Manaaki i ngā taonga i tukua mai e ngā tupuna:

Investigating Action-Orientated Climate Change Transitions to Water-Based Land Uses that Enhance Taonga Species

Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating Action-Orientated Climate Change Transitions to Water-Based Land Uses that Enhance Taonga Species

Professor Huhana Smith[1]
Derrylea Hardy[2]
Dr Rebecca Eivers[3]
Dr Christian Zammit[4]
Mercia Abbott[1]
Moira Poutama[5]

[1]Whiti o Rehua School of Art, Toi Rauwhārangi College of Creative Arts, Massey University, Wellington; School of People, Environment and Planning, Massey University[2]; Waiokōkopu Consulting[3]; NIWA[4]; Te Iwi o Ngāti Tukorehe Trust[5].

Published by the Horowhenua Coastal Climate Change Project Research Team

Funded by the Deep South National Science Challenge, Vision Mātauranga
Main Contract Holder: Massey University, Contract C01X1901

Reviewed by Rhian Salmond

Recommended citation:
Smith, H., Hardy, D.J., Eivers, R., Zammit, Z., Abbott, M., Poutama, M. (2022). *Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating Action-Orientated Climate Change Transitions to Water-Based Land Uses that Enhance Taonga Species.* Massey University, Palmerston North.

Horowhenua Coastal Climate Change Research Team (Project C01X1901)

Published by the Horowhenua Coastal Climate Change Project Research Team

C01X1901 Contract Holder:

School of People, Environment and Planning

Massey University

Private Bag 11052, Palmerston North, New Zealand

Image on front cover:

Field work by te tupuna awa - Ōhau River, 13 November 2020. Photograph by Huhana Smith

ISBN (digital): 978-0-9951027-7-4
ISBN (print): 978-0-9951027-6-7

EXECUTIVE SUMMARY

This report builds upon our considerable body of research and action taken for awa and whenua within the Waiwiri to Waitohu Stream hinterlands within Horowhenua to Kāpiti including the MBIE-funded Manaaki Taha Moana project (2009-2015, MAUX0907) and two consecutive Deep South National Science Challenge Challenge projects, (2015-2017, CO1X1445; and 2017-2019, C01X1412). In the third phase of this research, *Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating Action-Orientated Climate Change Transitions to Water-Based Land Uses that Enhance Taonga Species* (2020-2022, C01X1901), considers climatic, ecological and hydrological variables that might foster or inhibit the revitalisation of coastal taonga species – in particular, tuna (eels) and īnanga (whitebait).

Our coastal climate change research team worked intimately with key whānau and hapū members, including a refreshed farm board of directors and chair of Tahamata Incorporation from early 2021. The research team expanded to bring expertise in regenerative agriculture and sustainable farming practices to the Tahamata Incorporation farm board. The overall project was led by Professor Huhana Smith (Toirauwharangi College of Creative Arts at Massey University, Wellington) with Derrylea Hardy (research officer/project manager, Massey School of People, Environment and Planning), Mercia Abbott (Māori Massey Master of Design student), Dr Rebecca Eivers (freshwater ecologist, Waikōkopu Consultancy), Dr Christian Zammit (hydrologist, NIWA) and Moira Poutama (lead iwi researcher). Additional project support came from Rangimarkus Heke (iwi researcher at start of the project), Hadyn Fowler (Australian environmental artist), Maija Stephens (documentary photographer, Massey Māori student completing a degree in Photography) and Rachel Summers (GIS mapping, Massey School of People, Environment and Planning).

The research asked: *How can Māori land owners transition from agriculture to other land uses which enhance taonga species, including tuna and īnanga.* The team aimed to design the needs for more sustainably managed tuna and īnanga nurseries by the Ōhau River within Tahamata Incorporation farm, particularly in known īnanga or whitebait spawning areas south of the Ōhau loop area towards sea. The visual stocktake document has been collated for further discussion with shareholders and the farm board, as it became clear throughout the progress of this project that wider areas needed investigation, not just along the Ōhau River south of the loop.

Due to ongoing Delta to Omicron COVID variant restrictions and a range of delays experienced by the research team to hold group face to face events, we turned extensively to ZOOM hui. While field work continued on site, we collated data into a final digital wānanga that was presented on 7 October 2021 in two parts – one to shareholders and the other to interested local, regional council and other environmental bodies' representatives. A synthesised and edited version of these two presentations was then shared to help whānau and farm shareholders understand the intentions and findings of our reseach action, and for them to adjust their thinking to the complexities raised therein. The research team acknowledges that we must fast track adaptions with the changing climatic conditions experienced in 2020 and 2021. There were repeated disruptions to coastal farming business where the Board and shareholders are now witnessing more climate impacts in the coastal rohe. It was not lost on the team that climate change was happening during the research period with repeated flooding events of medium to major severity, from 16 July to 7 December 2021. We were experienced stronger, longer and more frequent flooding events, and more shocking disruptive events (such as the recent tornado and hailstorm in Levin, Horowhenua on Friday 20th May 2022), as well as changing surface and groundwater levels.

Our collaborative efforts relate to the Te Mana o Te Wai framework, within the Ministry for the Environment's Action for Healthy Waterways, government intitiatives for freshwater reforms[1], the recent National Adaptation Plan for climate change, read alongside Ihirangi's Rauora report too. Our methodologies are not unlike the aspirations within the Rauora report, as we increase whānau/hapū participation in our research in order to ensure effective adaptation to our changing climate via our digital wānanga, and our hui and hīkoi when we could meet. However, it is the wider region's Joint Climate Action Committee, convened by Horizons Regional Council, that is drawing on all these elements and grounding the space in indigenous knowledge systems.

Additionally, the iwi researchers continue to draw upon the skill sets of artists and designers with *Te Waituhi ā Nuku: Drawing Ecologies* group, who are working closely with the reutable contemporary art institution the Govett Brewster Art Gallery in Ngāmotu New Plymouth. The aim is to showcase creative converging co-intelligences, for reimagining enhanced futures for all, from 2022-2024.

