BEFORE THE INDEPENDENT HEARINGS PANELS APPOINTED TO HEAR AND MAKE RECOMMENDATIONS ON SUBMISSIONS AND FURTHER SUBMISSIONS ON PROPOSED PLAN CHANGE 1 TO THE NATURAL RESOURCES PLAN FOR THE WELLINGTON REGION

UNDER	the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	of Hearing of Submissions and Further Submissions on Proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region under Schedule 1 of the Act

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STATEMENT OF EVIDENCE OF JAMES MITCHELL BLYTH

ON BEHALF OF GREATER WELLINGTON REGIONAL COUNCIL

TECHNICAL EVIDENCE – OVERVIEW OF WATER QUALITY MODELLING

HEARING STREAM 2 – OBJECTIVES AND ECOSYSTEM HEALTH AND WATER QUALITY POLICIES

28 FEBRUARY 2025

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INTRODUCTION

1 My full name is James Mitchell Blyth. I am a Director and Water Scientist at Collaborations.

2 I have prepared this statement of evidence on behalf of Greater Wellington Regional Council (**the Council**) in respect of technical matters arising from the submissions and further submissions Proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region (**PC1**).

3 Specifically, this statement of evidence relates to the matters in the Section 42A Report – Objectives and Section 42A Report – Ecosystem Health and Water Quality policies. This statement of evidence does not relate to any specific provisions in PC1 but is intended to provide an overview of the water quality modelling that informed the development of PC1.

QUALIFICATIONS AND EXPERIENCE

4 I hold a Master of Science degree (**MSc**) with first class honours from the University of Waikato.

5 I am a Certified Environmental Practitioner (**CEnvP**) under the Environmental Institute of Australia and New Zealand (**EIANZ**).

6 I am a member of the New Zealand Freshwater Sciences Society.

7 I have 15 years' experience at roles within regional councils, industry (mining) and consulting, and have worked internationally. My experience covers a range of water sciences, including water quality, water resources, hydrology, hydraulics and wetlands. Throughout my career I have been involved in numerous water balance and catchment hydrological and water quality models. While working overseas, I was a technical consulting lead in hydrological and water balance modelling, and worked on models and trained staff in Africa, Canada, Laos, Thailand and Australia. Prior to joining Collaborations, I was the New Zealand lead for integrated catchment modelling at Jacobs New Zealand.

8 I have been involved in all four Whaitua processes the Council has run to date, and most recently was a technical advisor as part of the Council's project team for Whaitua Te Whanganui-a-Tara (**TWT**). I was involved in co-developing the catchment water quality models in Ruamāhanga Whaitua, and project managing Te Awarua-o-Porirua (**TAoP**) Whaitua catchment water quality modelling. These detailed models attempted to represent the current landuse, catchments, historical climate and streamflow in order to

predict the movement of contaminants from source (i.e. headwaters) to sink (rivers, lakes or the coast), and how effective landuse mitigations could be on these contaminants at scale.

9 My experience includes preparing evidence for the High Court, expert conferencing, and evidence at council-level hearings and Environment Court cases.

CODE OF CONDUCT

10 I have read the Code of Conduct for Expert Witnesses set out in the Environment Court's Practice Note 2023 (Part 9). I have complied with the Code of Conduct in preparing this evidence. My experience and qualifications are set out above. Except where I state I rely on the evidence of another person, I confirm that the issues addressed in this evidence are within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

SCOPE OF EVIDENCE

11 My evidence covers the following topics:

11.1 The purpose of water quality models used in the TAoP Whaitua and Whaitua TWT processes and an overview of how they were used to inform Whaitua Committees to help guide the setting of Target Attribute States (**TAS**) at multiple locations within each whaitua.

11.2 A more detailed description of the specific models involved in TAoP Whaitua and Whaitua TWT processes and how they are applicable to PC1.

OVERVIEW OF FRESH WATER QUALITY MODELS IN PC1

12 The Council has invested in a range of models prior to announcing PC1, with varying degrees of complexity. The primary purpose of these models was to inform the relevant Whaitua Committee on the magnitude of water quality improvement that could occur across a catchment, following a suite of management approaches, such as adopting best practice water sensitive urban design (**WSUD**) in urban development and a range of mitigations on rural land.

13 As the two Whaitua processes in PC1 (**TAoP and TWT**) have spanned a timeframe of almost 10 years, the models developed vary depending on the time and resources available for each Whaitua Committee and the approach adopted by the respective Whaitua project

teams. This was also driven by variations in the National Policy Statement for Freshwater Management, of which three revisions occurred (2014, 2017 and 2020).

14 The most complex modelling exercise was completed in TAoP over a 3-year period, with many of the outputs from this process used as a proxy for Whaitua TWT (see paragraph 20).

15 A catchment hydrological and water quality model known as the eWater 'Source Model', which was used to guide the TAoP Whaitua Committee in setting TAS at various sites[1]. Contaminants modelled were Suspended Sediment, *E. coli*, Total Nitrogen, Nitrate-Nitrogen, Ammoniacal-Nitrogen, Dissolved Inorganic Nitrogen, Total Phosphorus, Dissolved Reactive Phosphorus, Total and Dissolved Copper, and Total and Dissolved Zinc. Outputs of this freshwater model (such as daily flow, contaminant concentrations and contaminant loads) were fed into a suite of hydrodynamic, wave, sediment transport and contaminant dispersion models within the Porirua Harbour. Further descriptions of this model are in Evidence from John Oldman[2]. This allowed a coupled modelling approach to assess how land use changes together with mitigations could lead to improvements in fresh and coastal water quality, with comparisons to attribute states relative to the National Policy Statement for Freshwater Management (**NPS-FM**) 2014 (amended 2017)[3].

16 The first step in the Source Model was the building of a baseline version that represented the most current land use configuration within TAoP at the time of the modelling (2016)[1]. The model was calibrated at a range of locations to existing hydrological data (from the Council's river flow monitoring sites) to ensure the hydrological component of the model was representative of the catchment's response to climate variations (such as rainfall). Once a suitable flow calibration was achieved, the water quality component of the model was calibrated to existing State of Environment (**SOE**) data collected by the Council. Further detail on the calibration performance can be found in paragraphs 51 to 66.

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1 Easton, S., Shrestha, M., Cetin, L., Blyth, J. and Sands, M. 2019. Porirua Whaitua Collaborative Modelling Project – Baseline Modelling Technical Report. Prepared for GWRC by Jacobs New Zealand Limited. IZ080700.

2 Oldman, J.W. 2025. Statement of Evidence – Technical Evidence Hearing Stream 2 Harbour Modelling. Prepared for PC1 for GWRC.

3 Ministry for the Environment. 2017. National Policy Statement for Freshwater Management, 2014. Amendment 2017. Ministry for the Environment, New Zealand.

