Ruamāhanga Whaitua Committee - Scenario Modelling

Greater Wellington Regional Council

Technical Report

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Ruamāhanga Whaitua Committee - Scenario Modelling

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Jacobs New Zealand Limited

Level 3, 86 Customhouse Quay,
PO Box 10-283
Wellington, New Zealand
T +64 4 473 4265
F +64 4 473 3369
www.jacobs.com

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Executive Summary

Following the development of the baseline SOURCE model (Jacobs 2018), simulations were undertaken for nine scenarios, each incorporating a range of landuse changes and on farm mitigations in the Ruamahanga Catchment. The scenarios were developed by the Ruamahanga Whaitua committee and provide potential outcomes for water quality under different implementation timelines, landuse change options and scales of mitigations.

Overall, the scenario modelling results show a significant reduction in concentrations of many water quality parameters at the 20 river and stream reporting points. The greatest reductions were observed in phosphorus species (Total Phosphorus/Dissolved Reactive Phosphorus), suspended sediment, *E.coli* and Ammoniacal-N.

There are nine modelling scenarios. These were grouped under three categories, Business as Usual (BAU), which reflects the direction of the Proposed Natural Resources Plan, Silver (which has a higher level of land management mitigations) and Gold, which applies the same suite of mitigations in Silver, but over a shorter timeframe. Each category was modelled as three discrete time slices, 2025, 2040 and 2080, to reflect the possible water quality at that point in time.

Business as Usual (BAU) is the least intensive restoration approach with mitigations primarily relating to stock exclusion, Waste Water Treatment Plant (WWTP) upgrades and minimal pole planting and retirement. In some cases, BAU may not result in sufficient changes of water quality concentrations to meet the Ruamahanga Whaitua Committees' objectives, which relate to the National Policy Statement for Freshwater Management 'NOF bands' (for example, moving Nitrate-N toxicity from C band to B bands in Parkvale Stream). However, significant changes in concentrations of a number of water quality parameters occur at many sites downstream of WWTP's in the BAU scenarios, that are likely to meet the Whaitua objectives. This is particularly evident with NH_4-N, DRP and *E.coli*. Stock exclusion from water ways and dairy effluent management also help decrease *E.coli* concentrations substantially in BAU.

The Silver and Gold scenarios simulate similar mitigations packages; however, over different timeframes. The mitigations incorporate further on farm management practices such as fertilizer management, constructed wetlands and riparian planting. Gold has most of the mitigations in place between 2025 and 2040, while Silver stages the implementation over a longer timeframe (finishing in 2080). These scenarios also significantly increase the pole planting and retirement within the catchment. Upstream of Ruamahanga at Pukio (which is one of the most downstream reporting points prior to the confluence with Lake Wairarapa outflows), the Silver and Gold scenarios are simulating 10,812 ha of retirement and 27,679 ha of pole planting by 2080. This is equivalent to 3% and 7.8% of the total Ruamahanga Catchment, respectively.

This additional pole planting and retirement (over the BAU scenario) are effective in further reducing nutrient and sediment loads from the catchment; however, to meet this criteria, ~440 ha/year would need to be planted, and 172 ha/year retired (between 2017 and 2080).

Scenario modelling utilises the calibrated baseline model as a basis for simulating potential catchment mitigations. The calibrated model parameters are fixed, with only the inputs (relating to flow and nutrient concentrations) being modified to represent changing landuse and increasing 'restoration' activities in the catchment. The accuracy of the model is determined by the baseline calibration (Jacobs 2018) and the assumptions applied in the scenarios, particularly in Overseer modelling of on farm nutrient reductions. A key component that may affect the simulated nutrient and contaminant concentrations in the scenarios is the effect of hydrological flow reductions due to the establishment of mature trees and native scrub forests (from retirement and pole planting). Flow changes may occur in catchments where runoff is reduced through canopy interception and transpiration. Scenario modelling did not incorporate flow changes associated with these landuse changes. Furthermore, the scenario results could be influenced by climate change which were not incorporated in the modelling. The influences of these hydrological changes on the simulated concentrations at various reporting points are unknown; however, have the potential to reduce the magnitude of concentration decreases.

The outputs from the SOURCE modelling were used by the University of Waikato to simulate changes in Lake Wairarapa and Onoke. While DRP/TP median concentrations reduced >40% in streams and rivers through some scenarios (Silver and Gold), the lakes modelling showed this was insufficient to move Lake Wairarapa out of the its current ‘D’ band (below the national bottom line) for phosphorus. This is related strongly to the legacy nutrient effects and shallow nature of this lake. This is documented in the memorandum “Lakes Wairarapa and Onoke scenarios in comparison to baseline” (Allen 2017). The Ruamahanga Whaitua will need to consider the changes in water quality at all of the river reporting points and also the Lakes, to understand if these mitigation packages are effective in improving water quality in the entire system (to meet Objectives).

The outputs from the scenarios have been further described in a number of smaller technical summaries and fact sheets, which describe the changes observed at each reporting point and reasons for these changes. A detailed assessment of *E.coli* swimmability has been document in Jacobs 2017.

1. Introduction

1.1 Purpose of this report

This report provides a technical summary of the scenario modelling undertaken for the Ruamāhanga Whaitua Committee. The purpose is to:

- Provide a brief background on the baseline model and some context about how model parameters are influenced during scenario trials.
- Outline the scenarios modelled, their core assumptions and limitations.
- Discuss the modelling methodology and how the methodology influences results.
- Evaluate a case study subcatchment draining to a reporting point showing how the application of our modelling methodology has influenced the results. The case study sub-catchment is intended to provide a guide for interpreting the remainder of the Ruamāhanga catchment reporting point results.

A significant number of results were generated from the scenario modelling. This report should be used to help understand why certain changes have occurred in each of the catchments, without explicitly describing every result output.

1.2 Baseline model

The Ruamāhanga Catchment baseline water quality model was built and calibrated using the eWater Source modelling framework and is documented in the Jacobs 2018 report "IZ050100-NCM-RP-0001_Ruamahanga_Source_model_FINAL". A brief summary is presented in the following sections.

The inter-operating surface and groundwater modelling system applied in Source used a range of inputs from various Crown Research Institutes (CRI's) and consulting firms. The development framework includes:

- TOPNET (NIWA) provides total stream flow generated from the Hill catchments.
- Irricalc (Aqualinc) provides quickflow (surface runoff) inputs from the plains catchments and irrigation surface water demands (unrestricted).
- MODFLOW-SFR-MT3D (GNS) system, developed in parallel to the Source model, provided groundwater flux and nitrate loads for input to river links (reaches).
- Point-source inputs (discharge and effluent concentrations) from five wastewater treatment plants (WWTP) derived from monitoring data and included as inflow nodes within the node-link network.
- Surface water abstraction annual allocation and minimum low flow limits were modelled within Source and applied total daily abstraction (agglomerated per subcatchment) along the river links.
- Contaminant diffuse sources for nutrients were derived from Overseer modelling by AgResearch, SedNetNZ (for suspended sediment), in-stream monitoring data and literature values where local data was unavailable.

The variability in flow and water quality from spatially explicit landuse and soil combinations are integrated spatially within the Source model and the resulting contaminant concentrations and loads are simulated at a daily time-step over a representative historical period.

1.3 Catchments

There are 237 subcatchments within the Source model, further documented in the baseline technical report. The catchment areas do not change between the baseline and scenario models, the landuses types within these catchments may change (resulting in different loads out of the catchment). The total catchment area is ~354 km^2.

1.4 Landuse types and functional units

Landuse and soil maps (S-map) obtained from GWRC represent areas of poor (PD), imperfect (ID) and well drained (WD) soil types that were merged with landuse to derive the functional units. Functional units were categorised to capture the spatial variability in nutrient leaching and runoff derived from OVERSEER, producing 48 combinations. A single catchment may have a number of functional unit (FU) types. For example, hill country catchments may have various native bush and plantation forest FU's (i.e. Native_Bush_PD, Plantation_Forest_WD) and sheep and beef FU's. Each of these FU's will have a different area and a different nutrient input concentration.

Modifications in scenario modelling were applied to the areas of the functional units within catchments (for example, where land has been retired to native bush) and to the nutrient input concentrations, documented in **Section 1.5.**

1.4.1 Primary landuse areas

The dominant Ruamāhanga catchment landuse types have been summarised in **Table 1.1.** These do not represent the functional unit list, only a summary of the dominant landuses.

The landuse type 'Other' includes water, finishing, poultry, recreation, viticulture and horticulture. The dominant landuse in the catchment is sheep and beef, followed by native forest and dairy.

Table 1.1 : Ruamāhanga landuse areas

Landuse Type	Area (ha)	% of total catchment
Sheep and Beef	146,962	41.5%
Native Forest	83,888	23.7%
Dairy	30,029	8.5%
Other	17,528	4.9%
Mixed	16,725	4.7%
Lifestyle	12,184	3.4%
Plantation Forest	11,143	3.1%
Dairy Support	9,987	2.8%
Beef	8,974	2.5%
Urban	7,999	2.3%
Sheep	4,491	1.3%
Equine	2,036	0.6%
Arable Land	1,656	0.5%
Deer	709	0.2%

1.5 Contaminant modelling approaches

This section briefly describes the baseline modelling methodology for contaminants such as sediment, *E. coli* and nutrients. Further detail on the baseline modelling methodology is provided in Jacobs 2018.

1.5.1 Sediment

Suspended sediment concentration (SSC) was modelled in Source through the application of the SedNetNZ model developed for the Ruamāhanga catchment by Landcare Research (Dymond, 2010; Dymond et al. 2016). The SedNetNZ model maps sediment average annual sediment yields from total hillslope (surficial, gully, earthflow and landslide) and streambank erosion. SedNetNZ was adopted because it spatially represents the sediment yield from different erosion processes, and therefore enables modelling of mitigations that target specific erosion sources (for example, stream bank erosion) and allows for mitigations to be applied spatially to target specific areas (for example, to target the top 5% of sediment yielding land).

We used a sediment rating curve approach to disaggregate the annual average sediment load from SedNetNZ for each of the 237 sub-catchments, by delivering a proportion of the load each day for the 22-year modelling period (1/7/1992 to 30/6/2014).

The disaggregation was based on a power curve relationship (Equation 1):

$$SSC = bQ^a \qquad \text{(Equation 1)}$$

Where SSC is the suspended sediment concentration in milligrams per litre (mg/L), Q is flow in litres per second, *a* and *b* are constants and exponents. Equation 1 is also called a sediment rating curve.

The exponent (*a*) was fixed based on calibration of simulated versus observed SSC concentrations at three sites throughout the catchment. The constant (*b*) was scaled for each catchment to match the average annual SedNetNZ load.

1.5.2 *E.coli*

E.coli was modelled within the eWater Source software package. Microbial contamination of water sources are influenced by surrounding land use, and both point and nonpoint sources are of importance. *E.coli* can be generated from a variety of sources within a catchment including;

- Direct access of cattle to waterways;
- Overland flow through grazed paddocks entraining *E.coli*;
- Application of sprayed dairy effluent;
- Waste water discharge to streams, and
- Urban stormwater discharges, including pets, birds and wastewater infiltration and overflows

Representation of the relative source load of *E.coli* from these different sources was a focus in the selection and calibration of the baseline model, in regards to adopting an Event Mean Concentration (EMC) and Dry Weather Concentrations (DWC) load generation approach. Numerous literature sources informed the initial set of EMC/DWC parameters and guided calibration to in-stream monitoring data, including loads used in CLUES for pasture, other rural and urban sources.

The EMC's are applied to 'quickflow' in the model, representative of rapid runoff during rainfall events, primarily through overland flow. DWC's are applied to 'baseflow' in the model and could be considered the base load into the system.

1.5.3 Nutrients

Nutrient modelling in SOURCE included the following analytes:

- Total Nitrogen (TN)
- Nitrate-N (NO_3-N)
- Ammoniacal-N (NH_4-N)
- Total Phosphorus (TP)
- Dissolved Reactive Phosphorus (DRP)

Each of these analytes was modelled by assigning input concentrations to the 48 functional units, applied to the EMC and DWC's. These values were determined through Overseer modelling, literature data (where no data was available) and local water quality monitoring records. The input concentrations varied across the catchments, as Overseer modelling was undertaken on 16 representative farm types from within the region, and their nutrient leaching and runoff results were spatially distributed across 53% of the Ruamāhanga catchment. The spatial distribution of farm types to land use was developed by a Ruamāhanga modelling technical group made up of Greater Wellington, MPI, John Bright, and Terry Pariminter. The remaining 47% of the landuse is made up primarily of native and plantation forest, lifestyle, mixed and urban.

The Overseer annual average nutrient outputs were converted to concentrations using the sub-catchment (and functional units) mean annual flows. The 16 Overseer farm types that were modelled incorporated four dominant landuse types which were Sheep and Beef, Dairy, Dairy Support and Arable (see **Table 1.1** for their total areas). These 16 representative farms had variations in farm management practices, stocking rates and farming intensity. This is described in more detail in Jacobs 2018.

Water quality calibration in the baseline model involved modifying the EMC/DWC's. The adjustments for calibration were informed by literature data, so the calibrated EMC/DWC's remained within expected ranges. Calibration also included the application of attenuation factors assigned at the catchment scale. These attenuation factors represent a range of nutrient removal processes including denitrification, soil storage and stream bank and bed processes. They were represented as a simple percentage reduction in load lost from the system.

While the nutrient input concentrations were aggregated into 48 Function Units for the Source surface water modelling, a more detailed nitrate (NO_3-N) leaching raster was used as the input for the MODFLOW-MT3D modelling, where the unique combinations of soil, farm type and rainfall were applied as a gridded raster in the groundwater model.

1.6 Waste water treatment plants (WWTP)

There are five Waste Water Treatment Plants (WWTP) in the Ruamāhanga model. In the baseline model, all discharges are directly to a river link with no land treatment. These represent point source inputs.

2. Scenarios

2.1 Scenario list

A total of ten different scenario models were run over four different time periods. They are as follows:

- Baseline model (i.e., existing management practices between 1992 and 2014);
- Business as usual (BAU) scenario for 2025, 2040 and 2080;
- Gold scenario for 2025, 2040 and 2080; and
- Silver scenario for 2025, 2040 and 2080.

The baseline model provides the reference point for comparison against scenarios. Each scenario has a number of mitigation 'options' applied and inherently the discrete influence of specific mitigations on water quality results is difficult to discern at downstream catchments which have had a significant amount of inflows from various tributaries.

2.2 Scenario descriptions

The following sections provide an overview of the management options applied in each of the scenarios. These were developed by the Ruamāhanga Whaitua Committee.

Table 2.1 : BAU scenario description

Management Option	Description
Land Retirement	Retirement of very steep slopes and reversion to bush on class 7e and 8 (LUC) land. Retirement at a rate of 18 ha/yr.
Pole Planting	Pole (space) planting on steep slopes (class 7 land and above) at a rate of 135 ha/yr.
WWTP	WWTP are discharging partially to land. Discharge to water is allowed only under certain flow conditions (see **Appendix A**). Proportion of flow volume to be discharged to land: **Masterton:** - 60% (summer) and 5% (winter) by 2025, 100% (summer) and 80% (winter) by 2040, 100% (summer) and 97% (winter) by 2080 **Carterton:** - 35% by 2025, 60% by 2080. **Martinborough:** - 24% by 2025, 100% by 2040 **Greytown** - 20% by 2025, 100% by 2040 **Featherston** -0% (full course of model)
Minimum flow rules	Minimum flow rules (cease takes) were applied to all existing agglomerated surface water consents in the SOURCE model, based off Tables 7.1 and 7.2 in the GWRC Proposed Natural Resources Plan (PNRP). These were applied immediately (evident through 2025-2080 models).

Management Option	Description
Nutrient Mitigations (Tier 1)	Tier 1 (M1) stock exclusion of animals from stream access on dairy, dairy support, sheep and beef and arable farms was considered to occur by 2025 (any nutrient, *E.coli* and sediment reductions were therefore consistent across the three BAU scenarios). (Muirhead *et al.* 2016).

Table 2.2 : Silver scenario descriptions

Management Option	Description
Land Retirement	Retirement of very steep slopes and reversion to bush on in Eastern Hill Country on the top 5% of erosion prone land. Retire land by 2040.
Pole Planting	Pole (space) planting on steep slopes (class 6e and 7 land) but not including the top 5% of erosion prone land. Pole planting completed by 2040.
WWTP	WWTP are discharging only to land, includes all sites. 60% of the volume by 2025, 100% by 2040. The 40% of load that is discharged to the river (2025) can only occur when flow is greater than 3x the median flow.
Minimum flow rules	Minimum flow rules (cease takes) are the same as applied in the BAU model (see **Table 2.1**).
Nutrient Mitigations (Tier 1, 2 and 3)	Tier 1 (M1) applied immediately (2025 through to 2080). Tier 2 (M2- fertiliser management, constructed wetlands etc) applied by 2040. Tier 3 (5 m riparian buffer) applied by 2080. Mitigations only applied to dairy, dairy support, sheep and beef and arable farm types. (Muirhead *et al.* 2016).

Table 2.3 : Gold scenario descriptions

Management Option	Description
Land Retirement	Retirement of very steep slopes and reversion to bush on in Eastern Hill Country on the top 5% of erosion prone land. Retire land by 2025.
Pole Planting	Pole (space) planting on steep slopes (class 6e and above) but not including the top 5% of erosion prone land. Pole planting completed by 2040.
WWTP	WWTP are discharging only to land, includes all sites. 100% of the volume by 2025.
Minimum flow rules	Minimum flow rules (cease takes) are the same as applied in the BAU model (see **Table 2.1**).
Nutrient Mitigations (Tier 1, 2 and 3)	Tier 1 (M1) and Tier 2 (M2) applied immediately (2025 through to 2080). Tier 3 (10 m riparian buffer) applied by 2040. Mitigations only applied to dairy, dairy support, sheep and beef and arable farm types. (Muirhead *et al.* 2016).

2.3 Scenario reporting points

Discussions with GWRC identified a total of 25 reporting points in the Ruamāhanga catchment. Five of these were lake reporting points (Wairarapa and Onoke). The 20 remaining points that were assessed in the scenario trials are outlined in **Table 2.4.**

Table 2.4 : Reporting points, catchment area and co-ordinates

Reporting points	Total catchment area (ha)	Co-ordinates (NZTM)	
Huangarua River at Ponatahi Bridge	30,239	1809110.9	5433450.9
Kopuaranga River at Stuarts	16,686	1826760.0	5469569.0
Mangatarere River at SH2	11,947	1809768.0	5452160.0
Ruamāhanga River at Pukio	246,366	1796969.7	5429312.4
Ruamāhanga River at Te Ore Ore	31,078	1825238.6	5462371.0
Taueru River at Gladstone	49,244	1824148.0	5450815.0
Tauherenikau River at Websters	14,481	1794221.8	5438960.8
Waingawa River at South Rd	14,969	1824037.5	5456790.2
Waiohine River at Bicknells	39,320	1810473.9	5446861.2
Waipoua River at Colombo Rd Bridge	17,452	1825118.6	5462371.0
Parkvale Stream at weir	5,006	1813384.6	5448900.9
Ruamāhanga River at Wardells	64,284	1824577.7	5457270.2
Ruamāhanga River at Gladstone Bridge	133,694	1819925.6	5449559.8
Ruamāhanga River at Waihenga	236,089	1804111.3	5435911.3
Whangaehu River at 250m from Rua Confluence	14,578	1826209.0	5459282.0
Otukura Stream at Mouth	9,366	1793829.6	5437578.3
Makahakaha Stream at Mouth	6,192	1821065.6	5448899.5
Ruamāhanga River at U/S Lake Wai Outlet	254,496	1784197.9	5423956.4
Tauanui River at Mouth	4,155	1783915.1	5423674.8
Turanganui River at Mouth	6,740	1779267.6	5419205.8

These reporting points are presented in **Figure B1** in **Appendix B.**

2.4 Nitrate-N input maps (to GNS)

GNS developed and ran the MODFLOW MT3D model for Ruamāhanga Scenarios. The inputs to this model were a spatially distributed Geographical Information System (GIS) raster with leaching of Nitrate-N (kg/ha/yr) from various landuses within the catchment. No other analytes were modelled in MT3D.

To capture the changes of Nitrate-N in the groundwater fluxes, the updated leaching rates from mitigations modelled by Agresearch (Tier 1, 2 and 3) for the 16 farm types (represented by 4 landuses covering 53% of the catchment) were incorporated into new leaching maps (Muirhead *et al.* 2016), adapted from the baseline. The following Nitrate-N maps were produced:

- Baseline
- BAU-only one map for 2025, 2040 and 2080 as Tier 1 (stock exclusion) was the only mitigation applied.
- Silver 2025, 2040 and 2080, which varied based on timing of mitigations documented in **Table 2.2**.
- Gold 2025 and 2040, based on timing of mitigations documented in **Table 2.3**.

GNS incorporated these maps into their groundwater model, and provided Jacobs with revised groundwater fluxes that were assigned to each of the relevant models.

The surface water quality model also applied the same mitigations, however this was through a weighted average % reduction applied to the DWC's (for NO_3-N) (further described in **Section 3.7**).

The Nitrate-N maps supplied to GNS did not incorporate the changes in leaching due to other landuse management options, such as retirement of land to native bush. This was captured in the surface water model through area changes of functional units (as described in **Section 3.3**), however this would mean the groundwater flux NO_3-N loads may be slightly overestimated in the scenarios, although the magnitude of this is expected to be small given the groundwater model domain is on the lowlands where pole planting and retirement is limited, and therefore will likely have minimal impacts on simulated Nitrate-N concentrations.

2.5 Scenario result table calculations

All flows and concentrations are based off a 22-year flow simulation from 1/7/1992 to 30/6/2014, as per the calibrated baseline model detailed in Jacobs 2018.

Concentrations are calculated for the entire period off the daily timeseries. The following calculations have been undertaken on the daily flow and concentration timeseries.

- Mean Annual Daily Flow (MADF) – for each year calculated the annual daily average flow. The 22 results were then averaged to provide one MADF.
- Mean Annual Low Flow (MALF) – for each year determine the annual low flow. The 22 results were then averaged to provide one MALF.
- 7 day MALF (7-day average flow) – as above using a running 7-day average.
- Mean concentration for all the analytes
  - TN, NO_3-N, NH_4-N, TP, DRP, SSC and *E.coli*.
  - Dissolved Inorganic Nitrogen (DIN) has been calculated manually from NO_3-N and NH_4-N data.
- 5^{th}, 50^{th} and 95^{th} percentile concentrations for all the analytes utilising the Hazen method
- Annual maximum concentrations for ammonia (toxicity) or NH_4-N are required to for attribute state determination in the National Policy Statement for Freshwater Management 2014 (NPSFM) (amended 2017). These were determined by identifying the maximum value from each simulation year, then averaging the 22 values, with the purpose to reduce model bias.
- Average annual loads for each of the analytes. These represent a sum of the annual load based off the daily timeseries of flow and concentration (i.e. each of the 22 years of flow and concentration were multiplied to determine load totals for one species such as DRP, producing 22 annual loads). The 22 annual loads were then averaged to represent an average annual load.
- The NPSFM (amended 2017) swimmability standards for *E.coli*.
- Percentage (%) change between scenarios at each of the site, compared against the baseline model.

2.6 Scenario results distributions

The outputs from the scenarios models were:

- 200 timeseries of daily flow and concentrations (20 reporting points and 10 models including baseline)
- 46 tables which covered concentrations, flows, average annual loads, *E.coli* changes relative to swimming standards, summary concentrations and percentage changes between scenarios (for each water quality species).
- Leaching and runoff maps, *E.coli* loads by functional unit and sediment generation maps

These outputs were utilised by:

- GWRC
- The University of Waikato (lakes model inputs)
- NIWA (Bayesian Network Modelling)
- Landcare Research (Economics Modelling).
- Nick Taylor (Social Impact Assessment).

The 46 summary tables that were produced have been classified into five overall table categories, described in **Table 2.5**.

Table 2.5 : Summary result table descriptions

Result Table Number	Description
Table 1	MADF, MALF, 7-day MALF and mean, 5th, 50th and 95th concentrations (mg/L) for 8 analytes identified in **Section 2.5** at the 20 reporting points discussed in **Section 2.3**. A single table was generated for each scenario (total of 10 tables)
Table 2	MADF, MALF, 7-day MALF and mean, 5th, 50th and 95th loads (t/year) for 8 analytes identified in **Section 2.5** at the 20 reporting points discussed in **Section 2.3**. A single table was generated for each scenario (total of 10 tables)
Table 3	50th, 95th percentiles for *E.coli* at each of the 20 reporting points discussed in **Section 2.3**. In addition, includes the draft swimmability criteria as outlined in NIWA 2017, which includes the percentage of exceedances over 260 and 540 cfu/100 ml. There were a total of 10 tables.
Table 4	Presents the 5th, 50th and 95th concentrations (mg/L) from Table 1, summarised by analyte to include all the scenarios (and the baseline results). There are 8 summary tables, each including results for the 20 reporting points discussed in **Section 2.3**.
Table 5	Presents the percentage change from the baseline results, calculated from Table 4, summarised by analyte to include all the scenarios. There are 8 summary tables each including percentage changes for the 20 reporting points discussed in **Section 2.3**.