[1] Our work is informed by 2020 National Climate Change Risk Assessments report, and more recently the National Adaptation plan (2022). We are enanmoured by an emphasis on driving the values and principles of the Ihirangi indigenous leaders Rauora Report 'Exploring An Indigenous Worldview Framework for the National Climate Change Adapation Plan' 2021, however this needs to be lead by iwi and hapū, not Ministries.

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ACKNOWLEDGEMENTS

Mai i Ohaunuiananaia ki Waikawa ki te hukahuka o te tai,

ara te puwaha o Ōhau; ki te Pou o Ngāti Pareraukawa.

Ko Tirotirowhetu kei ko mai, ko te Pā Harakeke kei ko atu,

ko Te Hākari tiro whanui atu ko Tahamata,

kei te tua whenua ko Tikorangi, ko Poroporo, ko taku tuara tonu,

ko te pae maunga ko Tararua, ko ana Poutihi

hei turangawaewae mo te tupuna a whare o Tukorehe.

We wish to acknowledge the participation and input of the Board of Directors from Tahamata Incorporation, without whom this research would not have been possible. We also acknowledge the support, assistance and contributions of key whānau and hapū members from Ngāti Tukorehe for this project, including Dr Aroha Spinks (former Kaihautū Taiao / Environmental Science Director of WWF New Zealand) and her children; and Rangimarkus Heke who attended wānanga and hui in the initial stage of the project. We also acknowledge Australian environmental artist, Hadyn Fowler, who helped with the visual stocktake of opportunities for the Tahamata coastal Ōhau riverine region; Maija Stephens, a Māori documentary photographer who is completing her Degree of Photography) at Massey university as part of this project; Sita Venkateswar and Rachel Summers from Massey University's School of People, Environment and Planning, who contributed to our Regenerative Agriculture conversations via SREF Massey funded research and the GIS mapping work.

1 INTRODUCTION

1.1 Overview and Project Funding

This report gives an account of the research project entitled, *Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating Action-Orientated Climate Change Transitions to Water-Based Land Uses that Enhance Taonga Species (2020-2022, C01X1901).* The report provides stakeholders and funders of the project with an overview of how the project was conducted and its main research findings. It is also hoped that the research findings are beneficial to other Māori coastal communities throughout New Zealand who are grappling with the impacts of climate change in their rohe and how they are considering their adaptations to live with such uncertainty, be more resilient and better prepared.

The Deep South Te Kōmata o Te Tonga National Science Challenge (NSC)[2] is hosted by the National Institute of Water and Atmospheric Research (NIWA). Its mission is to enable New Zealanders to adapt, manage risk and thrive in a changing climate. The Deep South NSC is also working to understand the role of the Antarctic and Southern Ocean in determining New Zealand's future climate and the impact this role has on key economic sectors, infrastructure, and natural resources.

This research is funded by Deep South NSC – Vision Mātauranga (VM) - one of the five programmes, which aims to strengthen the capacity and capability of iwi/hapū/whānau and Māori business to deal with climate change impacts, risks, and adaptation: Ko ngā mahi inaianei hei oranga mo rātou āpōpō.

The five strategic elements of the VM programme are:

1) Kaupapa Māori research principles
2) Governance Māori
3) Engagement, collaboration, and partnerships
4) Research capability, capacity, and leadership
5) Transformative context and future-focused research.

The science projects are built around four research themes:

- Understanding climate change - linkages, pressure points and potential responses.
- Exploring adaptation options for Māori communities.
- Assistance to Māori businesses to aid decision-making and long-term sustainability.
- Products, services, and systems derived from mātauranga Māori.

In early-2015, the Deep South NSC funded an initial project with $250,000. This Phase 1 research and findings are summarised in Smith et al. (2017), which is available on the Deep South website.[3] This research not only comprehensively investigated adapations strategies, but also advanced contemporary art, culture, and design visual systems into exhibitions as research methods, and as

[2] See http://www.deepsouthchallenge.co.nz/programmes

[3] See: Smith, H., Allan, P., Bryant, M., Hardy, D., Manning, M., Patterson, M., Poutama, M., Richards, A., Richardson, J., Spinks, A. (2017). Adaptation Strategies to Address Climate Change Impacts on Coastal Māori Communities in Aotearoa New Zealand: A Case Study of Dairy Farming in the Horowhenua–Kāpiti Coastal Zone. Massey University, Palmerston North. Retrieved from: https://www.deepsouthchallenge.co.nz/projects/climate-change-coastal-maori-communities and https://www.deepsouthchallenge.co.nz/projects/risk-management-maori-coastal-assets

tangible ways for both gathering and disseminating knowledge to regional and national communities.

That project was further developed with another grant of $300,000, which ran from August 2017 to Jan 2019[4]. Phase 2 project was designed to fit within the Deep South NSC theme: Exploring Adaptation Tracks for Māori Communities, as well as relating to all aspects of the Deep South NSC Vision Mātauranga Themes. A report by Hardy et al. (2020) summarises the research findings can be found on the Deep South website[5]. A detailed report of the ecological economics of wetland expansion for Tahamata was also published[6]. Phase 2 developed and mapped Transition Action Plans to assist communities located on the coast between the Ōhau River and the Waikawa Stream in adapting to expected impacts of climate change. It also specifically focussed on land use adaptation options that were preferred by landowners, i.e., planting pā harakeke again for a sustainable fabric industry; protecting and enhancing fisheries and for developing strategies, which might enable whānau to live on ancestral lands again within quality papakāinga.

Climate Change Science: Phases 1 and 2 of this research examined the most recent climate change science with a view to informing decision making about how Māori coastal communities could adapt for likely future impacts in the coastal zone. A summary of the climate change science that informed that Phase 1 research, prepared by the climate change science expert advisor on the research team, Professor Martin Manning, is included in the Technical Report that summarises the Phase 1 research (Smith et al. 2017) and was updated again for the Phase 2 report (Hardy et al. 2019).