17 This calibrated TAoP baseline model was then used to assess scenarios of future land and water use in TAoP whaitua where a range of scenario mitigation packages were applied[4]. Scenario packages were developed over a number of months by a modelling leadership group (**MLG**), representative of a range of technical experts, in conjunction with the Whaitua Committee and Council Project Team. These scenario packages sought to represent progressively increasing levels of mitigations on both rural and urban landuses within a catchment. The development of these scenarios meant they were repeated in Whaitua TWT without change. The scenarios modelled accommodated projected population increase to 2043, urban development (infill and greenfield) and increased road traffic. More specifically they were:

17.1 Business as Usual (**BAU**): represented the regulatory and management approach at the time, informed by the Proposed Natural Resources Plan for the Wellington Region (**NRP**).

17.2 Improved (**IMP**): an increased level of land use change and mitigations compared to the BAU scenario. Included a range of actions with the potential to minimise the impact of urban and rural land uses, such as stormwater treatment, wastewater network upgrades, riparian planting, space planting and retirement of farmland. Land use change and mitigations applied in the BAU scenario are also applied in the Improved scenario.

17.3 Water Sensitive (**WS**): Included much the same actions as Improved, but with an increase in their extent and efficacy. Land use change and mitigations applied in the BAU scenario are also applied in the WS scenario.

18 The scenarios were intended to represent a range of commonly accepted land use practices and treatment devices that can lead to water quality (and hydrological) improvements downstream, with the scale of their implementation increasing through BAU to WS scenario. This provided a sensitivity analysis about how much effort was required to maintain or improve water quality across a range of freshwater and coastal sites in the whaitua.

19 The TAoP Whaitua Committee used the relative (%) change in concentrations and loads from the scenarios and compared this to current water quality states for a range of

[4] Easton, S., Shrestha, M., Cetin, L., and Sands, M. 2019. Porirua Whaitua Collaborative Modelling Project – Scenario Modelling Technical Report. Prepared for GWRC by Jacobs New Zealand Limited. IZ080700.

attributes in the NPS-FM 2017.[3] This change in water quality with increasing levels of effort also accounted for future growth and development. TAoP Whaitua Committee members used the scenario modelling results to assign TAS at various locations. Because of the sensitivity of the harbour receiving environments in TAoP Whaitua, harbour models were also used to inform the Committee how land use practices impact outcomes in locations of the Onepoto Arm and Pāuatahanui Inlet (such as sediment settling rates or mud content[5]).

20 The TAoP Source Model was used as a proxy in the Whaitua TWT process (where limited water quality modelling was completed)[6]. Catchments of similar land use configuration (urban and rural) where identified between TAoP and TWT, and a summary was provided of the changes in water quality concentrations, loads, and attribute states from the relevant TAoP catchment modelling (i.e. nitrate toxicity improvement from B to an A attribute state).

21 This modelling information formed part of a science library consisting of hundreds of technical documents on hydrology, water quality, landuse mitigations and current state information. A freshwater Expert Panel of scientists was convened, whom used their own expertise, supported by the science library and previous TAoP modelling, to predict water quality improvement from the same modelled mitigation packages (BAU, IMP, WS) at a range of locations as if it was applied in Whaitua TWT. The Whaitua TWT Committee used the Expert Panel's advice to help set TAS. Further detail on the Expert Panel process is described in Michael Greer's evidence (paragraph 35)[7] and in paragraph 90.

22 No harbour or coastal modelling was undertaken for Whaitua TWT, unlike TAoP. This is notable, as the TAoP harbour modelling scenarios were critical to informing the TAoP Whaitua Committee's recommendation to adopt sediment load reductions (PC1 targets a 40% reduction in loads in TAoP Whaitua)[8]. The same load reduction does not apply to Whaitua TWT. In place of a harbour model, a coastal expert panel was also convened to establish coastal objectives for Whaitua TWT following an assessment of the possible

[5] GWRC. 2018. Managing contaminants in Te Awarua-o Porirua whaitua – Sediment. Whaitua Committee workshop October 2018.

[6] Blyth, J. 2022. Whaitua Te Whanganui-a-Tara Expert Panel – Proxy Modelling Catchment Assessment. Greater Wellington Regional Council.

[7] Greer, M. 2024. Statement of Evidence – Hearing Stream Two. Prepared for Greater Wellington Regional Council Plan Change 1.

[8] Greer, M.J.C., O. Ausseil, J.E. Clapcott, S. Farrant, M.W. Heath and N. Norton. 2022. Whaitua Te Whanganui-a-Tara water quality and ecology scenario assessment (Aquanet Report). Aquanet Consulting Limited, Wellington, New Zealand.

coastal response to BAU, IMP and WS scenarios[9]. The information was available to the Committee alongside the freshwater Expert Panel outputs when setting TAS.

23 The models developed at the time of the TAoP Whaitua were high quality and could be considered good or best practice nationally. The modelling approach is still robust and appropriate to present day modelling standards, based on the information available at the time of their development.

MODELLING DETAIL – TE AWARUA-O-PORIRUA WHAITUA

24 While the Source Model (see **Figure 1**) was the complete modelling package used to inform flows, loads and concentration changes for TAoP Whaitua Committee, other submodels were developed to provide *inputs* into the Source Model. A description of each submodel has been provided in the following evidence, including an overview of the Source Model.

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[9] Melidonis, M., Oliver, M., Stevens, L., & Conwell, C. 2020. Whaitua Te-Whanganui-a-Tara Coastal Assessment Report. Prepared for GWRC. GW/ESCI-T-21/16