2.7 Supporting Technical Reports

Following delivery of the modelling results, a number of additional technical reports and outputs were requested from GWRC. These were used to support the NPSFM requirements for assessing human and ecological health. Due to the significant number of analytes, a fact sheet approach was undertaken (rather than a large technical report) to present key water quality summaries at each of the 20 reporting points.

The following documents provide further detailed analysis of the scenario modelling outputs.

- IZ090000_RP_Rua_Scenarios_Human_Health_E.coli_Rev2_Final (Jacobs 2017a). This document describes the swimmability changes at the reporting points through modelled mitigations, and where possible, compares against observed water quality data.
- IZ090000_RP_Rua_Scenarios_Ecological Health_Rev1 (Jacobs 2017b). This report summarises information contained within this current technical report, and is to be used as a reference for the assumptions, limitations and modelling methodology in support of the A3 fact sheets.
- A3 Fact sheets (summaries, concentrations, NOF bands, percentage change and charts) (Jacobs 2017c-g).
  - All_sites_DIN_A3_FactSheet_FINAL_Rev1. Dissolved Inorganic Nitrogen- 20 fact sheets
  - All_sites_DRP_A3_FactSheet_Final_Rev1. Dissolved Reactive Phosphorus- 20 fact sheets
  - All_sites_SSC_FactSheet_Final_Rev1. Suspended Sediment Concentration- 20 fact sheets

- Ruamahanga Factsheet A3 NO_3-N Final_Rev1. Nitrate-N summary fact sheets (3 pages)
- Ruamahanga Factsheet A3 NH_4-N Final_Rev1. Ammoniacal-N summary fact sheets (3 pages)

3. Methodology

The following section describes the methodology applied in the scenario models and how this influences changes in flows and concentrations.

3.1 Updated Groundwater Flux (GWF)

As described in **Section 2.4**, new GWF Nitrate-N concentrations are re-assigned to each link for the relevant scenario model.

GNS have also undertaken a variety of groundwater consent restrictions for BAU, Gold and Silver. Given GWF represents the baseflow in the model, these changes can lead to an increase or decrease in flow.

The Ruamāhanga modelling project team advised that irrigation supplied by groundwater (MODFLOW model) is considered constant over the BAU simulation, while during the baseline model it ramps up over time. This means the abstractions from groundwater are slightly higher in the BAU, Gold and Silver models, decreasing the GWF in some links, and correspondingly, the overall flow in various rivers.

The effects of a decrease in flows can lead to an increase in concentration (even with no landuse change or little to no mitigation practices being implemented).

3.2 SedNetNZ modelling

Suspended Sediment Concentration (SSC) modelling is undertaken in Source informed by sediment yields from SedNetNZ, as described in **Section 1.5.1**.

SedNetNZ has a number of sediment generation GIS layers, with the primary ones being:

- Four layers representing hillslope erosion. These are gully, earthflow, landslide and surficial.
- One layer representing stream bank erosion.

Each layer generates a portion of the annual average load based on a variety of factors, the factors are described by Dymond *et al.* 2016. An example of this is earthflow erosion, which is associated with slow movement of soil along basal and marginal shear planes, common in terrains underlain by crushed mudstone and argillite lithologies.

When mitigations are applied (% reductions on annual load) due to pole planting and retirement (defined in Dymond et al. 2014), they are assigned to different layers in GIS. The application of mitigations to SednetNZ yields was agreed with John Dymond (John Dymond 2017 pers, comm., 9 June) and were applied as follows:

- Pole planting is assigned to all four hillslope layers at the land parcel scale. A 70% reduction to the existing sediment loads would be assigned to the parcel for areas that are pole planted when poles reach a 15-year maturity.
- Retirement is applied to the landslide, gully and earthflow layers at the pixel/polygon scale. A 90% reduction to the existing sediment loads is assigned after a 10-year maturity period.
- Stock exclusion (Tier 1/M1) (and riparian planting) jointly has an estimated 80% reduction in stream bank erosion, and is applied to the stream bank erosion layer. Given stock exclusion is implemented first, this 80% reduction has been applied at Tier 1 mitigations with no further reductions in load due to riparian planting (Tier 3/M3). No reduction in phosphorus load was modelled due to stock exclusion.

This approach is undertaken for each scenario (BAU, Silver and Gold) as areas are increasingly pole planted and retired. For the Ruamāhanga scenarios, reductions in load were only applied when the areas reach maturity (15 and 10 years respectively).

In reality, sediment reductions would be occurring from pole planted areas prior to maturity, with the development of roots from willows and poplars often beginning to influence the hillslope erosion process after 7 years (Douglas *et al.* 2010).

The annual average loads per subcatchment are then used to update the constant (*b*) in the SSC power curve, as described in **Section 1.5.1**. Daily flow timeseries are exported for each catchment (in each scenario) and a macro runs a goal seek equation in Excel to determine the appropriate SSC power curve constant to apply to ensure the average annual load is matched to the SedNetNZ load from daily SSC concentrations. It is assumed the exponent (*a*) remains the same throughout mitigations.

3.3 Retirement of land

Retirement of land was informed by the Land Use Classification (LUC) data for BAU scenarios, and in addition the top 5% of erosion prone land for Gold and Silver scenario's (See **Table 2.1** – **Table 2.3)**. GIS analysis was undertaken to identify the relevant LUC classes for each scenario and retiring land starting with the steepest slope class, by converting the baseline landuse to native Bush FU type, as guided by the Ruamahanga modelling project team. Retirement essentially effects Sheep and Beef farms, given most retirement focused on steep and eroding slopes as per descriptions in **Table 2.1** to **Table 2.3.** Retirement was undertaken first, followed by pole planting. It was assumed that land that is retired cannot be pole planted.

This is undertaken through a land use area change in the model, i.e. Sheep and Beef decreases by 50 ha, Native Bush increases by 50 ha. Where this occurs, the Native_Bush EMC/DWC input parameters for all constituents except sediment would be applied to the land that has been retired, thereby decreasing the loads from that particular area in the model.

Table 3.1 : Retirement effects on nutrients and sediment

	Sediment	Nitrogen	Phosphorus	*E.coli*
Retired <10 years old	No change	Change to Native_Bush input concentrations as applied in the baseline model.		
Retired >10 years	Change to Native_Bush input concentrations. For Sediment, a 90% reduction in load is applied to the landslide, gully and earthflow SedNetNZ layers for the retired areas in GIS as advised by Dymond *et al.* 2014.			

The modelling assumptions described in **Table 3.1** meant that for nutrients, the effect of retirement was considered immediate. However, for sediment (treated separately through SedNetNZ), the 'effective' retired area is delayed by 10 years. Retired land less than 10 years old was not included in the sediment load reductions.   Phosphorus was also assumed to be reduced in concentration immediately following retirement, primarily due to reductions in fertilizer, increased grass and vegetation growth and less disturbance of land from stock. However, it could be argued that given phosphorus is often entrained with suspended sediment, then it could have been modelled as no change until 10 years of growth is achieved. For the purposes of these scenarios, the effects on phosphorus concentration reductions results in a faster rate or reduction by 2040.

The total area of land that is retired upstream of each reporting point is described in **Table B.1**, **Appendix B**. Retirement of land mitigation option will effect both median (50th) and 95th percentile concentration.

3.4 Pole planting

Pole planting (space planting) occurred at a rate of 135 ha/yr in BAU on steep slopes of class 7 land and above. The steepest land was pole planted first. GWRC provided a map of the current pole planted areas in the catchment, which was also incorporated into BAU modelling. Based on the BAU pole planting rate, 8,500 ha could be pole planted by 2080.

Following discussions with John Dymond and literature reviews (Dymond *et al.* 2014), it was agreed that pole planting primarily affects sediment and phosphorus, but results in no change to nitrogen (and its species) and

E.coli. The application of mitigations to SednetNZ sediment yields was agreed with John Dymond (John Dymond 2017 pers, comm., 9 June) and are described in **Table 3.2**.

Table 3.2: Pole planting effects on nutrients and sediment

	Sediment	Nitrogen	Phosphorus	*E.coli*
Pole planted <15 years	No change from baseline			
Pole planted >15 years	• Add the landslide, gully, earthflow and surficial layers in SedNetNZ • Apply a 70% reduction to the annual load for the landuse types that have been pole planted. • Apply the reduction at the lumped polygon scale (the parcel or property scale). • This process is undertaken in GIS	No change from baseline	• Subtract the Native_Bush EMC concentration from the existing landuse (pre pole planted) concentration (i.e. Sheep and Beef TP EMC concentration less Native Bush TP EMC concentration) • The difference is then reduced by 70% • The left over amount (30%) is then added to the Native_Bush EMC concentration for TP or DRP. • This process is undertaken in excel	No change from baseline

The approach above results in changing the nutrient generation rates rather than the landuse areas to avoid doubling up of the mitigation effects on other unmitigated nutrient types. Nitrogen and *E.coli* species are considered to remain the same given farming will continue under the pole planted areas, where TP/DRP are strongly influenced by sediment and are therefore have been assumed to be treated with the same reductions.

As per the retirement methodology (**Section 3.3**), the above analysis was compounded by the delayed effect of pole planting by 15 years. This meant that in all scenarios (BAU, Silver and Gold), pole planting had no effect on the 2025 results, while retirement had a very small effect. The mitigation effects become evident in 2040 and 2080, where pole planting and retirement of steep land begin to reduce nutrient and sediment concentrations. Gold and Silver have the same pole planted areas, as they are both completely planted by 2040.

For the Silver scenario land is planted on class 6e to 7 LUC land, and for Gold scenarios land is planted on class 6e land and above (**Table 2.2** and **Table 2.3)**. This LUC class which distinguished the scenarios had no effects on the final areas planted, as all land above class 7 was effectively retired first (i.e. fell within the top 5% or erodible land). Therefore, these two scenarios have the same pole planting influences on sediment, TP and DRP.

The values in **Table B.2, Appendix B** present the pole planted areas relative to the 20 reporting points.

3.5 Wastewater treatment plant (WWTP) mitigations

WWTP effluent mitigations varied depending on the scenario being modelled, as outlined in **Section 2.2**.

However, all scenarios included the following approaches:

- WWTP effluent flow and load was increased based on population growth assessments for the region (from statistics NZ).
- Receiving water flows were assessed to determine when WWTP effluent discharge could occur to the river. When it could not, it was assumed to be land treated.

- The proportion of WWTP effluent flow that was land treated was multiplied with the WWTP timeseries concentration to create a load. This load was then attenuated based on information gathered from consents, Overseer and literature data that was verified and agreed on with all district councils. I.e. 77% reduction to Nitrogen, 95% reduction *E.coli*.
- The revised 'attenuated' effluent load (reduced following land treatment) was then recalculated as a concentration, based on the corrected effluent flow timeseries (incorporating population increase). While flow increased due to the increased population, the concentration decreases due to land treatment. These 'effluent water' timeseries were loaded back into the corresponding Source models as point source discharge to the river (however now 'land treated').

The methodology applied for BAU, Silver and Gold is described in greater detail in **Appendix A**.

The effects of the WWTP mitigations are most evident at the links directly downstream, however their effects propagate throughout the catchment.

There is no reporting point downstream of the Featherston WWTP, so the changes in receiving waters here are only captured in Lake Wairarapa quality.

3.6 Minimum flow rules for surface water consents

Under the BAU, Silver and Gold models, minimum flow (cease take) rules were applied to every consented surface water take. In Source, all abstractions were agglomerated by sub catchment, so there may be multiple abstraction timeseries (from Irricalc) combined to represent a single abstraction for the river reach in that catchment.

Where no cease take or ramp down rules were applied to the existing baseline abstractions, flow stations and minimum flows were assigned based on Table 7.1–7.4 of the Proposed Natural Resources Plan (PNRP). These flows were scaled by assessing observed flow versus simulated in flow duration curves, to ensure the cease take was implemented correctly. This was agreed on through discussions with GWRC and John Bright in March 2017 and is described in Jacobs 2018.

Minimum flows in general have little effect on contaminants, but do result in a slight increase in flow in a number of reaches.

3.7 Nutrient and *E.coli* mitigations

On farm mitigations (M1, M2 and M3) were modelled against 16 representative farm types in the region in Overseer, by Agresearch (Muirhead *et al.* 2016). These farms collectively represent four landuse types; Dairy, Dairy Support, Arable and 'Sheep and Beef'. The 16 farms have increasing leaching rate reductions for each mitigation package. The 16 farms are spatially extrapolated across 53% of the Ruamahanga catchment to represent the typical farming practices expected (as discussed in Jacobs 2018).

Rather than apply the modelled Overseer nutrient reduction from M1, M2 and M3 mitigation packages to each of the 16 farm types and spatially extrapolate this in GIS to where these have been applied within the catchment, a simplification was undertaken which applied the nutrient reductions to the four landuse types using a weighted average based on the area each farm covered in the catchment. The purpose of this approach was to improve processing time, as mitigations could then be applied quickly as a percentage reduction to input concentrations on the appropriate landuse, averaged for the entire catchment (which is how the farms are represented in Source). The effects on model performance mean the nutrient reductions are averaged across the catchment, which may mean some of the FMU's may simulate slightly higher or lower nutrient concentrations depending on what farm types (and intensity of farming) is present.

The Ruamāhanga catchment area has been described in **Table 1.1**. The 16 farm types where nutrient mitigations were applied represent 53% of the total area. Modelling of mitigations was consistent with the Agresearch report, and could be considered conservative in its application as mitigations were not applied to the other relevant farming functional units such as Sheep, Beef and Deer (representing >4% of the catchment), nor any cropping. Sheep and Beef individual landuses were excluded as the method directly followed the Agresearch approach and the farm types modelled were a mixture of both landuses.

3.7.1 Mitigations Table

The Overseer leaching mitigations were converted into weighted average percentage reductions. These were applied to the baseline EMC/DWC's for the relevant functional unit type during model scenarios runs.

The mitigations are outlined in **Table 3.3**. The percentage reductions are not applied universally to both EMC and DWC's. For nitrogen species, Overseer N leaching is represented by DWC concentrations. Conversely, phosphorus species are informed by Overseer runoff rates and mitigations are applied to EMC's.

E.coli mitigations were advised by Agresearch based on a variety of studies on the effectiveness of stock exclusion and deferred/low rate effluent irrigation in reducing baseflow loads (DWC's) to streams and rivers. Two reports were used to inform the percentage reductions to apply for the different farm types (Muirhead 2013 and Muirhead 2016).

Email communication with Richard Muirhead on the 22nd of September 2017 indicated that a realistic estimate for riparian buffer planting would be a 10% reduction to EMC's. This has been further described in the report "IZ090000_RP_Rua_Scenarios_Human_Health_E.coli_Rev2_Final".

Table 3.3 : Tier 1 (M1), 2 (M2) and 3 (M3) mitigations and their applications to nutrient concentrations

Reductions applied	Mitigations applied to input concentrations		Percentage (%) reduction from baseline concentrations			
	Species	Scenario	Dairy	Sheep and Beef	Arable Farm	Dairy Support
Cumulative (i.e. application of M3 includes M1 and M2 effects)	TN, NH_4-N, NO_3-N (DWC's)	Baseline	-	-	-	-
		M1 (BAU/Gold/Silver)	4.1	0.1	0.0	1.6
		M2 (Gold/Silver)	23.9	3.8	4.8	23.3
		M3 5m buffer (Silver)	23.9	3.8	9.5	24.1
		M3 10m buffer (Gold)	23.9	3.8	9.5	25.7
	TP, DRP (EMC's)	Baseline	-	-	-	-
		M1	16.8	1.5	0.0	5.9
		M2	26.6	13.3	0.0	11.9
		M3 5m buffer	27.5	80.1	20.0	23.8
		M3 10m buffer	29.8	80.1	20.0	23.8
	E.coli (DWC's)	Baseline	-	-	-	-
		M1	69%	44%	0%	69%
		M2	69%	44%	0%	69%
		M3	69%	44%	0%	69%
	E.coli (EMC's)	Baseline	-	-	-	-
		M1	-	-	-	-
		M2	-	-	-	-
		M3	10%	10%	10%	10%
Individually (M1 is applied to bank erosion	Sediment (see **Section 3.2** for a description	Baseline	-	-	-	-
		M1 (net bank erosion reduction)	80%	80%	80%	80%
		M2 (constructed wetlands, applied after pole planting to hillslope layers)	6.4%	20.7%	0.0%	5.8%

Reductions applied	Mitigations applied to input concentrations		Percentage (%) reduction from baseline concentrations			
	Species	Scenario	Dairy	Sheep and Beef	Arable Farm	Dairy Support
layer, M2 to hillslope layers)	of SedNetNZ).	M3 (riparian planting, no change, as captured in M1 with stock exclusion)	-	-	-	-

3.7.2 Tier 1, 2 and 3 descriptions (M 1, 2, 3)

As described in Muirhead *et al.* 2016, Tier 1 mitigations include:

- Stock exclusion from streams and wetlands (all four farm types, but excluding sheep and beef as individual landuses)
- Deferred and or low rate effluent irrigation (dairy farms only)

Tier 2 mitigations are numerous; however, the primary mitigations include:

- Facilitated or constructed wetlands
- Optimal fertiliser and effluent application
- Efficient water irrigation

Tier 3 mitigations that have been modelled by Agresearch (Muirhead *et al.* 2016) include:

- split grass/clover swards, riparian planted buffer strips
- sediment traps, duration controlled crop grazing and off paddock wintering.

In regards to riparian planting, Agresearch had modelled 5 m riparian buffers (applicable to the Silver Scenario only) on the 16 Overseer representative farm models. Agresearch had applied a 26 m/ha average stream length on productive land that was not flat or free draining brown soils. To verify if this was representative of the streams within the catchment, an assessment was undertaken on the REC stream length (all orders) across productive land, which totalled ~4,412 km. Inclusion of flat and free draining soils (using the 26 m/ha rule applied to farm block) resulted in a total stream length of 6,875 km.

Following the method defined by Agresearch, the stream density based on productive land that was not flat or free draining was 5,188 km, closer to the REC stream lengths. Therefore, the 26 m/ha method was considered acceptable to proceed with Overseer modelling, given time constraints

This stream density was applied to the Overseer representative farm models to recalculate nutrient reductions from Silver and Gold 5 and 10 m buffers.

Riparian planting/buffer strips (Tier 3) had no additional reductions to sediment, as this has been assumed to be captured during the stock exclusion mitigations (Tier 1) following advice from John Dymond, (John Dymond 2017 Pers. Comm., 1 June.) In reality, these two activities may occur as a staged approach (stock exclusion first) or concurrently during mitigation work at the catchment level. Riparian planting would enhance bank stability through root distribution, and fencing alone would likely have less impact on sediment reduction at the stream bank level as a coupled approach. See **Table 3.3** for more detail.

4. Assumptions and Limitations

There are a number of assumptions and limitations undertaken throughout the scenario modelling which were implemented for various reasons, including time constraints, modelling efficiencies and practicalities. Some of these are described below.

4.1 Flow Calibration

Loads in the Source model are driven by the flow generation. The Source model uses flows from a range of inputs. The flow development framework includes:

- TOPNET (NIWA) provides total stream flow generated from the Hill catchments;
- Irricalc (Aqualinc) provides quickflow inputs from the plains catchments and irrigation surface water demands (unrestricted).
- MODFLOW-SFR-MT3D (GNS) system, developed in parallel to the Source model, provided groundwater flux and nitrate loads for input to river links (reaches);
- Point-source inputs (discharge and effluent concentrations) from five wastewater treatment plants (WWTP) derived from monitoring data and included as inflow nodes within the node-link network
- Surface water abstraction minimum low flow limits were modelled within Source and applied total daily abstraction (agglomerated per subcatchment) along the river links.

The subsequent calibration of these flows series was undertaken by each of the respective parties above, with Jacobs compiling the flow series in Source for the water quality modelling. At a number of sites, calibrations to observed data have often led to a simulation of flow higher than observed for many reaches (see Jacobs 2018). An accurate flow model is important to ensure generated loads are correctly attenuated. Subsequently, good calibrations of water quality data to observed information are increasingly difficult to achieve if the flows are inaccurate.

4.2 Minimum flow rules

The BAU minimum flow control rules were maintained throughout the Silver and Gold models as all the scenario models only considered existing consents which would not have greater restrictions imposed (except for the cease take rules). Any new abstractions were not modelled or considered in the scenarios, which would potentially occur particularly if landuse change through conversion was undertaken (see **Section 4.8**). This would have required re-runs from Irricalc and MODFLOW which was time constraining.

Application of flow rules in Source is described in Jacobs 2018 and **Section 3.6**. Through BAU, all unrestricted consents were assigned cease takes rules, scaled based on flow duration curves of the observed and simulated data at ‘control’ gauging sites.

4.3 Annual allocation

There are no annual abstraction allocation amounts applied to any surface water consents. Review of a number of existing Irricalc surface water abstractions showed no single consent reached their annual allocation volumes. For this reason, accounting for annual allocation restrictions in the models was not undertaken.

4.4 Pole planting and retirement delayed effects

As described in **Section 3.2, Table 3.1 and Table 3.2**, pole planting and retirement had delayed effects on sediment. These delays (primarily applied to sediment), were assigned only at maturity. An alternative approach could have been to apply a linear increase in reductions up their threshold values of 70 and 90%. Literature suggests that pole planting generally has little effect on sediment reduction when poles are <7 years old and they reach maturity at 15 years (Douglas *et al.* 2010). However once the roots are established after 7 years, each subsequent year of growth could have been assumed to have an increasing portion of sediment reduction.

4.5 Nutrient mitigations to certain landuses

As described in **Section 3.7**, mitigations applied to reduce nutrients were only assigned to four dominant functional units ('sheep and beef', dairy, dairy support and arable). A number of other FU's could have mitigations applied and represent >7% of the catchment area (see **Table 1.1**). Inclusion of these excluded FU's in the scenarios would have resulted in greater nutrient reductions. For example, Tier 1 mitigations (fencing in particular) may occur on all mixed and solely sheep or beef properties and lower sediment, phosphorus and *E.coli* loads from these areas. These functional units were excluded as the mitigations applied in scenarios followed the exact agresearch modelled farm types (Muirhead *et al.* 2016), with the 'sheep and beef' farm types representative of mixed farming and their corresponding management approaches and nutrient leaching rates. For this reason, these additional nutrient reductions have not been captured in the scenario results.

4.6 Catchment areas

Catchment delineation was dictated by accommodating several sources of flow inputs and therefore resulted in aggregation of REC catchments that resulted in the exclusion of some reporting points on small tributary sites or catchment reporting points that did not align with flow catchment boundaries in some locations. This is described in Jacobs 2018.

To improve on this would require updates of the hydrological models (TOPNET runoff, MODFLOW GWFlux and Irricalc quickflow) which was not possible in the project timeframes.

Overall, the effects of this are considered minor given the proportionate catchment size and that downstream points would have been calibrated to include this additional load (i.e. a higher attenuation rate would have been applied in the model to calibrate sites to observed data).

4.7 Netbank erosion

Following delivery of the results for Ruamahanga Whaitua Committee meetings in November 2017, a review of the SSC netbank mitigations identified that the 80% reduction in netbank load (see **Section 3.2**) has been applied to all of the 237 subcatchments within the Ruamahanga model, rather than catchments with solely agricultural landuse types. This means in some large native catchments, netbank erosion has been reduced when these values would remain unchanged. The resulting effects mean SSC concentration reductions (See **Table C.6**) are greater than would be expected for areas with large amounts of native forest (such as the western Tararua catchments), which can propagate through to downstream reporting points indicating a higher amount of SSC reduction than what is expected. It is worth noting that the effects of this greater reduction in SSC may be corrected to a degree by the exclusion of the landuse types identified in **Section 4.5.** The model currently simulates baseline (i.e. unmitigated) sediment loads off these landuses, and if mitigations were applied (pole planting, stock exclusion etc) then sediment reductions would be greater.

However, following progression of scenario modelling to in-stream freshwater objective (FWO) and load setting, a decision not to set in-stream objectives at the 21 FMU's for suspended sediment was accepted, due to:

- lack of SSC monitoring data to help inform concentrations
- average model calibration at these three locations (see Jacobs 2018).

Therefore, the SSC reductions will not be incorporated in the PNRP as FWO's. To set objectives for sediment in the Ruamahanga Catchment, the PNRP will incorporate SedNetNZ outputs as an annual load at each FMU, split out by erosion process and as either native, or non-native. This will provide a high level understanding of which FMU's contribute the most non-native load and can be targeted for sediment improvements. The natural progression to this method has meant the netbank erosion has been re-calculated at each FMU, and the load reductions due to fencing and riparian planting have only been applied to the non-native areas.

