural hydrological features and green infrastructure for stormwater management where practicable has been achieved through the operational water design by:

    i. Avoidance of the main floodplains where possible and minimising works in them when it has been necessary to cross floodplains.

    ii. Stream diversion design with the objective to recreate streams and habitats that replicate, as much as is practically possible, the natural state and habitats of the streams that existed prior to the Project becoming operational.

    iii. Wetland for stormwater quality treatment and hydrological mitigation.

Therefore, criterion (i) and (ii) have been achieved.

8.3 Best practicable option approach

This section assesses against the requirements for a best practical option approach. This section includes an assessment of effects against the criteria identified in Section 3 Table 3, which are detailed below.

8.3.1 Criteria / consideration for the assessment

The operational stormwater system should be the best practicable option for minimising the adverse effects on the environment of the operational stormwater discharges.

Resource Management Act

The AUP(OP) adopts the best practicable option criteria as defined in Section 2 of the Resource Management Act 1991. Project and stormwater design is assessed against the following RMA criteria:

i. the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and

ii. the financial implications, and the effects on the environment, of that option when compared with other options; and

iii. the current state of technical knowledge and the likelihood that the option can be successfully applied.

AUP(OP) BPO for infrastructure

The operation stormwater system should also be designed to represent the best practicable option for infrastructure as outlined in the AUP(OP) E1.3.14:

i. Adopt the best practicable option to minimise the adverse effects of stormwater discharges from stormwater network and infrastructure including road, and rail having regard to all of the following:
   - a) the best practicable option criteria as set out in Section 2 of the Resource Management Act 1991;
   - b) the reasonable timeframes over which adverse effects can be avoided as far as practicable, or otherwise minimised or mitigated;
   - c) the scale and significance of the adverse effects;
   - d) infrastructure investment priorities and the consequences of delaying infrastructural improvements in other areas;
   - e) the ability to prevent or minimise existing adverse effects having regard to the effectiveness and timeframes of other feasible methods, including land use controls;
   - f) opportunities to integrate with other major infrastructure projects or works;
   - g) the need to maintain and optimise existing stormwater networks and provide for planned land use and development; and
   - h) operational requirements and space limitations.

Operation and maintenance

The AUP(OP) also includes BPO for operation and maintenance:

ii. The proposed methods for operating and maintaining stormwater treatment processes and devices to ensure their continued and ongoing effectiveness (AUP(OP) E9.8.1.1.c).

iii. Methods for monitoring and reporting on the effectiveness of the treatment process (AUP(OP) E9.8.1.1.c).

8.3.2 Assessment of BPO – RMA

Criterion (i)

The nature of the discharge from the road will be stormwater with contaminants associated with vehicle traffic, as well as more runoff volume and higher peak flows. Stormwater management by stormwater treatment wetlands target the contaminants associated with roads such as sediment and metals, as well as providing detention of stormwater to mitigate the hydrological adverse effects.

The assessment of the nature of the discharge and the mitigation of adverse effects on the environmental is more fully covered in the following sections.

Criterion (ii)

Stormwater treatment wetlands are the BPO for stormwater treatment for a four lane state highway, as opposed to low impact devices because they are more effective, durable and safer and easier to maintain. Stormwater treatment wetlands chosen as the primary treatment device for the Project include some low impact design principles, as they use natural systems for stormwater treatment. Stormwater treatment wetlands have higher costs that alternative stormwater retention ponds, but are preferred as they are more effective at managing water quality effects. Sediment traps at the base of rock cuts are proposed as a BPO to collect sediment from these areas close to the source.

Vegetated and rock lined drains are considered to be the BPO for local roads that will be constructed, upgraded or modified. The vegetated drains will provide some water quality treatment and rock lined drains will be used where necessary to minimise erosion. For local roads, these options are considered to be BPO, given the low traffic volumes and the reduced need for treatment, considering the additional land requirements and capital and operational costs for full stormwater treatment.

Criterion (iii)

The Transport Agency has successfully implemented similar best practice stormwater management design on other similar projects such as the Northern Gateway (completed) and P-Wk (under construction). The operational stormwater design proposed for this project follows Auckland Council and Transport Agency guidance and is considered to represent best practice based on the current state of technical knowledge. In particular, the stormwater treatment wetlands will be based on GD01 which was released in 2017.

8.3.3 Assessment of BPO – AUP(OP)

Criterion (iv)

The BPO criterion outlined in criterion (iv) are addressed below:

a) refer to 8.3.2 above.

b) Reasonable timeframes have been considered in the design and assessment for the Project example include:

   a. Design life of assets is 100 years;

   b. The effects of climate change on peak flows as at 2130 have been incorporated into the design hydrology;

   c. The predicted change in traffic volumes from 2016 to 2046 have been considered in the State Highway Runoff technical report for the assessments of contaminants due to traffic; and

   d. The impact of forestry practises occurring concurrently to the construction and operation of the Project has been considered for hydrology.

c) the scale and significance of the adverse effects has been considered and the results of the assessment are detailed in the following sub-sections;

d) an alternative assessment for the Project is considered in the AEE;

e) the ability to prevent or minimise existing adverse effects has been considered and is detailed in the following sub-sections.

f) the opportunities to integrate with other major infrastructure projects have been assessed, and the southern part of the Project will integrate with the P-Wk project.

g) the operational water design has included provision to maintain and optimise existing stormwater networks in local roads crossed by the project, as detailed in the Operational Water Design technical report.

h) operational requirements including space limitations and safety matters are detailed in the Operational Water Design technical report, specifically regarding the preference for stormwater treatment wetlands and the location of these devices.

8.3.4 Assessment of BPO – operation and maintenance

Criteria (v) and (iv)

We recommend operation and maintenance plans to be certified by Auckland Council prior to operation. These plans will detail the operation and maintenance requirements for stormwater treatment devices. These should include methods for monitoring and reporting on the effectiveness of the treatment devices. The monitoring requirements should be for compliance with the design and operation and maintenance plan rather than for water quality monitoring. The approach required in GD01 is for design-based approach and it does not set water quality targets.

8.4 Water quality

This section assesses the likelihood and magnitudes of effects of the operational phase of the Project on water quality, including human impacts. The key topics that this section assesses against are:

- Contaminants;
- Other water quality;

- Reactional use;
- Drinking water; and
- Water users.

This section includes an assessment of effects against the criteria identified in Section 3 Table 3. The technical works to support this assessment can be found in the Operational Water - Road Runoff technical report. The Indicative Design for operational water management contains a number of devices and controls for water quality mitigation including constructed stormwater wetlands and erosion control requirements, refer to Section 7.

8.4.1 Criteria / consideration for the assessment

AUP(OP) E.1.3.8 requires avoid as far as practicable, or otherwise minimise or mitigate, adverse effects of stormwater runoff from greenfield development on freshwater systems, freshwater and coastal water by:

Contaminants

i. minimising the generation and discharge of contaminants, particularly from high contaminant generating car parks and high use roads and into sensitive receiving environments (AUP(OP) E.1.3.8b);

Other water quality

i. where practicable, minimising or mitigating the effects on freshwater systems arising from changes in water temperature caused by stormwater discharges (AUP(OP) E.1.3.8d); and

ii. providing for the management of gross stormwater pollutants, such as litter, in areas where the generation of these may be an issue (AUP(OP) E.1.3.8e).

After reasonable mixing, the contaminant or water discharged shall not give rise to any of the following effects in the receiving waters:

iii. Conspicuous oil or grease films, scums or foams, or floatable or suspended materials (RMA and AUP(OP) E8);

iv. Changes in colour and clarity than exceed ANZEEC guidelines for recreation guideline values (RMA, AUP(OP) E8);

v. Any emission of objectionable odour (RMA AUP(OP) E8); and

vi. Excessive growth of aquatic plants (ANZECC).

Recreational use

The potential effects of the Project on recreational uses were assessed against the following criteria:

i. the extent to which the discharge would avoid contamination and avoid more than minor adverse effects on the health of people and communities as affected by their contact with fresh water (NPS-FW); and

ii. the discharge should not increase the metal concentrations to toxic levels for skin contact, (ANZECC).

Drinking water

The potential effects on human drinking water from of the Project were assessed against the following criteria:

i. After reasonable mixing, the contaminant or water discharged shall not introduce or increase the concentration of any aesthetic determinands in the drinking water so that, after existing treatment, it contains aesthetic determinands at values exceeding the guideline values. (NES for sources of human drinking water);
ii. After reasonable mixing, the contaminant or water discharged shall not have a significant adverse effect on the quality of the water at any abstraction point. (NES for sources of human drinking water); and
iii. Potential adverse effects on water quality within water supply catchments will be avoided, remedied or mitigated as outlined in AUP(OP) E11.

Water users

The potential effects on existing water users from of the Project were assessed against the following criteria:

i. The rendering of freshwater unsuitable for consumption by farm animals (RMA Section 107) must not occur; (AUP(OP) E2); and
ii. Minimise effects on other water users (AUP(OP) E7).

8.4.2 Water quality effects - contaminants

The discharge of contaminants from the Project has been managed and minimised by the inclusion in the Indicative Design of stormwater treatment wetlands, which treat and reduce the contaminant discharge to the receiving environment.

The potential effects of the Project on contaminants has been assessed through:

- The Contaminant Concentrations Model (CCM); and
- The Contaminant Load Model (CLM).

The sub-sections that follow include a summaries of the likely changes in contaminants within receiving waterbodies due to the operational water management aspects of the Project, and also assesses this against the criteria.

Contaminant concentrations model results

The CCM provides site specific estimates of the predicted change in contaminant concentrations in freshwater receiving environments. The methodology for the CCM and full results are contained in the Operational Water - Operational Water - Road Runoff technical report.

Contaminant concentrations were assessed for the following three scenarios.

- “Existing - 2016 traffic without Project” is the existing scenario;
- “2046 traffic with Project, with treatment” is the Project scenario; and
- “2046 traffic with Project, without treatment” is the un-mitigated scenario.

The 95th percentile contaminant concentrations for TSS, Zinc, Copper and TPHs were calculated for all scenarios. These were compared to the Australia and New Zealand Environment Conservation Council (ANZECC/ARMCANZ) (2000) guideline trigger values for the 95% level of species protection in freshwater for slightly-to-moderately disturbed ecosystems.

The existing water quality at all the freshwater sites is considered to be good in relation to metals, with dissolved concentrations all below the default trigger values except for Copper at the Mahurangi River mouth.

The model predicts small increases in concentrations at all sites for “2046 traffic with Project, with treatment” compared to existing. This is a conservative assessment as the modelling methodology does not account for the expected transfer of traffic from the existing SH1 (no formal stormwater treatment) and on to the Project (with improved stormwater treatment). The largest proportional increases in metal concentrations occur in the catchments where the road footprint makes up a large proportion of the overall catchment, such as the Kourawhero Stream, the unnamed tributaries of the Hōteo River, and the Te Hana and Maeneene Creek tributaries.

With the stormwater wetland treatment accounted for the results of the assessment are summarised below:

- TSS – the predicted increases (0-2 mg/L increase) in TSS at the freshwater sites are negligible.
- Zinc – some small increases are predicted for zinc (0-0.0004 mg/L increase in dissolved Zinc). The predicted dissolved zinc concentrations at the freshwater sites “2016 traffic with Project, with treatment” are all below the ANZECC (2000) trigger values for 95% level of species protection in freshwaters.
- Copper – small increases are predicted for copper concentrations (0-0.0002 mg/L increase in dissolved copper). The predicted dissolved copper concentration “2046 traffic with Project, with treatment” at the freshwater sites are mostly below the ANZECC (2000) guideline trigger values for 95th level of species protection in freshwaters, except at the Mahurangi mouth. However, the Mahurangi Mouth site exceeds the trigger value in the existing case and there is no increase “2046 traffic with Project, with treatment”, as shown in Figure 26.

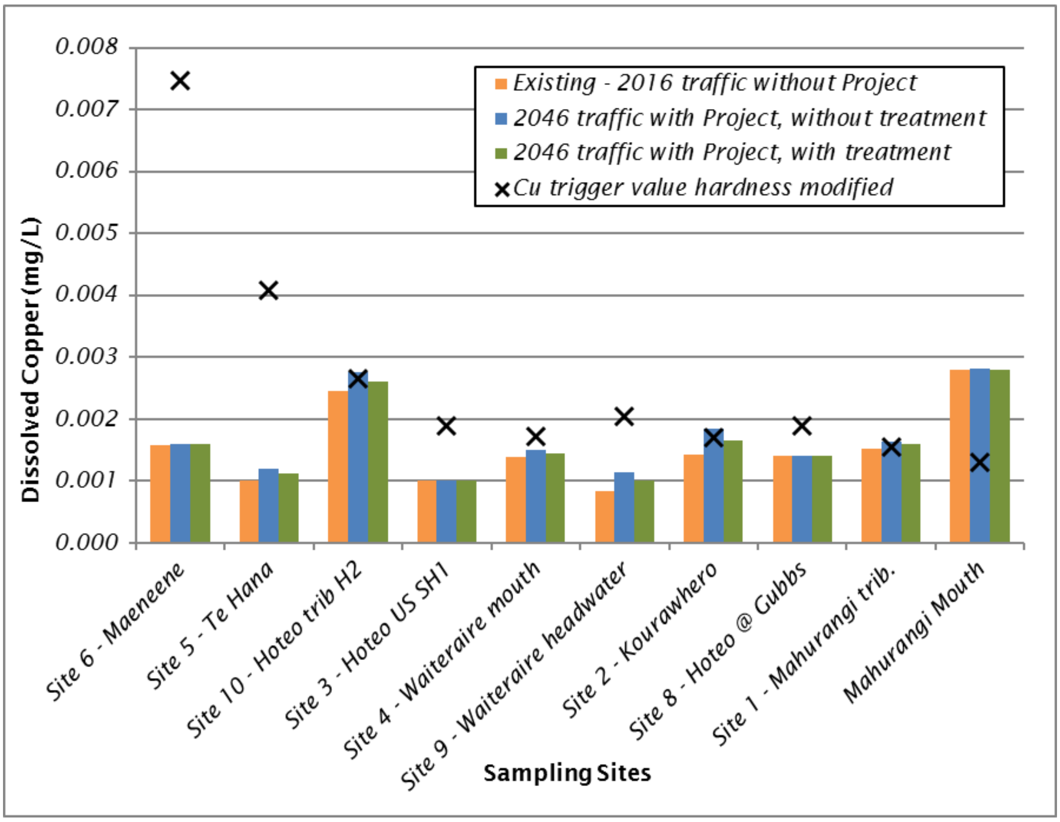

Figure 26 - Dissolved Copper 95th percentile concentrations at each site for the three scenarios.

