Warkworth to Wellsford

Hydrological Assessment Report

Technical Report

July 2019

QUALITY ASSURANCE

Prepared by

Jacobs GHD Joint Venture in association with Tonkin & Taylor Ltd. Prepared subject to the terms of the Professional Services Contract between the Client and Jacobs GHD Joint Venture for the Route Protection and Consenting of the Warkworth to Wellsford Project.

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GLOSSARY AND DEFINED TERMS

Refer to the Water Assessment Report for a master glossary and defined terms table.

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1 INTRODUCTION

1.1 Project description

The NZ Transport Agency (Transport Agency) is lodging a Notice of Requirement (NOR) and applications for resource consent (collectively referred to as "the Application") for the Warkworth to Wellsford Project (the Project).

The Project involves the construction, operation and maintenance of a new four lane state highway. The route is approximately 26 km long. The Project commences at the interface with the Pūhoi to Warkworth project (P-Wk) near Woodcocks Road, Warkworth. It passes to the west of the existing State Highway 1 (SH1) alignment near The Dome, before crossing SH1 just south of the Hōteo River. North of the Hōteo River the Project passes to the east of Wellsford and Te Hana, bypassing these centres. The Project ties into the existing SH1 to the north of Te Hana near Maeneene Road.

1.2 Project features

The key features of the Project, based on the Indicative Alignment, are as follows:

a) A new four lane dual carriageway state highway, offline from the existing State Highway 1, with the potential for crawler lanes on the steeper grades.

b) Three interchanges as follows:

   i. Warkworth Interchange, to tie-in with the Pūhoi to Warkworth section of SH1 and provide a connection to the northern outskirts of Warkworth.

   ii. Wellsford Interchange, located at Wayby Valley Road to provide access to Wellsford and eastern communities including Tomarata and Mangawhai.

   iii. Te Hana Interchange, located at Mangawhai Road to provide access to Te Hana, Wellsford and communities including Port Albert, Tomarata and Mangawhai.

c) Twin bore tunnels under Kraack Road, each serving one direction, which are approximately 850 metres long and approximately 180 metres below ground level at the deepest point.

d) A series of steep cut and fills through the forestry area to the west of the existing SH1 within the Dome Valley and other areas of cut and fill along the remainder of the Project.

e) A viaduct (or twin bridge structures) approximately 485 metres long, to span over the existing SH1 and the Hōteo River.

f) A tie in to existing SH1 in the vicinity of Maeneene Road, including a bridge over Maeneene Stream.

g) Changes to local roads:

   i. Maintaining local road connections through grade separation (where one road is over or under the other). The Indicative Alignment passes over Woodcocks Road, Wayby Valley Road, Whangaripo Valley Road, Mangawhai Road and Maeneene Road. The Indicative Alignment passes under Kaipara Flats Road, Rustybrook Road, Farmers Lime Road and Silver Hill Road.

ii. Realignment of sections of Wyllie Road, Carran Road, Kaipara Flats Road, Phillips Road, Wayby Valley Road, Mangawhai Road, Vipond Road, Maeneene Road and Waimanu Road.

iii. Closing sections of Phillips Road, Robertson Road, Vipond Road and unformed roads affected by the Project.

h) Associated works including bridges, culverts, drainage, stormwater treatment systems, soil disposal sites, signage, lighting at interchanges, landscaping, realignment of access points to local roads, and maintenance facilities.

i) Construction activities, including construction yards, lay down areas for storage of materials and establishment of construction access and haul roads.

A full description of the Project including its current design, construction and operation is provided in Section 4: Description of the Project and Section 5: Construction and Operation of the AEE contained in Volume 1 and shown on the Drawings in Volume 3.

The Indicative Alignment is a preliminary alignment for a state highway that could be constructed within the proposed designation boundary. The assessment within this WAR considers the effects of the Indicative Alignment, but also considers the sensitivity to effects if the alignment shifts within the proposed designation boundary when the design is finalised.

The final alignment for the Project (including the detailed design and location of associated works including bridges, culverts, stormwater management systems, soil disposal sites, signage, lighting at interchanges, landscaping, realignment of access points to local roads, and maintenance facilities), will be refined and confirmed at the detailed design stage.

1.2.1 Proposed stormwater design

A full description of the Project including its proposed design, construction and operation is provided in Section 4: Description of the Project and Section 5: Construction and Operation of the AEE contained in Volume 1 and shown on the Drawings in Volume 3.

A detailed description of the proposed Project design in relation to the water environment is contained in the Operational Water Design Technical Report and illustrated in the PAH156 stormwater drawing set. The proposed design aspects considered in this report include:

- The Project footprint by catchment;
- Changes in runoff from new impervious areas and higher runoff surfaces such as cuts;
- Diversions and flow routing; and
- Road drainage discharge points including attenuation and erosion protection.

1.3 Purpose and scope of this report

This Construction Water Management Design Technical Report (this Report) forms part of a suite of water related design and technical reports prepared for the Ara Tūhono – Pūhoi to Wellsford - Warkworth to Wellsford section (the Project).

These reports are listed below with a short description of each:

- **Water Assessment Report (WAR) –** This report contains a summary of the work carried out and assessment of water related effects associated with construction and operation of the Project.
- **Construction Water Management Design technical report** - This report contains indicative details of the proposed construction methodology, proposed erosion and sediment controls (ESCs), and other construction phase mitigation measures recommended to reduce and erosion and sediment laden stormwater discharges from entering the receiving environment during construction.
- **Operational Water Design technical report** – This report contains details of the operational stormwater management and other operational phase mitigation by design.
- **Existing Water Quality technical report** – This report summarises water quality monitoring carried out by Auckland Council and for the Project.
- **Catchment Sediment Modelling technical report** – Sediment models have been developed to predict changes in sediment and water quality within receiving watercourses associated with the Project. This report summarises the modelling methodology and results.
- **Operational Water - Road Runoff technical report** – An assessment has been carried out to predict changes to water quality in relation to the Project and pollutants.
- **Flood Modelling technical report** – A model has been developed to predict any changes to flood risk associated with the Project. This report summarises any changes.
- **Hydrological technical report (this report)** – Catchment analysis has been developed to predict catchment wide hydrological changes associated with the Project. This report summarises predicted changes to the hydrological environment.

The purpose of this report is to assess the hydrological changes that result from the Project, focussing on streams, rivers and catchments. The focus of the hydrological assessment is on the Operational phase of the Project as hydrological effects are most likely to result from the finished State Highway with impervious areas and larger scale permanent diversions, rather than from minor changes during the short-term construction phase. Figure 1 below summarises the relationship between each of the water related technical and assessment reports and the AEE.

The results of this report are used as the basis for assessment of hydrological effects in the Water Assessment Report and Ecology Assessment Report.

The flooding effects are assessed separately in the Flood Modelling technical report.