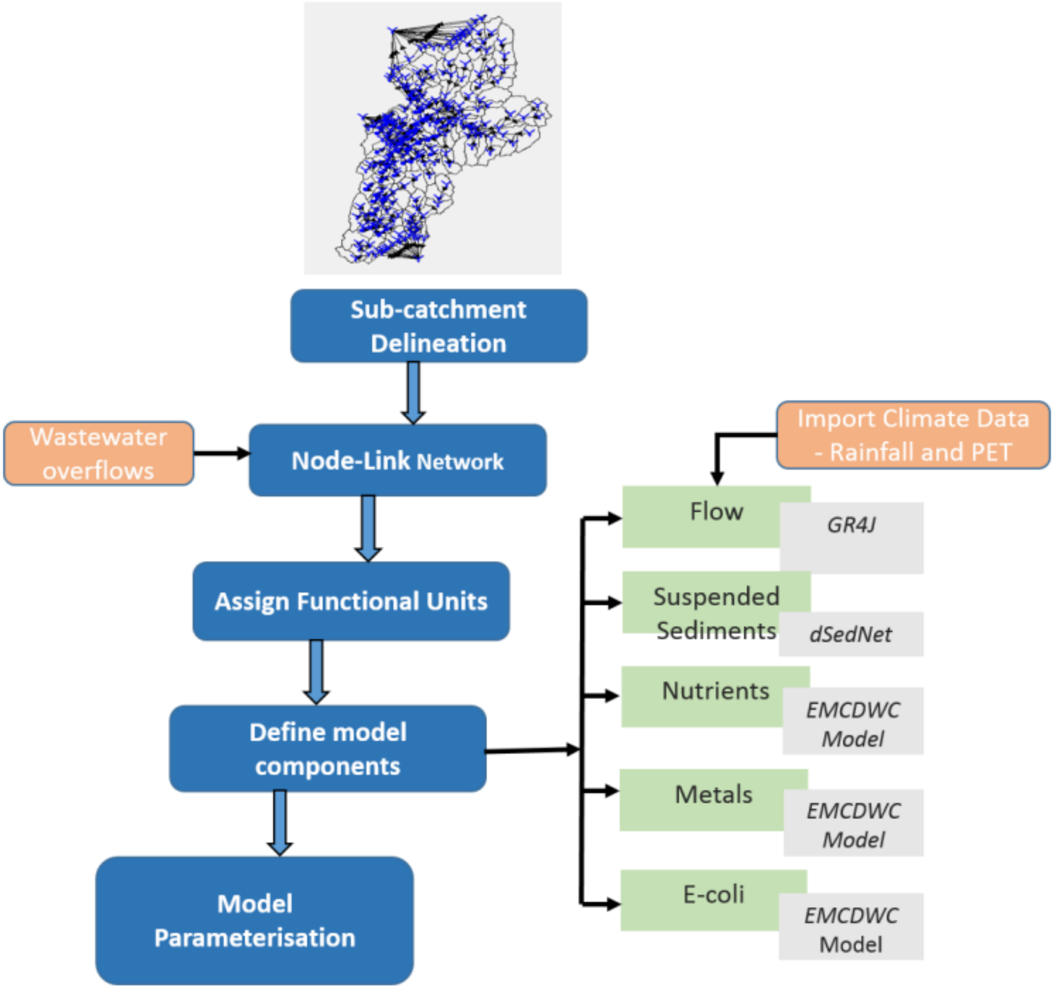

Figure 1. Overview of the Source Model developed in TAoP Whaitua process[1]. This was a daily flow and water quality model that had a number of internal modelling methods that varied by contaminant. For example, metal loads from different land uses were derived from a separate submodel, the Contaminant Load Model (CLM) that was then converted to concentrations to be used as inputs in the EMC/DWC model within Source. Further information is in paragraph 38.

SOURCE MODEL

25 The Source Model platform was developed in Australia by eWater. This was a nationally backed government organisation that sought to develop a new eco-hydrological modelling system for Australia. The eWater Source Model was developed and adopted as the National Hydrology Modelling Platform (**NHMP**) in Australia due to its ability to model water quantity, quality and environmental outcomes at various levels of complexity determined by the end user.

26 Source Models have also been developed in other regions around New Zealand for Councils including Bay of Plenty, Hawke's Bay and Tairawhiti (Gisborne) for certain catchments.

27 The Source Model has been used across several of the Council's Whaitua processes as it provides the ability to build a model that:

27.1 Spatially integrates catchment land use and practices, distributing this across a network of sub catchments and associated streams and river reaches.

27.2 Can import grid-based historical rainfall data (i.e. from **NIWA VCSN**) to account spatial and temporal variability of rainfall within a catchment.

27.3 Has sub-models embedded within the software that can simulate hydrology (i.e. rainfall runoff and ultimately, streamflow) and water quality for a range of contaminants, including movement of contaminants from overland flow, leaching or point source locations.

27.4 Can be run on any timestep, as determined by the user and application (i.e. daily, monthly, annual). Whaitua Source Models were run on a daily timestep.

27.5 Allows the user to include water allocation at exact locations, aligning with consents.

27.6 Can be calibrated for hydrology and water quality to observed data, such as Council hydrological monitoring stations or SOE monitoring sites.

28 Source Modelling was also selected by the Council for TAoP Whaitua as the model can be used for scenario testing, where the effectiveness of mitigations on improving water quality across a catchment scale can be considered. This also allows predictions of flow and water quality at un-monitored locations which is valuable in filling in gaps in understanding as costs are prohibitive to monitor everywhere.

29 The daily timestep was selected for modelling at the TAoP Whaitua scale as it provided a suitable approach to test regional changes to water quality from potential mitigations (that may eventually become policy), is reasonably efficient to run (hours) and finds the right balance in modelling complexity to simulate daily mean flows from catchments and correlate this with monthly monitoring from SOE monitoring sites. This timestep was preferable for the Council as opposed to sub-daily models that are increasingly complex to both build and calibrate, or annual average load models that provide limited information on hydrology and concentrations (which is necessary to estimate NPS-FM attribute states).

30 The TAoP Source Model utilised input data from scientific literature, spatial land use mapping, and other models, such as Contaminant Load Modelling (**CLM**), to develop a prediction of hydrology and contaminant generation across various catchments in rural and urban settings.

31 These other models that help inform the overarching Source Model are described in the following paragraphs.

CONTAMINANT LOAD MODELLING (CLM)

32 TAoP Whaitua developed a customised CLM[10]. CLM was first developed and applied by Auckland Regional Council (**ARC**) from a range of stormwater monitoring studies within the Auckland Region[11]. The TAoP Whaitua CLM is a spreadsheet-based annual average load model that was applied to a highly detailed spatial land use map of TAoP Whaitua. The CLM estimates average annual yields of contaminants (i.e. $g/m^2/year$) from certain land covers, land uses, or material types (i.e. roofs, roads, paved surfaces). This enables the quantification of average annual diffuse loads across catchments, but not concentrations of contaminants in the receiving water body. CLM also does not consider point source discharges, such as constructed wastewater overflows at distinct locations.

33 The customised CLM also draws on a 2011 SATURN traffic model to predict the number of vehicles per day (**VPD**) across all roads (from arterial to state highways), which enables those spatially mapped roads to be assigned to certain categories of contaminant yields (the highest on state highways). There are six VPD categories of roads in CLM, with increasing amounts of contaminants as VPD counts increase. Traffic modelling helps improve the spatial prediction of where contaminants, particularly metal loads such as Copper and Zinc, may be highest.

34 The customised version of CLM developed for TAoP Whaitua adopted the same ARC model but modified the yields (where possible) using local stormwater monitoring data and modern scientific literature (to 2017). This was undertaken for a range of surfaces, including roads, paved surfaces other than roads, urban grasslands and trees and

10 Moores, J., Easton, S., Gadd, J. and Sands, M. 2017. Te Awarua-o-Porirua Collaborative Modelling Project - Customisation of urban contaminant load model and estimation of contaminant loads from sources excluded from the core models. Prepared for GWRC. National Institute of Water & Atmospheric Research Ltd and Jacobs New Zealand Limited.

11 Auckland Regional Council. 2010. Development of the contaminant load model. Auckland Regional Council technical report 2010/004.

construction sites open for 12 months/year. This provides an improved estimate of local contaminant yields accounting for variations in climate and landform.

35 The CLM for TAoP Whaitua was used to estimate the total annual average load at reporting points and land use configurations for a number of contaminants, including Zinc, Copper, Total Nitrogen (**TN**) and Phosphorus (**TP**), Total Suspended Solids (urban area only) and *E. coli*.

36 The urban areas of the Source Model relied heavily on model parameters developed from CLM, while in rural areas Source Model parameterisation was informed by yields and land uses derived from Catchment Land use for Environmental Sustainability (**CLUES**) (see paragraph 40), and Daily SedNet (**dSedNet**) modelling (see paragraph 43).