Discussions with Lakes and Economics Modellers verified that this additional mitigation applied to Netbank erosion will have minimal effects, as:

- it solely influences SSC (no other contaminants or nutrients are effected)
- the lake SSC concentrations are mainly derived from re-suspension, and;
- economics modelling applied riparian planting and stock exclusion to agricultural landuse only, based off GIS landuse maps.

4.8 Landuse change and flow impacts

The Ruamahanga Modelling project team chose not to re-run all the flow models (TOPNET, Irricalc and MODFLOW) due to time constraints. Any landuse change (essentially retirement and pole planting) that was undertaken through the scenarios were applied to the baseline flow series, slightly modified due to:

- New GWF's provided by GNS for each scenario, which was primarily for revisions of the Nitrate-N loads entering the reaches (due to revisions of the Nitrate-N BAU, Gold and Silver leaching maps). These flow series encompassed any control rules applied to groundwater takes as modelled by GNS (not covered within this report).
- Increased flow from the WWTP's due to simulated population increase.

Overall, these flow changes were relatively minor when compared against the baseline model. In reality, landuse change would influence the hydrology of a catchment, particularly where retirement, pole planting and plantation forests (deforestation/reforestation) are considered. This can impact on in-stream nutrient concentrations in a complex manner, and has not been accounted for in scenarios. Retirement of land (depending on growth and establishment rates) is likely to have an incremental change on hydrology, reducing runoff, as plants mature and increased transpiration occurs. Pole planting (and plantation forests) may have a greater reduction in runoff in a shorter timeframe due to faster growth rates, however this could be offset by a more distributed planting density (typically 12-15 m spacing).

Long term (34 year) paired catchment studies in Glendhu in Otago have shown that large scale intensive plantation of *Pinus radiata* results in a noticeable change in the hydrological regime of a catchment. In Glendhu, planting two thirds of a catchment from tussock to *radiata* resulted in an annual water yield reduction of 33% (~273 mm). Afforestation also reduced the low flow (Q95) by an average of 26% (Fahey and Payne 2017). 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.

Without simulating cover change in TOPNET (given most retirement and pole planting occurs on the upper hillslopes) and incorporating this into the Source model, the effects of flow reductions potentially off-setting the nutrient load reductions (in regards to in-stream concentrations) are unknown. The effects on runoff are unlikely to be as significant as exhibited in the Glendhu trials, which essentially cover the catchment in dense pine forest. Overall, the scenarios will decrease the nutrient loads, but the reduced flow could mean a decrease in the magnitude of the simulated nutrient concentration reductions.

4.9 WWTP land discharge

Each of the scenarios had various land treatment applications of the WWTP loads. In some situations, (BAU and Silver models), this was also driven by the receiving river flows and various discharge control rules. An assessment of the river flows was undertaken to determine when discharge could occur under these scenarios and is further described in **Appendix A.**

In some circumstances WWTP loads could not be discharged to a river (due to flow restrictions) yet the proportionate amount that was allowed to be discharged to land (under the scenario) had been allocated. In this situation, it was assumed the discharge control rules took priority, and the WWTP loads were discharged to land.

Additionally, some of the control rules set by the Ruamāhanga Whaitua Committee were challenging to meet due to the receiving water flow series being unsuitable for WWTP loads discharge to water (Carterton in particular).

This influences described above occurred in the following situations:

- Carterton WWTP – BAU (all scenarios) and Silver 2025.
- Featherston WWTP – Silver 2025.
- Masterton WWTP – BAU 2025.

See **Appendix A** for a full description on how the discharge criteria differs between the planned versus actual scenarios.

4.10 Lakes model inputs/outputs

The constituent and flow outputs from Source catchment modelling were provided to the University of Waikato, whom developed hydrodynamic and biophysical models for Lakes Wairarapa and Onoke.

Given time constraints and additional steps involved in incorporating the lake outputs back into the Source model to transfer flow and nutrients from Lake Wairarapa to Onoke, the University undertook this by incorporating the flows/loads from the Lake Wairarapa with the river/stream flows/loads provided through Source, to determine the inflows that feed into Lake Onoke.

5. Results (reporting point example)

The following section looks at the results from a number of reporting points in the upper catchment, describing how the methods applied in **Section 3** have led to the corresponding concentration changes over the BAU, Silver and Gold scenarios. The purpose is to provide an overview of how these mitigations have effected contaminants and nutrients, which can be used to guide assessments in other catchments (and reporting points). The reason this was not undertaken for more sites is due to:

- The significant number of outputs generated from the Source modelling. Eight water quality parameters at 20 reporting points over 10 different models, with four statistical outputs (mean, median etc), results in over 4,800 results. This is broken down further to include flow changes, annual average loads, *E.coli* swimmability statistics and percentage changes from the baseline concentrations.
- Descriptions of *E.coli*, DIN, SSC, DRP, NH_4-N and NO_3-N have already been undertaken in technical reports and fact sheets (**Section 2.7**).

5.1 Reporting point locations

The reporting points that will be described in this example focus on:

- Ruamāhanga River at Te Ore Ore
- Ruamāhanga River at Wardells

Between these two sites, the Masterton WWTP discharges into the Ruamāhanga River. In addition, there are three other reporting points nearby which feed into Te Ore Ore and Wardells as tributaries. These are:

- Kopuaranga River at Stuarts
- Waipoua River at Colombo Rd Bridge
- Whangaehu River at 250 m from Rua Confluence

See **Figure 5.1** for an overview of the reporting point locations.

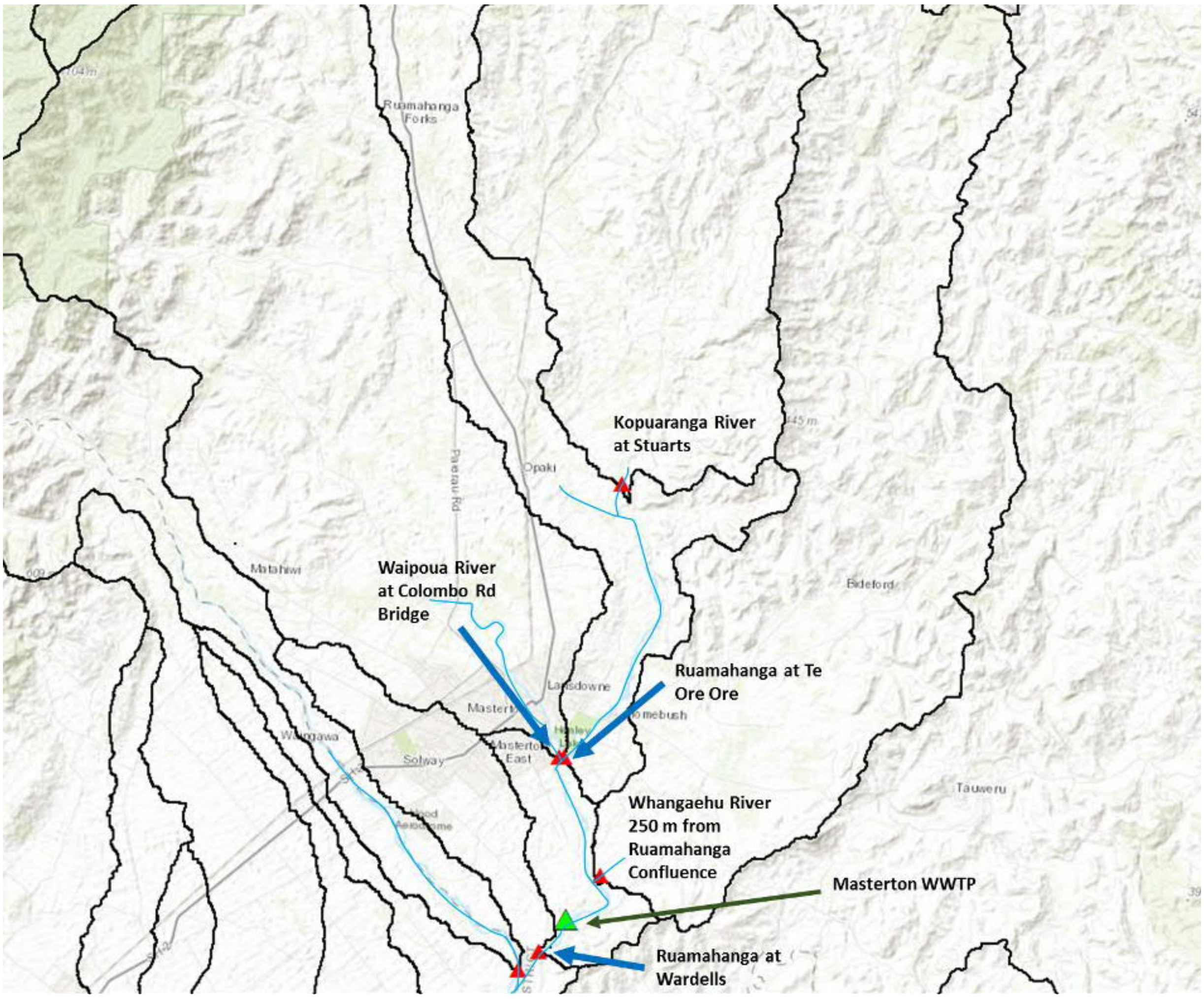

Figure 5.1 : Ruamāhanga River and the reporting points in the upper catchment

5.2 Mitigations configuration

The following section provides an overview of the effects of pole planting, retirement and on farm mitigations in the focus area presented in **Figure 5.1.** This is described in detail in **Section 3.**

Pole planting effects sediment, TP and DRP when poles are at maturity (15 years old) and has no effect on other nutrients (see **Section 3.2**). Retirement immediately effects NO_3-N, NH_4-N, TN, *E.coli*, TP and DRP (by changing to native bush functional unit), but effects sediment only when retired land is >10 years old.

Table 5.1 and **Table 5.2** outlines the total area (TA) and effective area (EA) for the five reporting points in **Section 5.1** in the BAU Scenario. The areas are cumulative. Gold and Silver areas can be found in **Appendix B** (**Table B.1** and **Table B.2**). For example, the total retired area in BAU 2080 for Waipoua River at Colombo Rd Bridge is 163 ha, while in 2040 there were 79 ha (**Table 5.1**). This means that an additional 84 ha were retired between 2040 and 2080.

For the downstream reporting points (Te Ore Ore and Wardells) which have flows and loads from multiple catchments, the TA and EA areas are inclusive of everything pole planted and retired upstream of that location. For this reason, the areas in **Table 5.1** and **Table 5.2** (and tables in **Appendix B**) for the sites upstream of Wardells cannot be added together as a sanity check of the total retired or pole planted areas for each reporting point.

Table 5.1 : Cumulative total and effective areas of retired land relative to each reporting point.

Reporting Point	BAU 2025		BAU 2040		BAU 2080	
	TA (ha)*	EA (ha)*	TA (ha)	EA (ha)	TA (ha)	EA (ha)
Kopuaranga River at Stuarts	0	0	0	0	0	0
Waipoua River at Colombo Rd Bridge	0	0	79	0	163	105
Whangaehu River at 250m from Rua Confluence	0	0	0	0	0	0
Ruamāhanga River at Te Ore Ore	0	0	52	0	61	52
Ruamāhanga River at Wardells	0	0	132	0	225	158

Table 5.2 : Cumulative total and effective areas of pole planted land relative to each reporting point

Reporting Point	BAU 2025		BAU 2040		BAU 2080	
	TA (ha)*	EA (ha)*	TA (ha)	EA (ha)	TA (ha)	EA (ha)
Kopuaranga River at Stuarts	2	0	2	2	4	2
Waipoua River at Colombo Rd Bridge	8	0	8	8	451	301
Whangaehu River at 250m from Rua Confluence	37	0	274	37	274	274
Ruamāhanga River at Te Ore Ore	2	0	2	2	231	3
Ruamāhanga River at Wardells	49	0	286	49	958	580

* TA and EA refer to 'Total Area' and 'Effective Area'. TA is the total amount of retirement or pole planting undertaken at that point in time, while EA is the effective area (10 to 15 years old).

Essentially:

- Ruamāhanga River at Te Ore Ore has 61 ha of retired land and 231 ha of pole planted land in BAU 2080. However only 52 ha of retired land is >10 years old, and 3 ha of pole planted land >15 years old.
- Ruamāhanga River at Wardells has 225 ha of retired land and 958 ha of pole planted land in BAU 2080. However only 158 ha of retired land is >10 years old, and 580 ha of pole planted land >15 years old.

Agresearch studies on farm mitigations were applied to the baseline nutrient generation rates (EMC/DWC's) as weighted average percentage reductions for dairy, dairy support, sheep and beef and arable farms. Knowing the corresponding area of each of these farm types at each reporting point will help determine the scale of effectiveness of the on farm mitigations.

Generally, the areas are fixed throughout the scenarios modelled for dairy, dairy support and arable farms, however sheep and beef areas were the primary landuse that was retired to native bush. Subsequently, the landuse areas may change between scenarios.

Table B.3 to **Table B.5** in **Appendix B** presents the area of dairy, dairy support and arable farms draining to each of the five reporting points outlined in **Section 5.1**. These landuse types are relatively unaffected by retirement, with only small changes in areas being simulated.

Table B.3 to **Table B.5** also present the changes in area of sheep and beef FU's between scenarios, due to retirement. This area change has compounding effects on nutrients, as the retired land has reduced nutrient loads equivalent to native bush.

5.3 WWTP influences

The influences of flow increases (from the WWTP) due to population changes have been described in **Section 3.5. Appendix A** describes the mitigations applied to the Masterton WWTP. The main difference between scenarios is the proportion of volume that is discharged to land, where BAU and Silver has a mixture of land and water discharges while Gold is entirely discharged to land (i.e. BAU 2025 land to water discharge ratio is 69:31 in summer and 5:95 in winter). See **Table A.3** for more details.

The proportionate volume that is treated by land has the following nutrient reductions (attenuations) applied.

- Nitrogen (and its species) – 77%
- Phosphorus (and its species) – 94%
- *E. coli* – 95%
- SSC – 100%

The highest amount of load will be removed from the WWTP in the Gold scenario, followed by Silver then BAU. Given the scenarios are modelled as a package (with numerous mitigations applied), it is difficult to discern the exact impact WWTP mitigations have on the downstream reporting point (Ruamāhanga at Wardells).

However, the influence of the WWTP mitigations can be examined through the following assumptions:

- BAU scenario considers Tier 1 mitigations only.
    - **Table 3.3** outlines the percentage reductions applied at Tier 1, which are relatively small for nitrogen and its species (0–4% for all farm types).
- Pole planting will have no effect on nitrogen and its species.
- Retirement at Wardells in BAU2040 is 132 ha, and 225 ha by 2080 (**Table 5.1**). By 2080, this is equivalent to 0.35% of the catchment area (see **Table 2.4**).

5.4 Results

5.4.1 River flow results

Flow changes between each of the reporting points can influence loads. Reduced flow with the same load would result in a higher concentration. Flow may have declined due to lower GWF assigned at each river link as an effect of simulating the maximum groundwater abstraction rates (through BAU, Silver and Gold). Alternatively, flow may increase due to greater discharge from the WWTP (population increase) and increased restrictions on abstractions due to cease take control rules being applied to all consents.

Table 5.3 presents the mean annual daily flow (MADF) at the five reporting points across the 10 scenarios. There is no change at three of the sites, as they are either upstream of the Masterton WWTP and on the fringe of the groundwater model domain, or have minimal surface and groundwater abstractions changes. A minor reduction in flow from the baseline is observed at Te Ore Ore, likely due to the effects of higher (compounded) groundwater abstractions lowering MADF by ~10 L/s. Slightly downstream, Wardells has a fluctuating MADF that is ~10 L/s less than the baseline in 2025 and 2040 (all scenarios). However, by 2080 the higher population and WWTP outflows has increased MADF to 26.3 m^3/s (equivalent to the baseline model).

The effects of flows on water quality at these sites could be considered minimal compared to the mitigations applied (on farm and pole planting/retirement), however flow changes may be greater than simulated for reasons discussed in **Section 4.8.**

Table 5.3 : Mean Annual Daily Flow (MADF) (m^3/s) at five upstream reporting points throughout the scenarios

Reporting Point	Baseline	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Kopuaranga River at Stuarts	4.73 – No change between scenarios									
Waipoua River at Colombo Rd Bridge	8.71 – No change between scenarios									
Whangaehu River at 250m from Rua Confluence	2.55 – No change between scenarios									
Ruamāhanga River at Te Ore Ore	13.44	13.43 – Minor decrease from baseline								
Ruamāhanga River at Wardells	26.30	26.29		26.30	26.29		26.3	26.29		26.3

5.4.2 Nutrient effects

As discussed in **Section 5.3,** given the relatively small mitigations to nitrogen and its species in the BAU model, and the small amount of retired land, it could be assumed that NO_3-N, NH_4-N and TN reductions between Te Ore Ore and Wardells are largely due to the WWTP land attenuation.

Table C.4, Table C.5 and Table C.7 present the percentage change between scenarios for these species.

- Ammoniacal-N (NH_4-N) median concentrations decrease 0% at Te Ore Ore (upstream of the WWTP), however at Wardells, the NH_4-N decreases are between 25.2% to 36.8% from 2025–2080 in the BAU scenario.
- Total nitrogen (TN) median concentrations decrease 0.1% at Te Ore Ore (upstream of the WWTP), however at Wardells, the TN decreases are between 4.1 to 11.7% from 2025–2080 in the BAU scenario.
- Nitrate-N (NO_3-N) median concentrations decrease 10.2% at Te Ore Ore (upstream of the WWTP), however at Wardells, the NO_3-N decreases are between 37% to 37.5% from 2025–2080 in the BAU scenario.
- Dissolved Reactive Phosphorus (DRP) median concentrations decrease 1.1% at Te Ore Ore (upstream of the WWTP), however at Wardells, the DRP decreases are between 22.6% to 57.4% from 2025–2080 in the BAU scenario.

These additional decreases in concentration between Te Ore Ore and Wardells can be attributed to reduced load from land treatment of Masterton WWTP, reductions in load from the Whangaehu catchment due to Tier 1 mitigations and BAU NO_3-N GWF inputs (external input driven by MODFLOW MT3D modelling).

Phosphorus (TP and DRP) decreases can also be attributed to pole planting and retirement, which depending on the area of land, can lead to significant reductions in concentrations. In addition, Tier 1 mitigations (see **Table 3.3**) apply 17% reductions in TP/DRP to dairy farms, but only 2% to sheep and beef. Hence, the proportional landuse relative to each reporting point will have an impact on phosphorus loads (see **Table B.3**).

In BAU 2080, there are 580 ha of effective mature pole planted land within the Wardells catchment, while Te Ore Ore only has 3 ha of pole planting. Similarly, there is 225 ha of retired land at Wardells, while only 61 ha is retired upstream of Te Ore Ore (**Table 5.1**).

Finally, WWTP land treatment reduce TP/DRP by 94%. The median concentrations (see **Table C.8** and **Table C.2**) show DRP/TP at Te Ore Ore in BAU 2025 has decreased by 0.5–0.6%. However, slightly downstream at Wardells the decrease is 22.6% (DRP) and 12.3% (TP). As pole planting and retirement is not effective in 2025, this indicates that ~0.6% of the concentration decrease is due to Tier 1 mitigations, and the remainder between Te Ore Ore and Wardells is due to the WWTP land treatment. DRP concentrations at Wardells in BAU 2080 have reduced by ~57.4%, while at Te Ore Ore, median reductions are only 1.1%. This clearly indicates the WWTP has the most significant effect on TP and DRP concentration decreases in the BAU scenario between these two reporting points.

A3 Fact sheets (see **Section 2.7**) for NO_3-N and DRP have been included in **Appendix B** for Te Ore Ore and Wardells.

5.4.3 *E.coli* effects

Stock exclusion and dairy effluent management (Tier 1) effectively lower *E. coli* DWC's by 69% and 44% for dairy and 'sheep and beef', respectively. For all other functional units, *E.coli* loads remain the same as baseline.

E.coli median concentrations decrease between 4.2 and 4.9% at Te Ore Ore in the BAU scenarios (see **Table C.3)**. The 95^{th} percentiles have a decrease of only 0.2–0.3%. The reason for the greater decrease in the 50^{th} percentile results is that the mitigation applied to the DWC's effectively occurs at regular baseflows in the water quality model. The 95^{th} percentiles are primarily driven by EMC's, which are unmitigated in the BAU scenario.

In regards to the downstream reporting point Wardells, a further reduction in the 50^{th} and 95^{th} concentrations are observed in BAU (~6% and 0.8%). This could be attributed to reduced load from the Whangaehu catchment, and also land treatment of the WWTP. The greater reduction in the 95^{th} concentrations is likely due to the WWTP land treatment, as it would be expected the similar influences on the 95^{th} concentrations (due to Tier 1 mitigations) observed at Te Ore Ore would occur at Wardells.

5.4.4 Sediment effects

Sediment reductions are primarily driven by pole planting, land retirement and WWTP attenuations. In addition, there is a significant reduction in net bank erosion (80%) through all BAU, Gold and Silver scenarios due to stock exclusion. This resulted in BAU median (50^{th}) SSC concentrations at Wardells decreasing with a predicted 9.7% decrease in 2025 and a 13.5% decrease in 2080 (see **Table C.6**).

Given pole planting and retirement is not effective in 2025, the 9.7% decrease is attributed to stock exclusion, resulting in bank stabilisation. The additional 3.8% decrease in median suspended sediment concentrations by 2080 is from retirement and pole planted land reaching maturity.

580 ha and 102 ha of pole planted and retired land are effective by BAU 2080 (**Table 5.1** and **Table 5.2**). This is equivalent to 0.9% and 0.2% of the total catchment draining to Wardells (see **Table 1.1** for reporting point catchment areas).

6. Discussion

Following the development of the baseline SOURCE model, simulations were undertaken for nine scenarios, each incorporating a range of landuse changes and on farm mitigations around the Ruamahanga Catchment.

The results show a significant reduction in concentrations of many water quality parameters at the 20 river reporting points. The outputs from the SOURCE modelling were used by the University of Waikato to simulate changes in Lake Wairarapa and Onoke.

While DRP median concentrations reduced >40% in streams and rivers through some scenarios (Silver and Gold), the lakes modelling showed this was insufficient to move Lake Wairarapa out of its current ‘D’ band (below the national bottom line) for phosphorus, related strongly to the legacy nutrient effects and shallow nature of this lake. This is documented in the memorandum “Lakes Wairarapa and Onoke scenarios in comparison to baseline” (Allen 2017). The Ruamahanga Whaitua Committee will need to consider the changes in water quality at all of the river reporting points and also the Lakes, to understand if these mitigation packages are effective in improving water quality in the entire system (to meet Objectives).

The scenarios provide a guide on the potential changes in water quality under different implementation timelines, landuse change options and various scales of mitigations. BAU is the least intensive restoration approach, and in some cases may not provide sufficient changes of water quality concentrations to meet the Ruamahanga Whaitua Objectives. However, Table C.1 to **Table C.8** show that significant changes in concentrations of most water quality parameters occur at many sites downstream of WWTP’s in the BAU scenarios. This is particularly evident with NH_4-N, DRP and *E.coli*. *E.coli* concentrations also decrease substantially in BAU, primarily due to the incorporation of stock exclusion from water ways and dairy effluent management. *E.coli* results are described in detail in the Jacobs 2017 Human Health summary report.

The Silver and Gold scenarios simulate similar mitigations packages, however over different timeframes. The mitigations incorporate further on farm management practices such as fertilizer management, constructed wetlands and riparian planting (see **Section 3.7.2**). Gold has most of the mitigations in place between 2025 and 2040, while Silver stages the implementation over a longer timeframe (finishing in 2080). These scenarios also significantly increase the pole planting and retirement within the catchment. Upstream of Ruamahanga at Pukio, Silver and Gold are simulating 10,812 ha of retirement and 27,679 ha of pole planting by 2080 (**Table B.1** and **Table B.2**). This is equivalent to 3% and 7.8% of the total Ruamahanga Catchment.

This additional pole planting and retirement (over the BAU scenario) are effective in further reducing nutrient loads from the catchment, however to meet this criteria, ~440 ha/year would need to be planted, and 172 ha/year retired (between 2017 and 2080). Consideration of the nutrients effects simulated in Gold and Silver of this large landuse change leading to the establishment of mature trees (and native scrub forests) needs to take into account that scenario modelling did not incorporate flow changes. Flow changes may occur in catchments where runoff is reduced through interception and transpiration, and could be further exacerbated by climate change.

The outputs from the scenarios have been further described in a number of smaller technical summaries and fact sheets, which describe the changes observed at each reporting point and reasons for these changes (see **Section 2.7**).