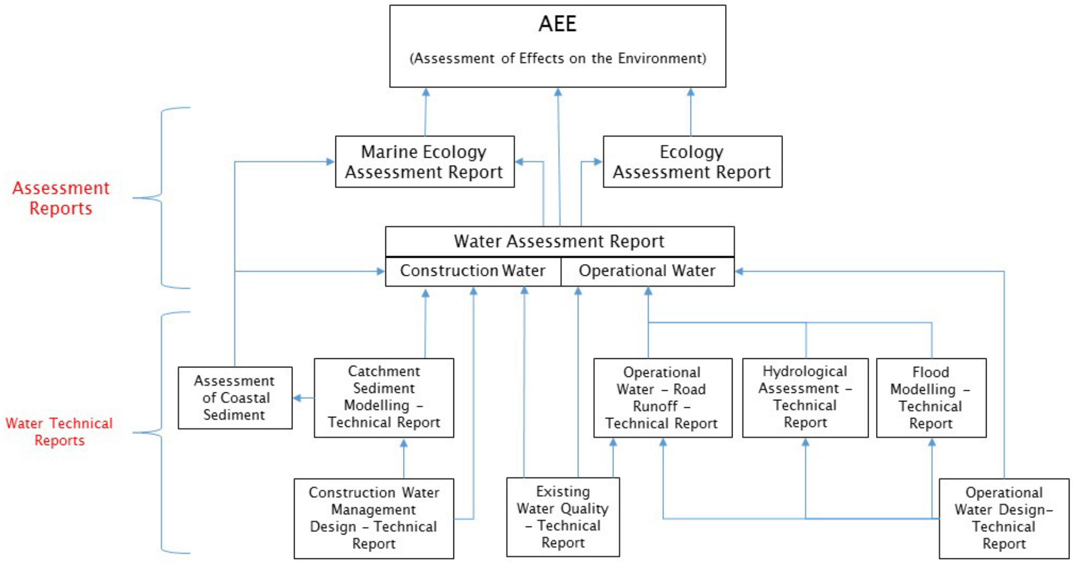

Figure 1 – Hydrological Technical Report – relationship to other reports

1.4 Report outline

The structure of this report is as follows:

- **Section 1** - Describes the Project and provides a summary of the purpose and scope this report;
- **Section 2** - Describes the methodology applied in the assessment;
- **Section 3** - Describes the existing and future environment;
- **Section 4** - Describes the results of the catchment analysis to inform hydrological effects assessment;
- **Section 5** - Describes recommended mitigation relating to design and final alignment; and
- **Section 6** - Provides a summary.

2 METHODOLOGY FOR HYDROLOGICAL ASSESSMENT

Section Summary

The methodology applied is an assessment of changes to impervious areas at the proposed operational stormwater discharge locations, and an assessment of changes in catchment area in these catchments. The assessment methodology is detailed below:

- Characterising the relevant existing and future receiving environment in the Project area, including an assessment of potential changes to hydrology associated with forest harvesting.
- Assessment of differences in pre-development (existing) and post-development impervious area to assess changes in land cover and associated changes in hydrology associated with the Indicative Alignment.
- Assessment of differences in pre-development (existing) and post-development catchment areas of streams and rivers associated with stream diversions and changes in flow routing and the associated changes in hydrology, including changes to natural wetland hydrology.

Potential ecological effects associated with changes in stream/wetland hydrology are assessed in the Ecology Assessment report.

In addition to assessing the Indicative Alignment a sensitivity assessment of potential changes to hydrology associated with different alignments and designs within the proposed designation boundary has been carried out.

This section details the methodology applied to assess changes to the hydrology associated with the Indicative Alignment.

The existing environment has been characterised as part of the Water Assessment Report. A literature review has been undertaken to inform the potential future changes in background hydrology that could occur due to forest harvesting in the catchments of the receiving watercourses. The indicative stormwater design incorporates 34 stormwater discharges to receiving freshwater bodies. The assessment of changes to hydrology has been carried out at the proposed surface water discharge locations. These locations were chosen to assess changes to hydrology as they display a variety of catchment sizes and all will incorporate flows from the Indicative Alignment.

For the existing case, the catchments upstream of the discharge locations have been delineated in two ways, firstly using the River Environmental Classification (REC) catchment, and also detailed catchments have been delineated using the digital elevation model (DEM).

For the post-development scenario, the impervious area of the Indicative Alignment draining to each discharge point will include the impervious road area and the areas of embankments/cuttings draining to each discharge point.

The upstream post-development catchment (non-road catchment) of the receiving stream or river comprises the existing land use of the up-stream 'non-road' catchment, taking into account any changes in catchment area associated with the Indicative Alignment and diversions.

2.1 Land cover change methodology

This assessment compares the impervious areas for the existing and post-development (with the Project) scenarios.

The River Environmental Classification (REC) is a national hydrological layer produced by NIWA that classifies the order of streams and sub-catchments. For assessing change in hydrology we are of the view that the REC provides an appropriate resolution.

For each REC catchment the existing (pre-development) impervious area was calculated accounting for existing roofs and roads. Then for the post-development scenario the Project imperviousness was calculated for each catchment including the pre-development impervious area and impervious area of the Indicative Alignment. The impervious area of the Indicative Alignment included the road area and the cut and fill embankments area. The majority of cuts will achieve some infiltration and therefore the assumption in this assessment that all cuts and fills are impervious is conservative.

2.2 Diversions and flow routing

The assessment involved determining the pre-development catchment areas of streams and rivers that would receive stormwater discharge from the operational Project.

The pre-development assessment involves delineating the catchment of each stream or river upstream of the proposed stormwater discharge points. This is done by aggregating the REC delineated catchments upstream of the proposed discharge point.

The post-development catchment areas were assessed based on the Indicative Alignment using GIS. This includes summing the areas of the proposed impervious Indicative Alignment, as well as areas of embankments and cuttings. The post-development assessment also includes any catchment area changes associated with clean water diversions as well as culverts and stream diversions.

The post-development catchment areas at each proposed stormwater discharge point were assessed for:

- The area of Indicative Alignment draining to each discharge point; and
- Upstream post-development catchment of the receiving stream or river.

2.2.1 Natural wetland Hydrology

The assessment involved comparing the location of natural wetlands, identified in the Ecology Assessment report, with the stream diversions, culverts and road embankment designs, and using judgement to predict likely changes in wetland hydrology as a result of the indicative design.

3 EXISTING AND FUTURE ENVIRONMENT

Section Summary

The proposed designation boundary extends into the catchments of three major rivers, the Mahurangi River, the Hōteo River and the Oruawharo River.

The Mahurangi River drains to the Mahurangi Estuary. The Indicative Alignment runs to the west of the left and right branches of the Mahurangi River, crossing some minor tributaries. The proposed Warkworth interchange northbound and southbound off-ramps cross the left branch in two locations.