37 The detailed spatial mapping (GIS layers of land use from CLM) was utilised as the input in the baseline Source Model[1] to help create urban functional units (**FUs**). FUs represent areas of similar hydrology and constituent generation, typically characterised through land use or rainfall-runoff response. When the Source Model was hydrologically calibrated to observed flow data, this involved modifying rainfall runoff parameters from each FU to try approximate the catchment's hydrological behaviour. See paragraph 51 for calibration outcomes.

38 CLM outputs were utilised in the Source Model by obtaining total load estimates (product of yield and area per FU) and dividing this by the total flow generated from each FU to produce a concentration. For the urban environment this created an Event Mean Concentration (**EMC**) for each contaminant, that was triggered and applied to flow from each FU as stormwater runoff during Source Model simulations. EMC input parameters in Source therefore represent the average concentration expected during storm events that would otherwise result in an average annual load as predicted by CLM.

39 For all other purposes of the TAoP Whaitua, the CLM was not used other than to provide inputs into the Source Model.

CATCHMENT LAND USE FOR ENVIRONMENTAL SUSTAINABILITY (CLUES)

40 Rural land use within the Source Model was derived from CLUES information provided by the National Institute of Water and Atmospheric Research (**NIWA**). This was coupled with the CLM to assign inputs in the Source Model as FUs across all TAoP Whaitua, accounting for urban and rural land use types[12].

41 CLUES was used to estimate annual average nutrient yields from rural FUs. CLUES yields from FUs for use in the Source Model were translated into Dry Weather Concentrations (**DWC**) values for TN as a leaching rate and EMC values for TP as a runoff generation rate, reflecting the physical pathway from land to stream of the respective nutrients, following the same approach described in paragraph 38.

42 The CLUES and CLM contaminant yields provided an ideal starting point for inputs to the Source Model. These were, however, modified slightly through the calibration process as discussed in paragraph 54.

DAILY SEDNET MODELLING (DSEDNET)

43 Within the Source Model is a submodel known as dSedNet. This was modelled in the rural areas to predict daily suspended sediment loads and concentrations from three erosion sources; hillslope erosion (surficial or surface erosion), landsliding and streambank erosion.

44 This dSedNet submodel is a dynamic implementation (i.e. daily timestep) of the static annual average SedNet load model that is commonly applied in New Zealand and Australia. The eWater modelling package Source is the only model that has the dSedNet plugin, which was developed to model sediment contributions to the Great Barrier Reef[13,14].

45 Complexities of how the dSedNet model functions is described in the TAoP Baseline Modelling Report[1], however has been summarised below for clarity.

[12] Green, M., Stevens, L., and Oliver, M.D. 2014. Te Awarua-o-Porirua Harbour and catchment sediment modelling: Development and application of the CLUES and Source-to-Sink models. Greater Wellington Regional Council, Publication No. GW/ESCI-T-14/132, Wellington.

[13] Waters, D.K., Carroll C., Ellis, R., Hateley L., McCloskey G., Packett R., Dougall C., Fentie. 2014. Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Whole of GBR, Technical Report, Volume 1, Queensland Department of Natural Resources and Mines, Toowoomba, QLD (ISBN: 978-1-7423-0999).

[14] Ellis, R.J. 2018. Dynamic SedNet Component Model Reference Guide: Update 2017, Concepts and algorithms used in Source Catchments customisation plugin for Great Barrier Reef catchment modelling. Queensland Department of Environment and Science, Bundaberg, Queensland.

46 Surficial erosion is modelled across the TAoP Whaitua in Source as the Revised Universal Soil Loss Equation (**RUSLE**). This predicts erosion at a grid, and accounts for rainfall erosivity, soil erodibility, slope steepness and length, land cover and land practices. Rainfall erosivity was calculated daily from NIWA virtual climate station network (**VCSN**) rainfall data, of which the timeseries available spanned from 1972 to 2016.

47 The proportion of surficial erosion that reaches a stream reach (within Source Model) was reduced through a Sediment Delivery Ratio (**SDR**), a common approach in sediment modelling. SDR was calculated by catchment area and had a mean of 0.56 in TAoP.

48 Streambank erosion is related to high flow events. This was modelled using a custom function in the Source Model for each stream network link greater than order 2, where flows greater than the 99.8th percentile (approximately the Mean Annual Flood) for that link would trigger streambank erosion. The quantity of sediment (kg/day) was based on the streamflow and calibrated constants and exponents (based on a calibration to annual loads).

49 Landslide erosion is typically confined to steep slopes (i.e. >26 degrees), with greater proportions of landslides on pastoral land. A rainfall-triggered power function was incorporated in the dSedNet model to represent shallow landslides, applied to all rural grassland and scrub and urban grassland FUs that occur over steep land as defined by the New Zealand Land Resource Inventory (**NZLRI**)[15]. This is dependent on preceding rainfall over a 3-day period and a rainfall intensity threshold >30 mm/d.

50 dSedNet modelling is therefore imbedded within the Source Model and requires the hydrological modelling components (such as streamflow and daily rainfall) and FUs to be able to simulate events such as landsliding and streambank erosion. This differs from the static annual average load model, SedNetNZ, that predicts a long-term estimates of sediment in a spatial application from the same erosion processes.

SOURCE MODEL CALIBRATION

51 While development of these Source Model inputs followed best practice, calibrating the model to known observed hydrology and water quality data was necessary to ensure the

[15] Lynn IH, Manderson AK, Page MJ, Harmsworth GR, Eyles GO, Douglas GB, Mackay AD, Newsome PJF 2009. Land Use Capability survey handbook – a New Zealand handbook for the classification of land. 3rd edition. AgResearch Hamilton; Manaaki Whenua Lincoln; GNS Science Lower Hutt, New Zealand.

inputs were scaled to levels appropriate for what was being reflected in reality (i.e. in-stream concentrations).

52 For hydrology, this involved modifying rainfall runoff parameters for each functional unit to achieve appropriate calibrations at the four Council river flow monitoring sites in TAoP Whaitua[1]. Refer to Figure 2 for the calibration site locations. The calibration periods varied depending on record length, with the longest being Porirua Stream at Town Centre (1972 to 2016) and the shortest Horokiri Stream at Snodgrass (2002 to 2016). When assessed following widely accepted international modelling practice[16], hydrological calibrations of simulated streamflow were 'satisfactory' at Porirua Stream at Town Centre and Taupo Stream at Flax Swamp and 'good' at Horokiri Stream at Snodgrass and Pāuatahanui Stream at Gorge.