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Appendix A. Wastewater Treatment Plant Assessments

A.1 Introduction

This section summarises the methodology that Jacobs used to develop contaminant loading rates at the following wastewater treatment plants (WWTPs) in the Ruamāhanga Whaitua:

- Carterton WWTP – owned and operated by the Carterton District Council (CDC);
- Featherston WWTP – owned and operated by the South Wairarapa District Council (SWDC);
- Greytown WWTP – owned and operated by the South Wairarapa District Council (SWDC);
- Martinborough – owned and operated by the South Wairarapa District Council (SWDC); and
- Masterton – owned and operated by the Masterton District Council (MDC).

Subsequently, the contaminant loading rates for each WWTP were fed into the Ruamāhanga Source Model.

A.2 Background

MDC and SWDC hold resource consents which authorise the discharge of wastewater to land and water from the Masterton, Greytown and Martinborough WWTPs, respectively. In addition, CDC and SWDC are in the process of applying for resource consents for the Carterton and Featherston WWTPs. These resource consents currently/will authorise the discharge of wastewater to land and water, which is consistent with existing practices. However, over time as upgrades are undertaken at each of the five WWTPs, it is expected that the volume of wastewater discharged to land will increase. This will result in a greater proportion of wastewater being subject to treatment within the underlying soils, thus resulting in improved environmental outcomes. The changes in environmental outcomes as a result of changes in the discharge regimes at each of the five WWTPs were assessed via different model scenarios.

A.3 Model Scenarios

A total of ten different models are being run over four different time periods. They are as follows:

- Baseline model (i.e., existing management practices between 1992 and 2014 at each WWTP);
- Business as usual (BAU) scenario for 2025, 2040 and 2080;
- Gold scenario for 2025, 2040 and 2080; and
- Silver scenario for 2025, 2040 and 2080.

The baseline model and nine model scenarios provide an assessment of existing and potential management options at each WWTP and in the wider Ruamāhanga Whaitua on economic, environmental, social and cultural values. It is noted that these management options, which are based on existing operations at each WWTP and potential changes to the discharge regime to improve environmental outcomes, were developed by the Ruamāhanga Whaitua Committee to provide the most amount of information possible using a limited number of scenarios. The baseline model and nine model scenarios are discussed below in further detail.

A.3.1 Baseline

The baseline model for each of the five WWTPs was built based upon existing operational practices (i.e., discharge data and, if applicable, consented land discharge areas between 1992 and 2014).

A.3.2 Business as usual

The BAU scenarios assume that existing policy, practices and investment will continue into the future at all five WWTPs. In relation to the Carterton and Featherston WWTPs, we have assumed that the currently lodged consent applications have been granted, and thus have applied the degree of treatment gained by these upgrades. In the BAU scenarios varying amounts of wastewater is discharged to land across the five WWTPs (**Table A.1**).

A.3.3 Gold

The Gold scenarios represent the greatest and most aspirational efforts with regard to making water quality improvements in the Ruamāhanga Whaitua, primarily in terms of timing (i.e. quicker adoptions of mitigations). In the Gold scenarios, all wastewater from the five WWTPs is discharged to land from 2025 to 2080 (**Table A.1**).

A.3.4 Silver

The Silver scenarios represent a moderate effort with regard to making water quality improvements in the Ruamāhanga Whaitua (as while the same mitigations as Gold are applied, it is over a longer timeframe). In this scenario, all wastewater from the five WWTPs is discharged to land with the exception of the 2025 model run (**Table A.1**).

Table A.1 : Discharge regimes at the five WWTPs as developed by the Ruamāhanga Whaitua Committee.

Scenario	Discharge to Land (%)	Discharge to Water (%)
Carterton		
Scenario 1 – BAU 2025	35	65
Scenario 2 – BAU 2040	35	65
Scenario 3 – BAU 2080	60	40
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	60	40
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Featherston		
Scenario 1 – BAU 2025	0	100
Scenario 2 – BAU 2040	0	100
Scenario 3 – BAU 2080	0	100
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	60	40
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Greytown		
Scenario 1 – BAU 2025	20	80
Scenario 2 – BAU 2040	100	0
Scenario 3 – BAU 2080	100	0
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	60	40

Scenario	Discharge to Land (%)	Discharge to Water (%)
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Martinborough		
Scenario 1 – BAU 2025	24	76
Scenario 2 – BAU 2040	100	0
Scenario 3 – BAU 2080	100	0
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	60	40
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Masterton		
Scenario 1 – BAU 2025	60 (summer) and 5 (winter)	40 (summer) and 95 (winter)
Scenario 2 – BAU 2040	100 (summer) and 80 (winter)	0 (summer) and 20 (winter)
Scenario 3 – BAU 2080	100 (summer) and 97 (winter)	0 (summer) and 3 (winter)
Scenario 4 – Gold 2025	100 (year round)	0 (year round)
Scenario 5 – Gold 2040	100 (year round)	0 (year round)
Scenario 6 – Gold 2080	100 (year round)	0 (year round)
Scenario 7 – Silver 2025	60 (year round)	40 (year round)
Scenario 8 – Silver 2040	100 (year round)	0 (year round)
Scenario 9 – Silver 2080	100 (year round)	0 (year round)

A.3.5 Assumptions

It is noted that in order to simplify the model, the nine model scenarios assume that there will be no upgrades to the five WWTPs (beyond those proposed in the currently lodged consent applications for the Carterton and Featherston WWTPs) which will result in a change in the quality of wastewater being discharged to land or water.

A.4 Model Inputs

A.4.1 Discharge regimes

Discharge regimes for the five WWTPs in the baseline model were based on each WWTPs consented discharge regime between 1992 and 2014. Discharge regimes for the five WWTPs in each of the nine model scenarios, as developed by the Ruamāhanga Whaitua Committee, are outlined in **Table A.1**.

However, it is noted that the discharge regimes outlined in **Table A.1** do not account for existing and/or proposed consent conditions which limit the discharge of wastewater to surface water at each of the five WWTPs based upon flow restrictions. As such, we developed flow separation rules which are consistent with the existing and/or proposed consent conditions so the nine model scenarios were representative of existing and/or proposed flow restrictions. The flow separation rules are outlined in **Table A.2**. In certain instances the flow separation rules meant that the discharge regimes developed by the Ruamāhanga Whaitua Committee and outlined in **Table A.1** could not be achieved because flow restrictions meant the discharge of wastewater to surface water was not allowed. Therefore, the updated discharge regimes as developed using the flow separation rules and used with the Ruamāhanga Source Model are outlined in **Table A.3**.

Table A.2 : Flow separation rules at each of the five WWTPs.

WWTP	Flow Separation Rules
Carterton	• No discharge to water between 1st of January and 30th of April; and • No discharge to water unless flow is greater than three times the median.
Featherston	• No discharge to water unless flow is greater than three times the median.
Greytown	• No discharge to water unless flow is greater than three times the median.
Martinborough	• No discharge to water unless flow is greater than three times the median.
Masterton	• No discharge to water between 1st of November and 30th of April unless flow is greater than 15.6 m^3/s; • No discharge to water between 1st of May and 31st of October unless flow is greater than 7.5 m^3/s; and • It should be noted that flow is scaled up due to inaccuracies in the flow modelling meaning simulated flow was higher than observed. The flow scaling approach was undertaken for surface abstraction, and this has been applied to the WWTP discharge criteria.

Table A.3 : Discharge regimes for the nine model scenarios at the five WWTPs using the flow separation rules.

Scenario	Discharge to Land (%)[1]	Discharge to Water (%)[1]
Carterton		
Scenario 1 – BAU 2025	***85***	***15***
Scenario 2 – BAU 2040	***85***	***15***
Scenario 3 – BAU 2080	***85***	***15***
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	***85***	***15***
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Featherston		
Scenario 1 – BAU 2025	0	100
Scenario 2 – BAU 2040	0	100
Scenario 3 – BAU 2080	0	100
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	***75***	***25***
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Greytown		

Scenario	Discharge to Land (%)[1]	Discharge to Water (%)[1]
Scenario 1 – BAU 2025	20	80
Scenario 2 – BAU 2040	100	0
Scenario 3 – BAU 2080	100	0
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	60	40
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Martinborough		
Scenario 1 – BAU 2025	24	76
Scenario 2 – BAU 2040	100	0
Scenario 3 – BAU 2080	100	0
Scenario 4 – Gold 2025	100	0
Scenario 5 – Gold 2040	100	0
Scenario 6 – Gold 2080	100	0
Scenario 7 – Silver 2025	60	40
Scenario 8 – Silver 2040	100	0
Scenario 9 – Silver 2080	100	0
Masterton		
Scenario 1 – BAU 2025	***69 (summer)*** and 5 (winter)	***31 (summer)*** and 95 (winter)
Scenario 2 – BAU 2040	100 (summer) and 80 (winter)	0 (summer) and 20 (winter)
Scenario 3 – BAU 2080	100 (summer) and 97 (winter)	0 (summer) and 3 (winter)
Scenario 4 – Gold 2025	100 (year round)	0 (year round)
Scenario 5 – Gold 2040	100 (year round)	0 (year round)
Scenario 6 – Gold 2080	100 (year round)	0 (year round)
Scenario 7 – Silver 2025	60 (year round)	40 (year round)
Scenario 8 – Silver 2040	100 (year round)	0 (year round)
Scenario 9 – Silver 2080	100 (year round)	0 (year round)

[1] ***Bold and italicised*** values indicates model scenarios with updated discharge regimes using the flow separation rules.

Carterton WWTP had the most significant change from **Table A.1**, where the 35:65 discharge ratio (land:water) was unable to be achieved. After assessing the receiving stream/rivers flow to ensure discharge to water could not occur over a third of the year (summer) and only when river flows exceeded 3x the median, the final discharge criteria of 85:15 (land:water) was established. Subsequently, the discharge criteria rules in **Table A.1**, particularly the 3x median rule, were too restrictive to allow regular discharges to water. This results in the scenarios modelled through BAU having a greater reduction in loads due to additional land treatment for the Carterton WWTP, reducing concentrations downstream greater than anticipated with the 35:65 discharge regime.

A.4.2 Daily discharge volumes

Daily discharge volumes for the five WWTPs in the baseline model were calculated using discharge data from each WWTP between 1992 and 2014. Daily discharge volumes for the BAU, Gold and Silver model scenarios for each time period were calculated using population loading rates (i.e., number of people divided by daily discharge volumes as calculated in the baseline model) and population growth projections for each town/district (see **Section A.4.5**).

A.4.3 Contaminant loading rates & attenuation factors

Contaminant loading rates for the five WWTPs were sourced from the relevant resource consent application documents which are outlined in **Table A.4**.

For the purposes of the modelling exercise, the attenuation factor was simply the percentage of treatment of an individual contaminant gained by discharging the wastewater to land. For example, if wastewater with a nitrogen concentration of 100 mg/L is applied to land, and the drainage from the base of the soil profile is estimated to be 10 mg/L, then this is a 90% attenuation factor. This attenuation factor includes treatment gained by cut and carry operations, and other soil profile losses.

The attenuation factor derived as part of this process was then applied to the portion of wastewater discharged to land under each of the scenarios. The attenuation factors that were used to calculate contaminant loading rates are described in **Table A.4**.

Table A.4 : Contaminant loading rates and attenuation factors used for each of the five WWTPs.

Contaminant	Attenuation factor (%)	Assumptions	Source
		Carterton	
Nitrogen	73	140 kg/N/Ha/yr is applied to land and 38 kg/N/Ha/yr is lost to water as per Overseer modelling.	EQO (2016)
Phosphorus	98	35 kg/P/Ha/yr is applied to land and 0.8 kg/P/Ha/yr is lost to water as per Overseer modelling.	EQO (2016)
E. coli	95	*E. coli* attenuation rates will be similar to those likely to be observed at the Masterton WWTP (i.e., 95% of *E. coli* will die off within the soil).	Green (2007)
Total suspended solids	100	All TSS applied to land will be attenuated before reaching the water table.	NA
		Featherston	
Nitrogen	88	Average of 237 kgN/Ha/yr is applied to land and 38.8 kg/N/Ha/yr is lost to water as per Overseer modelling. It is noted that this is representative of the discharge regime upon completion of Stage 2B of the upgrades at the Featherston WWTP.	LEI (2017)
Phosphorus	100	All phosphorus is removed from site via plant uptake.	LEI (2017)
E. coli	95	Assumed *E. coli* attenuation rates will be the similar to those likely to be observed at the Masterton WWTP.	Green (2007)
Total suspended solids	100	All TSS applied to land will be attenuated before reaching the water table.	NA
		Greytown	
Nitrogen	77	Concentration of nitrogen discharged from the Masterton WWTP is 11.5 mg/L and modelled drainage is 2.7 mg/L.	Green (2007)
Phosphorus	94	Concentration of phosphorus discharged from the Masterton WWTP is 3.2 mg/L and modelled drainage is 0.2 mg/L.	Green (2007)
E. coli	95	95% of *E. coli* will die off within the soil.	Green (2007)

Contaminant	Attenuation factor (%)	Assumptions	Source
Total suspended solids	100	All TSS applied to land will be attenuated before reaching the water table.	NA
Martinborough			
Nitrogen	77	Concentration of nitrogen discharged from the Masterton WWTP is 11.5 mg/L and modelled drainage is 2.7 mg/L.	Green (2007)
Phosphorus	94	Concentration of phosphorus discharged from the Masterton WWTP is 3.2 mg/L and modelled drainage is 0.2 mg/L.	Green (2007)
E. coli	95	95% of *E. coli* will die off within the soil.	Green (2007)
Total suspended solids	100	All TSS applied to land will be attenuated before reaching the water table.	NA
Masterton			
Nitrogen	77	Concentration of nitrogen discharged from the Masterton WWTP is 11.5 mg/L and modelled drainage is 2.7 mg/L.	Green (2007)
Phosphorus	94	Concentration of phosphorus discharged from the Masterton WWTP is 3.2 mg/L and modelled drainage is 0.2 mg/L.	Green (2007)
E. coli	95	95% of *E. coli* will die off within the soil.	Green (2007)
Total suspended solids	100	All TSS applied to land will be attenuated before reaching the water table.	NA

A.4.4 Discharge to land area

With regard to discharging wastewater to land, we applied the following assumptions.

Baseline

There is no discharge to land in the baseline model at the Carterton, Featherston, Greytown and Martinborough WWTPs. With regard to the Masterton WWTP, the land discharge area for the baseline model is 75 ha which is consistent with the historic discharge regime.

BAU, Gold and Silver 2025 scenarios

At the Carterton WWTP the land discharge area is 50 ha which is consistent with the existing consents. At the Featherston WWTP there is no discharge to land in the BAU scenario. Conversely, in the Gold and Silver scenarios the land discharge area is 70 ha which is consistent with currently lodged consent application. At the Greytown WWTP the land discharge area for the BAU, Gold and Silver scenarios is 16 ha as it is assumed that Stage 1B of the WWTP upgrade will have been completed. At the Martinborough WWTP the land discharge area for the BAU, Gold and Silver scenarios is 5.3 ha as it is assumed that Stage 1B of the WWTP upgrade will have been completed. At the Masterton WWTP the land discharge area for the BAU, Gold and Silver scenarios is 97 ha which is consistent with the existing consent.

Business as usual, Gold and Silver 2040 and 2080 scenarios

Using the daily discharge volumes and land discharge areas described in **Section A.4.2**, respectively, the discharge rate per Ha was calculated. The land discharge area for the BAU, Gold and Silver 2040 and 2080 scenarios at all five WWTPs was calculated by proportionally increasing the land area by the discharge volume increase.

A.4.5 Population growth statistics

Carterton

Population growth projections for Carterton for 2025 and 2040 time periods were estimated using medium population growth projections produced by Statistics New Zealand for the Carterton District on a five-yearly basis through to 2043. This data was then extrapolated using the annual average percentage change to estimate the population of Carterton in 2080.

Population growth projections were then down-scaled to reflect the percentage of the population of the Carterton District that is serviced by the WWTP, which is currently 55.2% and is assumed to remain constant through to 2080.

Featherston, Greytown & Martinborough

Population growth projections for Featherston, Greytown and Martinborough for 2025 and 2040 time periods were estimated using medium population growth projections produced by Statistics New Zealand for the South Wairarapa District on a five-yearly basis through to 2043. This data was then extrapolated using the annual average percentage change to estimate the population of each township in 2080.

Population growth projections will then be down-scaled to reflect the percentage of the population of each township that is serviced by each WWTP, which is assumed to be all residents.

Masterton

Population growth projections for Masterton for the 2025 and 2040 time periods were estimated using medium population growth projections produced by Statistics New Zealand for the Masterton District on a five-yearly basis through to 2043. This data was then extrapolated using the annual average percentage change to estimate the population of Masterton in 2080.

Population growth projections were then down-scaled to reflect the percentage of the population of the Masterton District that is serviced by the Masterton WWTP, which is currently 78.5% and is assumed to remain constant through to 2080.

A.5 Model Outputs

The inputs described in **Section A.4** were used to calculate contaminant loading rates for each WWTP for all of the model scenarios. These contaminant loading rates were then fed directly into the Source model as corrected timeseries of slightly increased flow (due to population increase) and reduced (or attenuated) nutrient loads due to the land treatment applications.

A.6 Council Verification

Prior to incorporating the five WWTP contaminant loads into the Source model, we sought agreement from CDC, MDC and SWDC that they were happy with our proposed methodology. MDC and SWDC were happy with our proposed methodology and after some minor adjustment CDC was also happy with our proposed methodology.

A.7 Summary

Jacobs developed contaminant loading rates for 10 different model scenarios at five WWTPs to assess the impact of different management options on water quality in the Ruamāhanga Whaitua. The contaminant loading rates were calculated using the inputs described in **Section A.4**, and subsequently fed directly into the Ruamāhanga Whaitua Source model.

A.8 References

EQO, 2017. Irrigation and land use – background & effects of discharge to land.

Green, S., 2007. Modelling the environmental effects of wastewater disposal at the Masterton land-based sewage effluent disposal scheme, Report prepared for Beca Carter Hollings & Ferner, HortResearch Client Report No. 21183.

LEI, 2017. Assessment of Environmental Effects of Discharge of Featherston Treated Wastewater to Land, Report prepared for South Wairarapa District Council.

Appendix B. Figures and Tables

Table B.1 : Retired land total and effective areas (hectares) at each reporting point, in each scenario. The values are cumulative, where lowland sites such as Pukio include all the areas upstream of this site.

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)	EA (ha)
Huangarua River at Ponatahi Bridge	107	0	107	107	107	107	2285	0	3240	2285	3240	3240	3240	0	3240	3240	3240	3240
Kopuaranga River at Stuarts	0	0	0	0	0	0	353	0	1068	353	1068	1068	1068	0	1068	1068	1068	1068
Mangatarere River at SH2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ruamāhanga River at Pukio	107	0	245	107	347	271	5376	0	10812	5376	10812	10812	10812	0	10812	10812	10812	10812
Ruamāhanga River at Te Ore Ore	0	0	52	0	61	52	452	0	1244	451	1244	1244	1244	0	1244	1244	1244	1244
Taueru River at Gladstone	0	0	0	0	0	0	1213	0	3310	1213	3310	3310	3310	0	3310	3310	3310	3310
Tauherenikau River at Websters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waingawa River at South Rd	0	0	7	0	7	7	0	0	5	0	5	5	5	0	5	5	5	5
Waiohine River at Bicknells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waipoua River at Colombo Rd Bridge	0	0	79	0	163	105	314	0	454	314	454	454	454	0	454	454	454	454
Parkvale Stream at weir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ruamāhanga River at Wardells	0	0	132	0	225	158	1241	0	3008	1241	3008	3008	3008	0	3008	3008	3008	3008
Ruamāhanga River at Gladstone Bridge	0	0	138	0	231	164	2468	0	6340	2468	6340	6340	6340	0	6340	6340	6340	6340
Ruamāhanga River at Waihenga	107	0	245	107	347	271	5272	0	10637	5272	10637	10637	10637	0	10637	10637	10637	10637
Whangaehu River at 250m from Ruamāhanga Confluence	0	0	0	0	0	0	452	0	1286	452	1286	1286	1286	0	1286	1286	1286	1286
Otukura Stream at Mouth	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	1	1	1
Makahakaha Stream at Mouth	0	0	0	0	0	0	218	0	341	218	341	341	341	0	341	341	341	341
Ruamāhanga River at U/S Lake Wai Outlet	107	0	245	107	347	271	5634	0	11092	5634	11092	11092	11092	0	11092	11092	11092	11092
Tauanui River at Mouth	0	0	0	0	0	0	5	0	8	5	8	8	8	0	8	8	8	8
Turanganui River at Mouth	2	0	67	67	152	67	123	0	131	123	131	131	131	0	131	131	131	131

Table B.2 : Pole planted land total and effective areas (hectares) at each reporting point, in each scenario. The values are cumulative, where lowland sites such as Pukio include all the areas upstream of this site.

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	TA (ha)*	EA (ha)*	TA (ha)	EA (ha)	TA (ha)	EA (ha)	TA (ha)*	EA (ha)*	TA (ha)*	EA (ha)*	TA (ha)*	EA (ha)*	TA (ha)*	EA (ha)*	TA (ha)*	EA (ha)*	TA (ha)*	EA (ha)*
Huangarua River at Ponatahi Bridge	204	0	1243	204	1669	1669	1697	0	3956	1697	3956	3956	1702	0	3956	1702	3956	3956
Kopuaranga River at Stuarts	2	0	2	2	4	2	526	0	899	526	899	899	526	0	899	526	899	899
Mangatarere River at SH2	0	0	0	0	1234	784	1467	0	1527	1467	1527	1527	1467	0	1527	1467	1527	1527
Ruamāhanga River at Pukio	926	0	2927	926	6920	5761	8993	0	27679	8993	27679	27679	8998	0	27679	8998	27679	27679
Ruamāhanga River at Te Ore Ore	2	0	2	2	231	3	1016	0	2424	1016	2424	2424	1016	0	2424	1016	2424	2424
Taueru River at Gladstone	658	0	1351	658	2242	2242	1415	0	8203	1415	8203	8203	1415	0	8203	1415	8203	8203
Tauherenikau River at Websters	0	0	0	0	247	34	473	0	530	473	530	530	473	0	530	473	530	530
Waingawa River at South Rd	0	0	0	0	611	324	1530	0	2489	1530	2489	2489	1530	0	2489	1530	2489	2489
Waiohine River at Bicknells	2	0	2	2	1333	873	1600	0	2629	1600	2629	2629	1600	0	2629	1600	2629	2629
Waipoua River at Colombo Rd Bridge	8	0	8	8	451	301	914	0	1548	914	1548	1548	914	0	1548	914	1548	1548
Parkvale Stream at weir	1	0	1	1	33	1	41	0	1284	41	1284	1284	41	0	1284	41	1284	1284
Ruamāhanga River at Wardells	49	0	287	49	959	581	2445	0	5917	2445	5917	5917	2445	0	5917	2445	5917	5917
Ruamāhanga River at Gladstone Bridge	707	0	1638	707	3813	3147	5390	0	16758	5390	16758	16758	5390	0	16758	5390	16758	16758
Ruamāhanga River at Waihenga	926	0	2927	926	6920	5761	8790	0	26501	8790	26501	26501	8794	0	26501	8794	26501	26501
Whangaehu River at 250m from Rua Confluence	37	0	274	37	274	274	513	0	1751	513	1751	1751	513	0	1751	513	1751	1751
Otukura Stream at Mouth	0	0	0	0	0	0	1	0	12	1	12	12	1	0	12	1	12	12
Makahakaha Stream at Mouth	3	0	3	3	3	3	3	0	3	3	3	3	3	0	3	3	3	3
Ruamāhanga River at U/S Lake Wai Outlet	926	0	2927	926	6920	5761	8994	0	28734	8994	28734	28734	8998	0	28734	8998	28734	28734
Tauanui River at Mouth	0	0	0	0	0	0	9	0	279	9	279	279	9	0	279	9	279	279
Turanganui River at Mouth	70	0	71	70	99	99	739	0	831	739	831	831	739	0	831	739	831	831

Table B.3 : Landuse area in the baseline model relative to each reporting point. Units are hectares and percentage of total upstream catchment area (bracketed values).