The Hōteo River is crossed by the Indicative Alignment, to the north of the existing SH1 crossing. The Hōteo River drains to the southern part of the Kaipara Harbour. The Indicative Alignment crosses multiple tributaries of the river including the Kourawhero Stream.

The Oruawharo River is an estuarine river that drains to the Kaipara Harbour. The Indicative Alignment crosses two tributaries of the river, Te Hana Creek and Maeneene Creek.

It is expected that the Matariki Forest, an exotic plantation forest within the Hōteo and Mahurangi catchments, will be felled within the proposed designation prior to the construction of the Indicative Alignment. The majority of the Matariki Forestry lots outside the designation will also be felled prior to 2030. It is likely the changes in hydrology associated with forest harvesting in the catchment could result in significant (30-80%) changes in flows. The changes to flow will be less if part of the catchment is in forestry or if the harvesting occurred in stages (within the catchment of interest). 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, 2004). 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.

3.1 Catchment overview

The Indicative Alignment extends into the catchments of three major rivers, which can further be divided into sub-catchments as detailed below:

- Mahurangi River, with sub-catchments of:
    - Mahurangi River (right branch); and
    - Mahurangi River (left branch);
- Hōteo River, with sub-catchments of:
    - Kourawhero Stream;
    - Waiteraire Stream; and
    - Several unnamed tributaries; and
- Oruawharo River, with sub-catchments of:

- Te Hana Creek; and
- Maeneene Creek.

The catchment boundary between the Mahurangi River and the Hōteo River is a low ridge to the west of Warkworth; on the western side of the ridge is Kourawhero Stream, a tributary of Hōteo River, and to the east is the Mahurangi River.

The catchment boundary between the Hōteo River and the Oruawharo River is a low ridge which runs in a north-eastern line through Wellsford approximately following Worthington Road; the Indicative Alignment crosses this ridge to the north-east of Wellsford. The catchments are shown on Figure 2.

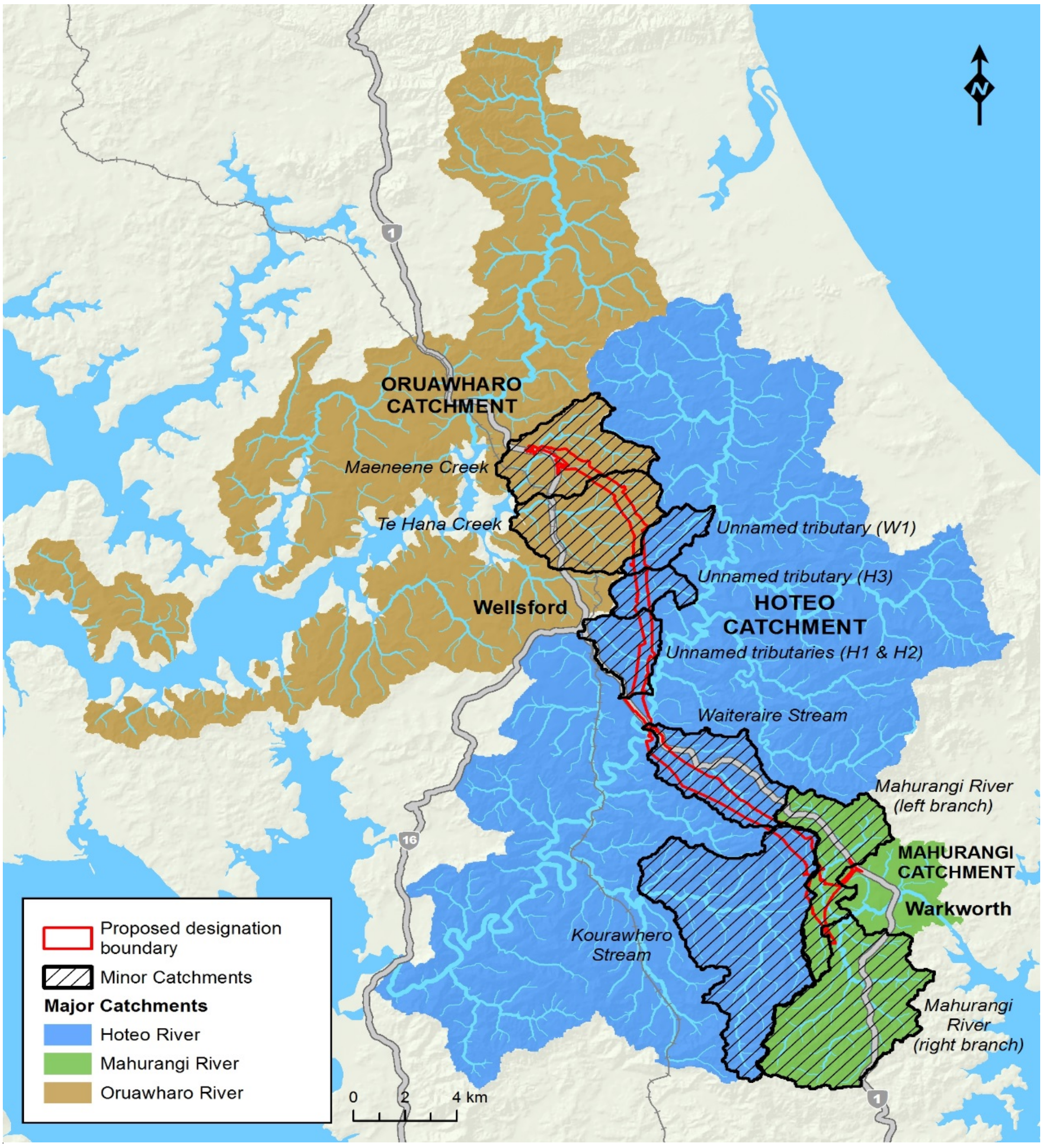

Figure 2 – Proposed designation boundary, freshwater catchments and marine environments

3.1.1 Mahurangi River

The proposed designation runs to the west of the right and left branches of the Mahurangi River. The proposed Warkworth interchange northbound and southbound off-ramps cross the left branch in two locations.

The right branch of the Mahurangi River has a catchment that is predominately pasture with approximately 1000 ha of forestry in the upper catchment (Redwood Forest), whereas the left branch is predominately flat land dominated by pasture and lifestyle uses.

The Mahurangi River is the main tributary of the Mahurangi Estuary, a long estuary flowing southwards from Warkworth on the eastern coast. There are many small bays and estuaries along the sides of the estuary with two larger arms to the south. Many of the small bays and upper estuaries have large intertidal areas which are exposed at low tide and are comprised of soft muddy sediment.

3.1.2 Hōteo River

The Indicative Alignment crosses the Hōteo River immediately north of the existing SH1 river crossing. A viaduct is proposed at this location.

The Hōteo River is situated at the northern boundary of the Auckland region, with a total catchment area of approximately 405km^2 and 28km of mainstream river length (Hart & Scott, 2014). The catchment upstream of the proposed crossing is approximately 200 km^2, therefore the crossing is in the middle reaches of the river.