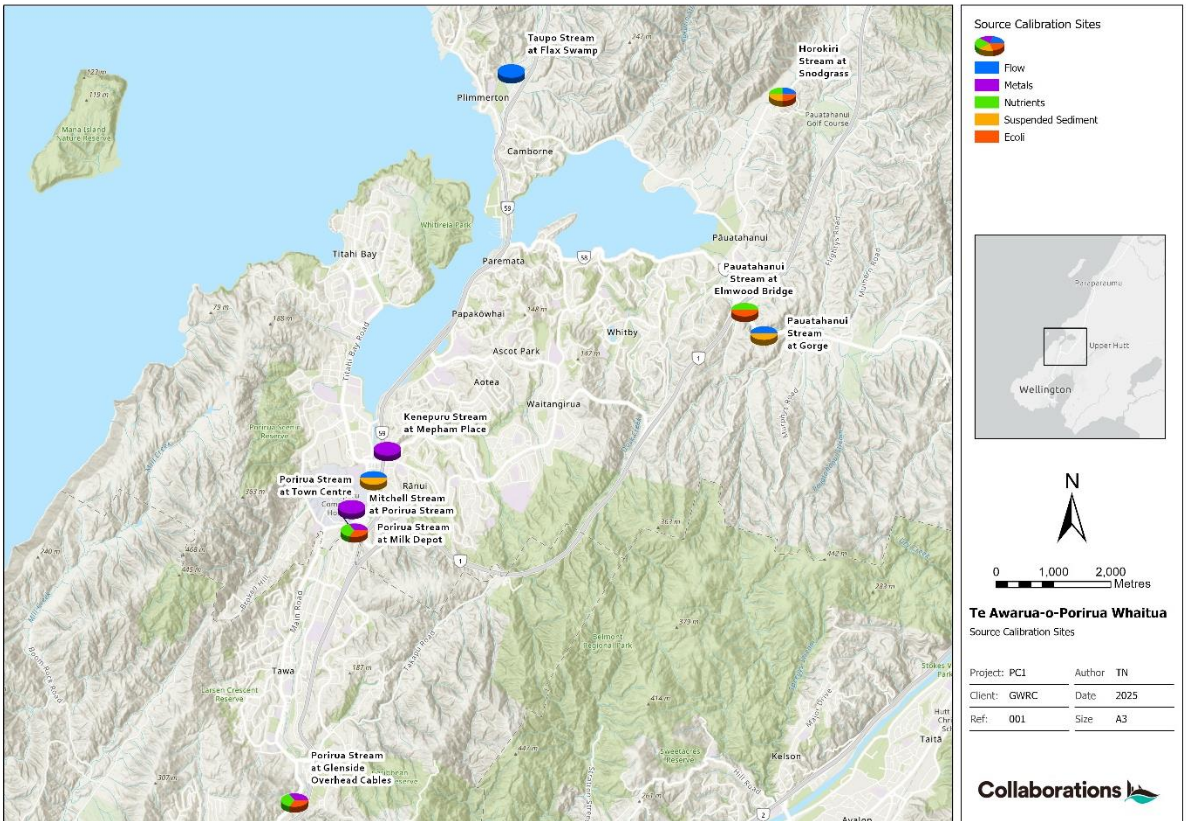

Figure 2. TAoP Source Model calibration sites for flow, nutrients, metals, suspended sediment and E. coli.

16 Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D. and Veith, T. L. 2007. Model Evaluation Guideline for Systematic Quantification of Accuracy in Watershed Simulations. Transactions of the ASABE 50 (3), 885–900.

53 Hydrological validation of those four sites all returned a ‘good’ modelling criteria, indicating that the adopted calibration parameters are suitably predicting streamflow for alternative time and rainfall periods.

54 Water quality calibration[1] involves attenuating generated contaminants (from FUs) by lowering their loads to align with concentrations in observed monitoring data. These factors simplify complex natural processes such as denitrification, filtration, and deposition into a lumped load reduction. Attenuation factors are common in all modelling (for example, the SDR in dSedNet is an attenuation factor) and there are acceptable ranges within literature.

55 Within the Source Model, the primary mechanisms to attenuate and calibrate loads to match observed concentrations was by modifying the inputs within acceptable literature bounds (i.e. changing initial EMCs and DWCs) and/or applying decay functions (half lifes) within the modelled stream reaches. Greater attenuation (load reduction) was evident through calibration in the rural environment (compared to urban) for all contaminants.

56 Calibration time periods of nutrients, sediment, metals (Zinc and Copper) and *E. coli* varied depending on the length of the observed dataset available from Council SOE river monitoring sites (see Figure 2 for calibration site locations). For example;

56.1 Nitrogen and phosphorus species had a 15 year calibration period (2001 to 2016) at three sites, with validation occurring at a fourth site.

56.2 Metals were calibrated at two sites, with ~8 years of monthly data (~2008 to 2016), and validated at two sites with only 12 months of data (2011 to 2012).

56.3 Sediment was calibrated to autosampling data at three sites, with ~3 years of continuous measurements (~2012/13 to 2016).

56.4 *E. coli* monitoring data was available at four sites and used to calibrate a 13 year period (2003 to 2016).

57 Nitrate calibration[1] was considered ‘good’ based on international performance criteria[16], although primarily underpredicted concentrations compared to observed data. This is in part driven by the smaller urban catchments where event-based flows are sub-daily, but hydrology is represented in a daily timestep, and where unknown contaminant sources are present in the observed data, but not directly in the model (such as sewer leaks or cross-connections).

58 Similarly, phosphorus calibration was also ‘good’, however tended to overpredict the simulated median concentrations but underpredict some of the event based (95th percentile) concentrations when compared to observed data.

59 While the Source Model simulated total and dissolved metals (Zinc and Copper), calibration and validation only occurred for the dissolved fraction, as no total metal concentrations were available in SOE data. The event mean concentrations, or EMCs, (see paragraph 38) derived from CLM and simulated hydrology represented total metals, and were therefore mitigated/attenuated to calibrate to dissolved forms of Zinc and Copper, to 10% and 30% of the total metal EMC, respectively. This process of calibration helps reduce uncertainty in yield estimates (i.e. copper load from paved surfaces) in the CLM.

60 Metal calibration was considered ‘very good’ at Porirua Stream at Glenside, and ‘satisfactory’ for Porirua Stream at Milk Depot, based on comparison to international literature[16]. Due the modelling architecture (i.e. daily timestep, catchment size) and SOE monitoring data being collected monthly (rather than event based), the model generally overestimated simulated mean and medians concentrations, and under-estimated event based (95th percentile) concentrations.

61 The dSedNet submodel within the Source Model was calibrated for suspended sediment daily load using observed data in TAoP from three continuous turbidity monitoring stations, which had been corrected to suspended sediment concentrations (Porirua Stream at Town Centre, Pauatahanui Stream at Gorge, and Horokiri Stream at Snodgrass)[1]. These sites had approximately three years of continuous monitoring, and while this monitoring is temporally highly detailed, the short duration may not be a full reflection of climatic variability and sediment loads that could be generated from large rainfall events.

62 Calibration of sediment for the monitoring period was ‘satisfactory to very good’ at Pauatahanui Stream at Gorge, and ‘very good’ at the other two sites, depending on the calibration metric. Figure 3 presents the calibration exceedance distribution for Porirua Stream at Town Centre, showing the robustness of the dSedNet modelling to estimate sediment loads over the calibration period. Comparison of the Source Model against other national sediment modelling tools (the Suspended Sediment Yield Estimator and SedNetNZ) confirms its reliability in predicting loads close to the observed data (see Table 1).