This Phase 3 report summarises the research undertaken (June 2020 to May 2022), with $250,000 + additional scholarship funding. This phase supported a Māori student for a Master of Design, (who gained Distinction in March 2022) and supported an undergraduate Māori photography student to record the project since September 2021 to June 2022.

[4] Note that a 3-month extension was granted to the research team to enable completion of final outputs, and wānanga with stakeholders.

[5] Hardy, D., Spinks, A. Richardson, J., Poutama, M., Patterson, M., Smith, H., Manning, M. (2019). Planning for Climate Change Impacts on Māori Coastal Ecosystems and Economies: A Case Study of 5 Māori-owned land blocks in the Horowhenua Coastal Zone. Massey University, Palmerston North. Retrieved from https://deepsouthchallenge.co.nz/resource/planning-for-climate-impacts-on-maori-coastal-ecosystems-and-economies/

[6] Patterson, M.G., Richardson, J., Hardy, D.J. (2019). The Real Economics of Adaptation to Climate Change on the Tahamata Dairy Farm – Assessing Future Scenarios from an Integrated Economic Production and Ecosystem Services Valuation Approach. Massey University, Palmerston North.

1.2 Geographic Location of the Research

The study site is located at the coast from the Kuku Ōhau Estuary to sea, and inland hinterlands in Horowhenua.

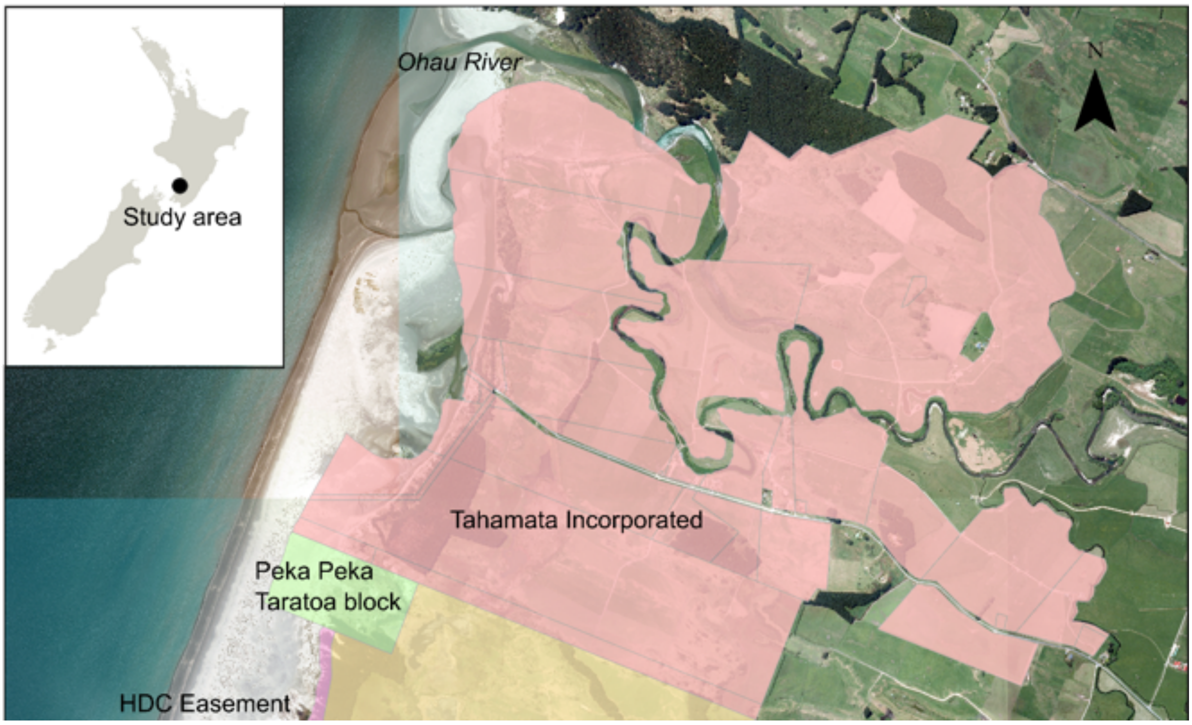

Figure 1.1 Aerial photo of study area in pink. ***Source*****: Laurie Cairns, 28 October 2017**

The Tahamata Incorporation block has an area of 452 hectares and straddles the Ōhau River upon ancestral lands known as Tahamata and Te Rauawa (northern side of river). Current landuse is dairy farming – with an effective grazing area of 310 ha. There are some areas of pine and macrocarpa forest on high inland dunes. There has been extensive effort to restore the Te Hākari/Te Hakiri dune wetland system, which has been protected by kawenata (covenant) since 2002. More recently as reported in *Hei whenua ora ki Te Hākari* report*,* by Ngā Whenua Rahui, we are delighted with the following findings.

> Te Hākari and Ransfield wetlands were historically rich in Māori cultural practices, providing mahinga kai, medicinal plants for rongoā, material for weaving, a reservoir for mātauranga and more, hence deserve our attention.
>
> The recent survey findings of fernbirds, mātuku and other native birds enhancing the importance of pest control operations in Te Hakari and Ransfield kawenata. The remnant population of native wetland species, combined with native revegetation, provides a good habitat for taonga species such as, mātuku, mātātā, kahu, black piwakawaka and others.[7]

[7] However, to improve the kawenata's current **fragile state**, Tahamata Inc. and Ransfield Inc., and Nga Whenua Rahui will need to collaborate on intensive pest management of all existing pest species. Monitoring is recommended on a 5–7-year rotational period to assess animal pest population trends. More traps have been supplied with committed yearly funds for more interplanting over the next 5-7 years has now been promised in budgets.

1.3 Research Aims and Purpose

The previous Phase 2 study recommended a transition plan for Tahamata (within the thin black line) that included staged protection and expansion of the wetland, stabilisation of the dunes and improving water quality through riparian planting. (See Figures 1.2 and 1.3 below, taken from Hardy et al., 2019).