The Hōteo River is classified as a priority catchment under the Auckland Council Sustainable Catchments Programme (SCP).

The Hōteo River drains to the southern part of the Kaipara Harbour, a large enclosed harbour estuary complex located on the western coast. The Kaipara Harbour is a complex drowned-valley enclosed estuary on the west coast of the Northland peninsula (Gibbs et al., 2012). The harbour is composed of intertidal flat and shallow sub-tidal habitats with deep channels following historic rivers. Sand barriers form north and south heads as well as tidal deltas, beach and dune systems.

The Indicative Alignment also crosses many tributaries of the rivers, and these are described below.

Kourawhero Stream

South of the tunnels the Indicative Alignment is the catchment of the Kourawhero Stream, which is a large tributary of the Hōteo River originating in the southern slopes of the Dome Ranges.

The proposed Warkworth interchange is within the catchment of a tributary of Kourawhero Stream in pasture to the west of Carran Road, the streams in this location are generally farm drains or small streams.

The Indicative Alignment then crosses at the head waters of the Kourawhero Stream multiple times, initially to the north of Kaipara Flats Road where the stream flows through pasture. The Indicative Alignment then goes up the southern slope of the Dome Ranges within an area of forestry and crosses the headstreams of the Kourawhero Stream, including crossing some wetlands.

Downstream of the Indicative Alignment the Kourawhero Stream flows in a westerly direction following a similar path to the Kaipara Flats Road, the stream flows into the Hōteo River at the settlement of Hoteo.

Waiteraire Stream

North of the tunnel the Indicative Alignment is in the catchment of Waiteraire Stream, another tributary of the Hōteo River. The Indicative Alignment runs to the south of the stream along the southern face of the valley and crosses multiple tributaries of the stream; the land use is predominantly forestry.

The Waiteraire Stream flows into the Hōteo River at the approximate location of the Indicative Alignment, the stream is crossed by the proposed Hōteo River viaduct.

Unnamed tributaries

The Indicative Alignment crosses several unnamed tributaries of the Hōteo River to the west of the Hōteo River, and to the east of Wellsford.

The first few of these tributaries drain directly to the Hōteo River, and comprise field drains and small streams that flow through undulating pasture in the vicinity of Wayby Valley Road.

The Indicative Alignment also crossed minor tributaries of Waiteitei Stream, a tributary of the Hōteo River, one of these is north of Whangaripo Valley Road and the other at Farmers Lime Road. These tributaries flow within defined valleys through pasture and drain west and north-west respectively into Waiteitei Stream. Waiteitei Stream flows in a south-easterly direction and flows into the Hōteo River to the east of the Indicative Alignment.

3.1.3 Oruawharo River

Two tributaries of the estuarine Oruawharo River are crossed by the Indicative Alignment, that is Te Hana Creek and Maeneene Creek.

The Oruawharo River is an estuarine river that flows west into the Kaipara Harbour, the river forms part of the boundary between Auckland region and Northland region. The catchment of the river is approximately 266 km^2. To the south of the river is the Okahukura Peninsula and to the north is the Puketotara Peninsula, the river includes the Hargreaves Basin bay.

The Indicative Alignment does not cross the Oruawharo River channel.

Te Hana Creek

Te Hana Creek is a small creek with a total catchment of approximately 1.7 km^2. The land use is generally rolling pasture. The Indicative Alignment crosses a number of tributaries of Te Hana Creek as shown on Figure 2.

Te Hana Creek becomes estuarine to the west of the existing SH1 and flows into Maeneene Creek prior to discharging to the Oruawharo River.

Maeneene Creek

Maeneene Creek is a small creek with a catchment of approximately 1.5 km^2. The Indicative Alignment crosses multiple tributaries of this creek, and the Ta Hana interchange located within this catchment.

Maeneene Creek becomes estuarine to the south of the existing SH1 highway, and flows into Oruawharo River.

3.2 Forest harvesting

It is expected that the Matariki Forest, an exotic plantation forest, will be felled prior to the construction of the Indicative Alignment, currently assumed to be 2030. Matariki forest currently (2017) comprises 35.2 km^2 of the Hōteo River catchment, this is located to the east of the catchment associated with the catchments of Waiwhiu Stream, Waiteraire Stream, Awatere Stream and a small amount in the Kourawhero Stream catchment.

A study into the effects of plantation forestry on hydrology and flooding (Fahey, 2004) indicates that the effect of harvesting on water yields can result in increased water yield for three to five years after clear-felling, and yields should return to pre-harvesting levels within 6-8 years with a return to plantation forestry.

Quinn et al (2009) found a decrease in annual runoff at a Waikato site after afforestation of 62% of its catchment, resulting in a 29% reduction in annual runoff after 6 years and estimated a 47% reduction in annual runoff would occur if the whole catchment was afforested. This calculated value is in the range of flow reductions recorded after whole catchment pine afforestation elsewhere in New Zealand (30–81%) (Fahey et al., 2004). It is also consistent with Farley et al.'s (2005) finding of an average 40% reduction in streamflow from analysis of 29 catchment studies of the effects of pine afforestation of grassland.

These studies indicate that following forest harvesting significant increases in stream flow and changes in channel morphology are likely to occur. The area within the designation that is in forestry is relatively small, but it is significant to many of the sub-catchments of the Kourawhero and Waiteraire Streams.

It is likely the changes in hydrology associated with forest harvesting in the catchment (majority of which is currently indicated to occur prior to 2030) could result in a significant (30-80%) change in flows. The changes to flow will be less if part of the catchment is in forestry or if the harvesting occurred in stages (within the catchment of interest). 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).

In the event that forest harvesting coincides with the Project construction, or if forest is harvested prior to the Project and not re-established, then the flows in tributaries impacted by forest harvesting may be significantly larger than are experienced in the existing situation. 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.

4 ASSESSMENT RESULTS

Section Summary

The Indicative Alignment results in small increases in imperviousness and changes in flow due to diversions and routing.

The proposed stormwater design has avoided most hydrological effects, and provides for mitigation of increased flow through extended detention attenuation in the stormwater treatment wetlands and through design criteria for stream diversions.

The predicted changes associated with the Project on hydrology are localised. Beyond the localised sub-catchment scale, the predicted changes are negligible.

Small sections of headwater streams (REC first order streams) will experience changes in flow, some reaches may have an increase in flow and others decreases. These changes will reduce further downstream; however, it is recommended that reaches with increased flow incorporate erosion control measures, such as riparian planting or the application of a geotextile. Some natural wetlands may experience measurable changes in water levels due to the Indicative Alignment which may result in changes to the characteristics of the natural wetlands.

Forest harvesting has been predicted to result in significant increases in stream flows. If the forest harvesting coincides with or occurs prior to the Project and is not re-established, then the flows in tributaries impacted by forest harvesting may be significantly larger than are experienced in the existing situation. This potential change in the hydrological regime will have to be reflected in the design at the time the Project is constructed.