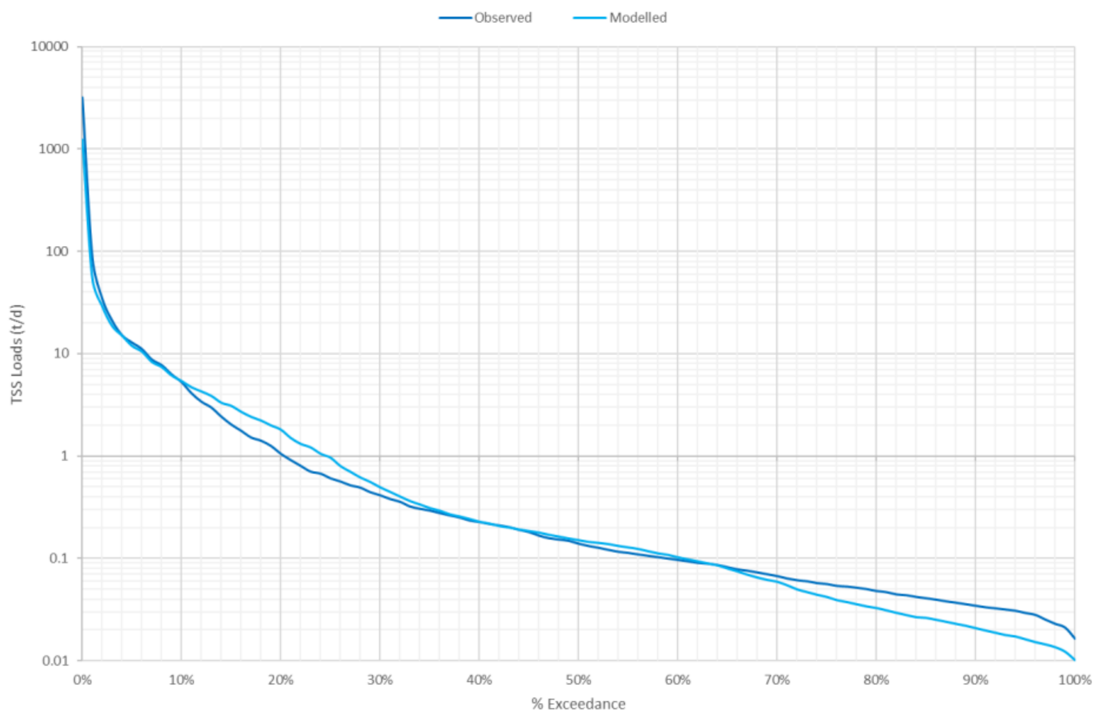

Figure 3. Modelled and observed daily total suspended sediment loads for Porirua at Town Centre from 1 May 2012 to 21 July 2016

Table 1. Annual average sediment loads (tonnes/year) from TAoP Source Model compared to observed data and other national sediment modelling tools.[1]

Model	Porirua at Town Centre	Horokiri at Snodgrass	Pauatahanui at Gorge
Area (ha)	3,992	2,884	3,838
Observed load[1] (2012/13-2016) (t/year)	2,092	1,483	2,616
Suspended Sediment Rating[2] (t/year)	N/A	N/A	2,958
Jacobs modelled (1975-2016) (t/year)	3,377	1,187	2,634
SSYE (t/year)	3,924	4,937	2,999
SedNetNZ Total Hill Erosion (t/year)	13,682	7,813	17,105
CLUES[3] area (ha)	4,108	3,306	4,168
CLUES[3] load (t/year)	8,206	8,162	8,066

Notes
1. Converted from observed continuous turbidity, see Table 4.1 for dates of record
2. Hicks et al., 2011.
3. Green et al. 2014, table 2.8. Loads are to the stream mouth.

63 Modelling human health effects in the Source Model was undertaken with EMCs generated from the customised CLM, as described in paragraph 32 and 38. Rural *E. coli* generation rates were derived off CLUES modelling, however had to be adjusted within literature ranges to better fit observed concentrations.

64 *E. coli* modelling incorporated wastewater overflows as point sources in the Source Model, with location and frequency of wastewater overflows modelled in MOUSE (Model for Urban Sewers developed by Danish Hydraulic Institute (**DHI**)) by Mott MacDonald for Wellington Water[1]. The time-series of wastewater overflow volumes at 223 locations was amalgamated in the Source Model to 48 locations, aggregated at the sub-catchment level. The timeseries was simulated for a 10-year period between 2005 and 2014 inclusive. This period was chosen by the MLG in TAoP Whaitua as representative of a range of climatic conditions. It is worth noting that wastewater overflows were also assigned average concentrations for sediment, nutrients and metals as provided by Wellington Water, which influenced concentrations, particularly at the 95th percentile[1].

65 *E. coli* calibration compared modelled daily concentrations to corresponding daily sample observations at four SOE sites (see **Figure 2**). Simulated *E. coli* concentrations were very good for three sites, and satisfactory at one site. The model performed well at predicting the 95th percentile concentrations (i.e. event based), due to the detailed inputs from the MOUSE modelling, however in the rural environment (Horokiri and Pāuatahanui Streams) had some underprediction of the median concentrations[1].

66 The baseline Source Model[1] was calibrated to observed data for flow and contaminants, and predicted the NPS-FM (2017)[3] attribute states, and custom attribute states (for dissolved copper and zinc) at calibration sites well for all contaminants. While the model may not represent all contaminant and flow pathways in finite detail on a sub-daily timestep, it provided a sound mechanism (using the best available data and literature) to estimate effects of future land use changes (growth and development) with the ability to test mitigation scenarios (see paragraph 17).

SOURCE SCENARIO MODELLING

67 As discussed in paragraph 17, the calibrated baseline Source Model was then used to test three different mitigation scenario packages: BAU, IMP and WS. This has been discussed in detail in a technical report, with the outputs predicting changes in loads, concentrations and water quality attribute states (i.e. *E. coli* attribute state of E changing to a C under the Water Sensitive scenario)[4].

68 The climatic time period selected by the MLG and the Council to run the scenarios was 2005-2014 inclusive (10 years on a daily time step), which accounted for inter-annual

variability and overlapped with previous calibration periods to existing monitoring data and other modelled inputs (such as Wellington Water's wastewater overflow modelling).

69 The resulting change in daily loads and concentrations from each scenario were subsequently derived from this decadal simulation, which was then used to determine the change in the mean, median, and 95th percentile concentrations for each attribute (i.e. dissolved zinc) from the baseline modelling.

70 No climate change modelling was undertaken in the Source Model, and from my understanding, only verbal conversations were held with the Whaitua Committee on climate change predictions. Subsequently, it could be assumed that the setting of TAS by the Whaitua Committee (off scenario results) may only account for climate change in a qualitative manner.

71 While I was not involved in these discussions, I believe the reason no climate change modelling was undertaken (based on my understanding from anecdotal conversations with staff involved) was due to limited methods available that could reliably modify climate inputs from NIWA VCSN at the time, for the required spatial resolution in the Source Model. In addition, the scenarios (see paragraph 17) were considered to provide a sensitivity analysis of the relative changes in water quality with increasing mitigation effort, and that the addition of climate change modelling would make it difficult to realise the positive or negative impacts of alternative practices being implemented amongst further growth.