Figure 1.2 Phase 1 climate change adaptation plan for the Tahamata Incorporated block

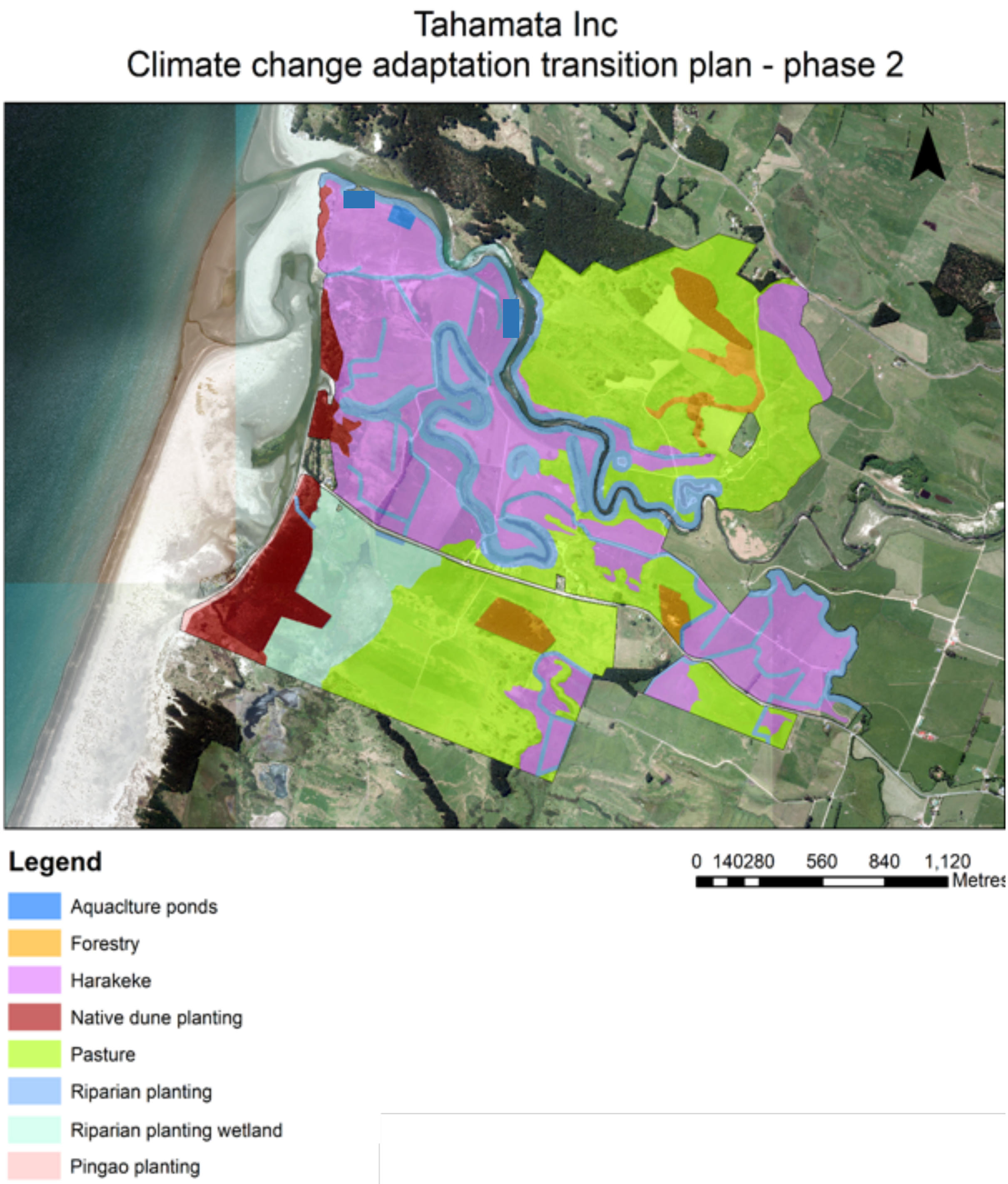

Figure 1.3. Phase 2 climate change adaptation plan for the Tahamata Incorporated block (with added updated aeas in blue for expanded ponding system areas.)

1.4 Mātauranga Māori and Related Initiatives to Restore Taonga Species in Coastal Waterways

Mātauranga Māori and cultural values informed decision making about adaptation to climate change throughout all phases of our research. Our implementation planning was informed by knowledge gathered about other similar or related initiatives being undertaken elsewhere, particularly by/with Māori. Various related enterprises identified in the literature were also explored to inform the preferred adaptation options in this project (see Appendix A).

1.4.1 Previous Research on Mātauranga Māori of Coastal Fishery Taonga Species

Previous research undertook an initial examination of many factors involved in restoring tuna and īnanga species, and potentially other fish species such as flounder, to enable improved customary take in the short term, and a potential fisheries industry in the longer term. In Chapter 3 of Hardy et al., historical accounts of abundant tuna and īnanga taonga species in the rohe are documented. Various other publications are also referred to in that report. Those accounts and literature reviews are not repeated here, but readers are encouraged to refer to these previous publications. Various photos included in that report are from National Library Collections and show the customary use of īnanga and tuna and their importance to tangata whenua in the Horowhenua region. A stocktake of freshwater taonga species was prepared for Te Wai Māori Trust, which includes an overview of methods used to assess the health of freshwater species, assessment of their abundance, and commercialisation opportunities for freshwater species. These are all useful sources for any groups wishing to embark on inland waterway fisheries restoration.

1.4.2 Previous Hīkoi to Fisheries and/or Aquaculture Operations

As depicted in Hardy et al. (2019), during Phase 2 of this project, Aroha Spinks and Moira Poutama visited and communicated with various New Zealand groups with expertise in this area, including Levin Eel Trading Company, a family-owned eel processing and eel export business based in Levin, Horowhenua region.