4.1 Changes in land cover

Changes in land cover such as impervious areas and cut slopes influence stream flows by modifying hydrological processes including the interception, evapotranspiration and infiltration of rainfall. This can cause changes in the runoff volume and rate in the receiving streams.

4.1.1 Literature review

Impervious surfaces such as road pavements prevent infiltration of rainfall. This has two potential hydrological outcomes, a loss of base flow in streams and an increase in storm flow. This can result in changes in stream health related to less water in dry weather (which may impact on stream habitats, water users and water quality), and increased flows in wet weather (which can result in stream erosion and contribute to flooding).

Increases in imperviousness are an issue in urbanised catchments due to cumulative effects of imperviousness. The percentage impervious surface area at which degradation of water quality begins is varied. (Klein, 1979) suggested that the initial threshold of degradation of stream water quality was approximately 15%. (Schueler, 1994) reported that the threshold was 10%–20%. Holland et al. (2004) reported that the adverse changes in physical, sediment, and water quality variables could be detected at 10% to 20%, Kim, Jeong & Bae, (2016) found controlling the percentage impervious surface area the within about 10% in watersheds is a fundamental strategy to mitigate the degradation of water quality. In general, the thresholds of percentage impervious surface area for degradation of biotic measures including fish and macro invertebrate diversity and abundance ranged from 3.6% to 15%, while the chemical water quality tended to have higher impact levels with thresholds ranging from 7.5% to 50%. (Kim, Jeong & Bae 2016)

For the Project, the predicted increases are generally less than 10% and are only greater than 15% for two first order catchments. At the spatial resolution beyond the first order catchments, the change in imperviousness is very low, (less than 1%). The predicted changes in imperviousness indicate there may be localised effects, but beyond the first order catchments where the road is located, the impact of the increase in imperviousness on water quality is likely to be negligible.

4.1.2 Indicative Alignment imperviousness

The catchments that the Indicative Alignment passes through are predominately rural with very low levels of imperviousness in the existing situation, and therefore the cumulative effects of the increased imperviousness due to the Project on stream flows are limited at a catchment scale.

The Indicative Alignment does pass through many small first order streams, in these first order streams the increase in imperviousness are more pronounced as the change within a smaller catchment is proportionally larger, but will have a very localised influence on stream flow.

The post-development percentage of imperviousness is illustrated in Figure 3 below, this figure illustrates that for most catchments the imperviousness is less than 5%, and this decrease moving further downstream from the catchment. The largest increases in imperviousness are in in the small headwater catchments, in particular in the sub-catchments of the Waiteraire Stream, where one catchment has an imperviousness of between 20-25%, which is due to the small scale of the sub-catchment. This analysis is also tabulated in Appendix A.

The limited number of catchments with resulting imperviousness larger than 15%, the effects associated with increased flow is likely to be localised. The main risk associated with localised increased flows is channel erosion, which can occur downstream of discharge points and can result in a degradation of water quality and habitats. This can be mitigated through stormwater detention and discharge erosion control, as detailed in Section 4.1.3, and in the design of channel diversions, this is discussed in Section 5.

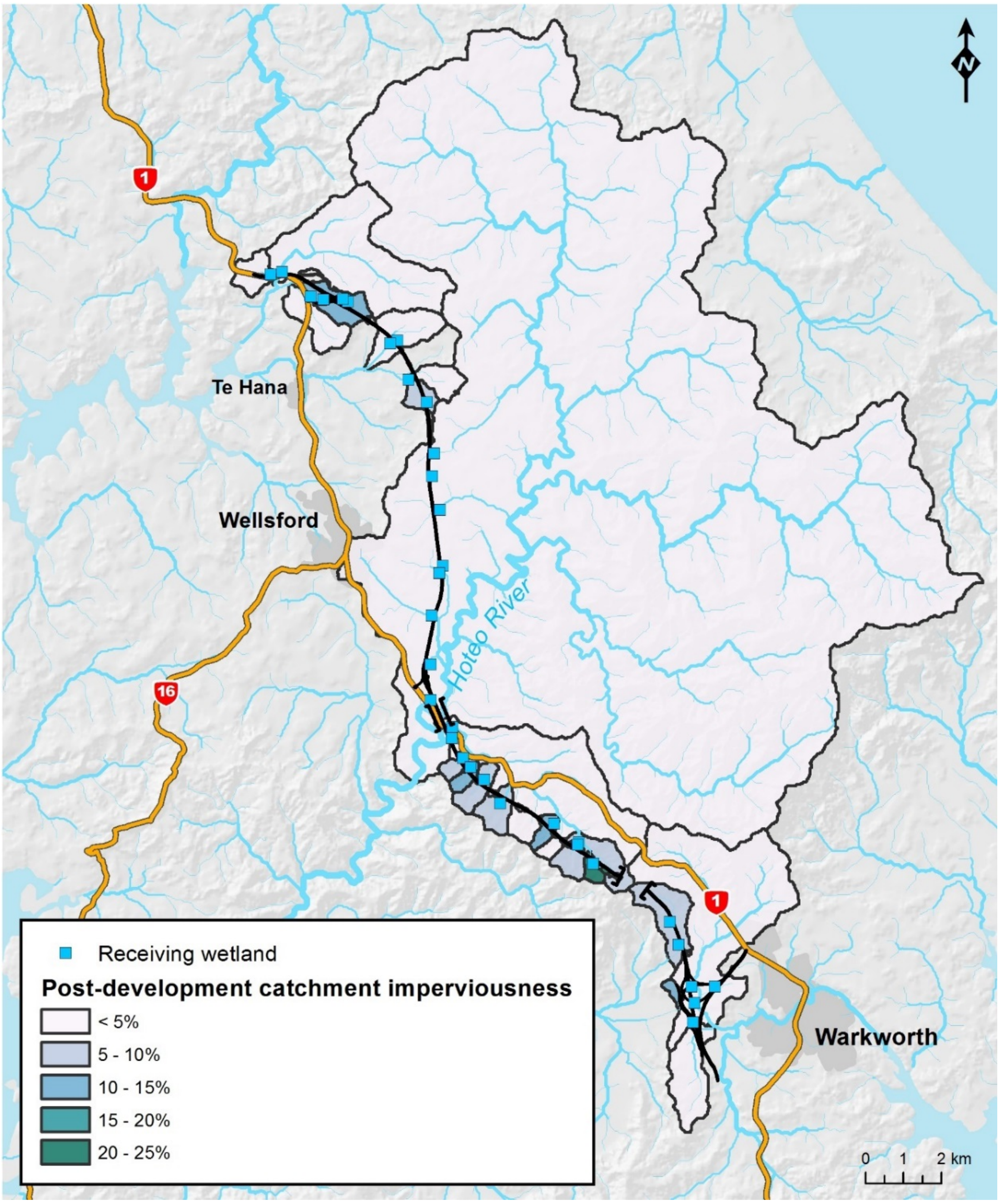

Figure 3 - Catchment imperviousness area (%) of receiving stormwater treatment wetland catchments for Post-development (with Project)

4.1.3 Mitigation in Design

The proposed Stormwater Design includes treating all road runoff with stormwater treatment wetlands, and in additional vegetated swales will be used to convey flows in many catchments.