- TPH - All monitored total petroleum hydrocarbon (TPH) concentrations for all petroleum hydrocarbon fractions and total hydrocarbons were below the laboratory level of detection (<0.7 mg/L). There is no change in TPH concentrations as a result of the Project and the concentrations remain below the laboratory level of detection. There are no ANZECC/ARMCANZ (2000) guideline trigger values for TPH in aqueous solutions or other relevant standards.

The CCM predicts very minor changes in freshwater quality as a result of the Project.

Freshwater contaminant loads model results

The CLM is a model developed by Auckland Council to estimate annual stormwater contaminant loads. The model estimated annual loads (kg/yr) of TSS, total Zinc, total Copper and TPHs. The methodology for the CLM and full results are contained in the Operational Water - Road Runoff technical report.

The results of the CLM showed a decrease in all contaminant loads predicted at the mouths of the Hōteo and Mahurangi Rivers, and at Te Hana Estuary downstream of the confluence of Te Hana Creek and Maeneene Creek. This is due to traffic being diverted from the existing SH1, which has no formal treatment devices, to the Project with stormwater treatment wetlands.

Therefore, the CLM predicts a negligible or slight positive effect on freshwater and estuarine water quality associated with the operation of the Project.

These results, when considered in conjunction with the existing sediment quality within the Kaipara and Mahurangi Harbours, suggest an expected negligible change in the long term estuarine sediment quality as a result of the Indicative Alignment with stormwater treatment in place.

Assessment of effects

The CCM has assessed the contaminant effects of the Project on freshwater quality, and has found the magnitude of the change is very minor or negligible, indicating that the effect has been minimised and is not significant.

The CLM has found that the Project will have a negligible contaminant effect on long term marine sediment in the sensitive receiving environments of the harbours, and a negligible or slight minor contaminant effect on freshwater and estuarine water quality.

8.4.3 Water quality effects – other water quality

Criterion (i) - temperature

The measured water temperature for sites monitored (see Water Quality technical report) was in the range of 10–15°C· the monitoring undertaken for this project was between June – September 2017 and therefore the temperatures are representative of winter conditions. The long-term water quality monitoring undertaken by Auckland Council and NIWA in the Hōteo River and Mahurangi River indicates that water temperatures are in the range of 7-16°C in winter (May to September) and 10-24°C in summer (October-April).

During summer the temperature of stormwater from impervious catchments is typically in the range of 20 to 25˚C, even in temperate climates. Where these catchments have stormwater treatment ponds for water quality and flow control purposes, stormwater temperatures may become even further elevated. Water temperatures in the range of 25 to 35˚C are routinely recorded downstream of stormwater ponds (Auckland Council, 2013).

Stormwater ponds can cause an increase in water temperature (Kelly, 2010). However, the stormwater treatment wetlands proposed for the Project will have good vegetation coverage and shading and are less likely to result in increased temperatures. Provided they are well shaded, evidence indicates that exceedances of the AUP(OP) technical limit of 25°C from stormwater treatment wetlands are infrequent (Auckland Council, 2013).

Water temperature in streams within long culverts remains cool during the day, free of algae and plants (Leong et al., 2007). Flow from culverts along the Indicative Alignment will contribute slightly cooler water to receiving environments, compared to the slightly warmer water that is expected to be discharged from the stormwater treatment wetlands.

The effects of the Project on the rivers, such as the Mahurangi River, Hōteo River and Oruawharo River, are likely to be negligible. This is because the area of road discharging to these rivers is relatively small compared with the catchment, and the stormwater treatment wetlands will be designed to prevent large increases in temperature.

Changes to the temperature of small tributary streams, such as Kourawhero Stream, the unnamed Hōteo tributaries, and Te Hana tributaries, could occur due to the discharges from stormwater treatment wetlands. The effect of this is expected to be minor due to their localised extent and temporary duration. The risk of increases in temperature will be managed by providing shading to wetlands, we therefore recommend a consent condition encouraging shading of wetlands.

Criterion (ii) - gross stormwater pollutants

Litter thrown from vehicles or blown off trailers or trucks accumulates along the roadway. Litter can get blown and washed into the stormwater system.

Litter will be intercepted in the forebays of the stormwater treatment wetlands. Furthermore, litter will also be trapped at the submerged or baffled low flow outlet of the stormwater treatment wetland. Programmed maintenance will remove litter and hence, we consider the effects of litter from the Project to be minor. We recommend that the consent condition for water quality treatment include for submerged outlets and for operation and maintenance plans.

Criterion (iii.a) - oil and grease films

No oil or grease films attributed to urban runoff were observed during the monitoring undertaken in the freshwater receiving environments (Water Quality technical report). Measurements for TPH and PAH at all freshwater sites monitored for this assessment were below detection.

Stormwater treatment wetland outlets will have submerged or baffled outlets for low flows so that films can be trapped at the main outlet. We consider the proposed stormwater wetland treatment devices will remove 60% of TPH and most oil and grease. There may occasionally be small films downstream of discharge points. These small areas of film would be temporary and be dispersed and volatised, therefore we consider the adverse effects of these areas of film to be negligible. We recommend the requirement for submerged or baffled outlets be included in consent conditions.

Criterion (iii.b) - scums or foams, or floatable or suspended materials

During sampling undertaken in the catchment the Project team observed what appeared to be natural biofilms at sample points on the Maeneene, Mahurangi and Hōteo . No other foams or floatable or suspended materials were observed.

The Project will not discharge any pollutants or biomass (e.g. decomposing plants, other biomass, washing detergents) that are likely to contribute to scums or foams, and as such the effect is negligible on the receiving environment.

Criterion (iv) - colour and clarity

In terms of clarity, the existing Mahurangi River at Warkworth has mean and median turbidity that are above guidelines (exceeds for 56% of record) and average clarity is low and below guidelines (exceeds for 37% of record), indicating that the watercourse has slightly elevated suspended solids. Turbidity and clarity are slightly poorer at the upstream Mahurangi FHQ site. Hōteo River at Gubbs has mean and median turbidity that are above guidelines (exceeds for 76% of record), indicating that the watercourse has slightly elevated suspended solids.

In terms of colour, the Hōteo , Maeneene, Te Hana and Mahurangi rivers/streams have yellow hues related to the weathered clays in the catchments, with Munsell values ranging from 20-37.5 (Water Quality technical report). For all individual sites the range is equal to or less than 10 points.

For the operational phase of the project, the earthworks will be stabilised and ground covers established, and permanent stormwater treatment will be in place. Therefore, we consider the effects from discharges of stormwater to colour and clarity in the Mahurangi River, Hōteo River and marine receiving environments to be negligible.

Criterion (v) - objectionable odour

Petroleum Hydrocarbons can cause an unpleasant odour. We anticipate the proposed stormwater wetland treatment devices will effectively remove TPH and therefore we do not expect odour downstream of stormwater discharges. No other contaminants from the Project would give rise to objectionable odours, therefore the effect is assessed as negligible.

Algal blooms can also cause objectionable odours, however, with the proposed treatment in place we do not expect operational discharges or permanent stormwater works to contribute significantly to the risk of these conditions developing. This is discussed further in the subsection below.

Criterion (vi) - aquatic plants

Excess growth of aquatic plants include algal blooms and macrophytes can be a nuisance. A number of factors contribute to excess growth of aquatic plants including light, water temperature, flow and nutrient concentrations. During sampling undertaken in the freshwater catchments, the Project team did not observe nuisance algal growth at the surface water sample points, although our monitoring occurred in winter when algal growth is less likely to occur. Algal blooms were, however, observed in stormwater ponds on the Northern Gateway Toll Road. These algal blooms were contained within the stormwater ponds by baffled outlets.

A number of factors contribute to macrophyte growth including, light, water temperature, flow and nutrient concentrations. Reductions in flows can result in increased temperature and reduced velocities which can create conditions that support the growth of macrophytes. No nutrients will be discharged as part of the project, therefore there are three mechanisms by which algal blooms may have the potential to develop due to the Project. These are:

- Algal blooms developing in stormwater treatment wetlands and discharging to streams and rivers;
- Algal blooms developing in poorly designed diversion channels and stream diversions; and
- Algal blooms developing in streams with reduced flows due to surface water diversions.

In relation to stormwater treatment wetlands, even with the best design there is the potential for algal blooms to develop during warm summer months. The design of baffle outlets will limit discharge of algae. The discharge volumes and frequency will be very low at times when algae have the greatest potential to develop most, hence the quantities of algae expected to be discharged is small. Algal blooms do, however, present a maintenance issue for stormwater treatment wetlands, and will need to be considered in the long-term maintenance programme for these devices.

The Project could result in algal blooms developing in stream diversions. Where a channel is too wide or not steep enough, and the flow is therefore too slow, the temperature can become high and instream conditions can result in algal blooms. These effects are minimised for new diversion channels through the adoption of the design criteria to ensure water depths and velocities are maintained, and also by providing riparian planting which is included in the stream diversion design requirements for type 1 and 2, discussed in the Operational Water Design technical report.

Reductions in flows due to surface water diversions can result in increased temperature and reduced velocities in streams and rivers which can create conditions that support the growth of algae. The Hydrological Assessment technical report indicates that for catchments larger than first order streams there would be negligible changes in catchment area, and for first order stream catchments the changes are generally less than 10% and never more than 25%.

With the proposed design criteria and a suitable maintenance regime, we consider the effect of the stormwater treatment wetlands, permanent diversions and changes in hydrology on the development of excessive growths of aquatic plants (algal blooms) in receiving freshwater to be minor.

We anticipate no change in the risk of algal blooms in the harbours for the reasons given above for wetlands and streams.

8.4.4 Water quality effects – reactional use

Criterion (i)

Auckland Council freshwater data indicates in the existing situation the suitability of the Hōteo River, Mahurangi River, Waiteitei and Waiwhiu Rivers suitability for recreational use is 'fair' quality with some sections being classified as having poor or intermittent quality (MfE, 2018). These river sites monitored by Auckland Council exceed E. coli indicators for swimming on some occasions. The Auckland Council data is consistent with the data we have collected, where all freshwater sites exceed E. coli on some occasions.

No major bacterial sources are associated with the Project. Some bacteria may exist in the discharge from stormwater treatment wetlands if the wetlands are inhabited by wildfowl. Wildfowl tend to prefer stormwater ponds to stormwater treatment wetlands. Dense planting of stormwater treatment wetland edges will reduce the accessibility of the wetlands to wildfowl. The proposed design avoids creating a desirable habitat for wildfowl. On this basis, we do not anticipate the potential bacteria introduced to stormwater by wildfowl will change the suitability of the receiving environments for contact recreation. Overall the predicted change in bacteria associated with the Project is assessed as having negligible effect on contact recreation.

Criterion (ii)

In the existing situation the concentration of metals is well below the toxic and irritating levels for contact recreation. The small predicted increases in metals associated with the treated stormwater discharges in some sub-catchments are not predicted to increase the concentration of metals in freshwater above the guidelines for recreation. In the marine receiving environments, where swimming is more likely, decreases in metals are predicted due to improved stormwater treatment. Overall the predicted change in metals associated with the Project is assessed as having negligible effect on contact recreation.

8.4.5 Water quality effects – drinking water

Criteria (i), (ii) and (iii)

Watercare currently take raw water for Wellsford's potable water supply from a surface water take upstream of Wilsons Road on the Hōteo River, and until very recently they also had a surface water abstraction on the Mahurangi River to supply drinking water to Warkworth. The raw water taken from the Hōteo and Mahurangi River is treated to meet drinking water standards.

Zinc can have aesthetic effects on drinking water and copper can have health effects (at high concentrations). TPH and hydrocarbons can have health and aesthetic effects (MoH 2008). Bacteria and algae can have health effects on drinking water.

As discussed in 8.4.2, the Project is expected to result in minor or negligible change in contaminants (TSS, metals and TPH), as identified in the Operational Water – Road Runoff technical report. Section 8.4.4 discusses bacterial sources; no major bacterial sources exist on the road and bacteria from stormwater treatment wetlands will be minimised through planting. Algae and other nuisance aquatic plants may have minor effects on freshwater quality in isolated areas, however this effect at the abstraction points will be negligible due to dilution and dispersion.

The predicted increases in sediment, metals, TPH, bacteria and algae are not expected to affect the ability of the treated water to meet NZ drinking water standard values (NZDWS 2008) and the effect is considered negligible.

There is the potential for accidental spill of contaminants entering the Hōteo and Mahurangi River, for example due to an accident involving a truck. We recommend the inclusion of valves on the low-level outlets from wetlands, so that in the event of a spill then valve can be closed to contain the spill material in the wetland. If an accidental spill occurs during the operational phase, it is likely that a large proportion of contaminants would be intercepted by the stormwater treatment wetlands, but some residual contaminants may be discharged to the Hōteo and Mahurangi Rivers. If this were to occur the volumes of residual contaminants discharged would be small, subject to mixing within the large Hōteo and Mahurangi River, and therefore the concentrations are unlikely to be dangerous to human health.

We assess the effects of the state highway operation on the drinking water supply to be negligible, but with the potential for lower probability moderate effects if a spill occurred that was not contained. We recommend that the Transport Agency be required to inform Watercare if an event resulting in a spill occurs (such as a collision involving a truck), so Watercare is able to determine what action, if any, is required. With conditions for shut-off valves for low-level outlets from wetlands and to alert Watercare about spills, we assess the risk to the drinking water supplies to be minor.

8.4.6 Water quality effects – water users

Criterion (i)

The operational discharges are not anticipated to alter the quality of water for stock drinking purposes for the reasons given above for drinking water, refer Section 8.4.5. The predicted increases in metals associated with the Project are well below stock water drinking guidelines (refer to the Water Quality technical report). With proposed mitigation measures in place, we consider the effect of the operational road runoff on stock drinking water quality to be negligible.

Criterion (ii)

With the exception of the Watercare's current surface water abstraction on the Hōteo River, there are no consented surface water abstractions on watercourses within the Mahurangi, Hōteo or Oruawharo catchments that are affected by the Project.

The permitted surface water abstraction rule in the Auckland Unitary Plan, allows the taking and use of no more than 5m^3/day of water from a river, stream or spring, outside of the wetland management area overlay subject to conditions. No information on permitted users is available from Auckland Council.

The operational discharges are not anticipated to alter the quality of water for other water users for the reasons given above for drinking water, refer Section 8.4.5. The hydrological effects of the Project are described in Section 8.5, while there are some minor changes the Project does not use water and will not affect the quantity of water available. With proposed mitigation measures in place, we consider the effect of the operational road runoff on other water users to be negligible.