They also visited Raglan Eels / Nitro EELS in Raglan and maintained email communication with Jan Mitchell regarding potential research. Raglan EELS Ltd is a leading Raglan based Ag-research company which has been focused on developing successful, sustainable aquaculture and biological solutions to restore lowland wetland ecosystems, based at a complex of coastal research ponds at Raglan. 'Nitro EELS' have developed a system to create new, highly productive ecosystems, constructed using NZ native plants and animals supercharged by farm nitrate runoff. First developed by Charles Mitchell, and now run by Charlie Young and Jan Mitchell. NitroEELS developed intellectual property to build and manage aquaculture ponds so they replicate prime wetland ecosystem functions for whitebait spawning and EEL rearing habitat. Rebecca Eivers, initially of Streamlined Ltd., and now of Waikōkopu Consultants, was approached to participate this project, and aid in developing the ponding systems for the restoration of īnanga and/or tuna. Her mahi is outlined in Chapter 4.

1.4.3 Related Initiatives

Te Hatete Trust has been developing its adjustments to climate change impacts within their whānau Waikawa River region. They are growing a Pā Harakeke towards supporting the sustainable fabric fabric industry. Iwi researcher Moira Poutama has advocated in earnest for the whānanu landholders to come together and they have been planting since 2021.

1.5 The Horowhenua Coastal Climate Change Research Team

The main purpose of this Phase 3 project is to further develop the Implementation Plan for expanded īnanga fisheries ponding systems as identified in light blue in Figure 1.3 above. For the new plans too, we aim to increase the areas in three places along the southern side of the river as above.

The Horowhenua Coastal Climate Change research team included many of the same core team from Phases 1 and 2, with very experienced kaupapa Māori and action-orientated research experts and designers, climate change hydrologists, freshwater ecologists, and ecological economists. With a proven track record in successful complex cross-cultural, collaborative research projects such as Manaaki Taha Moana (MTM) (MAUX0907) receiving a gold rating from MBIE in 2014. Phases 1 (CO1X1445) and 2 (C01X1412) have been favourably reviewed and received in innovative ways to improve local understanding of climate change complexities.

The project lead was Professor Huhana Smith, Head of School Whiti o Rehua School of Art, Toi Rauwhārangi College of Creative Arts at Massey University. Working as an experienced research team alongside Māori landholders/shareholders that worked within the coastal lands that lie between the Ōhau and Waikawa Rivers. The team engaged with a range of end users, stakeholders, and community local experts. Iwi and hapū researcher leaders from the rohe, Moira Poutama (Te Iwi o Ngati Tukorehe Trust) was the Kairangahau/Iwi Researcher. Moira coordinated and led all hui and wānanga with landowners, end users, stakeholders, and local experts involved in the research. She contributed Mātauranga Māori and local knowledge of place based on intricate her whakapapa connections, attended to all field work organisation, and contributed to written publications, including a comprehensive land, lagoon and aerial surveillance with New Zealand born, but Berlin based artist Hayden Fowler as part of a visual stocktake. Rangimarkus Heke (Te Iwi o Ngati Tukorehe Trust) was responsible for drawing all appropriate data for GIS mapping, which was later augmented by Rachel Summers from Massey Unversity's School of People, Environment and Planning. This aspect however was somewhat fragmented by the demands of COVID disruptions and was not realised to the extent envisaged. Rangimarkus Heke helped with field work actions alongside Moira Poutama and other whānau, as required.

Derrylea Hardy led the research proposal design and development, managed the project, and contributed to the research development of the Implementation Plan and the written outputs from the project.

Dr Christian Zammit led (and in collaboration with Dr Eivers) the analysis of climate change impact on combined sea level rise and flow regimes impacting īnanga spawning abilities along the Ōhau river across future emission pathways and time.

Dr Rebecca Eivers of Wai Kōkopu Consulting as an applied freshwater ecologist and wetlands specialist, led the fieldwork and site-specific hydrological data collection required for designing aquaculture ponds and provided the constructed/recreated wetland design concepts.

Mercia Abbott completed her Māori Master's in Design student (with Distinction). She worked closely with Drs Eivers and Zammit. Maija Stephens is the current documentary photographer working on gaining a degree in Photography at Massey University. She has until June 2022 to complete her documentary imagery, which rounds off the whole project.

1.6 Outputs and Outcomes from this Project

In addition to multiple wānanga/hui, this report is one of the main outputs required by the funder of the project, as described above. Online articles and chapters were published to communicate the research methods and findings, and a comprehensive master's design thesis was submitted and awarded Distinction. This report will be shared through libraries in the research rohe, the National Library and University libraries throughout New Zealand to foster widespread dissemination of research findings. Copies will also be downloadable from the Deep South National Science Challenge website (https://www.deepsouthchallenge.co.nz).

The research project intended to produce other material for land owners who participated in this study, such as maps or other tools; however, due to the extra demands of negotiating pandemics and isolation periods, the final online wānanga was edited to be a resource for whānau, hapū shareholders and landowners. A list of key outputs is in the appendices.

1.7 Ongoing Research

From the outset, it was intended that this project would be a continuing part of the wider interconnected and ongoing research that explores, with tangata whenua, the implications of what is required to adapt livelihoods to the reality of climate change impacts within the coastal zone. We aim to extend this research further and are applying again for more resourcing to develop the climate change adaptation ponding system as outlined in this report.

1.8 Outline of the Report

This chapter has provided an overview of the background and aims of the research, the research funding, the location of the research case studies, the research team and the potential for continuation of this research.

Chapter 2 describes the stakeholder engagement processes that were undertaken, including with local whānau and landowners, other researchers and central or local government.

Chapter 3 outlines hydrology and related modelled undertaken by Dr Christian Zammit, which linked in with the freshwater ecology research conducted by Dr Rebecca Eivers as described in Chapter 4. The landscape design work conducted by Mercia Abbott is summarised in Chapter 5. The Implementation Plan, and the Conclusions and Recommendations from this research are outlined in Chapter 6. Appendices are found at the end of the report.

2 STAKEHOLDER ENGAGEMENT PROCESSES

Embedded in the design of this research was meaningful engagement processes with landowners and other stakeholders in the local community, as well as with the wider research and academic community – this chapter provides a record of these processes.