The proposed design provides hydrological mitigation for runoff from impervious and cut areas by detention (temporary storage) with a drain down period of 24 hours for the difference between the pre-development and post-development runoff volumes from the 95th percentile, 24-hour rainfall event.

Retention is not provided for in the proposed design due to geotechnical limitations and the operational/safety constraints of the Indicative Alignment. However, the impact on base flow in the stream is predicted to be very localised as a result of the increase in imperviousness given that the catchments have low levels of existing impermeability.

4.1.4 Changes to alignment

This assessment has reviewed the potential changes associated with the Indicative Alignment. As a result of detailed design there is the potential that the final alignment shifts within the proposed designation boundary.

All catchments that the proposed designation boundary crosses through are predominantly rural/forestry with low levels of existing imperviousness. The proposed designation boundary also crosses many small first order streams.

A shift in the alignment or a change would likely result in similar changes to impervious area as the Indicative Alignment. That is, some pronounced but localised changes in impervious area to smaller first order receiving streams and small to negligible changes in larger streams and rivers.

There is also the potential that a shift in alignment could result in larger or smaller areas of cut and fill, and as a result of a larger or smaller impervious area. It is unlikely that an alternative alignment, still within the proposed designation, would result in a significantly larger impervious area, as the topography within the proposed designation is generally similar to that crossed by the Indicative Alignment, and the Indicative Alignment has a significant volume of earthworks already (approximately 12 million m^3). The experience from SH1 Puhoi to Warkworth project is that the design that is being constructed has less earthworks than anticipated during the consent design as a result of design development.

Based upon this assessment it is considered unlikely that any alignment within the proposed designation would result in significantly different changes to impervious areas within receiving streams than the Indicative Alignment.

4.2 Changes in catchment area

4.2.1 Indicative Alignment changes in catchments

There are two factors influencing the change in catchment area associated with the Indicative Alignment compared with the existing case. These are stream diversions of natural channels and changes in stormwater routing due to the road impervious area draining to adjacent catchments.

As recommended in NZTA P46 (April 2016), the Stormwater Design has avoided most changes in flows by locating culvert crossings to maintain the existing natural drainage patterns of the contributing catchment where possible. This means that there are a limited number of stream diversions, and where diversions occur they occur within single REC catchments, and tend to impact on first order streams. Within first order catchments where diversions occur, small sections of stream may be reclaimed or have a reduction in flow, with other sections having increased flows.

An increase in catchment area results in increased flow within receiving waterbodies and can result in increased flooding and erosion. The increases in flooding have been assessed in the Flood Modelling technical report, and are therefore not assessed within this report.

Figure 4 below illustrates the predicted change in catchment area associated with the Indicative Alignment, at the REC sub-catchment scale. The change in catchment area accounts for changes associated with diversions and changes in flow routing associated with stormwater treatment. For almost all catchments the changes are between +5% and -5% of the catchment, with less than 1% change for the Hōteo River catchment. This analysis is also tabulated in Appendix A.

Generally, the increases in catchment area associated with the Indicative Alignment are less than 5%, with a very limited number of catchments with a predicted increase in catchment area of greater than 5%. The effects associated with increased flow (associated with increased catchment area) is likely to be localised, and the risk associated with channel erosion can be mitigated through the design of stream diversions as discussed in Section 4.2.2.

We note that several of the catchments that have increases in catchment area are located in the Matariki Forest (from the tunnels to the Hōteo River). As such these catchments have been and will be, subject to significant changes in flows due to forest harvesting (refer to Section 3.2).

Decreases in catchment area can result in a reduction in flows, which can result in localised loss or reduction of headwater streams, and reductions to flow speeds, which can in turn result in water quality issues. Generally, the decreases in catchment areas are less than 5%, and so the change would be unlikely to result in any large changes. At a smaller scale the diversions and changes could result in very localised changes to flow, however in general these will be negligible given the small reaches where they would apply.