8.5 Water quantity

This section assesses the likelihood and magnitude of effects of the operational phase of the Project on water quantity (hydrology), and includes:

- The effects on hydrology from the stormwater network;
- The effects of the Project on streams; and
- The effects to wetlands.

This section includes an assessment of effects in the context of the criteria identified in Section 3 Table 3, which are repeated in the following sub-section. The technical works to support this assessment can be found in the Hydrological Assessment technical report. The Indicative Design for operational water management contains a number of devices and controls for water quantity mitigation including constructed stormwater wetlands, refer to Section 7.

8.5.1 Criteria / consideration for the assessment

The criteria for assessing effects on water quantity are listed below:

Hydrology

i. AUP(OP) E.1.3.8 seeks to avoid as far as practicable, or otherwise minimise or mitigate, adverse effects of stormwater runoff from greenfield development on freshwater systems, freshwater and coastal water by minimising or mitigating changes in hydrology, including loss of infiltration to:

   a. minimise erosion and associated effects on stream health and values;

   b. maintain stream baseflows; and

   c. support groundwater recharge.

ii. AUP(OP) E8.8.1.2 requires assessment of the methods proposed for the management of the adverse effects on receiving environments, including cumulative effects, having regard to

   a. The nature, volume and peak flow of the stormwater discharge;

   b. The sensitivity of the receiving environment to stormwater runoff flows;

   c. For discharge to streams the extents to which discharges are managed to maintain baseflow and interflow, reduce the duration and intensity of flows which will cause erosion and habitat degradation, reduce runoff to pre-development conditions and utilise natural flow paths and stream to help slow down water flows.

Streams

The potential effects of the Project on streams were assessed against the following criteria:

i. Avoid significant effects and avoid where practicable or otherwise mitigate other adverse effects on streams in the Natural Stream Management Area Overlay and Significant Ecological Area Overlay (AUP(OP) E3.3.1.a,d).

ii. Surface water diversions demonstrate the diversion will to the extent practicable avoid significant adverse effects and remedy or mitigate other adverse effects on life supporting capacity of freshwater, ecosystem processes (AUP(OP) E2.3.13.b).

iii. Retains sufficient stream flow conveyance capacity for all flows in streams (AUP(OP) E3.8.2.1.g).

iv. The diversion and discharge of stormwater must not cause more than minor bed erosion, scouring or undercutting at the point of discharge or immediately upstream or downstream, or result in other instability of any land or waterbody (AUP(OP) E3, E7 & E8.8.1.2.e).

v. Manage the effects of activities outside overlays avoiding where practicable or otherwise mitigating adverse effects and where appropriate restoring and enhancing the river, stream, wetland (AUP(OP) E3.3.2.a).

vi. Manage the effects arising from any permanent modification in stream state or function (AUP(OP) E3.8.1.c)

vii. Offset adverse effects arising from stream diversions and modifications (AUP(OP) E3 various).

viii. Enhancement of streams ecological functions (AUP(OP) E3.8.2.1.i,j).

Wetlands

The potential effects of the Project on wetlands were assessed against the following criteria:

i. Avoid significant effects and avoid where practicable or otherwise mitigate other adverse effects on wetlands in the Wetland Management Areas Overlay (AUP(OP) E3.3.1.e).

ii. Manage the effects of activities outside overlays avoiding where practicable or otherwise mitigating adverse effects and where appropriate restoring and enhancing the river, stream, wetland (AUP(OP) E3.3.2.a).

iii. Appropriate water levels and downstream flow regime will be maintained including … water levels and flows in wetlands ensure vegetation and habitat values of the wetland are protected through the year (AUP(OP) E2.3(6)(bii))

iv. Consider mitigation options where there are significant adverse effects on the matters identified in E2.3(6) including … wetland creation or enhancement of existing wetlands

v. Avoid significant effects and avoid where practicable or otherwise mitigate other adverse effects on wetlands in the wetland management areas overlay (AUP(OP) E3.3.1.e).

vi. Surface water diversions and other activities must not lower water levels in any wetlands, except for wetlands designed and used for stormwater management by a network utility (AUP(OP) E7.6.1.2(4)).

vii. Manage the effects of activities outside overlays avoiding where practicable or otherwise mitigating adverse effects and where appropriate restoring and enhancing the river, stream, wetland (AUP(OP) E3.3.2.a).

8.5.2 Water quantity effects - hydrology

The changes in hydrology have been managed and minimised in the Indicative Design by the inclusion of stormwater management systems as detailed in Section 7. A key feature are the constructed stormwater wetlands that include hydrological mitigation for the increase in flows from new impervious areas by providing detention and controlled release over a 24-hour period for the 95th percentile rainfall event.

The Indicative Design has been assessed within the Hydrological Assessment technical report; this has assessed:

- Changes in catchment imperviousness causing changes to hydrology; and
- Changes in catchment areas due to stormwater systems and stream diversions causing changes to hydrology.

This section includes a summary of the likely changes in hydrology associated with the Project, and then these changes have been considered in light of the hydrology criteria.

Changes in catchment imperviousness

The new impervious surfaces of the road prevents infiltration of rainfall into the ground surface. The cuts and fills associated with the Project will also be less pervious to rainfall compared with the pre-development land use.

The catchments (Mahurangi, Hōteo and Oruawharo) that the proposed designation passes through are predominately rural with very low levels of imperviousness. An assessment of the changes in catchment imperviousness has been undertaken.

The changes to catchment imperviousness associated with the Indicative Alignment are shown on Figure 27. The cumulative effects of the increased imperviousness on stream flows are very small at a river catchment scale (less than 5%). The largest increases in imperviousness (from 0% to 25%) are in in the small headwater sub-catchments, this is due to the larger size of the Project areas relative to the size of the sub-catchment at those locations.

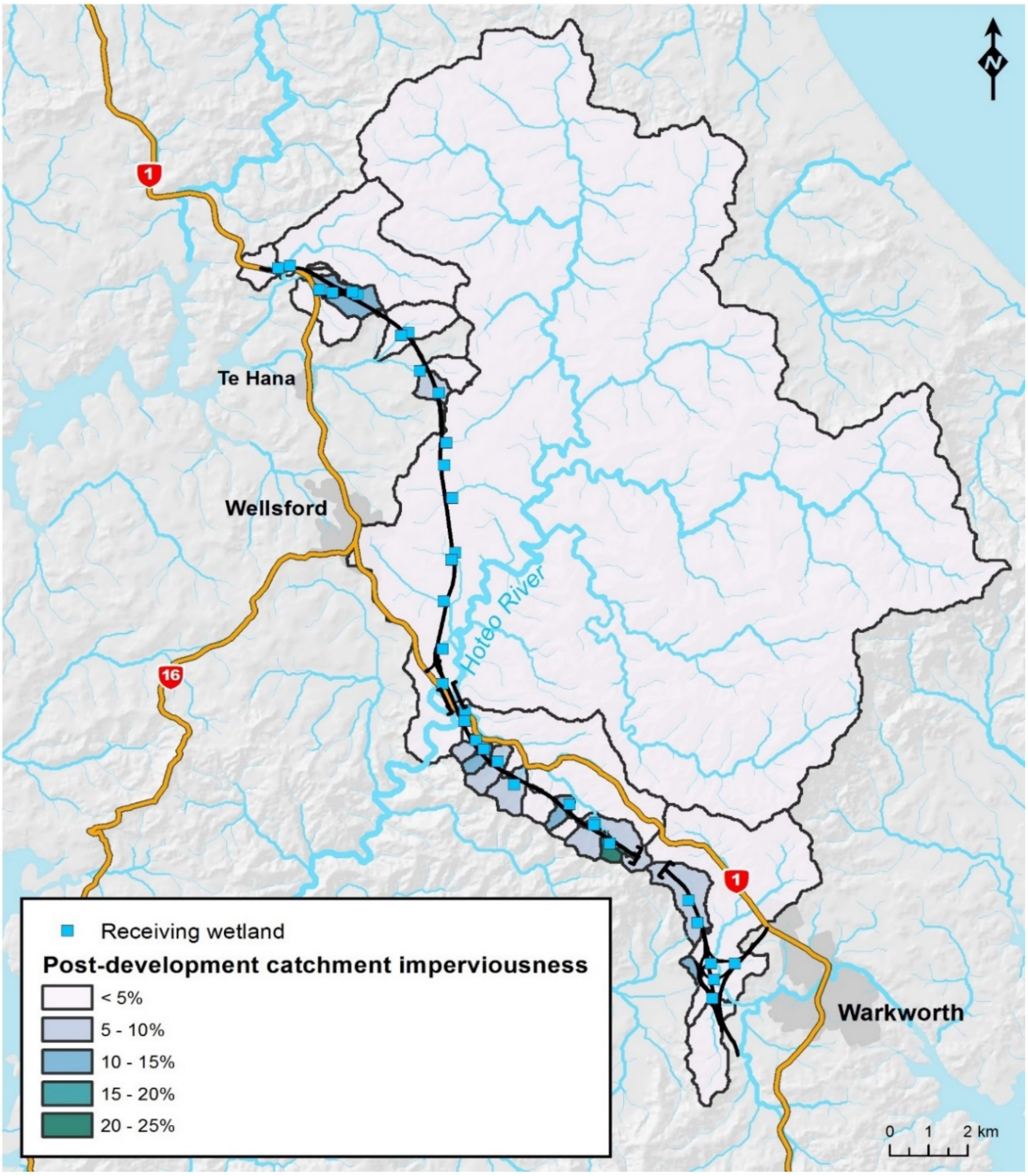

Figure 27 - Post-development (with Project) catchment imperviousness area of receiving stormwater treatment wetland catchments (REC delineated catchments)

Changes in catchment area

There are two factors influencing the change in catchment area in the Project scenario compared with the existing case – firstly stream diversions and secondly changes due to the road stormwater systems diverting runoff to wetlands with discharges in adjacent catchments.

For most freshwater catchments the changes in stream flow are less than 10% at the REC catchment[6] scale. There a limited number of catchments with increases larger than 10%, however these are localised and generally affect streams with catchments of less than 1 km^2. As such the changes to the flow within streams and rivers due to changes in catchment areas are small. The percentage changes in catchment area are illustrated in Figure 28.

6 The River Environmental Classification (REC) catchments are groups of rivers and parts of river networks that share similar ecological characteristics, including physical and biological. The REC catchments is a database by Ministry for the Environment.

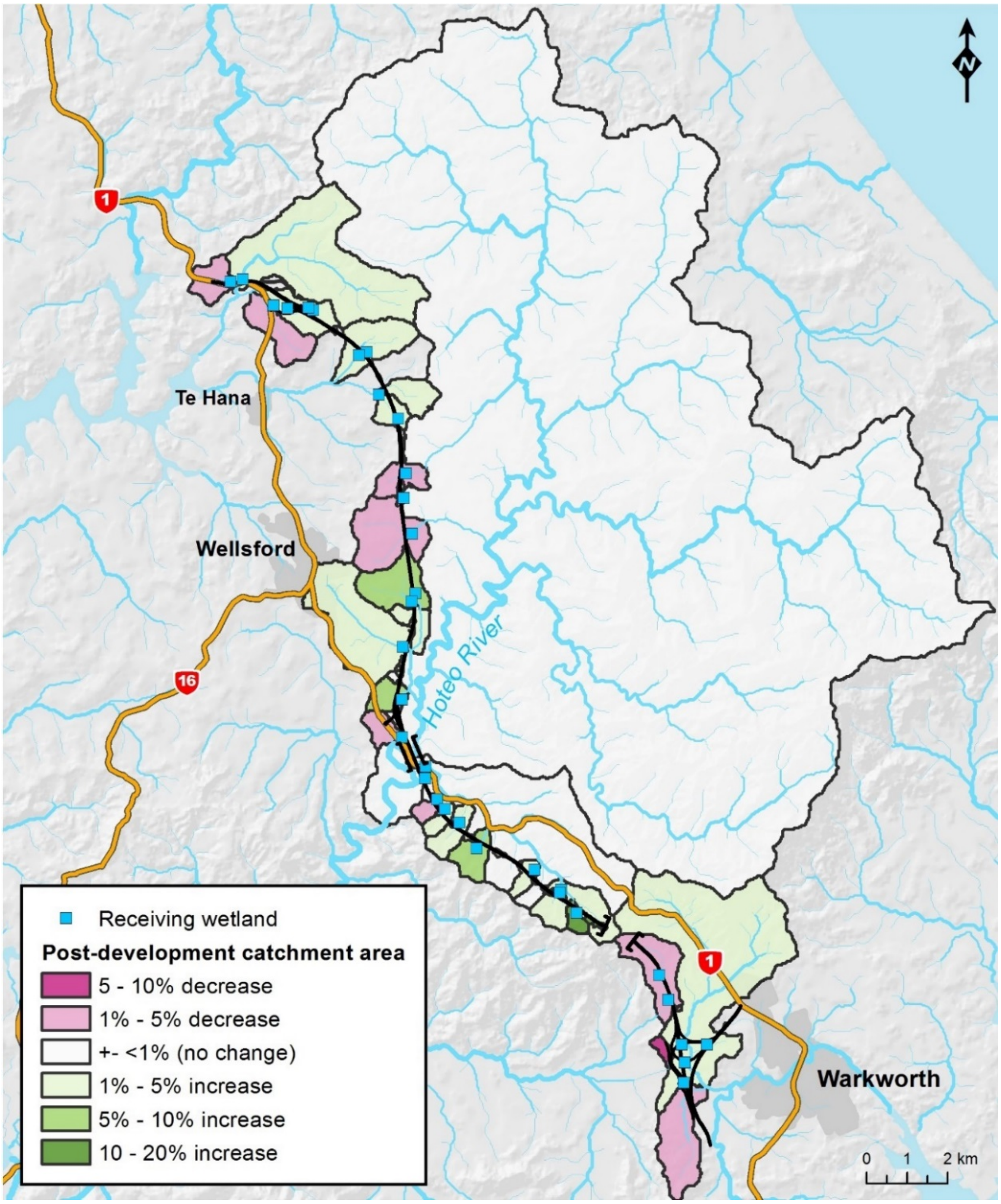

Figure 28 - Post-development change in catchment areas as a result of diversions and stormwater drainage (REC delineated catchments)

Assessment of effects – Criterion (ia) – minimising changes in hydrology including erosion

Minimising or mitigating changes in hydrology have been achieved as far as practicable through the integrated stormwater design referred to in Section 7.1 and 7.2. The extent of impervious catchment cannot be made smaller as it is necessary for the function of the road e.g. lanes, shoulders and median widths are determined by road design and safety requirements.