Reporting Point	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other**	Total***
Huangarua River at Ponatahi Bridge	-	46 (0.2)	-	25581 (84.6)	693 (2.3)	3918 (13.0)	30239
Kopuaranga River at Stuarts	808 (4.8)	281 (1.7)	-	14103 (84.5)	154 (0.9)	1339 (8.0)	16686
Mangatarere River at SH2	2842 (23.8)	357 (3.0)	40 (0.3)	2515 (21.0)	4190 (35.1)	2003 (16.8)	11947
Ruamāhanga River at Pukio	14438 (5.9)	5867 (2.4)	1556 (0.6)	132684 (53.9)	45104 (18.3)	46717 (19.0)	246366
Ruamāhanga River at Te Ore Ore	1115 (3.6)	549 (1.8)	3 (0.0)	17950 (57.8)	7487 (24.1)	3974 (12.8)	31078
Taueru River at Gladstone	298 (0.6)	246 (0.5)	587 (1.2)	39655 (80.5)	242 (0.5)	8217 (16.7)	49244
Tauherenikau River at Websters	267 (1.8)	419 (2.9)	-	944 (6.5)	11255 (77.7)	1596 (11.0)	14481
Waingawa River at South Rd	215 (1.4)	127 (0.9)	-	2389 (16.0)	9856 (65.8)	2382 (15.9)	14969
Waiohine River at Bicknells	6070 (15.4)	1036 (2.6)	227 (0.6)	3595 (9.1)	23641 (60.1)	4750 (12.1)	39320
Waipoua River at Colombo Rd Bridge	173 (1.0)	670 (3.8)	113 (0.6)	9862 (56.5)	2802 (16.1)	3832 (22.0)	17452
Parkvale Stream at weir	1246 (24.9)	553 (11.0)	-	980 (19.6)	42 (0.8)	2185 (43.6)	5006
Ruamāhanga River at Wardells	2322 (3.6)	1518 (2.4)	161 (0.3)	38490 (59.9)	10298 (16.0)	11495 (17.9)	64284
Ruamāhanga River at Gladstone Bridge	3564 (2.7)	2095 (1.6)	791 (0.6)	81249 (60.8)	20401 (15.3)	25593 (19.1)	133694
Ruamāhanga River at Waihenga	13451 (5.7)	5413 (2.3)	1487 (0.6)	128058 (54.2)	44818 (19.0)	42862 (18.2)	236089
Whangaehu River at 250m from Ruamāhanga Confluence	915 (6.3)	299 (2.1)	45 (0.3)	10335 (70.9)	5 (0.0)	2979 (20.4)	14578
Otukura Stream at Mouth	2790 (29.8)	2454 (26.2)	-	1611 (17.2)	83 (0.9)	2428 (25.9)	9366
Makahakaha Stream at Mouth	129 (2.1)	389 (6.3)	38 (0.6)	5155 (83.3)	4 (0.1)	477 (7.7)	6192
Ruamāhanga River at U/S Lake Wai Outlet	16146 (6.3)	6139 (2.4)	1556 (0.6)	136133 (53.5)	47016 (18.5)	47506 (18.7)	254496
Tauanui River at Mouth	-	-	-	617 (14.9)	2535 (61.0)	1003 (24.1)	4155
Turanganui River at Mouth	260 (3.9)	38 (0.6)	-	1810 (26.8)	3491 (51.8)	1141 (16.9)	6740

Table B.4 : Landuse area in the BAU 2080 model relative to each reporting point. Units are hectares and percentage of total upstream catchment area (bracketed values).

Reporting Point	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other**	Total***
Huangarua River at Ponatahi Bridge	-	46 (0.2)	-	25475 (84.2)	799 (2.6)	3918 (13.0)	30239
Kopuaranga River at Stuarts	808 (4.8)	281 (1.7)	-	14103 (84.5)	154 (0.9)	1339 (8.0)	16686
Mangatarere River at SH2	2842 (23.8)	357 (3.0)	40 (0.3)	2515 (21.0)	4190 (35.1)	2003 (16.8)	11947
Ruamāhanga River at Pukio	14438 (5.9)	5858 (2.4)	1556 (0.6)	132347 (53.7)	45451 (18.4)	46717 (19.0)	246366
Ruamāhanga River at Te Ore Ore	1115 (3.6)	549 (1.8)	3 (0.0)	17888 (57.6)	7549 (24.3)	3974 (12.8)	31078
Taueru River at Gladstone	298 (0.6)	246 (0.5)	587 (1.2)	39655 (80.5)	242 (0.5)	8217 (16.7)	49244
Tauherenikau River at Websters	267 (1.8)	419 (2.9)	-	944 (6.5)	11255 (77.7)	1596 (11.0)	14481
Waingawa River at South Rd	215 (1.4)	127 (0.9)	-	2382 (15.9)	9863 (65.9)	2382 (15.9)	14969
Waiohine River at Bicknells	6070 (15.4)	1036 (2.6)	227 (0.6)	3595 (9.1)	23641 (60.1)	4750 (12.1)	39320
Waipoua River at Colombo Rd Bridge	173 (1.0)	670 (3.8)	113 (0.6)	9699 (55.6)	2965 (17.0)	3832 (22.0)	17452
Parkvale Stream at weir	1246 (24.9)	553 (11.0)	-	980 (19.6)	42 (0.8)	2185 (43.6)	5006
Ruamāhanga River at Wardells	2322 (3.6)	1518 (2.4)	161 (0.3)	38265 (59.5)	10523 (16.4)	11495 (17.9)	64284
Ruamāhanga River at Gladstone Bridge	3564 (2.7)	2095 (1.6)	791 (0.6)	81018 (60.6)	20632 (15.4)	25593 (19.1)	133694
Ruamāhanga River at Waihenga	13451 (5.7)	5404 (2.3)	1487 (0.6)	127720 (54.1)	45165 (19.1)	42862 (18.2)	236089
Whangaehu River at 250m from Ruamāhanga Confluence	915 (6.3)	299 (2.1)	45 (0.3)	10335 (70.9)	5 (0.0)	2979 (20.4)	14578
Otukura Stream at Mouth	2790 (29.8)	2454 (26.2)	-	1611 (17.2)	83 (0.9)	2428 (25.9)	9366
Makahakaha Stream at Mouth	129 (2.1)	389 (6.3)	38 (0.6)	5155 (83.3)	4 (0.1)	477 (7.7)	6192
Ruamāhanga River at U/S Lake Wai Outlet	16146 (6.3)	6131 (2.4)	1556 (0.6)	135795 (53.4)	47362 (18.6)	47506 (18.7)	254496
Tauanui River at Mouth	-	-	-	617 (14.9)	2535 (61.0)	1003 (24.1)	4155
Turanganui River at Mouth	260 (3.9)	38 (0.6)	-	1658 (24.6)	3643 (54.1)	1141 (16.9)	6740

Table B.5 : Landuse area in the GOLD and SILVER 2080 model relative to each reporting point. Units are hectares and percentage of total upstream catchment area (bracketed values).

Reporting Point	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other**	Total***
Huangarua River at Ponatahi Bridge	-	46 (0.2)	-	22523 (74.5)	3932 (13.0)	3738 (12.4)	30239
Kopuaranga River at Stuarts	807 (4.8)	276 (1.7)	-	13070 (78.3)	1223 (7.3)	1310 (7.9)	16686
Mangatarere River at SH2	2842 (23.8)	357 (3.0)	40 (0.3)	2515 (21.0)	4190 (35.1)	2003 (16.8)	11947
Ruamāhanga River at Pukio	14430 (5.9)	5843 (2.4)	1537 (0.6)	122242 (49.6)	55916 (22.7)	46399 (18.8)	246366
Ruamāhanga River at Te Ore Ore	1113 (3.6)	544 (1.8)	3 (0.0)	16747 (53.9)	8731 (28.1)	3939 (12.7)	31078
Taueru River at Gladstone	298 (0.6)	245 (0.5)	568 (1.2)	36391 (73.9)	3552 (7.2)	8190 (16.6)	49244
Tauherenikau River at Websters	267 (1.8)	419 (2.9)	-	944 (6.5)	11255 (77.7)	1596 (11.0)	14481
Waingawa River at South Rd	215 (1.4)	127 (0.9)	-	2384 (15.9)	9861 (65.9)	2382 (15.9)	14969
Waiohine River at Bicknells	6070 (15.4)	1036 (2.6)	227 (0.6)	3595 (9.1)	23641 (60.1)	4750 (12.1)	39320
Waipoua River at Colombo Rd Bridge	168 (1.0)	670 (3.8)	113 (0.6)	9420 (54.0)	3256 (18.7)	3826 (21.9)	17452
Parkvale Stream at weir	1246 (24.9)	553 (11.0)	-	980 (19.6)	42 (0.8)	2185 (43.6)	5006
Ruamāhanga River at Wardells	2314 (3.6)	1512 (2.4)	161 (0.3)	35588 (55.4)	13306 (20.7)	11402 (17.7)	64284
Ruamāhanga River at Gladstone Bridge	3557 (2.7)	2089 (1.6)	772 (0.6)	75063 (56.1)	26741 (20.0)	25473 (19.1)	133694
Ruamāhanga River at Waihenga	13443 (5.7)	5389 (2.3)	1467 (0.6)	117790 (49.9)	55455 (23.5)	42545 (18.0)	236089
Whangaehu River at 250m from Ruamāhanga Confluence	915 (6.3)	298 (2.0)	45 (0.3)	9103 (62.4)	1291 (8.9)	2926 (20.1)	14578
Otukura Stream at Mouth	2790 (29.8)	2454 (26.2)	-	1610 (17.2)	84 (0.9)	2428 (25.9)	9366
Makahakaha Stream at Mouth	129 (2.1)	380 (6.1)	38 (0.6)	4837 (78.1)	345 (5.6)	463 (7.5)	6192
Ruamāhanga River at U/S Lake Wai Outlet	16107 (6.3)	6114 (2.4)	1537 (0.6)	125443 (49.3)	58107 (22.8)	47188 (18.5)	254496
Tauanui River at Mouth	-	-	-	609 (14.7)	2544 (61.2)	1002 (24.1)	4155
Turanganui River at Mouth	260 (3.9)	38 (0.6)	-	1679 (24.9)	3622 (53.7)	1141 (16.9)	6740

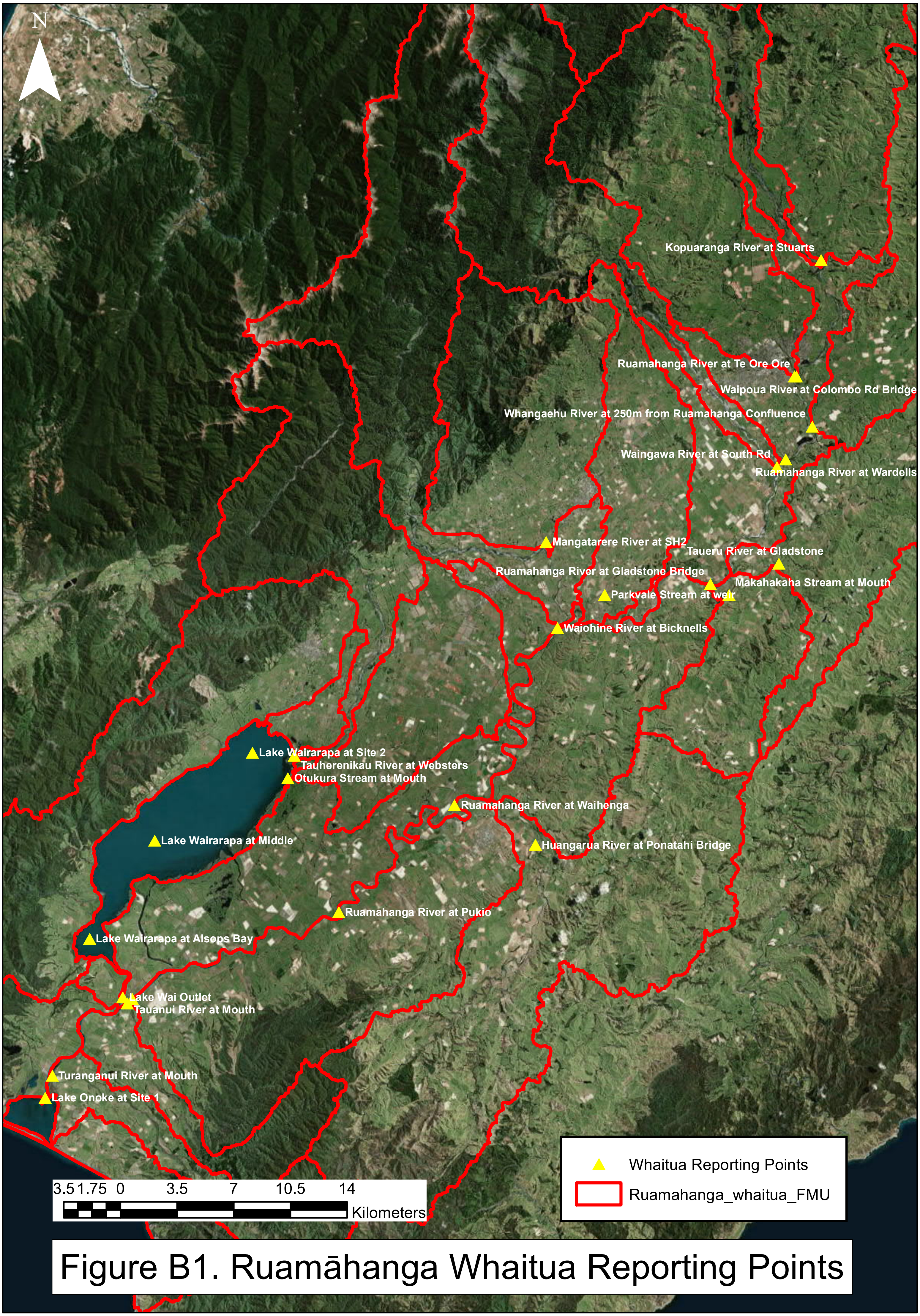


Figure B1. Ruamāhanga Whaitua Reporting Points

Ruamahanga River at Te Ore Ore

Dissolved Reactive Phosphorous (DRP)

Revision 1
Date: 2017-11-15

Introduction

This fact sheet presents results generated from modelling nine scenarios for the Ruamahanga Catchment. The results are compared to the baseline model, with a focus on the change in concentrations in the median and 95th percentiles. Dissolved Reactive Phosphorus (DRP) has no limit setting criteria defined in the National Policy Statement for Freshwater Management 2014 (amended 2017), however is required to be considered in relation to periphyton, and river and lake water quality conditions.

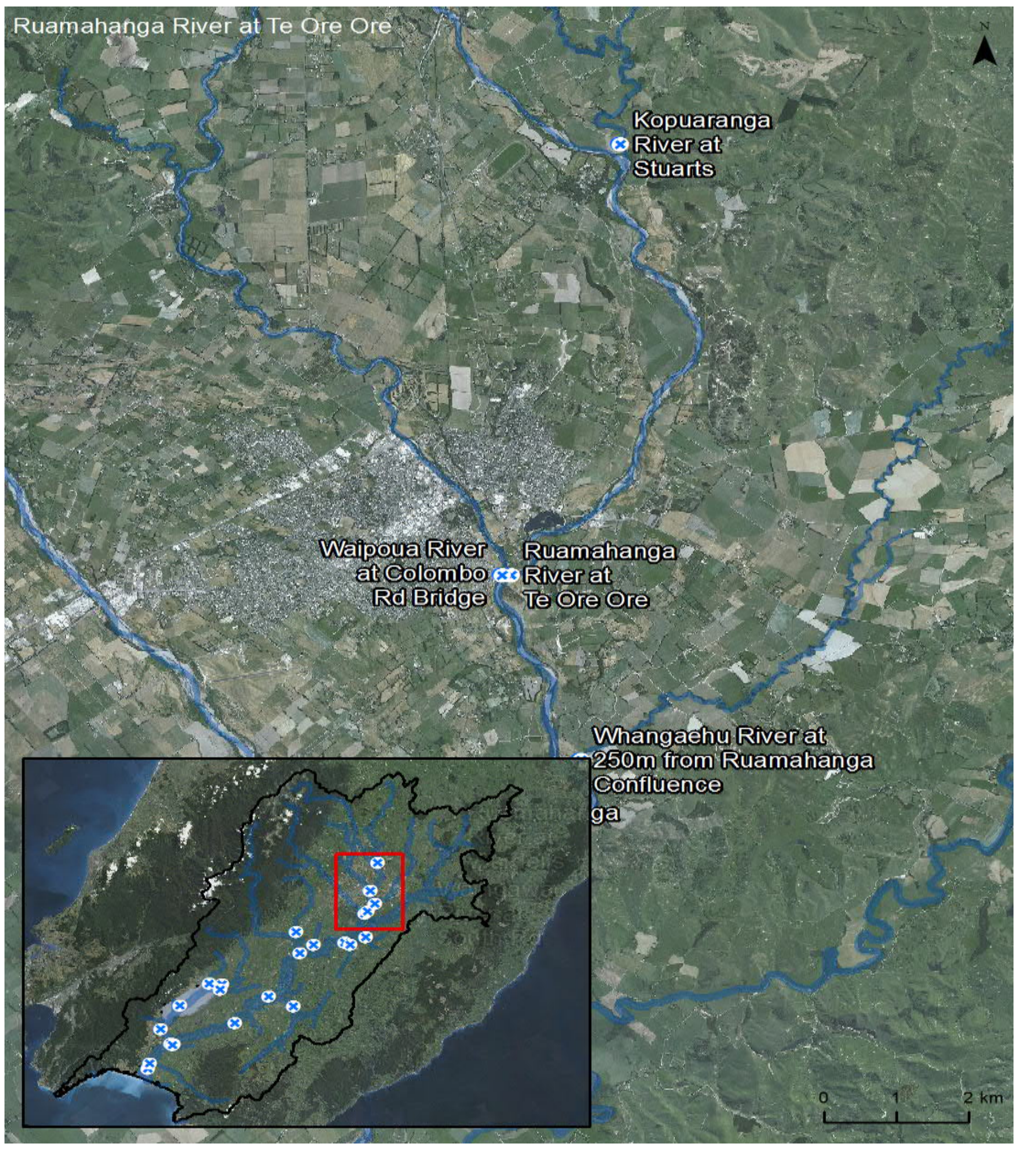
Summary

See Table 1, 2, and 3 for reference to the statistics presented in the summary below.

Ruamahanga River at Te Ore Ore has an upstream catchment area of ~31,078 ha. The catchment is 5.4% dairy/dairy support, 24.1% native bush and 57.8% sheep and beef. The remaining area (12.8%) is a variety of ‘other’ land uses including lifestyle and mixed of which no mitigations are applied. During BAU, 50th and 95th DRP percentiles decrease 1.1% and 1.9%, respectively by 2080. Land retirement of 61 ha occurs by 2080 (0.19% of the catchment at a rate of ~1 ha/yr from 2017), while only 3 ha of pole planted land is mature by 2080 and contributing to reduced DRP loads. Stock exclusion and effluent management has a ~16.8% reduction to DRP loads on dairy farms, however only 1.5% on sheep and beef. This tier 1 mitigation is the primary reason for the minor DRP reductions observed in BAU.

Silver and Gold scenarios lead to a significant increase in pole planting, peaking at 2,423 ha of mature trees by 2080 (7.8% of the catchment). This is equivalent to space planting upstream of this reporting point at a rate of ~38.5 ha/yr from 2017. Land retirement also rises to 1,244 ha (4.0% of catchment at a rate of 19.7 ha/yr from 2017). Mitigations such constructed wetlands and optimal fertiliser use (tier 2) and riparian planting/buffer strips (tier 3) contribute to further decreases in median and 95th percentiles, with reductions of 34.1% and 48.0% simulated by 2080 in both scenarios.

Location



Scenario Input Data

Table 1. Current landuse area in ha (% of total)

	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other	Total
Baseline Landuse	1115 (3.6%)	549 (1.8%)	3 (0.0)	17950 (57.8%)	7487 (24.1%)	3974 (12.8%)	31078

Table 2. Mitigation (area in ha)

Mitigation*	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Retirement	0	52	61	452	1244	1244	1244	1244	1244
Pole Planting	0	2	3	0	1015	2423	0	1015	2423

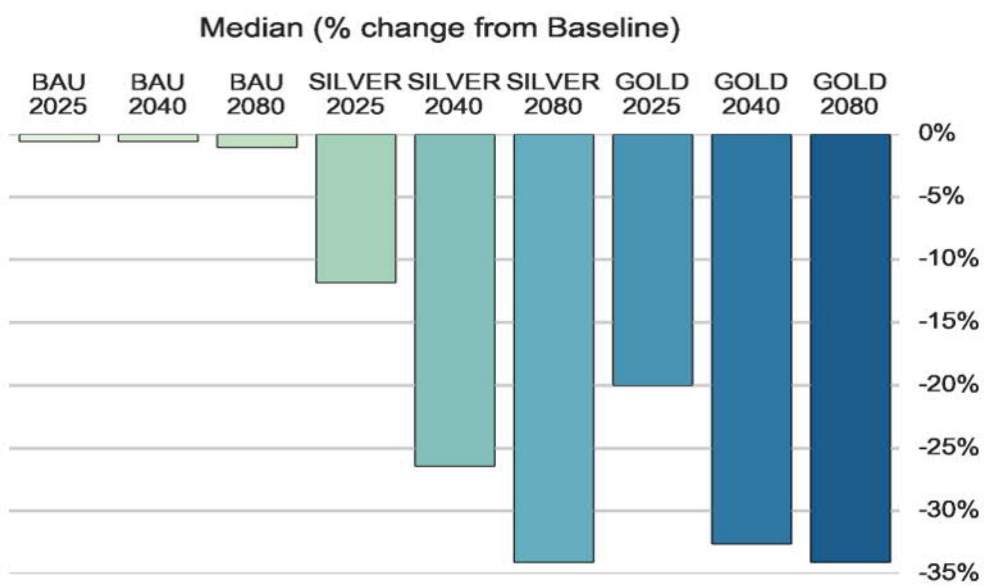
*Pole planting is effective for DRP at >15 years. Area given here is not reflective of the total area planted in the catchment.

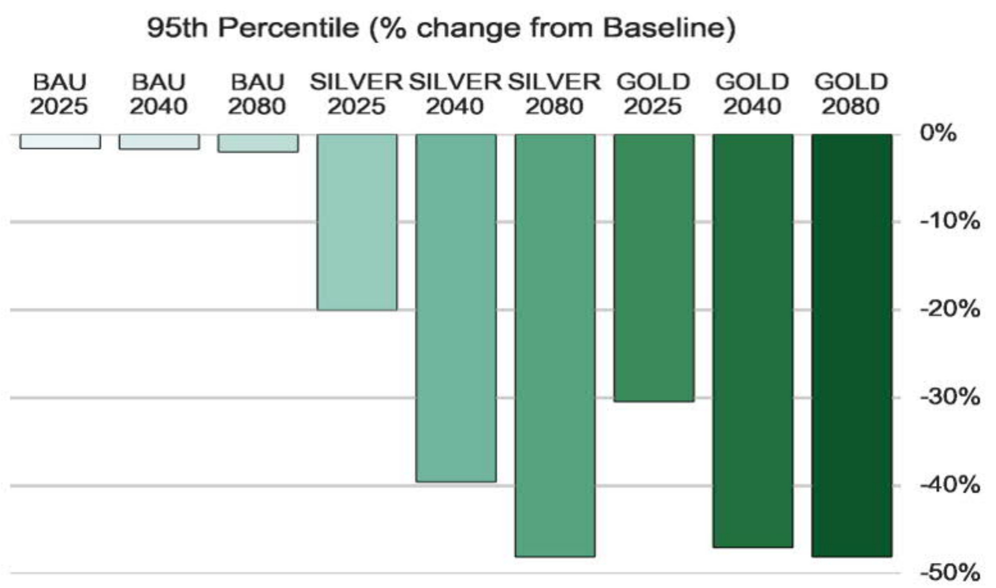
Disclaimer: This fact sheet should be read in conjunction with the report "IZ090000_RP_Rua_Scenarios_Ecological Health_Rev1", which provides further details on the scenario modelling, mitigations, assumptions and limitations. The results presented are based off modelling outputs and may not be an exact match to the observed data, which is dependent on the flow and water quality calibration achieved at various modelling sites. On farm mitigations reduce input concentrations, and are applied to Event Mean Concentrations (EMC's) linked to quickflow, and Dry Weather Concentrations (DWC's) which are linked to baseflows.

Scenario Results

Table 3. Water quality statistics

Statistic	Baseline	BAU 2025	BAU 2040	BAU 2080	SILVER 2025	SILVER 2040	SILVER 2080	GOLD 2025	GOLD 2040	GOLD 2080
Median (mg/L)	0.012	0.012	0.012	0.012	0.01	0.009	0.008	0.009	0.008	0.008
95th Percentile (mg/L)	0.021	0.021	0.021	0.021	0.017	0.013	0.011	0.015	0.011	0.011
Median (% change from Baseline)		-0.6%	-0.6%	-1.1%	-11.8%	-26.4%	-34.1%	-20.0%	-32.6%	-34.0%
95th Percentile (% change from Baseline)		-1.6%	-1.6%	-1.9%	-20.0%	-39.5%	-48.0%	-30.4%	-46.9%	-48.0%





Ruamahanga River at Wardells

Dissolved Reactive Phosphorous (DRP)

Revision 1

Date: 2017-11-15

Introduction

This fact sheet presents results generated from modelling nine scenarios for the Ruamahanga Catchment. The results are compared to the baseline model, with a focus on the change in concentrations in the median and 95th percentiles. Dissolved Reactive Phosphorus (DRP) has no limit setting criteria defined in the National Policy Statement for Freshwater Management 2014 (amended 2017), however is required to be considered in relation to periphyton, and river and lake water quality conditions.