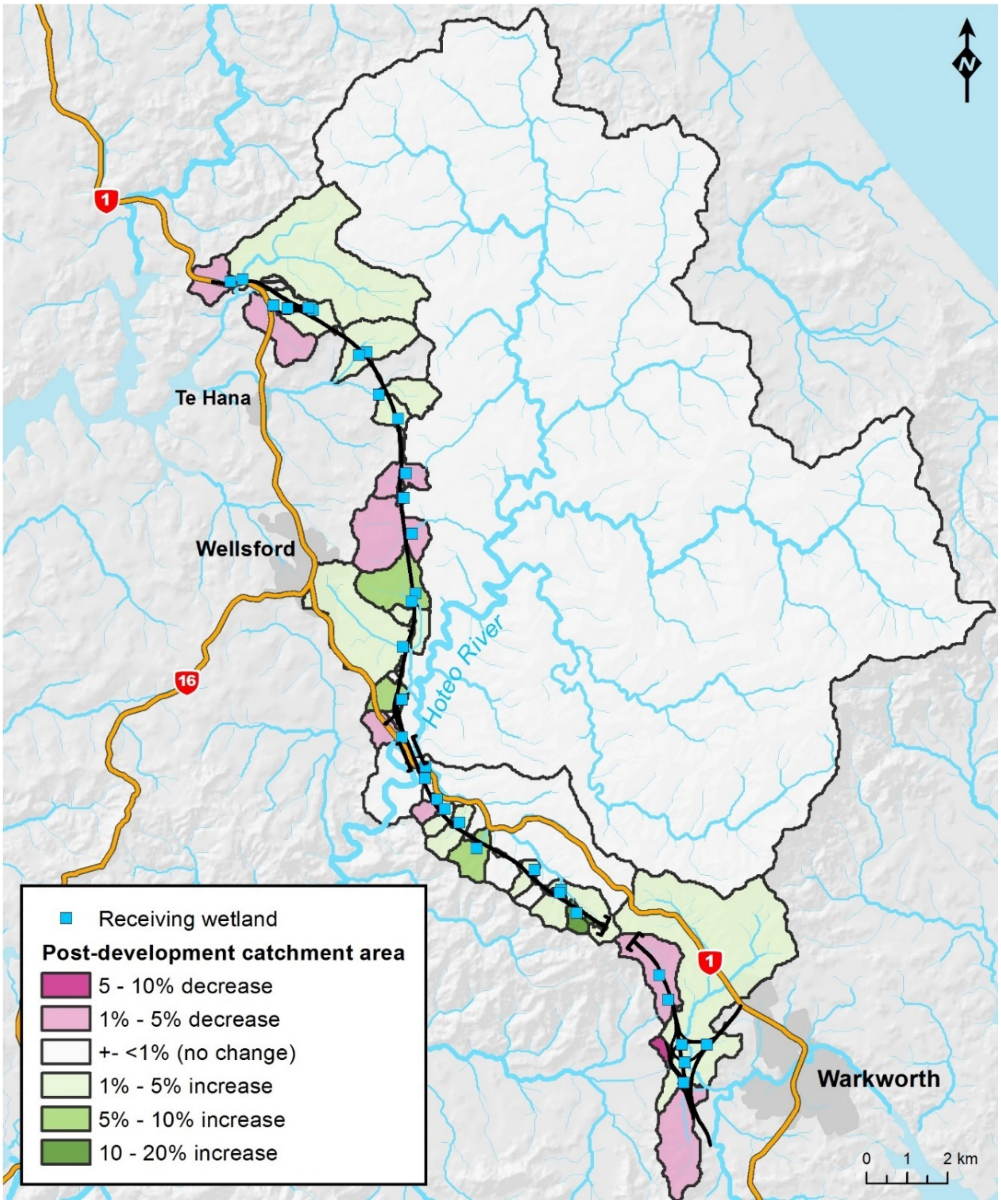

Figure 4 - Post-development change in catchment areas as a result of diversions and stormwater drainage (REC delineated catchments)

4.2.2 Mitigation in design

The proposed Stormwater Design has adopted the design recommendation of NZTA P46 to avoid most changes in flows by locating culvert crossings to maintain the existing natural drainage patterns of the contributing catchment where possible. Also in accordance with NZTA P46 all diversion channels will be designed to convey flood flows and mimic or improve natural stream form, with a stable form designed to prevent scour.

All stormwater and culvert discharges will have energy dissipation and erosion protection at discharge locations. This is required by NZTA P46 but is also often a resource consent condition.

The hydrological mitigation provided by stormwater detention in stormwater treatment wetlands is to mitigate for increased runoff due to additional impervious areas. It does not mitigate for more flow due to more/less flow from changes to catchments.

We recommend that 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 must be remedied. The threshold for percentage change in catchment/flows that causes erosion is unknown and is dependent in any catchment on the stream morphology including soils/rock banks and beds, as well as the riparian vegetation and debris in the stream. There will be more data on erosion in streams, and whether this is a real and significant issue, from the Puhoi to Warkworth project, especially because it has similar hydrological changes and streams/catchments. Potentially the information from Puhoi to Warkworth can be used to change the management approaches in the future.

A monitoring and remediate if necessary approach is recommended so the works in the streams can be limited to where it is required (if at all). We consider that this approach minimises works in the stream and disturbance of streams compared to an alternative strategy of early intervention by increasing the erosion resistance of streams as part of the Project as there is no certainty that these will be required.

We note that the changes in catchments/flows caused by the Project are significantly less than the changes that have occurred and will occur again in forestry catchments due to forest harvesting. In these catchments in the Matariki Forest the streams may have already been modified to have capacity for higher flows.

4.2.3 Effect on natural wetlands

Where the Indicative Alignment or stream diversions and culverts are located near to natural wetlands, there may be hydrological changes to natural wetlands.

Table 1 below discusses the impact of the Indicative Alignment and indicative stormwater design on the hydrology of natural wetlands within the designation.

Table 1 - Hydrological changes to natural wetlands

Wetland name	Indicative design	Hydrological change predicted
WN-W-Koura 1.	The indicative design includes diverting the channel, so flows to the east largely flow through culvert at chainage CH47200.	The location of the diversion channel will result in significant changes in the hydrology of the wetland. The wetland will become a channel and not a wetland.
WN-W-Koura 2, WN-W-Koura 3, WN-W-Koura 4.	The indicative design includes a bridge crossing with a 96 m span. With this span we predict the natural stream channel capacity and flooding pattern will be maintained. In our view the bridge in this location has avoided effects, compared with if a culvert had been proposed in this location.	We consider the bridge important in maintaining the existing hydrological conditions and connectivity for wetlands on the east and west of the Indicative Alignment. The ecological mitigation proposes wetland enhancement in this area. Restored or enhanced wetlands in this valley may be less likely to establish as swamp wetlands if they are located further out of the frequently wet area. The less hydrologically connected areas of valley may be able to support other natural wetland types, such as marsh wetlands.
WN-W-Koura 5.	The indicative design includes a culvert and a section of stream diversion in the wetland.	The culvert and stream diversion will occupy some of the wetland area resulting in the loss of wetland area and for the remaining wetland, the culvert and diversion are likely to result in a lower water level.
DVF-W-Koura-1.	The indicative design includes a culvert and a section of stream diversion downstream of the wetland.	The diversion channel is likely to have increased flow conveyance capacity compared with the existing swamp wetland downstream of this wetland, and this improved conveyance may result in a decrease in water level in this wetland.
HN-W-Hōteo -01.	The indicative design includes the road embankment and Hōteo bridge abutments in close proximity to this wetland.	The infilling of the wetland is likely to change the water levels in the remaining part of the wetland significantly by altering storage.
HN-W- Hōteo -02.	The indicative design includes diversion channels including the channel draining to CH37630, in close proximity to this wetland.	These stream diversions will alter flow patterns and may result in changes in the depth and frequency of small flood events. The close proximity of the diversion channel draining to CH37630 is likely to result in a lowering of the water level in this wetland.
HN-W- Hōteo -03.	The indicative design is not in close proximity to this wetland.	No hydrological impact on this wetland is predicted.
HN-W- Hōteo -04.	The indicative design includes a cut-embankment that will excavate part of the wetland and a cut off drain within the wetland.	The cut-off drain is likely to alter the hydrology for the remnant part of the wetland that is not impacted by the Indicative Alignment.

Wetland name	Indicative design	Hydrological change predicted
HN-W-Tehana-01.	The indicative design includes a fill embankment within this wetland and the wetland is culverted in four locations. To the northern end of the wetland there are stream diversions on the eastern side of the wetland.	The southernmost part of the wetland is likely to experience a significant reduction in water level for the small section upstream of culvert CH29380, downstream of culvert CH29380 there may be increases in water level due to loss of storage.
HN-W-TeHana-02.	The indicative design includes a stream diversion associated with culvert CH27090 in close proximity to this wetland.	We expect some lowering of water levels in the wetland associated with this stream diversion.
HN-W-TeHana-03.	The Indicative Alignment is within this wetland.	This wetland is under the Indicative Alignment, and therefore is expected to be lost.

4.2.4 Changes to stormwater design and alignment

The Indicative Alignment and proposed stormwater design has avoided significant changes in stormwater routing, with the current design providing for many small stormwater treatment wetlands and many culverts mimicking natural flow pathways.

The Indicative Alignment impacts on the hydrology of a number of natural wetlands, in the detailed design stage some of the effects associated with the location of diversions may be avoided or reduced.