The impact of the new impervious areas, with respect to water quantity, is mitigated by stormwater treatment wetlands, which will include hydrological mitigation for the increase in flows from new impervious areas by providing detention and controlled release over a 24-hour period for the 95th percentile rainfall event. This will reduce peak flows in the receiving watercourses to mimic existing conditions. This will in turn reduce stream erosion. Local erosion protection will be provided at outfalls to the steams.

As recommended in P46 (Transport Agency, 2016), the stormwater design has avoided most changes in flows by locating culvert crossings to maintain the existing natural drainage patterns of sub-catchment where possible. This means that there are a limited number of large stream diversions (not culvert stream diversions) which result in hydrological changes to flows.

Change in catchments areas can lead to increased flows into streams. There are two factors influencing the change in catchment area for the Project compared with the existing case – firstly stream diversions and secondly changes due to the road stormwater systems diverting runoff to wetlands with discharges in adjacent catchments. The effects of this were described in the previous section with most area are less than 10% at the REC catchment scale, but there are a limited number of catchments with increases larger than 10% which are typically headwater catchments of less than 1 km^2.

The effect of these flow changes cannot be easily assessed. We recommend a precautionary approach were streams with changes to catchment flows of more than 15% and with soft-bottoms that may be susceptible to erosion be monitored after construction for any erosion. If erosion is observed to occur, then the erosion should be remedied. A similar resource consent condition exists for P-Wk project and data will be available in the years after that project to help quantify this potential effect and the extent to which remediation was required.

With appropriate mitigation in place the Project will minimise and mitigate changes in hydrology and stream erosion as far as practicable. However, we also recommend monitoring and remediation for erosion prone streams.

Assessment of effects – Criterion (i)b,c – minimising changes in hydrology affecting stream baseflows and groundwater recharge

The impervious land cover introduced by the new road surfaces of the Project, as well as cuts and fills to a lesser extent, prevents natural infiltration of rainfall into the ground surface, which can result in a loss of baseflow and an increase in storm flow. This can result in changes in stream health related to less water in dry weather and erosion of the stream. A literature review carried out to inform the Hydrological Assessment technical report found that the percentage of impervious surface area within a catchment at which degradation of water quality begins is varied, however 10-20% imperviousness is generally reported as the threshold that results in degradation of stream water quality.

The cumulative effects of the increased imperviousness on stream flows are very small in the Mahurangi, Hōteo and Oruawharo Rivers (less than 5%). The largest increases in imperviousness (from 0% to 25%) are in in the small headwater sub-catchments, this is due to the impervious extent of the Project relative to the size of the sub-catchments at those locations.

The AUP(OP) hydrology mitigation encourages retention, which is most commonly achieved by infiltration of stormwater to ground through the base of swales and raingardens. However, the Project has geotechnical and operational limitations that for the main state highway that preclude the use of infiltration devices. The geotechnical limitations are that the Project will be constructed in cuts formed in weathered or base rock, or in fills formed from engineered (compacted) fills, and these materials will have low infiltration characteristics. The operational limitations are twofold; firstly stormwater devices that rely on infiltration do not perform well in the state highway environment due to the high contaminant loads; and secondly, maintenance is dangerous and expensive on the along the state highway and management devices located at a safe distance from the operational route is preferred. Swales/drains will still be used and some infiltration will be achieved but is not relied on, as detention will be provided in the stormwater treatment wetlands, which will minimise changes flows to mitigate erosion as well as discharging over longer periods to assist stream baseflows.

The effects of the imperviousness of the road surface on infiltration and stream baseflows are likely to be negligible to minor, given that for the majority of catchment the impervious road will occupy less than 5% of the catchment, but is relatively larger for small reaches of tributaries. There is no practicable mitigation for this effect, however it is not a significant effect. It is considered that the Indicative Design has fulfilled these criteria through minimising or mitigating as far as practical.

Assessment of effects – Criterion (ii)

Criterion (ii) is similar to Criterion (i) and the assessment above is relevant here. Note the ecological sensitivity of the receiving environment is detailed in the Ecology Assessment Report.

Forestry activity within the catchments of the Project have the potential to result in cumulative hydrological effects. It is expected that the Matariki Forest, a commercial plantation forest within the Hōteo and Mahurangi catchments, will be felled prior to and/or during the construction of the Indicative Alignment. It is likely the changes in hydrology associated with forest harvesting in the catchment could result in significant (30-80%) changes in flows, refer to Hydrological Assessment technical report. The changes to flow will be less if part of the catchment is in forestry or if the deforestation occurred in stages. However, if after harvesting the area was returned to forest, the flows could be expected to return to pre-harvesting levels within 6-8 years (Fahey, 1994). This potential change in the hydrological regime will have to be reflected in the design of bridges and culverts at the time the Project is constructed.

The indicative design for stormwater has considered and sought to minimise and mitigate the effects on receiving environments including cumulative effects. The design has considered the effects on hydrology, and the effect is considered minor.

8.5.3 Water quantity effects – streams

This section includes an assessment of effects to streams associated with the Project, as a result of hydrological changes, including modifications to streams, erosion, the ability to convey flow, and the life supporting capacity of the streams, as outlined in the criteria.

Criterion (i) – AUP(OP) management area overlays

The proposed operational water management approach includes avoiding works in the beds of streams within Natural Stream Management Areas Overlay and the Significant Ecological Areas Overlay. The Indicative Alignment proposes:

- Two bridges across the Mahurangi river (left branch);
- A viaduct over the Hōteo River and Waiteraire Stream; and
- A bridge across Maeneene Creek.

These are located where these areas are crossed and serve to prevent works within the beds of streams in these areas.

Criterion (ii) – Life supporting capacity

The surface water diversions have been designed to avoid adverse effects to the life supporting capacity of freshwater, while also providing mitigation to the loss of habitat through streams.

The diversion design includes three types of diversion channel, these channels provide for avoiding bank erosion, stream bed erosion, and land instability effects. The design criteria also include provision of sufficient capacity for flood flows.

Stream Diversion Type 1 "Lowland Stream" and Stream Diversion Type 2 "Steep Stream" will recreate habitats associated with their stream type. These will include low flow channels with habitats based on steps, run/riffle/pools, heterogeneity with rocks and longs and riparian vegetation. The designs also avoid introducing barriers to fish passage. These measures will preserve the life supporting capacity of the stream diversions.

Criterion (iii) – Flow conveyance

The permanent stream diversions will be designed to manage for flows up to the 100 year ARI event, so this criterion will be met.

Criterion (iv) – Erosion

To prevent erosion all stormwater outfalls will need to incorporate energy dissipation and/or erosion protection measures that will minimise bed scour and bank erosion. We recommend that these be a requirement of consent conditions. Based on this, we consider no more than minor bed erosion, scouring or undercutting will occur.

Criterion (v, vi, vii and viii) – Management of effects to streams

The operational water design has managed the effect of activities on streams through reducing changes to hydrology and erosion protection. A monitoring approach is recommended for streams that have increases in flows.

The stream diversions will be designed to enhance the streams above the existing case. A number of the streams in the Kourawhero headwaters, Hōteo tributaries, Te Hana tributaries and Maeneene tributaries are currently low functioning, with little riparian buffer and flowing through pasture. The stream diversions in these areas will incorporate riparian zones and other enhancing features, as detailed in the three types of stream diversions, and therefore these will enhance the existing streams.

The assessment of these diversions and recommended mitigation is detailed in the Ecological Assessment Report.

8.5.4 Water quantity effects – wetlands

This section includes an assessment of the magnitude of effects to wetlands associated with changes in hydrology due the Project. The level of effect depends on the ecological value and this assessment is in the Ecology Assessment Report. Also refer to Section 2.3 for the methodology to assess effects.

Assessment of effects - Criterion (ii, iii, iv) – other wetlands

There are a number of natural wetlands not identified on the Council's Wetland Management Areas Overlay of the AUP(OP) within the Kourawhero Stream and Hōteo catchments that are hydrologically connected to the surface water, these are shown on Figure 29 to Figure 31.

Where the Indicative Alignment or stream diversions and culverts are located near to natural wetlands, there may be hydrological changes to natural wetlands. Table 28 discusses for each wetland the hydrological change and magnitude of effect due to the Indicative Alignment and indicative stormwater design. The level of effect depends on the ecological value and this assessment is in the Ecology Assessment Report.

Table 28 - Hydrological changes to natural wetlands (full table in Hydrological Assessment)

Wetland name	Value*	Indicative design	Hydrological change predicted	Magnitude of effect	Level of effect
WN-W-Koura 1	Medium	Diversion channel through western wetland	Partial loss (18%) of wetland and potential loss of water flows	Medium	Moderate
WN-W-Koura 2	Very high	96m span bridge crossing these wetlands	Potential increase in water flows	Low	Moderate
WN-W-Koura 3	Medium		Small area loss, potential increase in water flows	Low	Low
WN-W-Koura 4	Medium		No effect	Negligible	Very low
WN-W-Koura 5	Medium	Culvert and a section of stream diversion in wetland	Partial loss (21%) of wetland area and potential lowering of water flows.	Medium	Moderate
DVF-W-Koura-1	Medium	Stream diversion to downstream of wetland	Potential lowering of water levels	Low	Low
HN-W-Hōteo - 01	High	Road embankment and viaduct abutments within wetland	Infilling and significant loss of area (56%) and change in water levels	High	Very high
HN-W-Hōteo - 02	High	Diversion channels in close proximity to wetland	Potential changes to flow patterns and potential lowering of water level.	Low	Moderate

Wetland name	Value*	Indicative design	Hydrological change predicted	Magnitude of effect	Level of effect
HN-W-Hōteo -03	Low	Cut-embankment and cut-off drain within wetland	Partial loss (45%) and lowering of water levels	Medium	Low
HN-W-Tehana-01	Low	Fill embankment, culverts and stream diversions within wetland	Partial loss (23%) of wetland area and lowering of water levels	Medium	Low
HN_T_TeHana_01b	Low	Fill embankment and indicative alignment within wetland	Partial loss (17%) of wetland and altering of regime	Medium	Low
HN-W-TeHana-02	Low	Indicative Alignment is within wetland	Almost total loss (99%) of wetland	Very high	Moderate
*Value is the ecological value as defined by the Ecological Assessment Report					

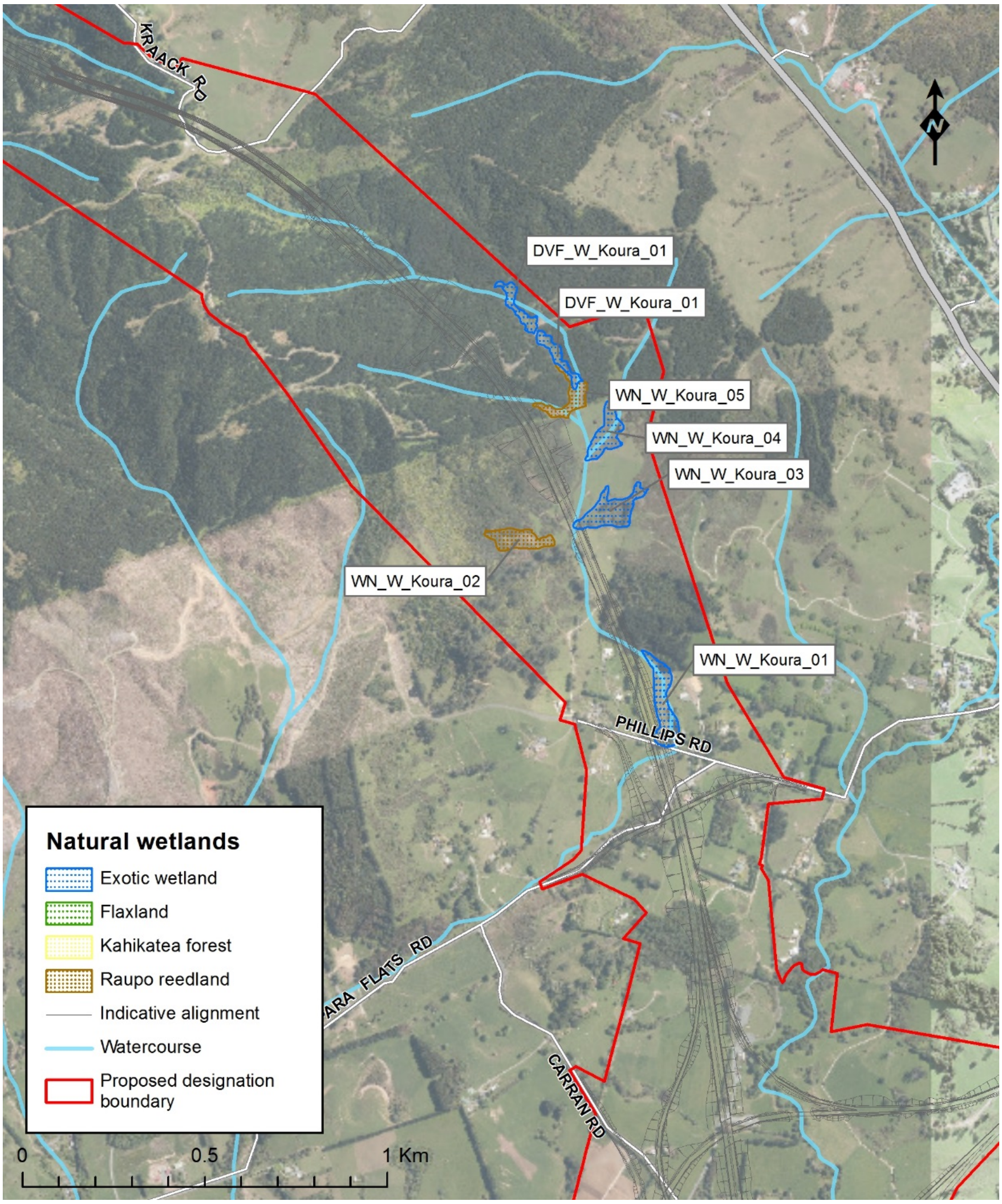

Figure 29 - Natural wetlands identified within proposed designation boundary – Kourawhero Stream