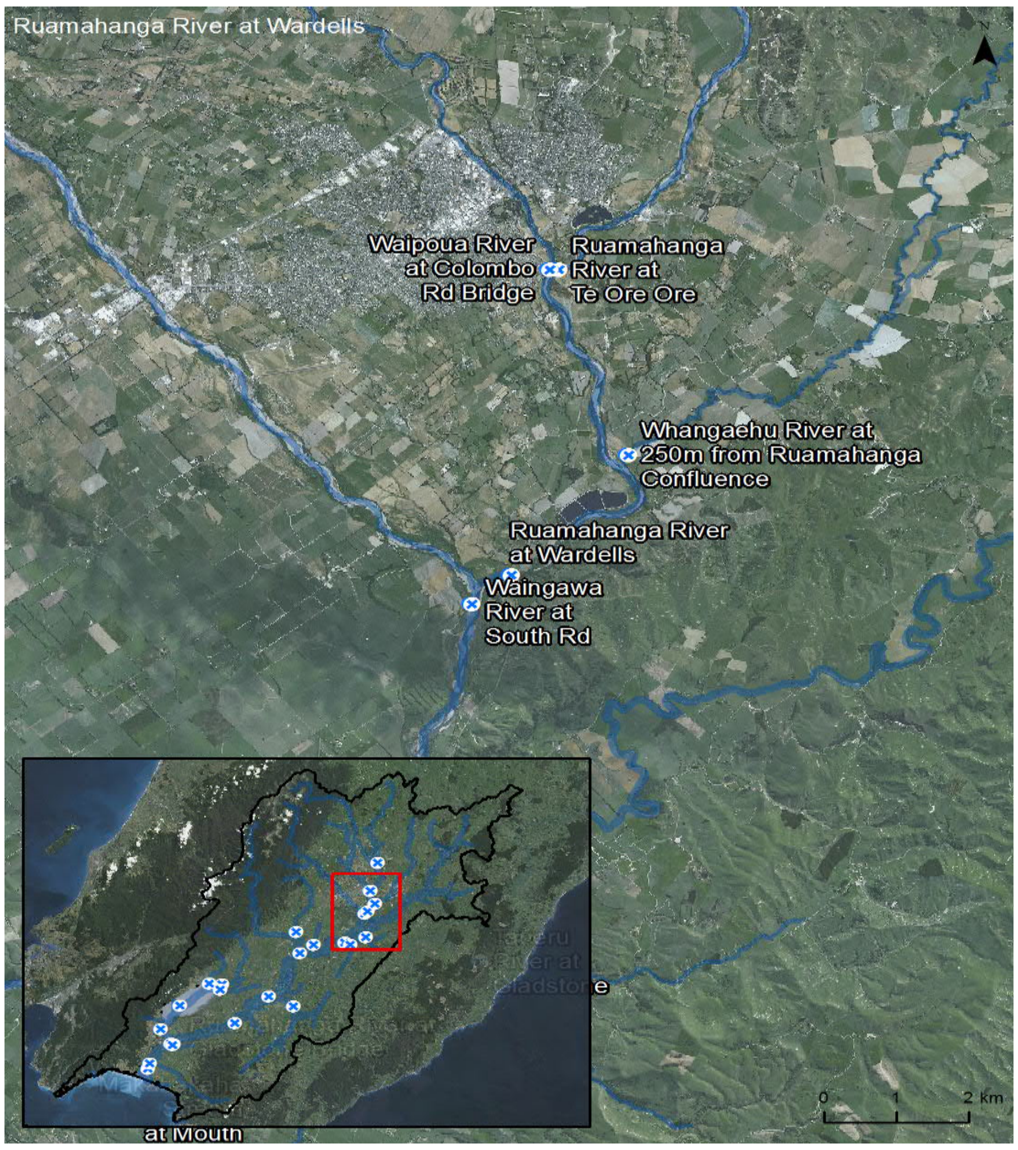
Summary

See Table 1, 2, and 3 for reference to the statistics presented in the summary below.

Ruamahanga River at Wardells has an upstream catchment area of ~64,284 ha. The catchment is 6.0% dairy/dairy support, 16.0% native bush, 59.9% sheep and beef and 0.3% arable. The remaining area (17.9%) is a variety ‘other’ land uses including lifestyle, mixed, horticulture and urban of which no mitigations are applied. During BAU, 50th and 95th DRP percentiles decrease by up to 57.4% and 51.4%, respectively by 2080. Land retirement of 225 ha occurs by 2080 (0.35% of catchment at a rate of ~3.5 ha/yr from 2017), while 580 ha of pole planted land is mature by 2080 and contributing to reduced loads (0.9% of the catchment at a rate of 9.2 ha/yr from 2017). Stock exclusion and effluent management has a ~16.8% reduction to DRP loads on dairy farms, however only 1.5% on sheep and beef. Significant reductions in DRP at Wardells are also attributed to nearly 100% land treatment of the upstream Masterton Waste Water Treatment Plant (WWTP) by 2080.

Silver and Gold scenarios lead to a significant increase in pole planting, peaking at 5,914 ha of mature trees by 2080 (9.2% of the catchment). This is equivalent to space planting upstream of this reporting point at a rate of ~93.9 ha/yr from 2017. Land retirement also rises to 3,008 ha (4.7% of catchment at a rate of 47.7 ha/yr since 2017). Mitigations such as 100% land treatment of Masterton WWTP, constructed wetlands and optimal fertiliser use (tier 2) and riparian planting/buffer strips (tier 3) contribute to further decreases in median and 95th percentiles, with reductions of 71.2% and 76.4%, respectively, simulated by 2080 in both scenarios.

Location



Scenario Input Data

Table 1. Current landuse area in ha (% of total)

	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other	Total
Baseline Landuse	2322 (3.6%)	1518 (2.4%)	161 (0.3)	38490 (59.9%)	10298 (16.0%)	11495 (17.9%)	64284

Table 2. Mitigation (area in ha)

Mitigation*	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Retirement	0	132	225	1241	3008	3008	3008	3008	3008
Pole Planting	0	49	580	0	2444	5914	0	2444	5914

*Pole planting is effective for DRP at >15 years. Area given here is not reflective of the total area planted in the catchment.

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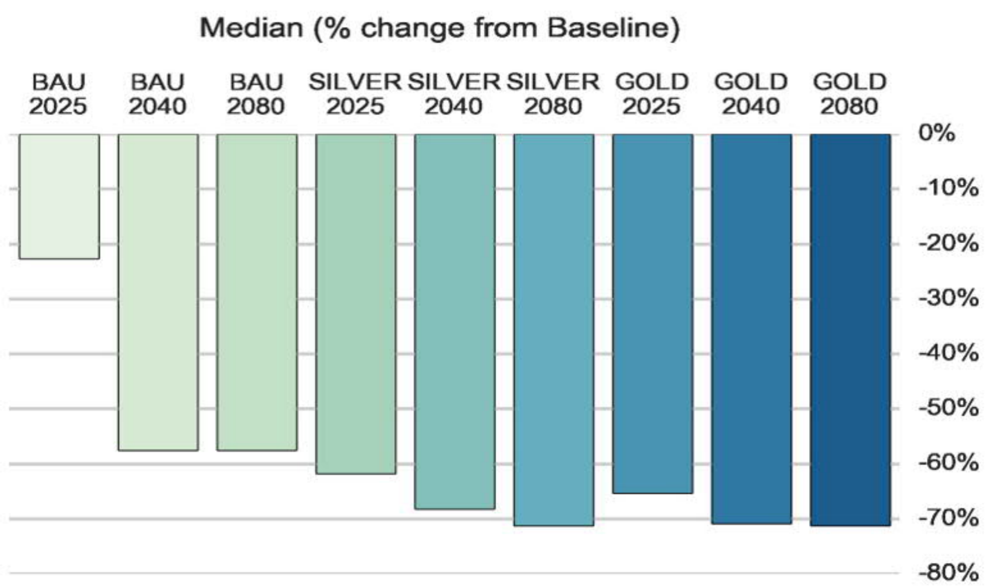
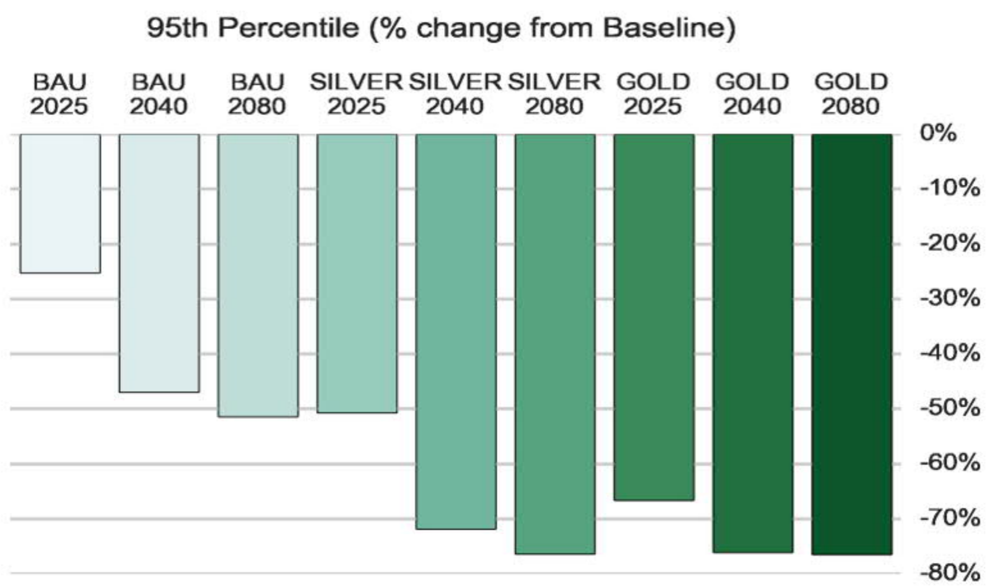
Scenario Results

Table 3. Water quality statistics

Statistic	Baseline	BAU 2025	BAU 2040	BAU 2080	SILVER 2025	SILVER 2040	SILVER 2080	GOLD 2025	GOLD 2040	GOLD 2080
Median (mg/L)	0.021	0.016	0.009	0.009	0.008	0.007	0.006	0.007	0.006	0.006
95th Percentile (mg/L)	0.04	0.03	0.021	0.019	0.02	0.011	0.009	0.013	0.01	0.009
Median (% change from Baseline)		-22.6%	-57.5%	-57.4%	-61.8%	-68.1%	-71.2%	-65.3%	-70.8%	-71.2%
95th Percentile (% change from Baseline)		-25.2%	-46.9%	-51.4%	-50.6%	-71.8%	-76.4%	-66.6%	-76.0%	-76.4%





Nitrate-Nitrogen (NO3-N)

All reporting sites

Final_Rev1

Date: 2017-11-30

JACOBS

Ruamāhanga Whaitua Committee

Introduction

This fact sheet presents the summarised results for Nitrate-Nitrogen (NO3-N) generated from modelling nine scenarios for the Ruamahanga Catchment. The results are compared to the baseline model, with a focus on the change in concentrations in the median and 95th percentiles. In addition, NO3-N has concentration limits defined in the National Policy Statement for Freshwater Management 2014 (amended 2017). This sets out Attribute States (bands) based on the median and maximum annual concentrations, with the bands ranging from A (excellent) to D (below the national bottom line).

The mitigations that reduce nitrogen loads are applied to all nitrogen species equally (i.e. Nitrate-N and Ammoniacal-N). These mitigations include (but are not limited to) stock exclusion and dairy effluent management (tier 1), constructed wetlands and optimal fertiliser use (tier 2) and riparian planting/buffer strips (tier 3). The reductions are applied to the model input dry weather concentrations for each of the relevant landuses (sheep and beef, dairy, dairy support and arable farms), and range from ~3.8% for sheep and beef farms, 9.5% for arable and 23.9–25.7% for dairy/dairy support. In addition, retirement of land results in conversion to native bush input concentrations (i.e. from sheep and beef) and land treatment of waste water treatment plants (WWTP) reduces the treated volumes NO3-N load by ~73-77%. This occurs at five WWTP's within Ruamahanga, although only Greytown, Masterton, Carterton and Martinborough are captured in the results at the 20 reporting sites. Pole planting is considered to have no effect in reducing load of nitrogen species.

Within the Ruamahanga Catchment, NO3-N is generally considered 'healthy', with all 20 reporting sites simulating A or B bands in the baseline model. The modelled scenarios simulate median (50th) percentile NO3-N reductions at 70% of the reporting sites of between 12–26% in Silver and Gold 2080 (the remaining 30% of sites have <10% NO3-N decreases). However, reductions in the 95th percentiles are smaller, with 75% of the reporting sites showing declines in the range of only 1–10% (with the remaining 25% of sites having >10% decreases in NO3-N 95th percentiles). This is driven by the mitigations described above only being applied to the dry weather concentrations representing leaching, which is assigned to baseflows, while the event mean concentrations (assigned to quickflow) are un-mitigated (except when land retirement or WWTP land treatment occurs). Due to this flow separation approach, it means NO3-N loads generated via baseflows have a greater reduction in concentration, lowering the median percentiles, while event based loads remain the same, leading to 95th percentiles only having a small decrease in concentrations.

While the mitigations are having a positive effect on the catchment by reducing NO3-N loads, the current Attribute State thresholds (to determine A–D bands) are expansive enough to encompass any of the reductions in concentrations that are occurring.

Disclaimer: This fact sheet should be read in conjunction with the report "IZ090000_RP_Rua_Scenarios_Ecological Health_Rev1", which provides further details on the scenario modelling, mitigations, assumptions and limitations. The results presented are based off modelling outputs and may not be an exact match to the observed data, which is dependent on the flow and water quality calibration achieved at various modelling sites. On farm mitigations reduce input concentrations, and are applied to Event Mean Concentrations (EMC's) linked to quickflow, and Dry Weather Concentrations (DWC's) which are linked to baseflows.

Location

Scenario Results

Table 1. National Objectives Framework Nitrate (toxicity) Attribute States

Site	Baseline	BAU2025	BAU2040	BAU2080	SILVER 2025	SILVER 2040	SILVER 2080	GOLD 2025	GOLD 2040	GOLD 2080
Huangarua River at Ponatahi Bridge	A	A	A	A	A	A	A	A	A	A
Kopuaranga River at Stuarts	B	B	B	B	B	B	B	B	B	B
Makahakaha Stream at Mouth	B	B	B	B	B	B	B	B	B	B
Mangatarere River at SH2	B	B	B	B	B	B	B	B	B	B
Otukura Stream at Mouth	B	B	B	B	B	B	B	B	B	B
Parkvale Stream at weir	B	B	B	B	B	B	B	B	B	B
Ruamahanga River at U/S Lake Wai Outlet	A	A	A	A	A	A	A	A	A	A
Ruamahanga River at Pukio	A	A	A	A	A	A	A	A	A	A
Ruamahanga River at Te Ore Ore	A	A	A	A	A	A	A	A	A	A
Ruamahanga River at Gladstone Bridge	A	A	A	A	A	A	A	A	A	A
Ruamahanga River at Waihenga	A	A	A	A	A	A	A	A	A	A
Ruamahanga River at Wardells	A	A	A	A	A	A	A	A	A	A
Tauanui River at Mouth	A	A	A	A	A	A	A	A	A	A
Tauherenikau River at Websters	A	A	A	A	A	A	A	A	A	A
Taueru River at Gladstone	A	A	A	A	A	A	A	A	A	A
Turanganui River at Mouth	A	A	A	A	A	A	A	A	A	A
Waingawa River at South Rd	A	A	A	A	A	A	A	A	A	A
Waiohine River at Bicknells	A	A	A	A	A	A	A	A	A	A
Waipoua River at Colombo Rd Bridge	B	B	B	B	B	B	B	B	B	B
Whangaehu River at 250m from Ruamahanga Confluence	B	B	B	B	B	B	B	B	B	B

Table 2. Concentrations (mg/L) and Percentage Reductions (%) from Baseline Modelling

Site	NOF Statistic	Baseline	BAU 2025	BAU 2040	BAU 2080	SILVER 2025	SILVER 2040	SILVER 2080	GOLD 2025	GOLD 2040	GOLD 2080
Huangarua River at Ponatahi Bridge	Median (mg/L)	0.3015	0.2901	0.2896	0.2896	0.2671	0.2532	0.2532	0.2532	0.2532	0.2532
	Median (% change from Baseline)		-3.8%	-3.9%	-3.9%	-11.4%	-16.0%	-16.0%	-16.0%	-16.0%	-16.0%
	95th Percentile (mg/L)	1.0542	1.0608	1.0539	1.0539	0.9705	0.933	0.933	0.9331	0.933	0.933
	95th Percentile (% change from Baseline)		0.6%	-0.0%	-0.0%	-7.9%	-11.5%	-11.5%	-11.5%	-11.5%	-11.5%
Kopuaranga River at Stuarts	Median (mg/L)	0.9663	0.8679	0.8679	0.8679	0.8387	0.7967	0.7967	0.7966	0.7965	0.7965
	Median (% change from Baseline)		-10.2%	-10.2%	-10.2%	-13.2%	-17.5%	-17.5%	-17.6%	-17.6%	-17.6%
	95th Percentile (mg/L)	2.1119	1.9206	1.9206	1.9206	1.8709	1.7766	1.7766	1.7769	1.7769	1.7769
	95th Percentile (% change from Baseline)		-9.1%	-9.1%	-9.1%	-11.4%	-15.9%	-15.9%	-15.9%	-15.9%	-15.9%
Makahakaha Stream at Mouth	Median (mg/L)	0.7769	0.7768	0.7768	0.7768	0.7488	0.7299	0.7299	0.7299	0.7299	0.7299
	Median (% change from Baseline)		-0.0%	-0.0%	-0.0%	-3.6%	-6.0%	-6.0%	-6.1%	-6.1%	-6.1%
	95th Percentile (mg/L)	1.691	1.6909	1.6909	1.6909	1.6337	1.5956	1.5955	1.5955	1.5955	1.5955
	95th Percentile (% change from Baseline)		-0.0%	-0.0%	-0.0%	-3.4%	-5.6%	-5.6%	-5.6%	-5.6%	-5.6%
Mangatarere River at SH2	Median (mg/L)	0.7512	0.7455	0.7446	0.7254	0.7017	0.7	0.6946	0.6926	0.6918	0.6874
	Median (% change from Baseline)		-0.8%	-0.9%	-3.4%	-6.6%	-6.8%	-7.5%	-7.8%	-7.9%	-8.5%
	95th Percentile (mg/L)	2.2003	2.2009	2.2009	2.1562	2.1915	2.1899	2.1889	2.1899	2.1895	2.1882
	95th Percentile (% change from Baseline)		0.0%	0.0%	-2.0%	-0.4%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
Otukura Stream at Mouth	Median (mg/L)	1.4279	1.4126	1.4126	1.4126	1.2128	1.2128	1.2126	1.2072	1.2072	1.2072
	Median (% change from Baseline)		-1.1%	-1.1%	-1.1%	-15.1%	-15.1%	-15.1%	-15.5%	-15.5%	-15.5%
	95th Percentile (mg/L)	1.5856	1.5052	1.5052	1.5052	1.298	1.2981	1.2979	1.2918	1.2918	1.2918
	95th Percentile (% change from Baseline)		-5.1%	-5.1%	-5.1%	-18.1%	-18.1%	-18.1%	-18.5%	-18.5%	-18.5%
Parkvale Stream at weir	Median (mg/L)	1.4818	1.4794	1.4794	1.4794	1.3095	1.3093	1.3093	1.2949	1.2949	1.2949
	Median (% change from Baseline)		-0.2%	-0.2%	-0.2%	-11.6%	-11.6%	-11.6%	-12.6%	-12.6%	-12.6%
	95th Percentile (mg/L)	1.8463	1.8573	1.8573	1.8573	1.7306	1.7306	1.7305	1.7211	1.7211	1.7211
	95th Percentile (% change from Baseline)		0.6%	0.6%	0.6%	-6.3%	-6.3%	-6.3%	-6.8%	-6.8%	-6.8%
Ruamahanga River at U/S Lake Wai Outlet	Median (mg/L)	0.5013	0.4734	0.4732	0.4723	0.4142	0.41	0.4099	0.4093	0.4093	0.4092
	Median (% change from Baseline)		-5.6%	-5.6%	-5.8%	-17.4%	-18.2%	-18.2%	-18.4%	-18.4%	-18.4%
	95th Percentile (mg/L)	0.9307	0.9209	0.9202	0.9159	0.8796	0.8536	0.8533	0.8531	0.8531	0.8529
	95th Percentile (% change from Baseline)		-1.1%	-1.1%	-1.6%	-5.5%	-8.3%	-8.3%	-8.3%	-8.3%	-8.4%
Ruamahanga River at Pukio	Median (mg/L)	0.4578	0.4191	0.4188	0.4173	0.3859	0.3801	0.3799	0.379	0.379	0.3788
	Median (% change from Baseline)		-8.5%	-8.5%	-8.8%	-15.7%	-17.0%	-17.0%	-17.2%	-17.2%	-17.2%
	95th Percentile (mg/L)	0.9507	0.9405	0.9401	0.9367	0.9049	0.8801	0.8798	0.8794	0.8793	0.8791
	95th Percentile (% change from Baseline)		-1.1%	-1.1%	-1.5%	-4.8%	-7.4%	-7.5%	-7.5%	-7.5%	-7.5%
Ruamahanga River at Te Ore Ore	Median (mg/L)	0.3662	0.3446	0.3446	0.3427	0.3334	0.3206	0.3206	0.3207	0.3207	0.3207
	Median (% change from Baseline)		-5.9%	-5.9%	-6.4%	-9.0%	-12.5%	-12.5%	-12.4%	-12.4%	-12.4%
	95th Percentile (mg/L)	0.9463	0.9402	0.9402	0.9373	0.9145	0.8744	0.8744	0.8741	0.874	0.874
	95th Percentile (% change from Baseline)		-0.6%	-0.6%	-1.0%	-3.4%	-7.6%	-7.6%	-7.6%	-7.6%	-7.6%
Ruamahanga River at Gladstone Bridge	Median (mg/L)	0.5187	0.4505	0.4501	0.4482	0.4226	0.4133	0.4131	0.4132	0.4132	0.4128
	Median (% change from Baseline)		-13.2%	-13.2%	-13.6%	-18.5%	-20.3%	-20.4%	-20.3%	-20.3%	-20.4%
	95th Percentile (mg/L)	1.0346	1.0212	1.0204	1.0141	0.9846	0.9532	0.953	0.9529	0.9529	0.9528
	95th Percentile (% change from Baseline)		-1.3%	-1.4%	-2.0%	-4.8%	-7.9%	-7.9%	-7.9%	-7.9%	-7.9%
Ruamahanga River at Waihenga	Median (mg/L)	0.4398	0.3991	0.3987	0.3973	0.3703	0.364	0.3638	0.3629	0.3629	0.3627
	Median (% change from Baseline)		-9.3%	-9.4%	-9.7%	-15.8%	-17.2%	-17.3%	-17.5%	-17.5%	-17.5%
	95th Percentile (mg/L)	0.9542	0.9436	0.943	0.9385	0.911	0.8853	0.885	0.8847	0.8846	0.8844
	95th Percentile (% change from Baseline)		-1.1%	-1.2%	-1.7%	-4.5%	-7.2%	-7.3%	-7.3%	-7.3%	-7.3%
Ruamahanga River at Wardells	Median (mg/L)	0.6625	0.5388	0.5383	0.5352	0.4971	0.4886	0.4882	0.4882	0.4881	0.4877
	Median (% change from Baseline)		-18.7%	-18.7%	-19.2%	-25.0%	-26.2%	-26.3%	-26.3%	-26.3%	-26.4%
	95th Percentile (mg/L)	1.2717	1.2451	1.2449	1.2348	1.2004	1.1669	1.1655	1.1663	1.1663	1.1654
	95th Percentile (% change from Baseline)		-2.1%	-2.1%	-2.9%	-5.6%	-8.2%	-8.4%	-8.3%	-8.3%	-8.4%
Tauanui River at Mouth	Median (mg/L)	0.1271	0.1275	0.1275	0.1275	0.1267	0.1263	0.1263	0.1262	0.1262	0.1262
	Median (% change from Baseline)		0.4%	0.3%	0.3%	-0.3%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
	95th Percentile (mg/L)	0.3367	0.3367	0.3367	0.3367	0.3289	0.3285	0.3285	0.3285	0.3285	0.3285
	95th Percentile (% change from Baseline)		0.0%	-0.0%	-0.0%	-2.3%	-2.4%	-2.4%	-2.4%	-2.4%	-2.4%
Tauherenikau River at Websters	Median (mg/L)	0.0633	0.0623	0.0623	0.0623	0.0558	0.0557	0.0557	0.0552	0.0552	0.0552
	Median (% change from Baseline)		-1.7%	-1.7%	-1.7%	-11.9%	-12.0%	-12.0%	-12.8%	-12.8%	-12.8%
	95th Percentile (mg/L)	0.2872	0.3013	0.3013	0.3013	0.2532	0.2532	0.2532	0.2498	0.2498	0.2498
	95th Percentile (% change from Baseline)		4.9%	4.9%	4.9%	-11.9%	-11.8%	-11.9%	-13.0%	-13.0%	-13.0%
Taueru River at Gladstone	Median (mg/L)	0.724	0.7236	0.7237	0.7237	0.6981	0.6594	0.6594	0.6594	0.6593	0.6593
	Median (% change from Baseline)		-0.0%	-0.0%	-0.0%	-3.6%	-8.9%	-8.9%	-8.9%	-8.9%	-8.9%
	95th Percentile (mg/L)	1.4038	1.4037	1.4037	1.4037	1.3625	1.2908	1.2908	1.2908	1.2907	1.2907
	95th Percentile (% change from Baseline)		-0.0%	-0.0%	-0.0%	-2.9%	-8.1%	-8.1%	-8.0%	-8.1%	-8.1%
Turanganui River at Mouth	Median (mg/L)	0.1572	0.1571	0.1538	0.1538	0.1508	0.1502	0.1502	0.1502	0.1502	0.1502
	Median (% change from Baseline)		-0.0%	-2.1%	-2.1%	-4.0%	-4.4%	-4.4%	-4.4%	-4.4%	-4.4%
	95th Percentile (mg/L)	0.62	0.6199	0.6069	0.6069	0.5963	0.5945	0.5945	0.5945	0.5945	0.5945
	95th Percentile (% change from Baseline)		-0.0%	-2.1%	-2.1%	-3.8%	-4.1%	-4.1%	-4.1%	-4.1%	-4.1%
Waingawa River at South Rd	Median (mg/L)	0.0952	0.094	0.094	0.0938	0.0927	0.0925	0.0925	0.0925	0.0925	0.0925
	Median (% change from Baseline)		-1.2%	-1.2%	-1.4%	-2.6%	-2.8%	-2.8%	-2.8%	-2.8%	-2.8%
	95th Percentile (mg/L)	0.24	0.2398	0.2398	0.239	0.2391	0.2386	0.2386	0.2386	0.2386	0.2386
	95th Percentile (% change from Baseline)		-0.1%	-0.1%	-0.4%	-0.4%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
Waiohine River at Bicknells	Median (mg/L)	0.1948	0.182	0.182	0.1805	0.1691	0.1688	0.1688	0.1667	0.1667	0.1666
	Median (% change from Baseline)		-6.6%	-6.6%	-7.4%	-13.2%	-13.4%	-13.4%	-14.5%	-14.5%	-14.5%
	95th Percentile (mg/L)	0.6632	0.645	0.645	0.6377	0.6373	0.6363	0.6362	0.6352	0.6352	0.6351
	95th Percentile (% change from Baseline)		-2.7%	-2.7%	-3.8%	-3.9%	-4.1%	-4.1%	-4.2%	-4.2%	-4.2%
Waipoua River at Colombo Rd Bridge	Median (mg/L)	0.8012	0.6562	0.6562	0.6507	0.6169	0.6115	0.6115	0.6096	0.6096	0.6096
	Median (% change from Baseline)		-18.1%	-18.1%	-18.8%	-23.0%	-23.7%	-23.7%	-23.9%	-23.9%	-23.9%
	95th Percentile (mg/L)	1.8535	1.8257	1.8257	1.7994	1.7557	1.7355	1.7355	1.7354	1.7354	1.7354
	95th Percentile (% change from Baseline)		-1.5%	-1.5%	-2.9%	-5.3%	-6.4%	-6.4%	-6.4%	-6.4%	-6.4%
Whangaehu River at 250m from Ruamahanga Confluence	Median (mg/L)	1.3948	1.3591	1.3591	1.3591	1.1339	1.1275	1.1275	1.1273	1.1273	1.1273
	Median (% change from Baseline)		-2.6%	-2.6%	-2.6%	-18.7%	-19.2%	-19.2%	-19.2%	-19.2%	-19.2%
	95th Percentile (mg/L)	1.5004	1.4636	1.4636	1.4636	1.2589	1.2202	1.2202	1.22	1.22	1.22
	95th Percentile (% change from Baseline)		-2.5%	-2.5%	-2.5%	-16.1%	-18.7%	-18.7%	-18.7%	-18.7%	-18.7%