In the detailed design stage it may be that the stormwater treatment wetland designs are modified to provide for fewer and larger stormwater treatment wetlands, or to provide fewer culverts and more stream diversions. This in turn would include increased localised changes in stream flows, where flow is routed from one catchment to another.

Given that the Indicative Alignment and proposed designation flows through many small catchments, any changes are likely to remain within first order streams, and as such will be localised. Any changes to flow routing within small, first order streams are unlikely to result in changes greater than those assessed within this report, and are likely to be mitigated through the mitigation in design. Therefore, changes to stormwater discharge points and culverts within small catchments are unlikely to result in significant changes to hydrology when designed in line with NZTA guidelines and the proposed mitigation in design.

A change in the alignment within the proposed designation is unlikely to result in significant changes to flow routing, because, as stated above, the proposed designation flows through many small catchments.

A change to the Indicative Alignment and associated diversions could have increased effects on natural wetlands, if it resulted in greater diversions near wetlands or if the embankment occupied more natural wetlands.

The Stormwater Design generally provides for bridges across larger streams and rivers, including the Mahurangi River (left branch), the Kourawhero Stream, the Waiteraire Stream, the Hōteo River and the Maeneene Creek. It is unlikely but possible for the smallest of these streams, that the bridges could be changed to culverts if flooding effects and ecological linkages could be maintained and resource consent conditions met.

There is no potential for the Hōteo River viaduct to become a culvert because of the large flows and flooding issues that exist.

Stream diversions of the other large streams could potentially result in significant changes to flows, erosion and water quality within the streams, especially if larger streams are diverted into other catchments. Therefore, it is recommended that any diversions to streams that result in change of catchment area of 15% or greater are assessed and mitigation is provided, both for catchments that receive more or lesser flow.

5 RECOMMENDED MITIGATION

Section Summary

The Indicative Alignment results in small increases in imperviousness and changes in flow and water levels due to diversions and routings.

This section discusses hydrological mitigation, including mitigation in design included within the indicative design and including an adaptive management approach for managing stream erosion.

The Ecology Assessment report discusses ecological mitigation, which will include mitigation for the residual hydrological effects on stream and wetlands, where these changes in hydrology have ecological effects.

5.1 Mitigation by design

The Project includes the following recommendations for mitigation:

- The proposed design provides hydrological mitigation of runoff from impervious surfaces and cuts by detention (temporary storage) in wetlands and a drain down period of 24 hours for the difference between the pre-development and post-development runoff volumes from the 95th percentile, 24-hour rainfall event.
- The proposed Stormwater Design has adopted the design recommendation of NZTA P46 to avoid most changes in flows by locating culvert crossings to maintain the existing natural drainage patterns of the contributing catchment where possible. Also in accordance with P46 all diversion channels will be designed to convey flood flows and mimic or improve natural stream form, with a stable form designed to prevent scour.
- All stormwater and culvert discharges will have energy dissipation and erosion protection at discharge locations.
- 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 must be remedied, similarly if a decline in water quality is observed due to a reduction in flow, then riparian planting should be provided to mitigate the effect.

5.2 Alignment recommendations

This report has also considered the potential changes to hydrology associated with changes to the Indicative Alignment.

Based upon this assessment it is considered unlikely that any alignment within the proposed designation would result in significantly different changes to impervious areas within receiving streams as associated with the Indicative Alignment.

Any changes to flow routing within first order streams, such as a reduction in stormwater treatment wetlands or reduction in culverts, are unlikely to result in changes greater than those assessed within this report and will be localised.

A change to the proposed Stormwater Design resulting in flow diversions of larger streams or rivers could result in significant changes to hydrology. As such it is recommended that diversions of larger streams are avoided where practicable. Where this is not possible we recommend that an assessment into potential changes associated with the diversion is undertaken and any effects mitigated to prevent significant effects. The Hōteo River must not be diverted or culverted as part of the Project and therefore, diversion and culverting of the Hōteo River has not been proposed.

6 SUMMARY

The Project's proposed stormwater design has avoided many hydrological effects, and provides for hydrological mitigation.

Forest harvesting is likely to occur prior to the Project construction and has been predicted to result in measurable increases in stream flows (30-80%) based upon the existing (2017) flows. This potential change in the hydrological regime will have to be reflected in the design at the time the Project is constructed.

The Indicative Alignment results in increases in imperviousness and changes in flow due to diversions and changes in flow routing. The predicted changes associated with the Project on hydrology are localised, and beyond the sub-catchment scale, the predicted changes are negligible.

Within the sub-catchment scale there will be some effects for headwater (first order) streams that may increase flows. Streams with increased flows may experience increased erosion. We recommend that any erosion susceptible streams (e.g. soft bank/bottom materials) that have changes of more than 15% in peak flows be monitored post construction and any erosion remedied.

The effects may also result in a decrease in flows within first order streams and natural wetlands that have reduced flows. Natural wetlands are particularly sensitive to changes in flows. The natural wetlands in the Kourawhero may experience measurable changes as a result of the Project. These changes have been reduced through the indicative Project design, through the incorporation of the bridge across the Kourawhero Stream main channel. This bridge is a key component of the mitigation proposed in the Ecology Assessment.

Changes to the alignment or Stormwater Design following detailed design are unlikely to change the outcomes of this assessment. However, we recommend that if the detailed design includes diversion of large streams these are assessed and mitigation identified if required.

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APPENDIX A – CHANGES IN AREA AND IMPERVIOUSNESS

Discharge point for catchment	Change in catchment area (%)	Change in imperviousness (%)
Wetland_24480_East	1%	1%
Wetland_24100_East	-1%	1%
Swale_MCQ0_1060	-1%	0%
Wetland_26000_East	1%	13%
Swale_MCB0_0	0%	2%
Wetland_27960_West	3%	5%
Wetland_28980_West	2%	3%
Wetland_29860_East	1%	7%
Swale_MCF0_420	-3%	4%
Wetland_31620_East	0%	9%
Wetland_32660_East	-1%	4%
Wetland_34320_West	6%	12%
Swale_MCR0_40	2%	10%
Swale_MCR0_420	1%	4%
Wetland_36920_East	10%	18%
Swale_MCD0_100	-1%	5%
Wetland_37580_West	0%	1%
Swale_MCE0_520	0%	1%
Swale_MCE0_20	0%	5%
Wetland_39460_North	-4%	10%
Wetland_39900_North	1%	11%
Swale_MCX0_0	4%	10%
Wetland_40850_South	7%	8%
Wetland_42350_North	4%	14%
Wetland_43150_North	3%	10%
Wetland_43300_North	3%	9%
Wetland_43800_South	19%	22%
Swale_MCG0_840	-1%	7%
Wetland_48220_West	1%	1%
Wetland_MC30_1845	1%	5%
Wetland_48940_West	1%	3%
Swale_MCO0_600_South	-7%	9%
Wetland_49380_West	1%	3%
Swale_MCZ0_590	-1%	1%