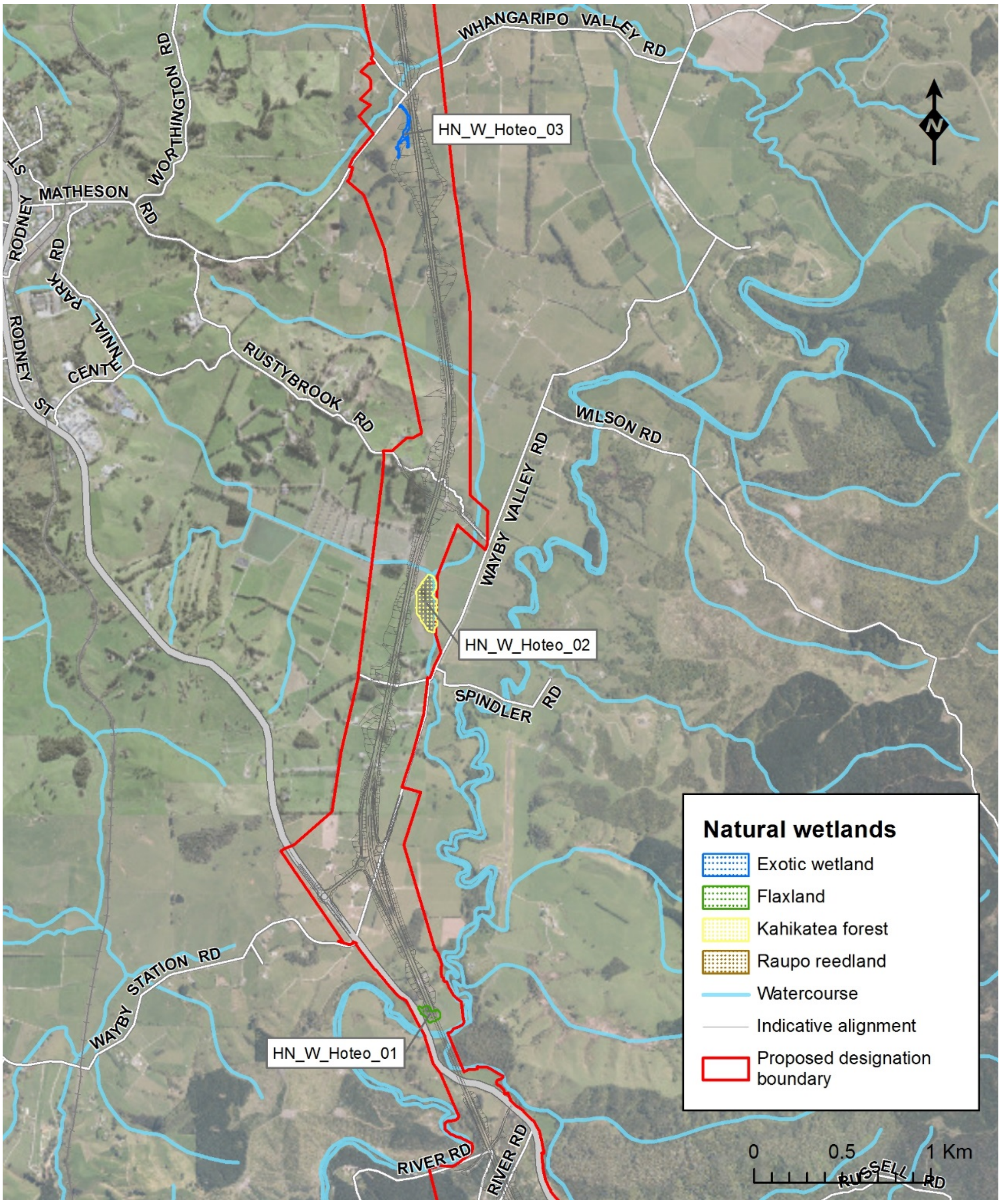

Figure 30 - Natural wetlands identified within proposed designation boundary – Unnamed Hōteo tributaries

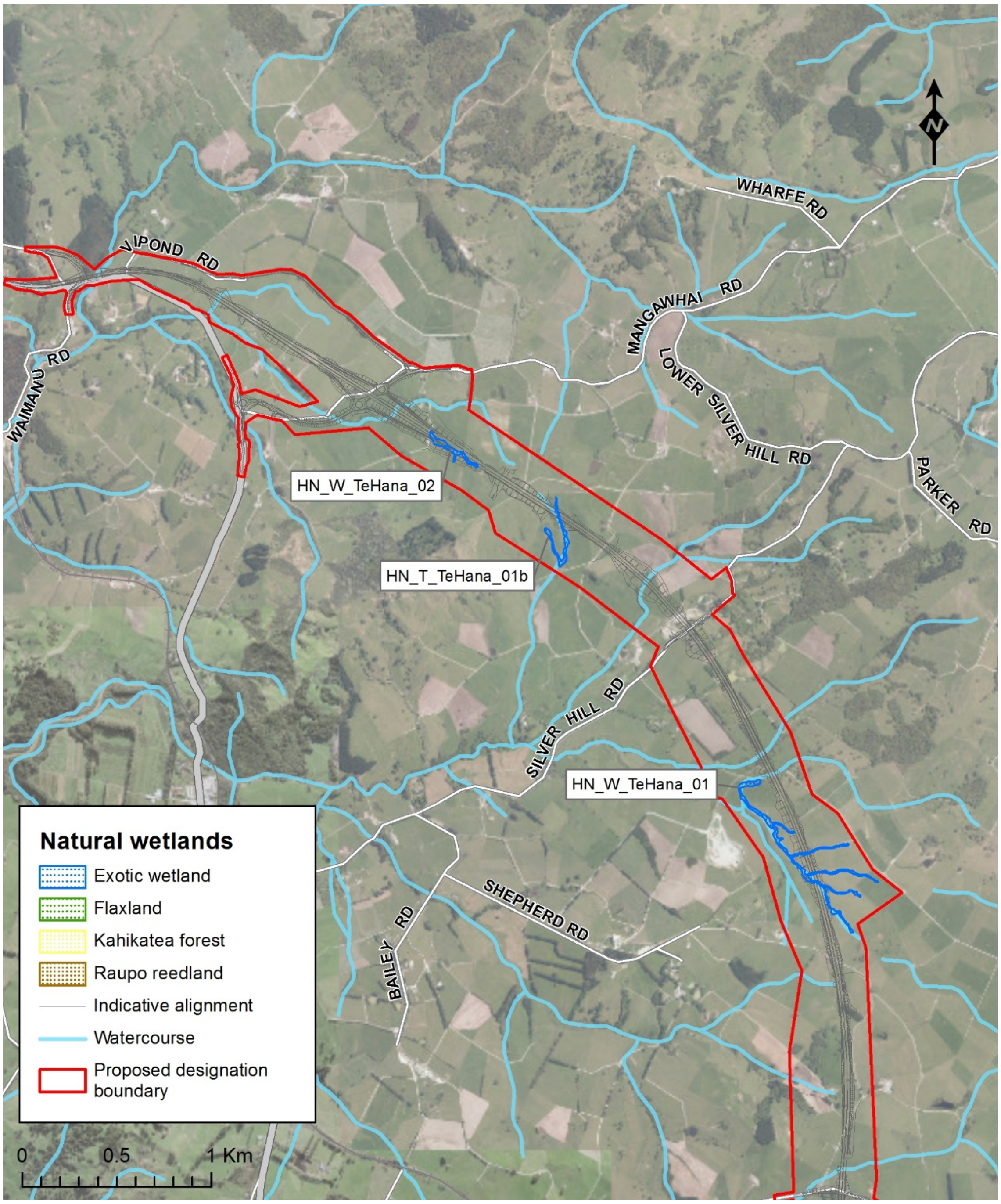

Figure 31 - Natural wetlands identified within proposed designation boundary– Te Hana and Maeneene Creek

As summarised in Table 28, a number of wetlands will be impacted by the road embankment and/or stream diversions and culverts, likely resulting in loss of wetland area, lowering of water levels in some locations and/or times within the natural wetlands, and increases in water levels in some locations and/or times due to loss of storage and changes in flood patterns. The level of effect of these hydrological changes on the aquatic habitats within the natural wetlands is contained in the Ecology Assessment Report.

The effects on these wetlands will be further refined and mitigation options explored during the detailed design. Where practicable the design will be refined to reduce the effect on wetlands. To achieve this, we recommend a consent condition that wetlands be avoided where practicable or otherwise effects on them minimised including maintaining similar flows.

A bridge across the Kourawhero Stream is proposed to mitigate effects on three of the more sensitive wetlands in the Kourawhero Stream catchment. The magnitude of effect to these wetlands is low (moderate level of effect) due to the bridge, however without a bridge the magnitude of effect would be high. The associated ecological mitigation is detailed in the Ecology Assessment report. The ecological mitigation proposes wetland enhancement in the area of the bridge (Wetlands WN-W-Koura 2, WN-W-Koura 3, WN-W-Koura 4).

8.6 Flooding

This section assesses the likelihood and magnitudes of flooding impacts/effects of the operational phase of the Project. The key topics that this section assesses are:

- Project vulnerability to flooding;
- Flooding effects on others;
- Overland flow paths; and
- Other flooding considerations.

This section includes an assessment of effects in the context of the criteria identified in Section 3 Table 3. The technical works to support this assessment can be found in the Flood Modelling technical report.

8.6.1 Criteria / consideration for the assessment

The criteria for assessing flooding effects are listed below:

Vulnerability to flooding

i. The type of activity being undertaken and its duration and its vulnerability to natural hazard events (E36.9(2.b)).
ii. Consider the potential effects on public safety and other property (E36.3(3.d)).

Flooding effects on others

i. Ensure all development does not cause or worsen the flood hazards, flood depths or velocities for a range of flood events, to other properties upstream or downstream of the site beyond the land or structures owned or controlled by the person undertaking the activity (AUP(OP) E3 & E36).
ii. Provide for flood mitigation measures which reduce flood-related effects and provide for culverts and bridges where those measures do not create or exacerbate flooding upstream or downstream or otherwise increase flood hazards (AUP(OP) E36).
iii. Ensure the discharge does not cause or increase nuisance or damage to other properties (AUP(OP) E9).
iv. Ensure the discharge does not create or exacerbate flood risks (AUP(OP) E1).

Overland flow paths

i. Maintain the function of overland flow paths to convey stormwater runoff safely from a site to the receiving environment. Require changes to overland flow paths to retain their capacity to pass stormwater flows safely without causing damage to property or the environment (AUP(OP) E36).

Other

i. Consider the ability to use of non-structural solutions, such as planting or the retention or enhancement of natural landform buffers to avoid, remedy or mitigate the hazard, rather than hard engineering solutions or protection structures (E36).

ii. Consider the long-term management, maintenance and monitoring of any mechanisms associated with managing the risk of adverse effects resulting from the placement of infrastructure within a hazard area to other people, property and the environment including the management of hazardous substances (E36).

8.6.2 Flooding effects – vulnerability to flooding

Vulnerability to flooding - Criterion (i)

The operation of the Project has been considered in relation to the duration and vulnerability to flood hazard. The design requirement from NZTA is for the carriageway level to be set at a freeboard above predicted 1 in 100 year flood levels. There are similar design requirements for the capacity of culverts and bridges, refer to the Operational Water Design technical report.

The Indicative Design and flooding assessment allowed for climate change to the end of the design life (2130) and as such the vulnerability of the Project for the duration of the project life has been considered.

The flood modelling has included an assessment of the vulnerability of the new State Highway to flooding, as detailed in the Flood Modelling technical report. The results indicate that for the modelled areas, that is for the Mahurangi River, the Kourawhero stream and the Hōteo River floodplains, the carriageway has a freeboard equal to or greater than 0.5 m on the road and 1.0m at each culvert above the 100 year ARI flood level incorporating climate change. This meets the design criteria and complies with guidance, taking into account the vulnerability of the road to flooding.

An additional flood related natural hazard is debris flows, which are fast flowing mixtures of water with a medium or high proportion of solids, such as fallen trees, stumps, boulders, gravels and soils, which move down watercourses. Debris flows are triggered by heavy rainfall and can often occur in conjunction with landslides within the catchment. A less severe hazard is large woody debris, especially from forestry catchments after felling, that can be carried by floods and can block culverts. In the Operational Water Design technical report, a risk framework was used to assess the risk from debris to culvert blockage. Using this risk framework the Indicative Design includes mitigation measures to reduce the risk of blockage of culverts by including secondary flow paths, debris control structures, enlarged culverts and relief inlets. We recommend that these hazards are considered in more detail using a risk based approach at the detailed design stage.

Vulnerability to flooding - Criterion (ii)

As identified above, the flood model does not predict flooding to the new State Highway from a 100 year flood and incorporates the appropriate freeboard. Therefore, flooding of the Hōteo River or other watercourses for a 100 year ARI flood would not result in flooding of the new State Highway, and there is no predicted danger to road users on the new State Highway. Public safety is therefore improved over the existing SH1, because the Project has a higher standard of flood resilience than the existing SH1.

8.6.3 Flood effects – flood effects on others

This section includes a summary of the effects of the Project on flooding to other properties upstream or downstream of the site beyond the land or structures owned or controlled by the person undertaking the activity, that is to properties outside of the proposed designation boundary and public roads within the proposed designation boundary.

The Flood Modelling technical report assessed the changes in flooding associated with the Indicative Alignment by developing flood models for the following three locations:

1. Mahurangi River and its tributaries crossings.
2. Crossings of Kourawhero Stream south of the proposed tunnel; and
3. Hōteo River adjacent to Wayby Valley Road;

The Project has been designed to minimise increases in flood risk outside of the proposed designation boundary and to have no more than minor effects on other property. The flood modelling was carried out to assess the Indicative Design and to identify changes in flooding. The flood models have included change in flood storage due to the road and embankments, and changes in conveyance due to the culverts, bridges and diversions. Flood modelling was carried out for the pre-development and operational phase (without ecological mitigation planting) scenarios for the 2, 10, 20 and 100 year ARI events with an allowance for climate change. The pre-development scenario includes the Pūhoi to Warkworth section of state highway as it is consented and under-construction.

For the Mahurangi River and the Hōteo River models, the effects of ecological mitigation planting on flooding has also been assessed. Flood modelling was carried out for the 100 year ARI events with an allowance for climate change for the operational phase with planting scenario. The mitigation planting within the Kourawhero catchment was not modelled as it would not be consequential to the flood assessment.

The broad patterns of change in flood extends and depths due to the Project are as follows:

- The flood models indicate that the Hōteo viaduct, the Kourawhero and Mahurangi bridges, and all culverts in the modelled areas do not result in significant changes to the extents of flood inundation.
- The flood depths will increase due to the presence of the Project. Generally, these changes are contained inside the proposed designation boundary, however these locations do sometimes extend beyond and onto areas of adjacent pasture. There is no predicted increase in flood depth or hazard to dwellings or other structures outside of the proposed designation boundary. A description of the changes in

flood depth for each flood model are detailed below with summaries in Table 29 to Table 31.