Table 3. Current landuse area in ha (% of total)

Site	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other	Total
Huangarua River at Ponatahi Bridge	-	46 (0.2%)	-	25581 (84.6%)	693 (2.3%)	3918 (13.0%)	30239
Kopuaranga River at Stuarts	808 (4.8%)	281 (1.7%)	-	14103 (84.5%)	154 (0.9%)	1339 (8.0%)	16686
Makahakaha Stream at Mouth	129 (2.1%)	389 (6.3%)	38 (0.6%)	5155 (83.3%)	4 (0.1%)	477 (7.7%)	6192
Mangatarere River at SH2	2842 (23.8%)	357 (3.0%)	40 (0.3%)	2515 (21.0%)	4190 (35.1%)	2003 (16.8%)	11947
Otukura Stream at Mouth	2790 (29.8%)	2454 (26.2%)	-	1611 (17.2%)	83 (0.9%)	2428 (25.9%)	9366
Parkvale Stream at weir	1246 (24.9%)	553 (11.0%)	-	980 (19.6%)	42 (0.8%)	2185 (43.6%)	5006
Ruamahanga River at Gladstone Bridge	3564 (2.7%)	2095 (1.6%)	791 (0.6%)	81249 (60.8%)	20401 (15.3%)	25593 (19.1%)	133694
Ruamahanga River at Pukio	14438 (5.9%)	5867 (2.4%)	1556 (0.6%)	132684 (53.9%)	45104 (18.3%)	46717 (19.0%)	246366
Ruamahanga River at Te Ore Ore	1115 (3.6%)	549 (1.8%)	3 (0.0%)	17950 (57.8%)	7487 (24.1%)	3974 (12.8%)	31078
Ruamahanga River at U/S Lake Wai Outlet	16146 (6.3%)	6139 (2.4%)	1556 (0.6%)	136133 (53.5%)	47016 (18.5%)	47506 (18.7%)	254496
Ruamahanga River at Waihenga	13451 (5.7%)	5413 (2.3%)	1487 (0.6%)	128058 (54.2%)	44818 (19.0%)	42862 (18.2%)	236089
Ruamahanga River at Wardells	2322 (3.6%)	1518 (2.4%)	161 (0.3%)	38490 (59.9%)	10298 (16.0%)	11495 (17.9%)	64284
Tauanui River at Mouth	-	-	-	617 (14.9%)	2535 (61.0%)	1003 (24.1%)	4155
Taueru River at Gladstone	298 (0.6%)	246 (0.5%)	587 (1.2%)	39655 (80.5%)	242 (0.5%)	8217 (16.7%)	49244
Tauherenikau River at Websters	267 (1.8%)	419 (2.9%)	-	944 (6.5%)	11255 (77.7%)	1596 (11.0%)	14481
Turanganui River at Mouth	260 (3.9%)	38 (0.6%)	-	1810 (26.8%)	3491 (51.8%)	1141 (16.9%)	6740
Waingawa River at South Rd	215 (1.4%)	127 (0.9%)	-	2389 (16.0%)	9856 (65.8%)	2382 (15.9%)	14969
Waiohine River at Bicknells	6070 (15.4%)	1036 (2.6%)	227 (0.6%)	3595 (9.1%)	23641 (60.1%)	4750 (12.1%)	39320
Waipoua River at Colombo Rd Bridge	173 (1.0%)	670 (3.8%)	113 (0.6%)	9862 (56.5%)	2802 (16.1%)	3832 (22.0%)	17452
Whangaehu River at 250m from Ruamahanga Confluence	915 (6.3%)	299 (2.1%)	45 (0.3%)	10335 (70.9%)	5 (0.0%)	2979 (20.4%)	14578

Table 4. Retirement (area in ha)

Site	BAU 2025	BAU 2040	BAU 2080	SILVER 2025	SILVER 2040	SILVER 2080	GOLD 2025	GOLD 2040	GOLD 2080
Huangarua River at Ponatahi Bridge	107	107	107	2285	3240	3240	3240	3240	3240
Kopuaranga River at Stuarts	0	0	0	353	1068	1068	1068	1068	1068
Makahakaha Stream at Mouth	0	0	0	218	341	341	341	341	341
Mangatarere River at SH2	0	0	0	0	0	0	0	0	0
Otukura Stream at Mouth	0	0	0	0	1	1	1	1	1
Parkvale Stream at weir	0	0	0	0	0	0	0	0	0
Ruamahanga River at U/S Lake Wai Outlet	107	245	347	5634	11092	11092	11092	11092	11092
Ruamahanga River at Pukio	107	245	347	5376	10812	10812	10812	10812	10812
Ruamahanga River at Te Ore Ore	0	52	61	452	1244	1244	1244	1244	1244
Ruamahanga River at Gladstone Bridge	0	138	231	2468	6340	6340	6340	6340	6340
Ruamahanga River at Waihenga	107	245	347	5272	10637	10637	10637	10637	10637
Ruamahanga River at Wardells	0	132	225	1241	3008	3008	3008	3008	3008
Tauanui River at Mouth	0	0	0	5	8	8	8	8	8
Tauherenikau River at Websters	0	0	0	0	0	0	0	0	0
Taueru River at Gladstone	0	0	0	1213	3310	3310	3310	3310	3310
Turanganui River at Mouth	2	67	152	123	131	131	131	131	131
Waingawa River at South Rd	0	7	7	0	5	5	5	5	5
Waiohine River at Bicknells	0	0	0	0	0	0	0	0	0
Waipoua River at Colombo Rd Bridge	0	79	163	314	454	454	454	454	454
Whangaehu River at 250m from Ruamahanga Confluence	0	0	0	452	1286	1286	1286	1286	1286

Appendix C. Scenario modelling results

The results presented in the eight tables below show the percentage change between the baseline water quality results and each scenario. These are the ‘Table 5’ results, as described in **Section 2.6**.

Table C.1 : DIN percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	-3.8	0.6	-3.9	0.0	-3.9	0.0	-11.5	-8.0	-16.0	-11.5	-16.0	-11.5	-16.0	-11.5	-16.0	-11.5	-16.0	-11.5
Kopuaranga River at Stuarts	-10.1	-8.8	-10.1	-8.8	-10.1	-8.8	-13.2	-11.0	-17.5	-15.5	-17.5	-15.5	-17.5	-15.5	-17.5	-15.5	-17.5	-15.5
Makahakaha Stream at Mouth	0.0	0.0	0.0	0.0	0.0	0.0	-3.6	-3.4	-6.0	-5.6	-6.0	-5.6	-6.0	-5.6	-6.1	-5.6	-6.1	-5.6
Mangatarere River at SH2	-8.3	-2.9	-7.9	-2.8	-7.3	-4.4	-11.7	-3.2	-11.8	-3.9	-9.6	-3.7	-12.7	-4.0	-12.4	-3.9	-10.2	-3.7
Otakura Stream at Mouth	-1.1	-5.1	-1.1	-5.1	-1.1	-5.1	-15.0	-18.1	-15.0	-18.1	-15.1	-18.1	-15.4	-18.5	-15.4	-18.5	-15.4	-18.5
Parkvale Stream at Weir	-0.1	0.7	-0.1	0.7	-0.1	0.7	-11.7	-5.1	-11.7	-5.1	-11.7	-5.1	-12.6	-5.6	-12.6	-5.6	-12.6	-5.6
Ruamāhanga River at U/S Lake Wai Outlet	-6.1	-1.0	-6.4	-1.4	-6.5	-1.7	-17.9	-5.5	-18.8	-8.6	-18.7	-8.6	-18.9	-8.7	-18.9	-8.7	-18.8	-8.7
Ruamāhanga River at Pukio	-9.4	-1.2	-10.0	-1.6	-10.1	-2.0	-16.8	-5.2	-18.1	-7.9	-17.9	-7.9	-18.4	-8.0	-18.4	-8.0	-18.2	-8.0
Ruamāhanga River at Te Ore Ore	-5.9	-0.6	-5.9	-0.6	-6.4	-0.9	-8.8	-3.4	-12.3	-7.5	-12.3	-7.5	-12.3	-7.6	-12.3	-7.6	-12.3	-7.6
Ruamāhanga River at Gladstone Bridge	-13.4	-1.5	-13.7	-1.8	-14.1	-2.2	-19.0	-5.2	-20.8	-8.2	-20.8	-8.2	-20.8	-8.2	-20.8	-8.2	-20.8	-8.3
Ruamāhanga River at Waihenga	-10.0	-1.1	-10.4	-1.3	-10.5	-1.8	-16.6	-4.7	-18.0	-7.5	-17.9	-7.5	-18.3	-7.6	-18.3	-7.6	-18.2	-7.6
Ruamāhanga River at Wardells	-18.9	-1.7	-19.4	-2.2	-19.9	-2.9	-25.4	-5.7	-26.8	-8.2	-26.8	-8.2	-26.8	-8.2	-26.8	-8.2	-26.8	-8.2
Tauanui River at Mouth	0.3	0.2	0.3	0.2	0.3	0.2	-0.3	-1.9	-0.6	-2.1	-0.6	-2.1	-0.7	-2.1	-0.7	-2.1	-0.7	-2.1
Tauherenikau River at Websters	-1.1	4.8	-1.1	4.8	-1.1	4.8	-10.1	-12.1	-10.2	-12.0	-10.2	-12.1	-10.9	-13.2	-10.9	-13.2	-10.9	-13.2
Taueru River at Gladstone	-0.1	0.0	-0.1	0.0	-0.1	0.0	-3.5	-2.9	-8.9	-8.1	-8.9	-8.1	-8.9	-8.0	-8.9	-8.1	-8.9	-8.1
Turanganui River at Mouth	0.0	0.0	-2.1	-2.1	-2.1	-2.1	-4.0	-3.8	-4.4	-4.1	-4.4	-4.1	-4.4	-4.1	-4.4	-4.1	-4.4	-4.1
Waingawa River at South Rd	-1.4	-0.1	-1.4	-0.1	-1.7	-0.4	-2.8	-0.3	-2.9	-0.5	-2.9	-0.5	-2.9	-0.5	-2.9	-0.5	-2.9	-0.5
Waiohine River at Bicknells	-11.3	-3.0	-11.1	-3.0	-10.8	-3.7	-17.0	-4.1	-17.0	-4.5	-16.0	-4.5	-18.1	-4.7	-17.9	-4.7	-17.0	-4.6
Waipoua River at Colombo Rd Bridge	-18.0	-1.5	-18.0	-1.5	-18.6	-2.9	-22.8	-5.2	-23.6	-6.4	-23.6	-6.4	-23.7	-6.4	-23.7	-6.4	-23.7	-6.4
Whangaehu River at 250m from Ruamāhanga Confluence	-2.8	-2.4	-2.8	-2.4	-2.8	-2.4	-19.1	-13.6	-19.5	-17.7	-19.5	-17.7	-19.5	-17.7	-19.5	-17.7	-19.5	-17.7

Table C.2 : DRP percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	1.7	-0.7	1.4	-1.5	-0.1	-4.0	-14.4	-29.5	-27.4	-58.1	-34.9	-68.1	-22.4	-41.8	-32.9	-67.3	-34.8	-68.1
Kopuaranga River at Stuarts	-0.6	-1.9	-0.6	-1.9	-0.6	-1.9	-11.4	-23.4	-24.3	-45.8	-30.9	-49.1	-19.9	-35.9	-30.6	-49.1	-30.9	-49.1
Makahakaha Stream at Mouth	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-21.2	-26.0	-38.4	-47.0	-49.6	-61.1	-31.0	-37.7	-49.6	-61.2	-49.6	-61.2
Mangatarere River at SH2	-54.4	-56.5	-54.2	-56.4	-55.2	-58.0	-57.8	-61.1	-62.8	-73.3	-63.7	-75.7	-59.6	-67.6	-64.1	-75.3	-63.9	-76.0
Otakura Stream at Mouth	-7.3	-6.9	-7.3	-6.9	-7.4	-7.2	-13.0	-20.3	-19.7	-42.3	-22.1	-49.3	-16.5	-27.5	-22.5	-47.4	-22.6	-49.8
Parkvale Stream at Weir	2.2	-0.1	2.2	-0.1	2.2	-0.1	-8.1	-14.1	-22.4	-33.0	-28.1	-42.0	-13.1	-21.0	-26.9	-39.1	-28.1	-42.1
Ruamāhanga River at U/S Lake Wai Outlet	-21.5	-4.0	-46.6	-9.1	-47.1	-13.2	-50.9	-20.0	-58.8	-46.4	-61.4	-54.4	-55.5	-36.0	-61.1	-53.2	-61.4	-54.7
Ruamāhanga River at Pukio	-25.5	-11.0	-48.3	-17.6	-48.8	-21.0	-51.7	-27.1	-59.9	-51.5	-62.3	-58.3	-56.6	-41.8	-62.1	-57.2	-62.3	-58.6
Ruamāhanga River at Te Ore Ore	-0.6	-1.6	-0.6	-1.6	-1.1	-1.9	-11.8	-20.0	-26.4	-39.5	-34.1	-48.0	-20.0	-30.4	-32.6	-46.9	-34.0	-48.0
Ruamāhanga River at Gladstone Bridge	-16.4	-11.6	-45.1	-23.5	-45.5	-27.8	-51.4	-33.5	-60.2	-59.6	-63.5	-67.0	-56.1	-50.2	-63.2	-66.1	-63.5	-67.0
Ruamāhanga River at Waihenga	-27.0	-11.7	-45.9	-17.2	-46.5	-21.0	-50.2	-27.9	-57.9	-51.5	-60.6	-58.3	-54.4	-41.8	-60.3	-57.2	-60.7	-58.6
Ruamāhanga River at Wardells	-22.6	-25.2	-57.5	-46.9	-57.4	-51.4	-61.8	-50.6	-68.1	-71.8	-71.2	-76.4	-65.3	-66.6	-70.8	-76.0	-71.2	-76.4
Tauanui River at Mouth	0.1	-0.3	0.1	-0.3	0.1	-0.3	-5.1	-7.8	-11.4	-16.4	-15.1	-22.2	-8.0	-11.6	-14.1	-20.7	-15.1	-22.2
Tauherenikau River at Websters	0.9	-0.1	0.9	-0.1	0.9	-0.1	-0.5	-2.0	-2.3	-4.3	-3.3	-5.4	-1.2	-2.8	-3.1	-5.2	-3.1	-5.2
Taueru River at Gladstone	-1.1	-1.5	-1.6	-2.3	-3.0	-4.3	-19.7	-27.1	-42.8	-58.3	-52.0	-71.4	-31.0	-41.1	-50.7	-69.5	-52.0	-71.4
Turanganui River at Mouth	-3.6	-4.1	-6.4	-6.6	-6.8	-7.1	-19.4	-21.0	-45.6	-50.9	-49.5	-55.4	-25.9	-28.4	-49.7	-55.6	-49.7	-55.6
Waingawa River at South Rd	-0.9	-1.4	-0.9	-1.4	-3.8	-5.3	-9.3	-12.0	-23.1	-28.5	-26.3	-32.6	-13.5	-17.6	-26.4	-32.3	-26.5	-32.7
Waiohine River at Bicknells	-50.5	-20.6	-50.4	-20.1	-51.3	-22.6	-52.5	-27.5	-56.0	-47.0	-57.1	-50.4	-53.6	-38.3	-56.9	-49.7	-57.3	-51.0
Waipoua River at Colombo Rd Bridge	-0.7	-1.7	-0.8	-1.8	-2.7	-4.0	-15.5	-26.0	-31.3	-51.0	-38.7	-65.2	-23.0	-37.5	-37.8	-63.9	-38.8	-65.2
Whangaehu River at 250m from Ruamāhanga Confluence	-1.7	-2.0	-1.7	-2.1	-1.7	-3.0	-10.4	-24.0	-22.0	-51.5	-25.9	-59.7	-19.5	-37.4	-24.8	-59.0	-26.1	-59.7

Table C.3 : *E.coli* percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	-14.8	1.2	-14.9	1.0	-14.9	1.0	-23.6	-8.8	-29.2	-13.7	-30.9	-16.5	-28.2	-12.4	-30.9	-16.5	-30.9	-16.5
Kopuaranga River at Stuarts	-2.9	-0.3	-2.9	-0.3	-2.9	-0.3	-8.5	-5.2	-16.7	-12.9	-19.4	-15.9	-15.4	-11.6	-19.4	-15.9	-19.4	-15.9
Makahakaha Stream at Mouth	-24.7	-9.3	-24.7	-9.3	-24.7	-9.3	-28.3	-14.1	-31.5	-18.6	-33.1	-21.1	-30.8	-17.4	-33.1	-21.1	-33.1	-21.1
Mangatarere River at SH2	-63.1	-41.8	-62.9	-40.4	-61.5	-35.2	-63.9	-42.5	-65.3	-74.1	-64.7	-72.7	-65.1	-73.7	-66.2	-74.3	-64.7	-72.7
Otakura Stream at Mouth	-11.9	-0.9	-11.9	-0.9	-11.9	-0.9	-14.7	-4.1	-17.5	-7.3	-20.4	-10.6	-16.1	-5.8	-20.4	-10.6	-20.4	-10.6
Parkvale Stream at Weir	-24.0	0.6	-24.0	0.6	-24.0	0.6	-24.7	-2.6	-25.5	-5.7	-26.3	-9.0	-25.1	-4.2	-26.3	-9.0	-26.3	-9.0
Ruamāhanga River at U/S Lake Wai Outlet	-18.0	-0.3	-20.6	-0.4	-20.6	-0.4	-24.6	-4.9	-29.9	-9.4	-31.5	-12.4	-28.8	-7.9	-32.0	-12.3	-31.5	-12.4
Ruamāhanga River at Pukio	-19.4	-0.4	-21.2	-0.5	-21.2	0.0	-25.4	-5.6	-30.7	-10.0	-32.5	-12.6	-29.8	-8.7	-32.8	-12.6	-32.5	-12.6
Ruamāhanga River at Te Ore Ore	-4.2	-0.2	-4.2	-0.2	-4.9	-0.3	-9.6	-3.2	-16.4	-9.8	-19.2	-12.8	-15.2	-8.3	-19.2	-12.8	-19.2	-12.8
Ruamāhanga River at Gladstone Bridge	-5.0	-1.0	-5.0	-1.0	-5.4	-1.1	-10.2	-5.7	-16.6	-11.6	-19.1	-14.5	-15.3	-10.3	-19.2	-14.5	-19.1	-14.5
Ruamāhanga River at Waihenga	-18.9	-3.5	-19.2	-3.5	-19.1	-3.2	-23.7	-9.5	-28.7	-16.4	-30.7	-19.1	-27.8	-15.1	-31.0	-19.1	-30.7	-19.1
Ruamāhanga River at Wardells	-5.8	-0.7	-5.8	-0.7	-6.0	-0.8	-10.9	-5.6	-17.1	-10.7	-19.7	-13.4	-15.9	-9.3	-19.8	-13.4	-19.7	-13.4
Tauanui River at Mouth	-4.6	-0.4	-4.6	-0.4	-4.6	-0.4	-7.7	-3.8	-11.3	-7.8	-14.3	-11.1	-9.9	-6.2	-14.3	-11.1	-14.3	-11.1
Tauherenikau River at Websters	-4.9	-0.1	-4.9	-0.1	-4.9	-0.1	-5.7	-2.8	-6.4	-5.5	-7.1	-8.4	-6.1	-4.2	-7.1	-8.4	-7.1	-8.4
Taueru River at Gladstone	-4.7	-0.9	-4.7	-0.9	-4.7	-0.9	-10.4	-6.9	-17.8	-14.9	-20.5	-17.9	-16.5	-13.5	-20.5	-17.9	-20.5	-17.9
Turanganui River at Mouth	-11.8	-0.5	-13.6	-2.5	-13.6	-2.5	-17.6	-7.2	-20.3	-10.6	-22.9	-13.9	-19.1	-9.1	-22.9	-13.9	-22.9	-13.9
Waingawa River at South Rd	-9.3	-0.7	-9.3	-0.7	-10.2	-0.7	-11.4	-3.1	-13.5	-5.6	-15.7	-8.1	-12.5	-4.4	-15.7	-8.1	-15.7	-8.1
Waiohine River at Bicknells	-67.1	-46.3	-66.8	-45.1	-65.1	-40.5	-67.8	-47.0	-69.3	-70.8	-69.0	-71.8	-69.2	-70.3	-70.1	-71.8	-69.0	-71.8
Waipoua River at Colombo Rd Bridge	-13.8	-0.6	-13.8	-0.6	-14.7	-1.4	-18.3	-6.2	-21.9	-10.2	-24.2	-13.2	-21.0	-8.9	-24.2	-13.2	-24.2	-13.2
Whangaehu River at 250m from Ruamāhanga Confluence	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-4.6	-5.4	-9.1	-12.6	-12.2	-15.5	-7.7	-11.1	-12.2	-15.5	-12.2	-15.5