72 The number and extent of mitigations increased from BAU through to the WS scenarios, however primarily involved:

72.1 Modifying land use and water quality parameters within the model aligning with growth and a mitigation practice, such as increased urban infill, greenfield and lifestyle blocks to 2043, or changing rural pastoral land use to 'native forest' (where it was retired in the mitigation scenario).

72.2 Reducing wastewater overflow frequency to reflect greater investment in three waters infrastructure.

72.3 Treating urban and road stormwater runoff with best practice WSUD practices, such as bio-retention, media filtration and catchment scale mitigations like constructed wetlands.

72.4 Hydrological modifications due to mitigations such as the implementation of rainwater tanks on new dwellings, or changing runoff parameters where land use may be retired or streams are fenced and riparian planted.

73 Mitigations were considered to be in full effect at the stated treatment rate in each scenario. There was no 'development time' applied in the model to represent the establishment of a mitigation or its performance improvement over time (for example, planting of poles often requires ~7 years to establish and up to 15 years to reach maturity where sound interlocking root structure is present, stabilising hillslopes from landsliding)[17].

74 The three scenarios provided a good indication of the extent of effort required to result in a certain level of water quality improvement, with some large mitigation packages simulated. For example, the Water Sensitive scenario considered reducing wastewater overflows from an average of 12 to two per year, and retiring LUC class 6e, 7e and 8 pastoral land (along with other mitigations).

75 The outputs of these scenarios were used by the TAoP Whaitua Committee to guide the setting of TAS at various catchments and by certain timeframes, and also used in the TWT Whaitua proxy catchment assessment[6].

MODELLING DETAIL - TE WHANGANUI A TARA WHAITUA

76 Modelling for the Whaitua TWT process was reduced in scale compared to TAoP Whaitua process. This was for a number of reasons including Council and Committee desires to complete the Whaitua process in a shorter period. Further, a new version of the NPS-FM was gazetted in 2020[18] in the middle of the Whaitua TWT which somewhat changed what the Whaitua Committee needed to deliver on.

77 Subsequently, there was not sufficient time to build and calibrate a complete baseline hydrological and water quality Source Model for the Whaitua TWT process. Alternative approaches were necessary to help inform the Committee on potential improvements that may be achievable in water quality through improved management of land and water in urban and rural environments.

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17 Douglas, G.B., McIvor, I.R., Manderson, A.K., Todd, M., Braaksma, S. & Gray, R.A. (2010). Effectiveness of Space-Planted trees for controlling soil slippage on pastoral hill country. AgResearch Grasslands, Plant and Food Research, Horizons Regional Council and Greater Wellington Regional Council.

18 Ministry for the Environment. 2020. National Policy Statement for Freshwater Management 2020. Ministry for the Environment, New Zealand

78 This was primarily completed through an Expert Panel process. See Michael Greer's evidence for more detail (paragraph 35)[7] and paragraph 90 for a description of this process.

79 To support this Expert Panel, a number of models were developed to provide advice on baseline catchment loads including CLM and dSedNet models discussed below. These models were useful for the Whaitua Committee and Expert Panel in understanding landuse proportions, catchment load contributions and potential 'hot spots' in contaminants. In addition, a proxy catchment assessment was completed, as described in paragraph 20. No scenarios (i.e. Improved or Water Sensitive) were modelled due to time constraints.

CONTAMINANT LOAD MODEL (CLM)

80 As described in paragraph 32, a CLM was built for Whaitua TWT using the customised input parameters for Wellington[10]. The purpose was to provide an overview of where urban contaminants (Total Suspended Solids (**TSS**), Total Zinc, Total Copper, Total Phosphorus, Total Nitrogen, and *E. coli*) may be coming from to help identify land uses that are problematic or catchments with high loads. This was used by the Expert Panel and the Whaitua Committee to help inform Whaitua Implementation Plan (**WIP**) recommendations.

81 The TWT CLM[19] was built in 2019/2020. This utilised spatial zoning and aerial imagery from 2012/13, and the Land Cover Database (**LCDB**) v4.1, which aligns the land use with the same period as TAoP CLM.

82 No scenario modelling (i.e. BAU, Improved or Water Sensitive) was undertaking using this baseline CLM due to Whaitua time constraints.

DAILY SEDNET MODELLING (DSEDNET)

83 A dSedNet model[20] was developed within a Source Model for Whaitua TWT to provide an estimate of baseline sediment loads, predictions of suspended sediment concentrations (**SSC**) and the differences in sediment generation between catchments in their current

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[19] Easton, S., and Hopkinson, O. 2020. Contaminant Load Model Development – Whaitua Te Whanganui-a-Tara. Prepared for Greater Wellington Regional Council. IZ130500.

[20] Easton, S., and Cetin, L. 2020. dSedNet model development and results – Whaitua Te Whanganui-a-Tara, Prepared for Greater Wellington Regional Council. IZ130500.

state. This information was used by the Whaitua Committee and Expert Panel to assess variations in sediment contribution by catchment.

84 This first required a hydrological model. The same submodel and calibrated parameters from the TAoP Source Model[1] were applied to TWT catchments and functional units, and the predicted daily flow was validated at four Council hydrological monitoring stations (see **Figure 4**); Hutt River at Taita Gorge, Mangaroa River at Te Marua, Wainuiomata River at Leonard Wood Park and Whakatikei River at Dude Ranch.