Mahurangi River

For the Mahurangi River, the difference in pre and post development scenarios are negligible at most locations along the Indicative Alignment, however there are some locations with increased flood depths. Figure 33 shows the change in flood depth for the post development scenario compared to pre development for the 100 year ARI event at the Warkworth Interchange. The changes to flood depth are summarised in Table 29 and discussed below:

- There are predicted increases in flooding immediately upstream of culverts. These are within areas of pasture within the proposed designation boundary, with increases of up to 1.8m for the 100 year ARI event. These increases are generally confined to the riparian zone and are generally in areas already at risk of flooding. The design of diversions channels in the final design could reduce this flooding further.
- A small increase in flooding is predicted along Carran Road within the proposed designation boundary. Carran Road floods in the pre-development case, there is a modelled local increase of up to 75mm in an area currently at risk of flooding up to 9mm in depth. However, there are other parts of Carran Road that flood up to 1.25 m, therefore the project does not alter the overall flood risk to the road. In addition to this Carran Road is likely to be realigned due to the construction, and as such localised increases are unlikely to be realised.
- Increases in flood depth of up to 1m upstream of Bridge 5 and Bridge 6 along the left branch of the Mahurangi River. This is within small areas immediately upstream of the bridges, entirely within the proposed designation boundary and within areas of pasture.

The impact of the planting proposed within the Mahurangi Catchments on flooding has been assessed. The model predicts that for the 100 year ARI event there is no change to the flood extent associated with the planting. The model predicts that there will be increases of up to 100 mm located within riparian margins of the left branch of the Mahurangi River, however this is within areas that are already at risk of flooding with flood depths of over 1.5 m.

There is no predicted increase of flood depth to dwellings outside of the proposed designation boundary associated with the Project.

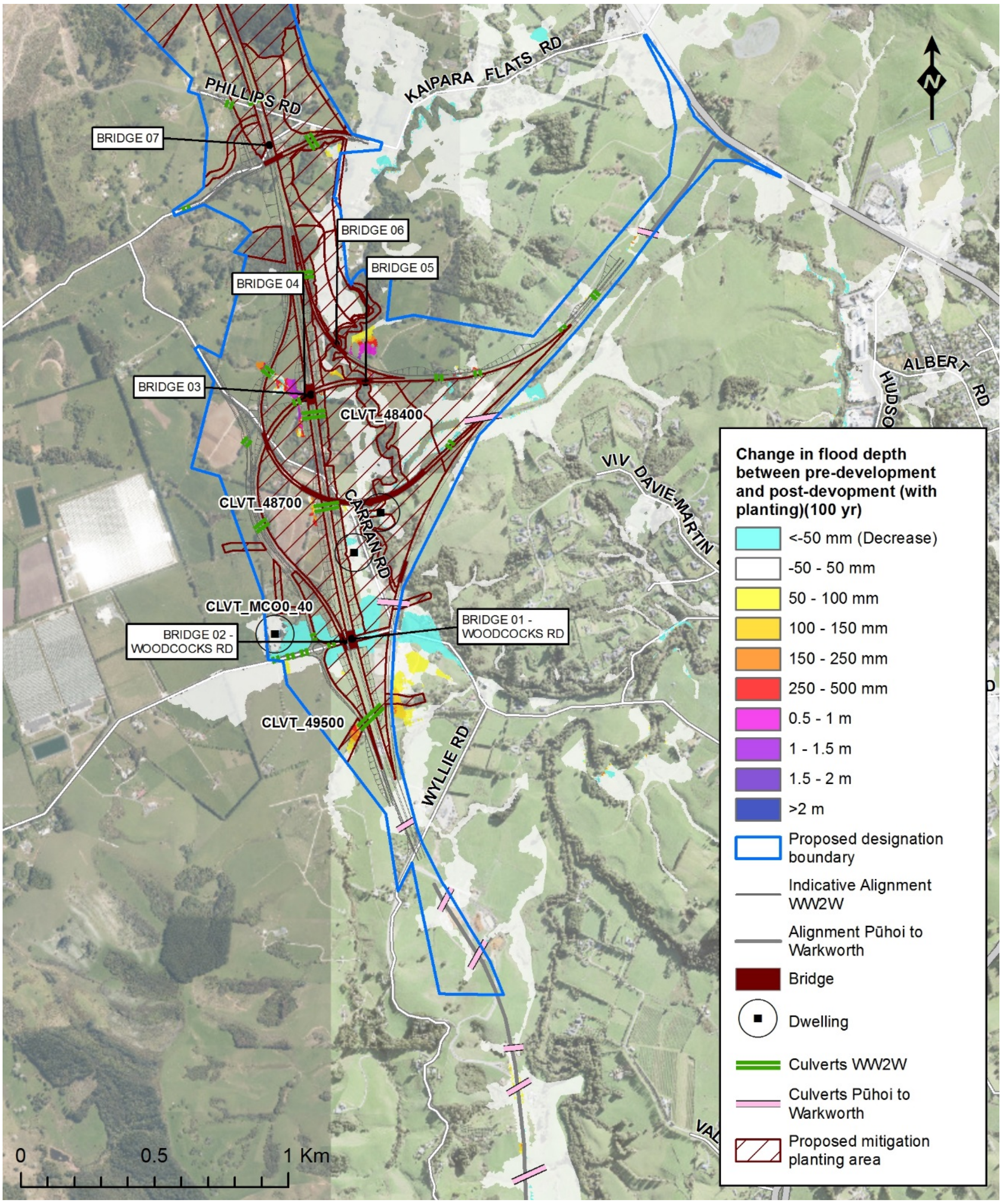

Figure 32 - Change in flood level due to the Project (including ecological mitigation planting) for 100 Year ARI Event for the Mahurangi River

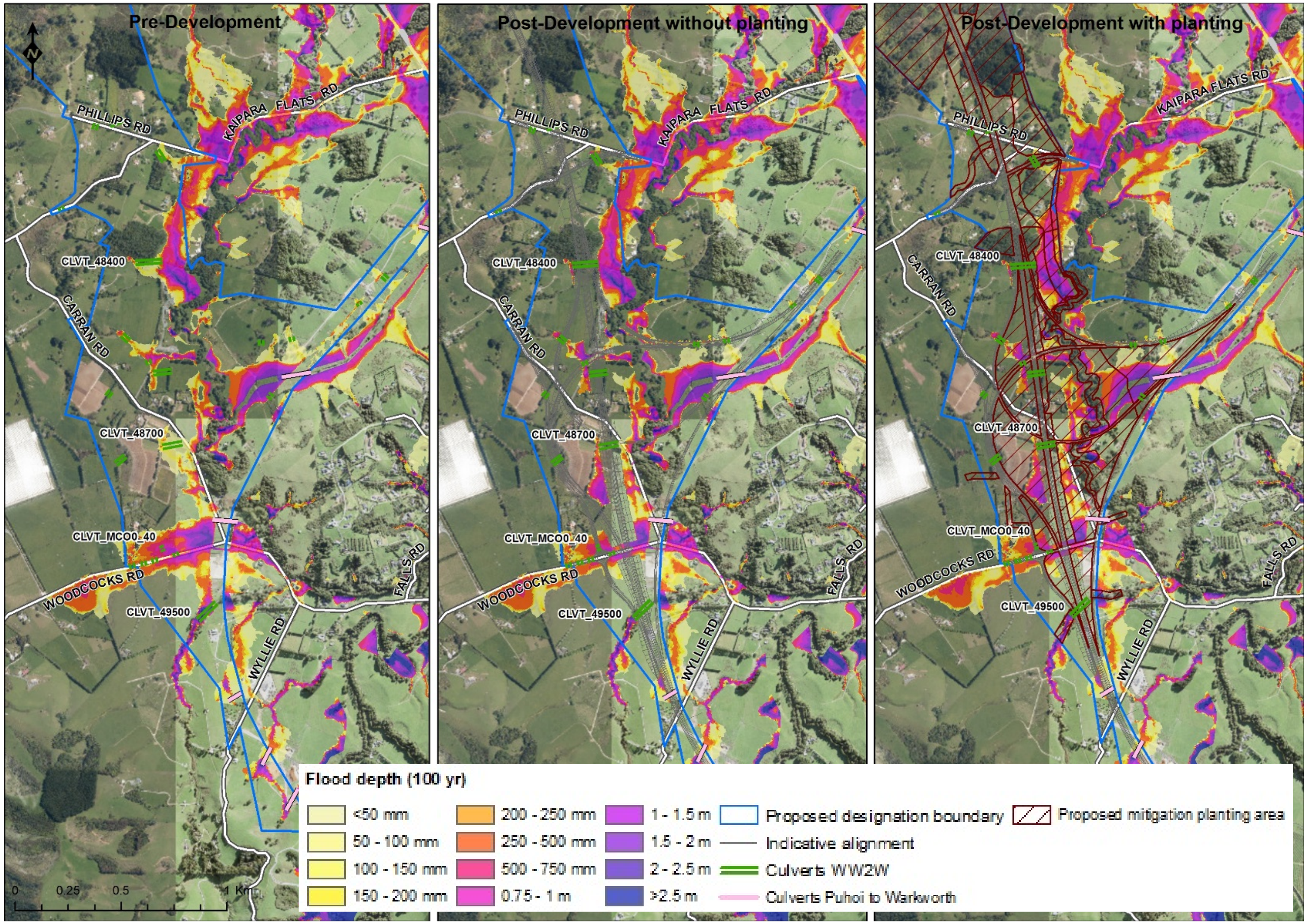

Figure 33 - Pre and post development (with and without mitigation planting) flood depths for 100 Year ARI Event for Mahurangi River

Table 29 - Flood model results for changes to flooding levels associated with the Indicative Alignment for the 100 year ARI event for the Mahurangi River flood model

Project element cause	Specific location	Within des.	Maximum flood depth (m)			Land use
			Pre-dev.	Post-dev.	Increase	
Culvert	CLVT_49500	Yes	2.0m	2.2m	≤0.25m	Forest, riparian margin, pasture
	CLVT_48700	Yes	0.4m	1.8m	≤1.8m*	Pasture
	CLVT_48400	Yes	1.5m	1.6	≤1.1m*	Pasture
Earthworks	Carran Road	Yes	1.25m	1.25m	≤0.08m	Local road
Bridges	Bridge 5	Yes	1.25m	1.4m	≤0.25m	Pasture
	Bridge 6	Yes	1.25m	1.5m	≤0.25m	Pasture
Planting	Kaipara Flats Road	No	3.6m	3.6m	≤0.1m	Riparian margin
	East of Carran Road	No	1.68m	1.74m	≤0.1m	Riparian margin
*Depth to be reduced through using diversion channels in design						

Kourawhero Stream

For the Kourawhero stream, the modelling has found that the interaction of the Indicative Alignment with the existing floodplain causes change over the upstream flood levels in the locations discussed below. All locations are entirely within the proposed designation, boundary and the changes to flood depth are summarised in Table 30 and described below:

- There are two areas located in the northern part of the model at culverts 46150 and 45650 where increases in flood depth are small and confined to areas over forestry land cover, these are entirely within the proposed designation boundary (Figure 34).
- Large increases in flood depth are predicted north of Kaipara Flats Road within the proposed designation boundary (Figure 34), This is associated with the earthworks being sited within the existing floodplain. In this area there are 3 residential properties (dwellings) affected by flood increases of up to 1m in this area, although the existing flood extent also impacted two of these properties (Figure 35). These are properties are located within the proposed designation boundary and are likely to be purchased by the Crown. The worst effect area in this area is pasture directly upstream of culvert 47200 with an existing flood depth of 450mm, the “with Project” scenario shows an increase up to 2 m for the 100 year ARI event.
- The model predicts that a small section of Philips Road will get inundated due to flood water, with increases of up to 0.5m in a small section, however Philips Road will be realigned as part of the Project and therefore this increase will be less than modelled. No change is predicted along Kaipara Flats Road.

There is mitigation planting planned within the Kourawhero Stream catchment, however given that the floodplain of the Kourawhero Stream is well within the proposed designation boundary, this has not been modelled as any increase in flooding due to planting would not result in changes outside of the proposed designation boundary.

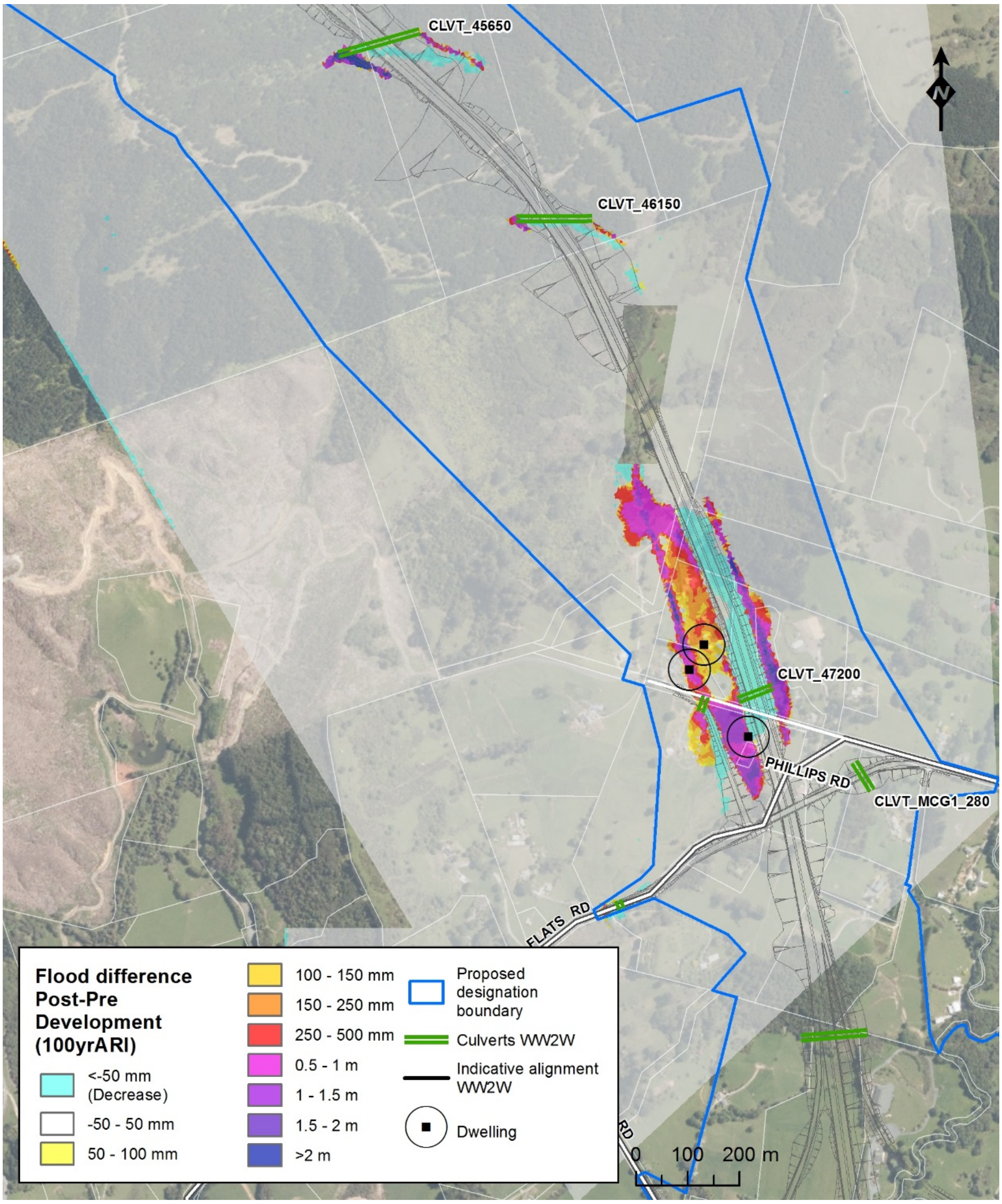

Figure 34 - Change in flood level due to the Project (excluding planting) for 100 Year ARI Event for the Kourawhero River