2.1 Engagement with Whānau Landowners and Local Community in the Case Study Rohe

2.1.1 During Proposal Development

This project builds upon established relationships between our research team and case study stakeholders, who were continuously involved in developing the research through funded hapū-based researchers in the project, and ongoing hui, Wānanga/Hīkoi (see extensive engagement in Hardy et al., 2019.[8], in which feedback from stakeholders in support of this continued research included (ibid., p.178):

> At a whānau Wānanga on 12/4/19, feedback from Ransfield Inc, Gardiner Farm MK2 B8 and Te Hatete Trust reflected they are encouraged by and support the potential of this mahi. Feedback included a desire to continue research on transition planning and implementation in the rohe (proposal is intended to do research and planning requested by these and other stakeholders). Kōrero in relation to Pekepeka block research included preference for dune stabilisation options, as well as wetland enhancement for increasing inanga. "*Have kura/wananga to encourage learning and enable people to see the revitalisation as it progresses*"…
>
> One attendee stated that the research had given them "*more passion to get our act together*". Kōrero from reps of ngā uri ō Nepia Taratoa whānau included: "*To be able to stand on the whenua and appreciate the kōrero about it and to get a sense of how the whānau may like to see it used would be a lovely first step. There are a few of us who would really appreciate an organised hīkoi … place to walk to and appreciate the larger project 'tiaki whenua' which is something we have always aspired to*".
>
> An email from a Tahamata Board rep states:
> "*Last night we had a Board meeting and I presented a short summary of the work that you have been doing. It was very well received by those Board members present and I would like to congratulate everyone for such a wonderful resource document that you have created. Please pass this on to the rest of the team from Tahamata Board. The Board is very interested in pursuing an environmental plan [that includes land and water based activities) for the farm, based on your findings in the report… The Board … seek your advice as to how we could move these things forward*".

[8] Hardy, D., Spinks, A. Richardson, J., Poutama, M., Patterson, M., Smith, H., Manning, M. (2019). *Planning for Climate Change Impacts on Māori Coastal Ecosystems and Economies: A Case Study of 5 Māori-owned land blocks in the Horowhenua Coastal Zone*. Massey University, Palmerston North.

2.1.2 Project Initiation and Stocktake Phase

A stakeholder hui was held in September 2020 at Tukorehe Marae, Kuku to go over the project aims and research plan.

On 19-20 November 2020, our first Wānanga/Hīkoi with Deep South Te Kahui Māori, Deep South engagement team and representatives from Horowhenua District Council; Tonkin & Taylor, Auckland; Te Runanga o Toarangatira, Te Runanga o Raukawa, kuia from Tukorehe, Massey Masters Student, and interested other landholders from Tukorehe. While a large invite list was sent out, there were apologises from Horizons Regional Council, MFE and others. See agenda in Appendix B.

We held a big discussion at the marae with the group and hapū reps on using Climate Change modelling projects to: a) understand and predict water generation /movement for our case study and for NZ within time frames 5-10 years to allow interest to grow; b) acknowledge heavy use of Climate Change info across cryo/hydro spheres; c) understand the Climate Change hydrologist's role in sharing how rain is converted to groundwater and surface water; d) make the science accessible for decision making; e) understand Climate Change projections for NZ and implications for Manawatū Whanganui region; f) look at creating Eiver's designed sedimentation pond train as ways to enhance īnanga taonga species with extra design effort coming from Masters student Mercia Abbott, and g) help shareholders of Tahamata Incorporation adapt to Climate Change with ideas to be discussed with them during 2021.

2.1.3 Te Hatete Trust, returning Pā harakeke to Waikawa River

Moira Poutama has been a strong whānau advocate for replanting a complete pā harakeke on Te Hatete Trust landholdings near the Waikawa River.

2.1.4 Research Team Hui

Additionally, a series of powerful team research meetings were led by iwi and hapū researchers via ZOOM or face to face hui between September to December 2020. The intent was to develop: a) team cohesion; b) organise and undertake site visits; c) finalise the start of the Massey Masters student within the project; d) begin to plan actions required to profile Ōhau River in relation to creation of sedimentation ponds; e) collate key data and reports, and f) determine what are our design criteria might be for this project. These team zui continued throughout 2021.

The team planned to draw upon the wānanga and hīkoi experiences and build upon tasks required for 2021. It was intended to invite key participating stakeholders to complete responses to wānanga and hīkoi and to five themes[9] by the proposed 21 Jan 2021 hui. This included Sarah McCarter, Cynthia Wards, Tom Bowen (Horizons R Council), Rangitopeora Wiremu and members of DS Te Kahui Māori. However, these in-person meetings were not able to take place due to Covid.

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[9] The 5 themes were:
Explore interconnections between all entities
Connect Mātauranga Māori approaches with others
Establish co-funding opportunities
Feed into a Māori-led Climate Change Implementation Plan
Help transition coastal Māori communities to water-based land uses that enhance taonga species

For this pilot project of sedimentation ponding systems, the team (led by Rebecca Eivers) aimed to: Design, (with planting programme) a plan for more resilient ecosystem processes. This was all about sussing the earthworks and ponding systems and working with planners over diversions that might minimise risk.

The team led by Christian Zammit sought to: a) Understand what design criteria to we need for Mean or other changes in extremes; b) Determine SLR; c) Understand 4 representative concentration pathways; d) Know about the 6 global Climate Change models; e) Look at a regional climate model and dynamic downscaling of data; f) Understand ensemble of hindcasts and potential futures whilst, g) Understanding so much uncertainty and unpredictability! What an ask but this report is testament to the translation of that material and how to make it readable to the hapū shareholders and communities of interest.

The team managed to source all materials needed for the river profiling task which was completed by Moira Poutama, Rangimarkus Heke, Mercia Abbott, Rebecca Eivers and Huhana Smith. Moira Poutama and Rangimarkus Heke would readily report to the wider whanau on range of matters arising from the hands on work; for example via Tukorehe face book invites to come an look for whitebait eggs!

A comprehensive preliminary stocktake of key relevant ecological and hydrological factors of the area was compiled by Moira Poutama and Haydn Fowler. See Appendix C.