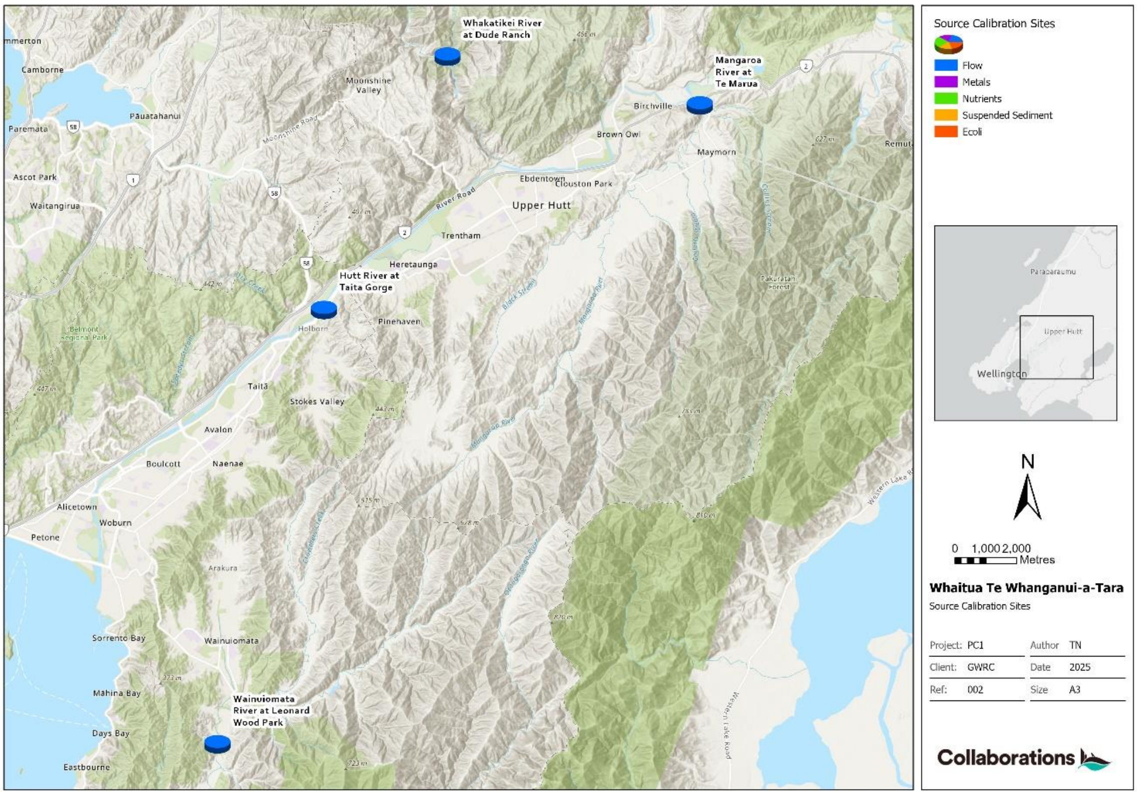

Figure 4. Flow validation sites used in the baseline TWT Whaitua dSedNet model.

85 Hydrological validation comparisons focussed on matching high flows for sediment load prediction, and overall was considered satisfactory to international standards[16] for the purposes of load estimation.

86 The same dSedNet modelling approach undertaken in TAoP, including calibrated sediment parameters for streambank erosion and landsliding, was applied in Whaitua TWT Source Model. Unlike TAoP Whaitua there was no continuous monitoring data available to validate the model. However, the model was compared to other national sediment models and to two autosampled flood events captured in 2019.

87 Sediment modelling results from dSedNet that were validated against the limited monitoring data and other national models were acceptable to assume a re-calibration. was not necessary at this time, and that the model could adequately predict baseline sediment loads to help inform the Whaitua Committee and Expert Panel.

88 The Source Model for Whaitua TWT was not used for any other water quality modelling and is representative of a baseline hydrological and sediment model only, that has been validated, but not re-calibrated. The outputs of this model (annual average load estimates by catchment) have been used to predict sediment load reductions required to meet visual clarity targets, particularly where the current median clarity falls below NPS-FM 2020 national bottom lines[18]. The sites where this is applicable has been detailed in Section 9 of Greer *et al*. 2024[21] .

EXPERT PANEL

89 An overview of the Whaitua TWT Expert Panel has been presented in paragraph 20, Michael Greer's evidence (paragraph 35)[7] and in detail in the technical report produced by the panel for the Whaitua Committee[8].

90 The approach involved the selection of a number of expert scientists with experience in the region and with the NPS-FM (2020). A science library was available to the Expert Panel, which provided a collection of local, national and international scientific literature, technical reports and assessments. The Expert Panel utilised this background information and an understanding of the current state of water quality attributes[18] and land use in six different spatial areas to then assess how these areas and attributes may respond under different mitigation scenarios (**BAU, IMP and WS**). Four tiers of attributes were considered;

90.1 Tier 1 attributes were dissolved metals (Zinc and Copper), nitrogen (Ammonia, Nitrate toxicity and Dissolved Inorganic Nitrogen), Dissolved Reactive Phosphorus, Fine Suspended Sediment, faecal matter (*E. coli*) and hydrological flow.

90.2 Tier 2 attributes were plant growth (Periphyton Cover, Macrophytes and Cyanobacteria), as driven by Tier 1 attributes,

[21] Greer, M.J.C., Blyth, J., Eason, S., Gadd, J., King, B., Nation, T., Oliver, M., Perrie, A. 2023. Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region. Torlesse Environmental Limited, Christchurch, New Zealand.

90.3 Tier 3 attributes were invertebrate community health (through the Macroinvertebrate Community Index or **MCI**) and fish diversity, affected by both Tier 1 and 2 attributes, and

90.4 Tier 4 attributes were the holistic ecosystem health effects (accounting for Tier 1 to 3) and suitability of contact recreation (swimming/wading).

91 Individual assessments of the predicted change in water quality were completed by each panellist, with their level of confidence assessed in a scale (0 to 3). Individual assessments were compiled and jointly discussed with the panel to create a 'final' expert panel recommendation, with any disagreements noted.

92 This output was used to predict water quality attribute state changes across the spatial units which was then disaggregated to the catchment level to help in the setting of target attribute states by the Whaitua Committee.

CONCLUSION

93 The Council has invested in a number of models across both Whaitua. The purpose of these models was to provide an understanding of baseline conditions (such as catchments that may generate higher loads than others) and inform the Whaitua Committee on current water predicted quality states, even across un-monitored locations. These models also provided a future prediction about the health of waterbodies in the face of population growth and effectiveness of various levels of landuse management or mitigations.

94 Simplified annual average load models (such as CLUES and CLM) were built and customised for the Wellington Region to provide the best estimate of contaminant yields and loads by land use. This information was fed into more complex models such as the TAoP Source Model, which reduced the modelling timestep (to daily) with the aim of representing the existing hydrological and water quality conditions in greater detail.

95 The TAoP Source Model was built and calibrated to Council daily flow and monthly SOE water quality monitoring data at a number of locations, which formed a robust and reliable modelling approach to ensure the model predicted the movement of water and contaminants across the existing (~2012) landscape appropriately.

96 This calibrated baseline model enabled the simulation of three mitigation packages (BAU, IMP, WS) that predicted the health of the water bodies and water quality changes in the face of future growth and development, with the adoption of a range of mitigation

strategies such as comprehensive WSUD and rural land use change. Scenario simulations were run on a daily timestep over a 10-year period from 2005-2014 (inclusive) to capture a range of climatic variations which would influence hydrology and contaminant transport. The outputs of this Source Model were fed into a dynamic harbour model in TAoP Whaitua to predict the movement of sediment and settling in various arms of the harbour, which the Committee used to understand the level off effort required on land to achieve coastal objectives.

97 In my opinion, the TAoP Source Model was a robust approach to consider the relative changes in loads and concentrations across a broad landscape such as the Whaitua through the adoption of a range of interventions.

98 While the Whaitua TWT did not build a complete Source Model, the outputs from the TAoP Source Model were used in this Whaitua process as a 'proxy' to help inform the Expert Panel about how mitigation scenarios could achieve potential reductions in contaminants. I consider this to be appropriate given the similarities in landuse, climate and landform across TAoP and TWT, and that this proxy modelling information was also considered amongst a wider resource (the science technical library) and debated robustly amongst five qualified freshwater scientists.

99 Subsequently, both Whaitua Committees utilised outputs from complex modelling approaches and the same mitigation scenario packages to assess potential improvements in water quality, that they then used to identify and suggest TAS at various catchments.

100 Whilst the plan change provisions were not modelled in a Source Model, due to the timing of PC1 and staging of the various Whaitua, the models informed the TAS that inherently provisions were drafted around.

DATE: 28 FEBRUARY 2025

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