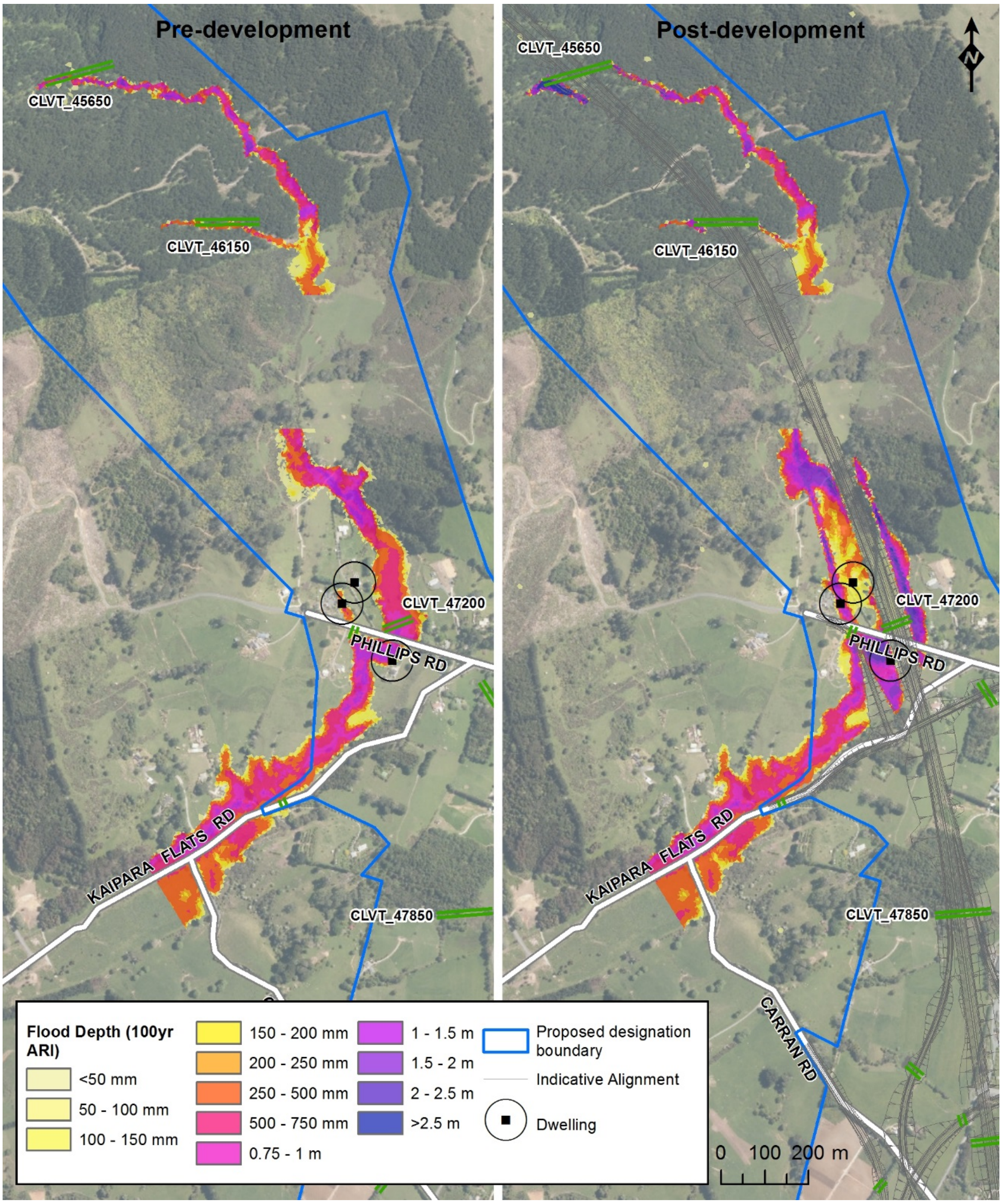

Figure 35 - Pre and post development (without planting) flood depths for the 100 Year ARI Event for Kourawhero Stream

Table 30 - Flood model results for changes to flooding levels associated with the Indicative Alignment for the 100 year ARI event for Kourawhero Stream

Project element cause	Specific area	Within des.	Flood depth (m)			Land use
			Pre-dev.	Post-dev.	Increase	
Culverts	CLVT_46150	Yes	1.5m	3.5m	≤2.0m	Forestry
	CLVT_45650	Yes	0.5m	1.5m	≤1.0m	Forestry
Culverts, earthworks and diversions	CLVT_47200	Yes	0.5	2.5m	≤2.0m	Pasture/ riparian margin
	Phillips Road (CLVT _MCG1_280)	Yes	0.80m	1.7m	≤0.98m	Dwelling (11 Phillips Rd)
		Yes	0.0m	0.13m	≤0.13m	Dwelling (18 Phillips Rd)
		Yes	0.55m	1.52m	≤0.97m	Dwelling (30 Phillips Rd)
		Yes	0.2m	0.5m	≤0.5m	Local road
		Yes	1.25m	2.5m	≤1.5m	Pasture

Hōteo River

For the Hōteo River, the occupation of floodplains by the embankment of the Indicative Alignment does not result in a substantial change in terms of extent of flood inundation. However, the model identifies some changes to flood depth within the proposed designation boundary and some adjacent pasture land. The localised changes in flood extents and flood levels associated with the Hōteo River model are detailed below, and depths summarised in Table 31.

- One area of increased flooding is an area to the north of Rustybrook Road. The Indicative Alignment is predicted to increase the flood depth by more than 2 m within the proposed designation boundary and up to 0.6 m immediately outside for the 100 year ARI event. Both of these areas are pasture (Figure 36) and in these areas the pre-development flood depth is up to 1m. Insignificant increases of flood depth are predicted for 2, 10, and 20 year ARI events. Although increase in depth is between 0.5-2 m (for 100 year ARI event), it is only to a small area of land that is mainly within the proposed designation boundary and on pasture, and therefore the effect is considered minor due to the small impact of increased flooding to grass in the 100 year ARI event. This model does not incorporate the effect of diversion channels on flooding, which would likely decrease the extent of flooding. We consider that the flooding in this area can be reduced at the detailed design stage to meet a performance standard set in resource consents. It is recommended that prior to construction the final flood risk of the design is assessed with modelling.
- At the junction of Rustybrook Road and Wayby Valley Road there is a predicted increase in flood depth at an area currently at risk of flooding. Outside the proposed designation boundary there is predicted 0.05-0.1 m increase for the 100 year ARI event, the pre-development flood depth is 0.55-2.0 m in this area and therefore the increase does not change the potential flood hazard in this area. There is a residential property within the proposed designation boundary (237 Rustybrook road) which has an increase in flooding of 0.05 m, however compared to the pre-development flood depth of 2.18 m this is insignificant, as the hazard to the property was high in the pre-development scenario.
- North of the interchange of SH1 and Wayby Valley Road, the Indicative Alignment increases the flood depth for 100 Year ARI event by up to 250 mm within the

proposed designation boundary across pasture and up to 100mm outside, over pasture. The flood depth increase was also observed within and outside the proposed designation boundary for 10 and 20 Year ARI events, however increases were confined within the proposed designation boundary for the 2 year ARI event. The model shows that the project increases the flood depth for 100 Year ARI event over Wayby Valley Road between 50 and 100 mm (Figure 37). The existing flood depth at all these locations is over 1.0 m in the pre-development scenario, and although there are localised increases of flooding, the peak flood depth and durations in these areas do not change significantly.

The impact of the planting proposed within the Hōteo Catchment on flooding has been modelled for the 100 year ARI event (Figure 37). The model predicts that for the 100 year ARI event there is no change to the flood extent associated with the planting. The model predicts that there will be increases in flood depth upstream of the proposed viaduct, ranging between 50 mm to 150 mm (Figure 36), however the pre-development flood depth is over 2.5 m in this area (Figure 37) therefore the increase does not alter the already high flood hazard. The increase is 150 mm immediately upstream of the viaduct, which extends beyond the proposed designation boundary, however this reduces to a 50 mm increase further away from the viaduct. The increase in flood depth does not directly affect dwellings. These changes are a minor effect on pasture as the land is already subject to considerable flooding (Figure 37).

Table 31 - Flood model results for changes to flooding levels associated with the Indicative Alignment for the 100 year ARI event for the Hōteo River

Project element	Specific area	Within des.	Max flood depth (m)			Land use
			Pre-dev.	Post-dev.	Increase	
Earthworks / culverts	North of Rustybrook Road	Yes	1.0m	3.1m	≤2.75m	Pasture
		No	0.1m	0.5m	≤0.5m	Pasture
	Junction of Rustybrook Road and Wayby Valley Road	No	0.55m	0.6m	≤0.05m	Local road
		No	2m	2.1m	≤0.1m	Pasture
		Yes	2m	2.1m	≤0.1m	Pasture
		Yes	2.18m	2.23m	≤0.05m	Dwelling (237 Rustybrook Road)
	Interchange of SH1 and Wayby Valley Road	Yes	1.0m	1.0m	≤ 0.10m	Local road
		Yes	1.0m	1.0m	≤ 0.25m	Pasture
		No	1.45m	1.5m	≤ 0.1m	Pasture
Planting	North of viaduct	Yes	2.5m	2.6m	≤ 0.15m	Pasture
		No	2.8m	2.9m	≤ 0.15m	Pasture

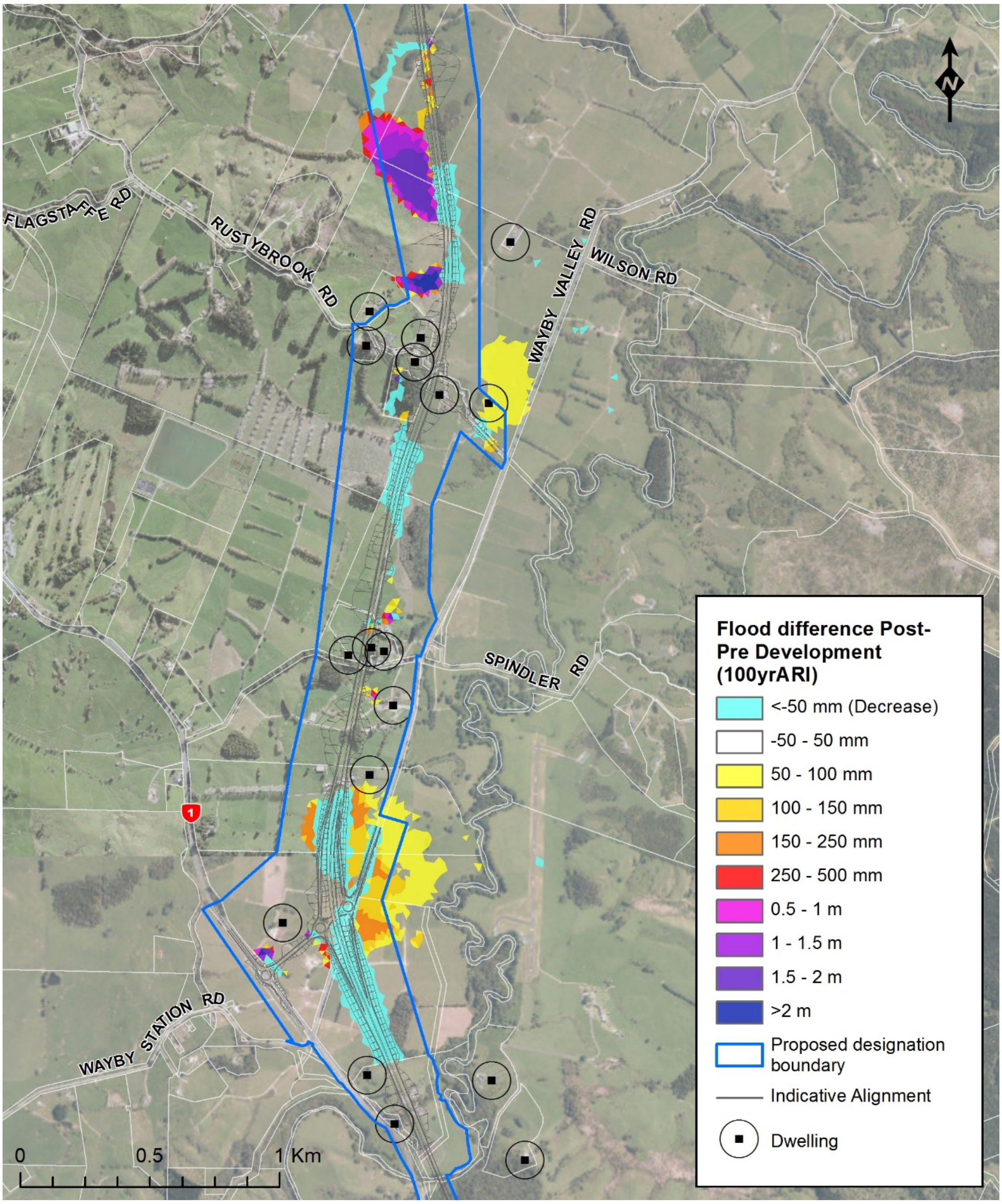

Figure 36 - Change in flood level due to the Project for 100 Year ARI Event for Hōteo River