Table C.4 : NH_4-N percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	-1.7	0.4	-1.9	-0.1	-1.9	-0.1	-9.6	-8.2	-14.3	-11.8	-14.3	-11.8	-14.3	-11.8	-14.3	-11.8	-14.3	-11.8
Kopuaranga River at Stuarts	0.0	0.0	0.0	0.0	0.0	0.0	-3.2	-2.5	-9.0	-7.6	-9.0	-7.6	-9.0	-7.6	-9.0	-7.6	-9.0	-7.6
Makahakaha Stream at Mouth	0.0	0.0	0.0	0.0	0.0	0.0	-3.4	-3.3	-5.7	-5.5	-5.7	-5.5	-5.8	-5.6	-5.8	-5.6	-5.8	-5.6
Mangatarere River at SH2	-55.7	-40.5	-54.2	-38.5	-44.7	-25.9	-55.7	-40.5	-58.5	-38.5	-49.9	-25.9	-59.9	-40.5	-58.5	-38.5	-49.9	-25.9
Otakura Stream at Mouth	-2.3	0.4	-2.3	0.4	-2.3	0.4	-4.1	0.3	-4.9	0.3	-4.9	0.3	-5.0	0.3	-5.0	0.3	-5.0	0.3
Parkvale Stream at Weir	3.4	3.1	3.4	3.1	3.4	3.1	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Ruamāhanga River at U/S Lake Wai Outlet	-21.6	-6.8	-41.4	-18.6	-37.4	-18.4	-39.3	-14.7	-43.2	-27.6	-39.1	-26.7	-43.8	-27.7	-43.2	-27.6	-39.1	-26.7
Ruamāhanga River at Pukio	-20.7	-23.4	-36.2	-33.8	-32.2	-32.6	-33.3	-31.2	-38.6	-39.8	-34.8	-37.6	-39.3	-40.0	-38.6	-39.8	-34.8	-37.6
Ruamāhanga River at Te Ore Ore	0.0	0.0	0.0	0.0	-0.9	-1.0	-2.7	-2.2	-6.2	-5.4	-6.2	-5.4	-6.2	-5.4	-6.2	-5.4	-6.2	-5.4
Ruamāhanga River at Gladstone Bridge	-22.7	-7.2	-31.9	-17.5	-31.5	-19.1	-32.8	-17.8	-35.3	-23.2	-34.6	-22.8	-35.3	-23.2	-35.3	-23.2	-34.6	-22.8
Ruamāhanga River at Waihenga	-21.4	-22.9	-32.0	-31.7	-27.7	-30.4	-30.9	-30.7	-34.7	-37.7	-30.6	-35.6	-35.3	-38.0	-34.7	-37.7	-30.6	-35.6
Ruamāhanga River at Wardells	-25.2	-22.6	-37.7	-32.3	-36.8	-34.1	-37.8	-32.5	-40.5	-37.4	-39.4	-37.2	-40.5	-37.4	-40.5	-37.4	-39.4	-37.2
Tauanui River at Mouth	0.6	0.3	0.6	0.3	0.6	0.3	-0.1	-0.3	-0.4	-0.5	-0.4	-0.5	-0.4	-0.5	-0.4	-0.5	-0.4	-0.5
Tauherenikau River at Websters	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0
Taueru River at Gladstone	0.0	0.0	0.0	0.0	0.0	0.0	-3.4	-3.0	-8.7	-8.2	-8.7	-8.2	-8.7	-8.2	-8.7	-8.2	-8.7	-8.2
Turanganui River at Mouth	0.0	0.0	-2.2	-2.1	-2.2	-2.1	-4.1	-3.8	-4.5	-4.1	-4.5	-4.1	-4.5	-4.1	-4.5	-4.1	-4.5	-4.1
Waingawa River at South Rd	0.2	0.0	0.2	0.0	-0.2	-0.3	0.0	0.0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Waiohine River at Bicknells	-28.1	-54.2	-26.8	-52.9	-19.2	-44.7	-28.1	-54.2	-32.5	-54.1	-26.4	-46.4	-33.6	-55.4	-32.5	-54.1	-26.4	-46.4
Waipoua River at Colombo Rd Bridge	0.2	0.1	0.2	0.1	-1.1	-1.4	-3.9	-3.7	-5.4	-4.7	-5.4	-4.7	-5.4	-4.7	-5.4	-4.7	-5.4	-4.7
Whangaehu River at 250m from Ruamāhanga Confluence	1.3	0.0	1.3	0.0	1.3	0.0	-3.7	-3.8	-8.2	-10.7	-8.2	-10.7	-8.2	-10.7	-8.2	-10.7	-8.2	-10.7

Table C.5 : NO_3-N percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	-3.8	0.6	-3.9	0.0	-3.9	0.0	-11.4	-7.9	-16.0	-11.5	-16.0	-11.5	-16.0	-11.5	-16.0	-11.5	-16.0	-11.5
Kopuaranga River at Stuarts	-10.2	-9.1	-10.2	-9.1	-10.2	-9.1	-13.2	-11.4	-17.5	-15.9	-17.5	-15.9	-17.6	-15.9	-17.6	-15.9	-17.6	-15.9
Makahakaha Stream at Mouth	0.0	0.0	0.0	0.0	0.0	0.0	-3.6	-3.4	-6.0	-5.6	-6.0	-5.6	-6.1	-5.6	-6.1	-5.6	-6.1	-5.6
Mangatarere River at SH2	-0.8	0.0	-0.9	0.0	-3.4	-2.0	-6.6	-0.4	-6.8	-0.5	-7.5	-0.5	-7.8	-0.5	-7.9	-0.5	-8.5	-0.5
Otakura Stream at Mouth	-1.1	-5.1	-1.1	-5.1	-1.1	-5.1	-15.1	-18.1	-15.1	-18.1	-15.1	-18.1	-15.5	-18.5	-15.5	-18.5	-15.5	-18.5
Parkvale Stream at Weir	-0.2	0.6	-0.2	0.6	-0.2	0.6	-11.6	-6.3	-11.6	-6.3	-11.6	-6.3	-12.6	-6.8	-12.6	-6.8	-12.6	-6.8
Ruamāhanga River at U/S Lake Wai Outlet	-5.6	-1.1	-5.6	-1.1	-5.8	-1.6	-17.4	-5.5	-18.2	-8.3	-18.2	-8.3	-18.4	-8.3	-18.4	-8.3	-18.4	-8.4
Ruamāhanga River at Pukio	-8.5	-1.1	-8.5	-1.1	-8.8	-1.5	-15.7	-4.8	-17.0	-7.4	-17.0	-7.5	-17.2	-7.5	-17.2	-7.5	-17.2	-7.5
Ruamāhanga River at Te Ore Ore	-5.9	-0.6	-5.9	-0.6	-6.4	-1.0	-9.0	-3.4	-12.5	-7.6	-12.5	-7.6	-12.4	-7.6	-12.4	-7.6	-12.4	-7.6
Ruamāhanga River at Gladstone Bridge	-13.2	-1.3	-13.2	-1.4	-13.6	-2.0	-18.5	-4.8	-20.3	-7.9	-20.4	-7.9	-20.3	-7.9	-20.3	-7.9	-20.4	-7.9
Ruamāhanga River at Waihenga	-9.3	-1.1	-9.4	-1.2	-9.7	-1.7	-15.8	-4.5	-17.2	-7.2	-17.3	-7.3	-17.5	-7.3	-17.5	-7.3	-17.5	-7.3
Ruamāhanga River at Wardells	-18.7	-2.1	-18.7	-2.1	-19.2	-2.9	-25.0	-5.6	-26.2	-8.2	-26.3	-8.4	-26.3	-8.3	-26.3	-8.3	-26.4	-8.4
Tauanui River at Mouth	0.4	0.0	0.3	0.0	0.3	0.0	-0.3	-2.3	-0.7	-2.4	-0.7	-2.4	-0.7	-2.4	-0.7	-2.4	-0.7	-2.4
Tauherenikau River at Websters	-1.7	4.9	-1.7	4.9	-1.7	4.9	-11.9	-11.9	-12.0	-11.8	-12.0	-11.9	-12.8	-13.0	-12.8	-13.0	-12.8	-13.0
Taueru River at Gladstone	0.0	0.0	0.0	0.0	0.0	0.0	-3.6	-2.9	-8.9	-8.1	-8.9	-8.1	-8.9	-8.0	-8.9	-8.1	-8.9	-8.1
Turanganui River at Mouth	0.0	0.0	-2.1	-2.1	-2.1	-2.1	-4.0	-3.8	-4.4	-4.1	-4.4	-4.1	-4.4	-4.1	-4.4	-4.1	-4.4	-4.1
Waingawa River at South Rd	-1.2	-0.1	-1.2	-0.1	-1.4	-0.4	-2.6	-0.4	-2.8	-0.6	-2.8	-0.6	-2.8	-0.6	-2.8	-0.6	-2.8	-0.6
Waiohine River at Bicknells	-6.6	-2.7	-6.6	-2.7	-7.4	-3.8	-13.2	-3.9	-13.4	-4.1	-13.4	-4.1	-14.5	-4.2	-14.5	-4.2	-14.5	-4.2
Waipoua River at Colombo Rd Bridge	-18.1	-1.5	-18.1	-1.5	-18.8	-2.9	-23.0	-5.3	-23.7	-6.4	-23.7	-6.4	-23.9	-6.4	-23.9	-6.4	-23.9	-6.4
Whangaehu River at 250m from Ruamāhanga Confluence	-2.6	-2.5	-2.6	-2.5	-2.6	-2.5	-18.7	-16.1	-19.2	-18.7	-19.2	-18.7	-19.2	-18.7	-19.2	-18.7	-19.2	-18.7

Table C.6 : SSC percentage change per scenario from baseline nutrient concentrations*

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	7.2	-4.6	-6.9	-17.7	-18.0	-26.9	-17.6	-27.1	-50.7	-59.4	-64.0	-69.7	-12.9	-22.4	-54.6	-61.9	-64.0	-69.7
Kopuaranga River at Stuarts	-7.2	-7.0	-7.8	-7.6	-7.9	-7.7	-20.5	-20.5	-40.5	-40.8	-51.8	-51.6	-25.2	-25.1	-48.1	-48.2	-51.8	-51.6
Makahakaha Stream at Mouth	-7.4	-7.4	-13.8	-13.8	-13.8	-13.8	-19.8	-19.8	-39.1	-39.1	-43.5	-43.5	-24.6	-24.6	-43.5	-43.5	-43.5	-43.5
Mangatarere River at SH2	-21.6	-12.6	-22.3	-13.3	-29.3	-23.4	-23.3	-14.5	-41.2	-36.4	-41.4	-36.6	-26.5	-18.2	-41.2	-36.4	-41.4	-36.6
Otakura Stream at Mouth	-64.5	-34.7	-64.5	-34.7	-65.2	-50.5	-66.1	-36.8	-69.0	-72.8	-69.0	-72.8	-66.7	-40.3	-69.0	-72.8	-69.0	-72.8
Parkvale Stream at Weir	-15.9	-19.6	-23.0	-26.5	-58.1	-59.7	-20.5	-24.1	-64.9	-65.9	-74.8	-75.5	-29.3	-32.5	-64.9	-65.9	-74.8	-75.5
Ruamāhanga River at U/S Lake Wai Outlet	-8.0	-8.5	-16.4	-16.8	-19.1	-20.1	-14.8	-15.6	-33.4	-35.2	-41.6	-43.1	-17.3	-17.7	-35.8	-37.7	-41.6	-43.1
Ruamāhanga River at Pukio	-8.4	-8.6	-16.7	-17.0	-19.8	-20.8	-15.7	-16.5	-33.5	-36.1	-41.2	-43.4	-17.8	-18.5	-36.1	-37.9	-41.2	-43.4
Ruamāhanga River at Te Ore Ore	-8.8	-9.1	-9.0	-9.4	-9.2	-9.6	-14.7	-14.8	-27.6	-26.3	-33.7	-30.8	-18.4	-18.3	-31.6	-29.0	-33.7	-30.8
Ruamāhanga River at Gladstone Bridge	-8.5	-8.2	-17.4	-21.5	-20.7	-26.0	-14.9	-17.2	-34.8	-41.1	-43.0	-49.8	-17.7	-20.7	-37.2	-44.6	-43.0	-49.8
Ruamāhanga River at Waihenga	-8.7	-8.6	-17.1	-17.8	-20.4	-21.7	-15.8	-17.3	-33.7	-36.6	-41.4	-43.1	-18.4	-19.0	-35.9	-38.8	-41.4	-43.1
Ruamāhanga River at Wardells	-9.7	-8.2	-12.5	-13.8	-13.5	-15.9	-15.6	-16.1	-31.2	-36.5	-37.8	-42.3	-19.0	-19.7	-34.3	-39.9	-37.8	-42.3
Tauanui River at Mouth	-13.2	-13.5	-14.7	-15.0	-14.7	-15.0	-13.3	-13.5	-35.4	-35.6	-44.2	-44.4	-14.4	-14.7	-35.4	-35.6	-44.2	-44.4
Tauherenikau River at Websters	-12.6	-12.9	-12.6	-12.9	-12.7	-13.1	-12.7	-13.0	-13.6	-14.0	-13.6	-14.0	-12.7	-13.0	-13.6	-13.9	-13.6	-14.0
Taueru River at Gladstone	-8.4	-8.1	-31.6	-30.7	-36.7	-36.6	-21.3	-21.6	-54.2	-54.5	-67.4	-67.5	-25.1	-25.0	-57.6	-58.0	-67.4	-67.5
Turanganui River at Mouth	-13.2	-13.2	-18.1	-18.1	-18.1	-18.1	-8.7	-8.7	-60.5	-60.5	-61.5	-61.5	-22.3	-22.3	-60.7	-60.7	-61.5	-61.5
Waingawa River at South Rd	-7.5	-7.9	-7.5	-7.9	-10.5	-11.1	-7.9	-8.3	-14.4	-15.0	-14.6	-15.2	-8.7	-9.1	-14.4	-15.0	-14.6	-15.2
Waiohine River at Bicknells	-10.2	-9.7	-10.4	-9.8	-12.6	-11.8	-10.7	-10.2	-15.2	-15.5	-15.3	-15.6	-11.2	-10.6	-15.0	-15.3	-15.3	-15.6
Waipoua River at Colombo Rd Bridge	-9.8	-9.3	-16.5	-15.8	-24.1	-23.2	-12.8	-12.4	-44.2	-43.2	-48.5	-47.8	-22.7	-22.5	-45.6	-44.9	-48.6	-47.8
Whangaehu River at 250m from Ruamāhanga Confluence	-6.0	-6.1	-10.6	-23.7	-11.4	-28.7	-21.6	-24.0	-37.8	-55.9	-74.1	-66.6	-23.3	-23.7	-41.9	-61.0	-74.1	-66.6

* See **Section 4.7** for limitations in the SSC concentrations presented above.

Table C.7 : TN percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	-1.6	0.5	-1.8	-0.1	-1.8	-0.1	-9.4	-8.1	-14.1	-11.8	-14.1	-11.8	-14.1	-11.8	-14.1	-11.8	-14.1	-11.8
Kopuaranga River at Stuarts	0.0	0.0	0.0	0.0	0.0	0.0	-3.2	-2.6	-8.9	-7.8	-8.9	-7.8	-8.9	-7.8	-8.9	-7.8	-8.9	-7.8
Makahakaha Stream at Mouth	0.0	0.0	0.0	0.0	0.0	0.0	-3.6	-3.4	-5.9	-5.6	-5.9	-5.6	-5.9	-5.6	-5.9	-5.6	-5.9	-5.6
Mangatarere River at SH2	-8.0	-1.3	-7.4	-1.2	-13.5	-4.0	-8.6	-1.4	-8.6	-1.7	-5.2	-1.6	-9.1	-1.7	-8.6	-1.7	-5.2	-1.6
Otakura Stream at Mouth	-2.0	0.8	-2.0	0.8	-2.0	0.8	-3.6	0.8	-4.6	0.7	-4.6	0.7	-4.6	0.7	-4.7	0.7	-4.7	0.7
Parkvale Stream at Weir	3.4	3.1	3.4	3.1	3.4	3.1	3.2	3.1	3.1	3.0	3.1	3.0	3.1	3.0	3.1	3.0	3.1	3.0
Ruamāhanga River at U/S Lake Wai Outlet	-0.8	0.1	-5.0	-0.3	-6.2	-1.0	-7.7	-2.5	-10.6	-5.4	-10.4	-5.4	-10.7	-5.5	-10.7	-5.4	-10.4	-5.4
Ruamāhanga River at Pukio	-2.7	0.1	-5.9	-0.2	-7.2	-1.1	-8.1	-3.0	-10.9	-6.0	-10.6	-6.0	-10.9	-6.0	-10.9	-6.0	-10.6	-6.0
Ruamāhanga River at Te Ore Ore	-0.1	0.0	-0.1	0.0	-0.9	-0.3	-2.8	-2.4	-7.0	-6.8	-7.0	-6.8	-7.0	-6.8	-7.0	-6.8	-7.0	-6.8
Ruamāhanga River at Gladstone Bridge	-1.8	0.0	-5.4	-0.6	-6.0	-1.4	-8.0	-3.3	-11.6	-7.3	-11.5	-7.3	-11.6	-7.3	-11.6	-7.3	-11.5	-7.3
Ruamāhanga River at Waihenga	-2.3	0.0	-5.1	-0.5	-6.3	-1.2	-7.4	-2.9	-10.4	-6.2	-10.2	-6.1	-10.4	-6.2	-10.4	-6.2	-10.2	-6.1
Ruamāhanga River at Wardells	-4.1	-0.4	-11.1	-1.2	-11.7	-2.6	-13.3	-4.1	-16.7	-7.3	-16.6	-7.3	-16.7	-7.3	-16.7	-7.3	-16.6	-7.3
Tauanui River at Mouth	0.7	0.2	0.7	0.2	0.7	0.2	-0.1	-0.4	-0.4	-0.7	-0.4	-0.7	-0.4	-0.7	-0.4	-0.7	-0.4	-0.7
Tauherenikau River at Websters	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0
Taueru River at Gladstone	0.0	0.0	0.0	0.0	0.0	0.0	-3.4	-3.0	-8.8	-8.2	-8.8	-8.2	-8.8	-8.2	-8.8	-8.2	-8.8	-8.2
Turanganui River at Mouth	0.0	0.0	-2.1	-2.1	-2.1	-2.1	-4.0	-3.8	-4.3	-4.1	-4.3	-4.1	-4.3	-4.1	-4.3	-4.1	-4.3	-4.1
Waingawa River at South Rd	0.0	0.0	0.0	0.0	-0.4	-0.2	-0.2	0.0	-0.3	-0.2	-0.3	-0.2	-0.3	-0.2	-0.3	-0.2	-0.3	-0.2
Waiohine River at Bicknells	-7.4	-0.9	-7.1	-0.8	-12.1	-2.2	-7.9	-1.0	-8.1	-1.4	-7.2	-1.3	-8.2	-1.4	-8.1	-1.4	-7.2	-1.3
Waipoua River at Colombo Rd Bridge	0.2	0.1	0.2	0.1	-1.1	-1.5	-3.9	-4.0	-5.4	-5.1	-5.4	-5.1	-5.4	-5.1	-5.4	-5.1	-5.4	-5.1
Whangaehu River at 250m from Ruamāhanga Confluence	1.0	0.0	1.0	0.0	1.0	0.0	-3.9	-3.8	-8.0	-10.7	-8.0	-10.7	-8.0	-10.7	-8.0	-10.7	-8.0	-10.7

Table C.8 : TP percentage change per scenario from baseline nutrient concentrations

Reporting Point	BAU 2025		BAU 2040		BAU 2080		Silver 2025		Silver 2040		Silver 2080		Gold 2025		Gold 2040		Gold 2080	
	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Huangarua River at Ponatahi Bridge	1.9	-0.8	1.6	-1.6	0.2	-3.9	-13.9	-29.4	-26.9	-58.0	-34.3	-67.9	-22.0	-41.8	-32.4	-67.1	-34.3	-67.9
Kopuaranga River at Stuarts	-0.6	-1.8	-0.6	-1.8	-0.6	-1.8	-11.4	-23.4	-24.6	-45.1	-30.9	-49.0	-19.9	-35.7	-30.6	-49.0	-30.9	-49.1
Makahakaha Stream at Mouth	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-21.1	-26.0	-38.3	-46.9	-49.3	-60.9	-30.9	-37.6	-49.4	-61.0	-49.4	-61.0
Mangatarere River at SH2	-52.3	-28.4	-52.2	-28.4	-54.5	-32.7	-57.4	-37.2	-65.8	-55.9	-67.9	-60.4	-60.5	-44.7	-68.0	-59.5	-68.2	-61.1
Otakura Stream at Mouth	-7.5	-6.9	-7.5	-6.9	-7.5	-7.2	-12.9	-20.1	-19.8	-41.9	-21.8	-49.1	-16.4	-27.4	-22.8	-47.2	-22.8	-49.4
Parkvale Stream at Weir	2.3	-0.7	2.2	-0.8	2.2	-0.9	-5.2	-13.2	-16.3	-31.6	-20.4	-39.5	-9.0	-19.7	-19.5	-36.6	-20.4	-39.7
Ruamāhanga River at U/S Lake Wai Outlet	-10.7	-4.6	-23.5	-6.6	-24.6	-9.0	-31.0	-21.8	-42.2	-43.9	-46.5	-53.7	-36.9	-32.5	-45.6	-51.4	-46.6	-54.1
Ruamāhanga River at Pukio	-16.2	-4.8	-28.0	-7.4	-29.1	-9.8	-34.7	-21.9	-45.0	-44.6	-49.1	-54.2	-40.3	-33.8	-48.4	-52.0	-49.2	-54.6
Ruamāhanga River at Te Ore Ore	-0.5	-1.7	-0.5	-1.7	-1.1	-2.0	-11.8	-20.1	-26.5	-39.4	-33.9	-47.9	-19.8	-30.2	-32.4	-46.9	-33.9	-47.9
Ruamāhanga River at Gladstone Bridge	-10.6	-2.9	-27.5	-8.3	-28.3	-11.1	-36.5	-25.2	-48.2	-50.1	-52.7	-60.2	-42.7	-38.6	-52.1	-59.1	-52.7	-60.3
Ruamāhanga River at Waihenga	-16.3	-4.7	-26.2	-7.3	-27.3	-9.4	-33.5	-23.2	-43.5	-44.8	-48.1	-54.7	-38.8	-33.1	-47.2	-52.6	-48.2	-55.1
Ruamāhanga River at Wardells	-12.3	-10.3	-38.2	-16.8	-38.7	-20.3	-45.4	-31.8	-54.7	-55.0	-59.1	-63.6	-50.6	-45.6	-58.5	-62.7	-59.1	-63.7
Tauanui River at Mouth	0.1	-0.3	0.1	-0.3	0.1	-0.3	-5.1	-7.7	-11.3	-16.2	-14.9	-21.7	-7.9	-11.2	-13.8	-20.2	-14.9	-21.6
Tauherenikau River at Websters	0.9	-0.1	0.9	-0.1	0.9	-0.1	-0.5	-1.7	-2.4	-4.3	-3.4	-5.6	-1.3	-2.7	-3.2	-5.2	-3.2	-5.3
Taueru River at Gladstone	-1.1	-1.5	-1.6	-2.3	-2.8	-4.2	-19.2	-26.9	-41.7	-57.6	-51.0	-70.5	-30.3	-40.7	-49.6	-68.7	-51.0	-70.5
Turanganui River at Mouth	-3.6	-4.1	-6.4	-6.6	-6.8	-7.0	-19.5	-20.9	-46.0	-50.6	-50.0	-55.1	-26.1	-28.3	-50.1	-55.3	-50.1	-55.3
Waingawa River at South Rd	-0.9	-1.3	-0.9	-1.3	-3.8	-5.4	-9.4	-11.9	-23.2	-28.4	-26.4	-32.5	-13.5	-17.6	-26.4	-32.3	-26.5	-32.5
Waiohine River at Bicknells	-40.7	-10.5	-40.7	-10.5	-42.7	-14.8	-44.2	-18.8	-50.1	-36.9	-52.7	-43.4	-46.2	-26.5	-51.4	-40.3	-52.9	-44.2
Waipoua River at Colombo Rd Bridge	-0.8	-1.8	-0.8	-1.8	-2.7	-4.2	-15.4	-26.2	-30.9	-52.0	-38.0	-65.8	-22.9	-37.6	-37.2	-64.4	-38.1	-65.9
Whangaehu River at 250m from Ruamāhanga Confluence	-1.4	-2.0	-1.4	-2.1	-1.5	-3.0	-10.4	-24.0	-21.7	-51.6	-25.7	-59.9	-19.3	-37.4	-24.7	-59.2	-25.9	-60.0