Overall, the entire project was impacted upon by COVID outbreaks – the new normal for eveyone – and the inability to hold many of our planned hui and hīkoi on whenua with whānau land holders of Tahamata Incorporated. Our research team hoped to meet more meaningfully with our hapū shareholders and Tahamata Incorporation on site as this project was all about codesigning implementable climate change mitigation plans based on accumulated phases of research and action. It was hard to create that dynamic dialogue and deep engagement via a computer screen.

Despite COVID, we still managed to pull considerable information together for a significant online wānanga that was presented in two parts – first to landholders and second to other interested parties including local and regional councils' representatives. The edited digital wānanga provided the best avenue to engage our people and help seed other projects within it.

2.1.3 Two-day kanohi ki te kanohi Wānanga in Wellington

A two-day kanohi ki te kanohi wānanga was held in Wellington on 15-16 Juy 2021 between the key members of the research team. The purpose of this was to align different science (modelling, hydrology, ecology), cultural, and art disciplines to create the foundation for the Adaptive Implementation Plan. The different disciplinary workstreams were brought together to develop an informed understanding of how they key factors in develoing a ponding system for taonga species to be restored in the rohe. This formed the basis of material presented to whānau and stakeholders in the final wānanga.

2.1.4 Final Stakeholder Wānanga

While we held the first wānanga and hīkoi in November 2020 with a range of participants, subsequent working team wānanga were required to be held in homes. Due to impacts of COVID, many of our planned hui and hīkoi on whenua with whānau land holders of Tahamata Incorporated were severely curtailed. We had to change our arrangements regularly. Despite this we managed to pull considerable information together for a significant online wānanga, the final wānanga for this project, which was filmed on 7 October 2021 at Massey University, Pukeahu/Wellington campus. This was intended to be a 2-day wananga, the first day with whanau/hapū; and the second with the wider research community and government entities. However, due to Covid restrictions, this was turned into two online presentations that were recorded and turned into online material. This was presented in two parts – first to landholders, and second to other interested parties including local and regional council representatives. The edited digital wānanga provided the best avenue to engage our people and help seed other projects within it. This is explored more fully in Chapters 4-6. See panui in Appendix D.

Figure 2.1 Studio set up for Final Stakeholder Wānanga

2.1.5 Public Exhibition

Again, COVID disruptions put lengthy delays between safe face to face conversations, however the principle investigator managed to draw in Govett Brewster Art Gallery to begin discussions in September 2021 for developing a large-scale exhibition by 2024. This conversation has since developed into an expanded activation with a range of water, marine and environmental entities including Taranakai iwi, to gather visions and co-intelliences via this reputable institution. *Te Waituhi ā Nuku: Drawing Ecologies* and the GBAG are developing a series of site-based events, seminars and workshops, which began on 9 February 2022 at Ngāmotu New Plymouth and as explained further in sections 2.3.2. The aim of a major public exhibition at a reputable institution such as Govett Brewster Art Gallery (GBAG), Ngāmotu/New Plymouth is to be a starting point for long-term public action, which is connecting community in ways of shared understanding our inter-relations with awa (water in the land), takutai (coast) and moana – our surrounding oceans, rivers and other waterways. Special attention is being paid to the care required for the wellbeing of our planetary ecology considering all climate change stressors today.

As part of this trajectory, a smaller curatorium is developing an exhibition that will open in 26 November 2022 called *Liquid Constituencies*[10]. Such fluidity brings together indigenous and non-indigenous artsits and designers from Chile, Australia, Pacific islands and Aotearoa New Zealand.

2.2 Other related research opportunities to extend the reach of this research

Massey University, Whiti o Rehua School of Art, Toirauwhārangi College of Creative Art Students, Wānanga and Hīkoi was hosted by Huhana Smith, on 5-6 July 2021. This also included talking to Massey University-led projects with hapū as outlined below.

A) V*isualising Regen Ag: GIS, Photovoice and Citizen-Science Collaborations*, Strategic Research Excellence Fund, Massey University, 2021, extended to Dec 2022.

Using a range of visualisation methodologies, including GIS technologies, drone aerial footage, vertical and oblique aerial photos and photo-video voice, this project makes visible the transformations underway in agriculture. This project aims to chronicle changes to associated land use practices and their impacts. In this project, all non-academic collaborators and farmers, Māori and non-Māori are positioned as co-researchers or 'citizen-scientists,' actively involved in co-designing the research and generating data to contribute to the aims of the project.

The rationale for this project is to create transformational change that hinges on harnessing and respecting diverse knowledge, practice and power of communities. All stakeholders are encouraged

[10] A curatorium or curatorial discussion group is assisting in conceptualising an exhibition focused on artists' works from locations within the area within the rotating current of the Te Moana-nui-a-Kiwa or the South Pacific Ocean (scientifically termed the 'Pacific Gyre'). Te Moana-nui-a-Kiwa circles south between Australia and Aotearoa New Zealand returning past Rapa Nui to the equatorial area before returning south through the waters between the Solomon Islands, Tuvalu, Vanuatu, Fiji, Tonga, and other nations. The exhibition will reflect ways artists convey the interconnection of water with being and place, in the interest of engaging dialogue about the world we live in. The exhibition is scheduled for December 2022 – March 2023 and will be one of several contextual exhibitions bringing an expanded view of artists engaged with waterways, coastlines and oceans in Te Moana-nui-a-Kiwa, as well as other exhibitions that will focus more specifically on the Taranaki region.

to engage meaningfully and purposefully. The project connects academic institutions with local knowledge of place or kōrero tuku iho [ancestral knowledge] of lands in Māori land tenure, to encourage sustainability, changes in agricultural practices and enhance food systems. The team encourages a deepening of conversations with Māori over relationships with whenua, especially when dovetailing this project with climate change adaptations that are trying to return Māori land use back to old/new ways - for example, via the sustainable harakeke fabric industry; creating biochar for freshwater health or 'engineering' naturalised ponding systems by river systems to increase taonga species and biodiversity.