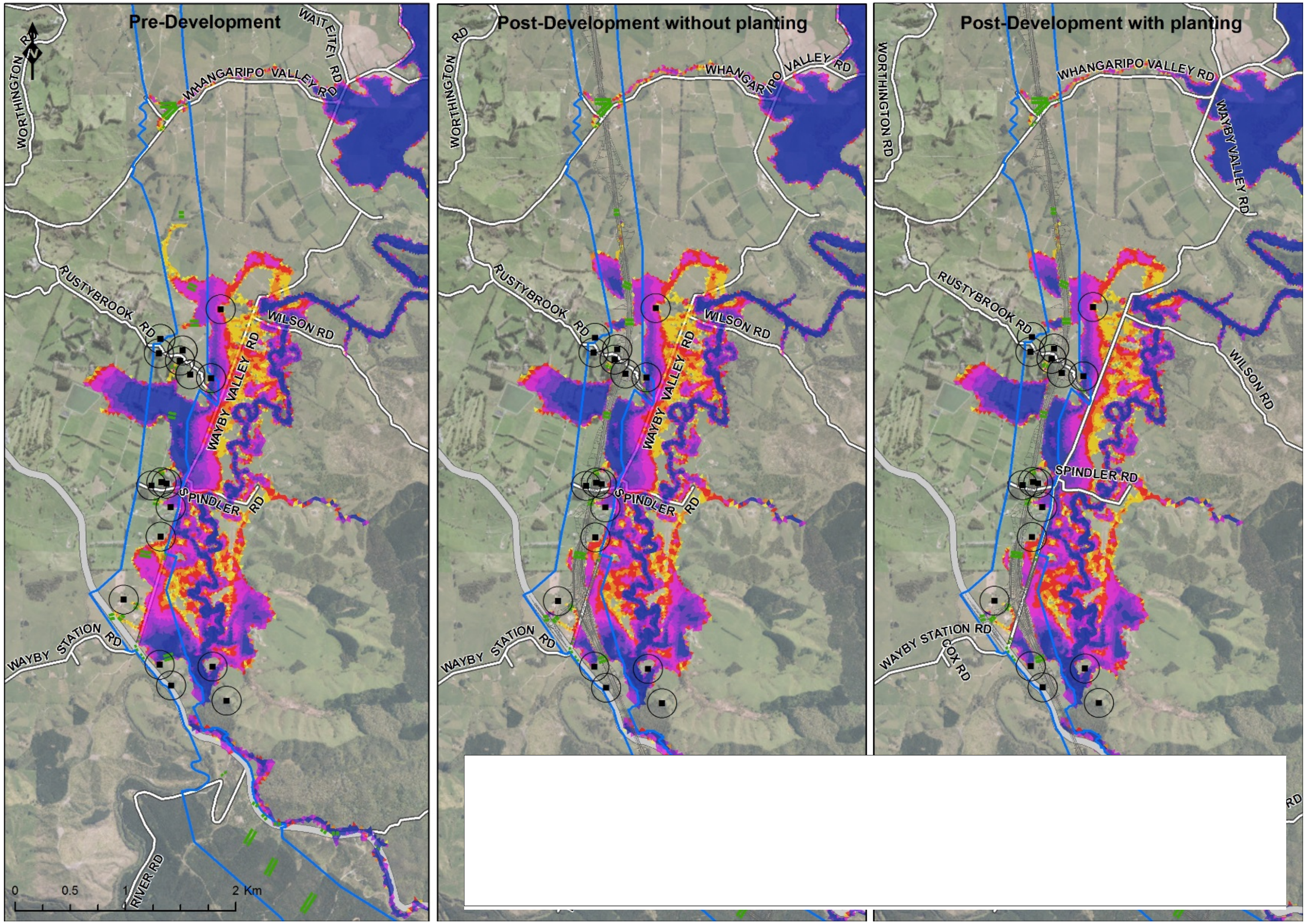

Figure 37 - Pre and post development flood levels for 100 Year ARI Event for Hōteo River

Flooding effects on others - Criterion (i) and (iii) – flood hazard/risks to others

During the route options assessment, a multi-disciplinary options analysis was undertaken to select the Indicative Alignment, this included favouring route options with lesser flood effects, among other issues. The alternative route options, as outlined in Section 4 of the AEE, considered flood effects. However, complete avoidance of floodplains has not been possible as the Indicative Alignment needs to cross the Mahurangi River, the Kourawhero River and the Hōteo River.

Where possible fill areas and stormwater treatment devices have been located out of the 100 year ARI floodplain, none the less there are locations where these features occupy flood storage especially as the Hōteo River has an extensive floodplain that must be crossed by the Project.

The flood modelling undertaken for this Project (as described above) indicates that the majority of increases in flood levels and extents are within the proposed designation boundary. These are all permitted by the criterion and will not affect properties upstream or downstream of the proposed designation boundary.

The increases in depth outside of the proposes designation boundary:

- Effects are generally less than 150 mm in increase, with one exception where the increase (600 mm) is very localised to immediately adjacent to the proposed designation boundary and on pasture.
- Effects are generally restricted to land which is already flooded and the current land use is pasture, and as such there is no increase to flood hazard, and as such any effect is minor.
- For all local roads, increases in flood levels are localised and do not result in significant changes in the peak flood level or flood durations along the road, and therefore there is minor effect on flood hazard and accessibility.

Therefore, in our view these increases in flood levels result in only minor increases in the effects of flooding, which might include small increases in duration and small increases in inundation to pasture and local roads.

Alternate alignments within the proposed designation boundary may result in differing increases in flood levels and extents.

We recommend conditions are developed to limit the increase in flood levels outside of the proposed designation boundary and to local roads, with the conditions recognising that a more stringent standard would be appropriate for managing increases in flood levels, extents and velocities that impact on residential property and public roads, than for with pastoral land.

Flooding effects on others - Criterion (ii) – culverts and bridges

The design life of the Project is 100 years and the cross drainage, bridges, road embankment and flood effects assessment has been undertaken on 2130 climate change flows (MfE 2016).

The bridges, will be designed to a withstand flood loading in a 2500 year ARI event as per the Bridge Manual 3rd edition (NZTA 2013). We assess the design as being resilient to flooding for the duration of its design life.

Culverts and stream diversions will be designed to convey the 100 year ARI climate change event.

The operational design meets Transport Agency Bridge Manual and Transport Agency P46 criteria for the design the cross drainage, bridges and the embankment height.

Stream diversions are designed to convey the 100 year ARI event. The cross drainage and culverts are designed to convey the 100 year ARI climate change event and will provide 500mm of freeboard to the edge of the seal. The effect of the embankment, cross drainage and bridges has been tested within a hydraulic model to provide estimates of changes in flood depth and extent.

The hydraulic modelling and assessment of flood effects demonstrates that within the proposed designation boundary, the combined changes to flood storage and conveyance does result in increases in flood levels within the proposed designation boundary, but beyond the proposed designation boundary the flood levels increases are limited the floodplain areas and are not predicted to cause damage to property or the environment.

For the Kourawhero Stream, in order to reduce the impact of the Indicative Alignment and stream diversions on the natural wetlands hydrological regime, a bridge with a span of 96m was designed. This bridge will cater for the flood flows in the Kourawhero Stream, and is wide enough to avoid upstream increase to flood levels. A smaller bridge may be included during detailed design; however, this should be designed to ensure that the peak flood flow is accommodated.

As with Criterion (i), we recommend conditions are developed to limit the increase in flood levels outside of the proposed designation boundary, requiring no increase greater than 100mm in flooding to residential property outside of the proposed designation boundary. We recommend that no changes to the flooding depth for flood frequencies up to the 100 year ARI be acceptable for dwelling floor levels outside the proposed designation boundary.

We also recommend conditions are developed for culverts and bridges that account for climate change and the risk of blockage, and limit increases in flood effects beyond the proposed designation boundary.

Flooding effects on others - Criterion (iv) – stormwater discharges

The stormwater discharges from the Project may result in small changes to stream flow durations, timing and peaks due to the increased stormwater runoff from the impervious area of the road. This change was not included within the flood model.

The stormwater treatment wetlands will be used for detention of minor rainfall events for hydrological mitigation (95th percentile rainfall events) to provide stream protection, but they will not provide for flood attenuation of extreme rainfall events. The small scale of impervious areas relative to the catchment sizes mean that the Project will not significantly change catchment scale flooding. The Project impervious area (road surface) is 25 ha (0.4%) and 150 ha (0.4%) of the Mahurangi and Hōteo catchments, respectively.

8.6.4 Flood effects – overland flow paths

Cross drainage has been provided to mimic natural flow paths where practical and consequently the number of stream diversions are minimised. Design criteria have been developed to convey flood flows to minimise changes in flood risk and to provide for flood risk.

8.6.5 Flooding effects - Other

Criterion (viii)

The Indicative Alignment does not propose any hard engineering protection structures in terms of flood risk protection.

The indicative stormwater management design incorporates stormwater treatment wetlands to provide stormwater retention, over hard engineering retention ponds. The stormwater wetlands include wetland and riparian planting which have the potential for wider ecological benefits. Additionally, the diversion channels will incorporate natural landforms including riparian plant.

Criterion (ix)

The culverts, bridges and embankment structure will be subject to NZTA's asset management system, to provide for ongoing maintenance and monitoring throughout the design life of the Project.

8.7 Recommended management

The following section summarises the water management and mitigation approaches that we recommend are included to provide for the operational water design, maintenance and monitoring.

8.7.1 Stormwater discharges

- Water quality treatment for the replacement stage highway is designed to follow GD01 guidelines;
- Stormwater treatment wetlands to have dense, healthy planting in emergent, littoral and riparian zones in designs which are maintained in operation;
- Stormwater treatment wetlands to include vegetation coverage and partial shading so that increased temperatures are avoided;
- Stormwater treatment wetlands to include deeper zones to reduce nuisance plant growth;
- Stormwater treatment wetlands to have forebays and submerged or baffled low flows outlets so that floatables and litter can be trapped in the wetland;
- Stormwater treatment wetlands to include valves on the low-level outlets from wetlands, so that in the event of a spill then valve can be closed to contain the spill material in the wetland;

- Stormwater treatment wetlands discharging to stream environments to achieve the hydrology mitigation requirements specified in the AUP(OP) (Table E10.6.3.1.1);
- Sediment traps or alterative mitigation for sediment eroded off rock cuts;
- Vegetated roadside drains for water quality treatment for ancillary roads;
- Minimise erosion in receiving environments from stormwater and culvert outlets;
- The design of stormwater outlets shall consider various rainfall and tailwater levels to ensure the critical storm is considered;
- Water collected from the tunnels that is not suitable for treatment such as washdown water and contaminated firefighting water, shall be collected by the NZTA and transferred for treatment and disposal off-site in accordance with any necessary council approvals or consents;
- Operation and maintenance plans to be certified by Auckland Council prior to operation; and
- Keep a record of maintenance of stormwater treatment devices.

8.7.2 Streams and natural wetlands

- Provide bridges across main rivers (Mahurangi, Hōteo and Maeneene) as well as across the Kourawhero for ecological mitigation;
- Design for culverts or bridges for the 100 year ARI rainfall event;
- Design for stream diversions to manage the 100 year ARI rainfall event;
- Fish passage in culverts to be provided for all permanent streams and all instances where there are fish present or potential for fish habitat upstream in intermittent streams;
- Erosion control for outfalls and culverts to minimise bed scour and bank erosion in receiving environments;
- Stream diversions to have natural stream forms where the diverted streams are permanent and supporting fish habitats;
- Stream diversions to be in general accordance with stream diversion requirements for channel stability, in-stream habitat and riparian planting;
- Monitoring over a limited post-construction period for erosion prone streams. Target monitoring of streams with changes to catchment flows of more than 15% and with soft-bottoms that may be susceptible to erosion. If erosion is observed to occur then the erosion must be remedied;
- Provide for a bridge to maintain the hydrological connectivity between the natural wetlands on the east and west side of the Indicative Alignment in the Kourawhero floodplain; and
- Wetlands be avoided where practicable or otherwise effects on them minimised and mitigated including maintaining similar flows.

8.7.3 Flooding

- Climate change is allowed for in all aspects in all the hydrological aspects of the operational water design;
- TP108 hydrology methodology is used for the sizing of culverts with Bridge Manual approaches being acceptable for bridges;

- Calibrated hydraulic models are used for assessing flood effects the Hōteo and Mahurangi floodplains from the final alignment to ensure that the flood effects are no worse than those identified in this assessment;
- Outside of the proposed designation boundary and for local roads limit the increase in flood levels to
    - no greater than 100mm for residential property
    - no changes to the flooding depth for flood frequencies up to the 100 year ARI be acceptable for dwelling floors
    - no change in flood risk to people and environment for other land uses.

  Prior to construction the final flood risk of the design is assessed with modelling.
- Hazards from debris flows and woody debris are considered and minimised in more detail using a risk based approach at the detailed design stage.

8.7.4 Drinking Water

- Transport Agency to inform Watercare if a spill occurs on the state highway within the Mahurangi catchment and Hōteo catchments (upstream of Wilson Road), so Watercare can take action to protect their surface water take for so long as Watercare continue to use these surface water takes.

8.8 Operational water management conclusion

An integrated stormwater management design is proposed that includes stormwater collection and conveyance network, treatment systems and devices, culverts and watercourse diversions and consideration of the floodplain (refer Section 7). The assessment has found that the Project has incorporated the required integrated stormwater management, and that the design of the Project has applied the Best Practicable Option to comply with the RMA and AUP(OP).

The water quality effects assessment includes an estimation of change to contaminants and changes to other water quality factors, as supported by the Operational Water – Road Runoff technical report. An assessment of the effects of the Project has found, with the proposed management approaches and mitigations in place, that the effect of the Project on water quality, including human health impacts, is minor or less.

The assessment of water quantity (hydrological) effects, as supported by the Hydrological Assessment technical report, includes an assessment of the magnitude of effects of the operational phase of the Project on hydrology in streams (including erosion) and in wetlands. An assessment of the effects of the Project has found, with the proposed management approaches and mitigations in place, that the effect of the Project on hydrology and streams is minor or less. The effect on wetlands from the Indicative Design has been assessed as moderate, and recommends further design refinement to minimise and mitigate these effects.

The flood effects assessment is based upon the modelling results from the Flood Modelling technical report, and assesses the vulnerability of the Project to flooding, as well as the effects to other properties upstream or downstream of the Project. An assessment of the flood effects of the Project have found that the effect of the Project on flooding is generally minor or less.

Water management and mitigation approaches are recommended to ensure the effects are as they have been assessed (refer Section 8.7). Overall it is concluded that adverse effects on the environment from a stormwater/flooding perspective, during the operational phase of the Project, are generally minor or less.