Much of the data for this project comes from spatially disparate sources. This ReGen Ag project innovatively weaves together aesthetics and creativity through visual and textual storytelling around regenerative food systems and subsequent transformations in land use. Geographic Information Systems (GIS) tools allow researchers to collect farmers' data and add other layers of information from the wider region. GIS allows all participants to engage as citizen-scientists, collecting, curating and managing their own data using ArcGIS Story Maps and Survey123. Farmers then can contribute a range of information such as multimedia, photographs, maps and diagrams related to their own location, their own local knowledge of place from Māori and non-Māori perspectives, even down to their own farm or paddock scale. Collected by the researchers, this will provide a spatial overview of whakapapa, kōrero tuku iho and ReGen Agriculture that shapes daily/monthly/yearly practices in the Horowhenua and Taranaki regions. Drone surveys are a useful tool for capturing pasture health, small-scale management practices, detailed current environmental assessment and track seasonal changes on individual farms. This research is a pilot programme to develop database structure for capturing the direct effects of ReGen Ag practices on the landscape, which will later be able to feed into a long-term study.

The ReGen Ag project team co-designs and co-creates communicative objects of lasting value that narrate the ways our research participants envision and articulate their relationships with whenua in Taranaki and Horowhenua, particularly as cultivated through the growing of kai. This project was extended to December 2022 due to COVID disruptions.

B) Te Aho Tapu Hou – the new sacred thread (Funded by NSC Science for Technological Innovation Seed Projects led by Dr Faith Kane, College of Creative Arts, Massey.)

As an Aotearoa New Zealand first, this project aims to develop the technology and processes to take muka (harakeke/NZ flax) fibre to a machine spun yarn (or thread). Rangi Te Kanawa (Ngāti Maniapoto) and Massey University researchers are working in partnership with AgResearch towards this aim. We aim to develop new knowledge to adapt current wool processing infrastructure to process muka fibre into yarn for sustainable industrial manufacture of high-quality textiles, whilst incorporating first principles embedded in traditional muka processing.

Te Kanawa has developed a process and associated prototype technology for mechanically extracting muka fibres from leaf. This has opened the possibility for scaled production of muka-based products. The technology is predicated on mātauranga Māori manual muka processing techniques and results in a fibre of high quality. However, the knowledge required to further process the fibre, within New Zealand, to manufacture spun yarn and subsequently high-quality textiles, does not exist. Our project entails iterative experimental work using fibre science alongside mātauranga principles to create the pathway for muka fibre to be spun into textile yarn. This will be evaluated in terms of its suitability for sustainable manufacture of high-quality textiles.

By resolving the science and technology challenges that currently impede progress of a modern muka textile industry, this research has the potential to create a new high value product that benefits Aotearoa New Zealand by unlocking opportunities for Māori communities and organisations.

C) Te Muka Taura - A site-based exploration of harakeke for dye extraction and muka colouration. (Funded by NSC Kaupapa Kākano Seed Project Fund and led by Angela Kilford, College of Creative Arts, Massey.)

Focussing on materials, manufacturing technology, design with Vision Mātauranga grounded in Tukorehetanga, this project aims to highlight the knowledge of natural dyes used in the colouration of Māori textiles. There is customary use of three main plant dyes used for colouring muka (fibre from harakeke; *Phormium tenax*). Harakeke cultivated for weaving can also produce a dye due to the tannins occurring naturally in an extracted solution. The dyes found within harakeke are, however, not fully understood. Based in Mātauranga Māori, this project brings textile researchers and Māori practitioners together with scientists and whānanu to deepen understanding of natural dyes for customary and contemporary application.

Initial research into muka colouration has revealed how tannins can accelerate the dye process, indicating a potential for tannin to be an effective and sustainable colourant for muka. Within this project, the dye yield of harakeke cultivars and other plants specific to the Kuku, Horowhenua region, will be tested to predetermine the effectiveness of the dyes. The emphasis is on the dye's ability to bond with muka, based on the tannin component. This will provide new insights into the efficacy of plant dyes in Aotearoa New Zealand.

Through an analysis of dyeing practices, this project expands the potential for muka colouration. In doing so, the work takes place on iwi whenua and contributes to fibre colouration of extant plants growing within regions. Within the wider context of a reinvigorated harakeke industry, the hau kaīnga communities are renewing sustainable practices to benefit their communities by providing opportunities to diversify agricultural practices more towards enterprises that maintain the values of active kaitiakitanga.

D) Biochar – A site-based exploration of Biochar at Waikōkopu Grove and Orchard, Kuku.

Figure 2.2 Biochar burn images, April 2021.

As part of our *Te Waituhi ā Nuku: Drawing Ecologies'* exploration of Biochar, our first burn took place on 6 April 2021 with Phil Stevens from Slow Farms, Ashurst. Our second biochar burn took place on 13-15 May 2022. The collective nature of the group, means that gathering on the whenua at Kuku, and taking time to share kai and korero, is the most important and best part of the whole project! The latest hui saw the team once again camping in the olive grove; hanging out, chatting, eating, snapping branches, chopping wood, and feeding the kiln over a four hour period. Under Phil's expert tuition, the confidence is building with biochar making. Using two, flame-cap kilns, we made a large amount of biochar, and got through a large stockpile of firewood collected from the grove; dead orchard trees and olive tree prunings. This biochar will be used on site for the next part of this carbon sequestering project.

The next step in the project is to create biochar sediment basins by bagging Kuku biochar into used coffee sacks and placing them at strategic sites, in and close to the waterways. The **Waikōkopu** stream snakes around the farm at Kuku and receives water run-off from neighbouring buildings, State Highway 1, as well as adjacent paddocks. This causes problems for the surrounding freshwater ecology. There has been a massive and ongoing effort to eradicate the invasive blackberry that chokes the stream, and plans are underway to re-plant and restore this small but vital water way. The **Kuku Biochar Project** forms part of that restoration.

As well as being an excellent soil amendment, biochar can be used in sedimentation basins or trenches to directly intercept water flows, where it filters nitrates and other pollutants. This part of the project will experiment with using biochar for stream restoration and for improving water quality. Data will be collected upstream and downstream from the sacks, to test the efficacy of biochar to mitigate harmful particulates and nitrogen run-off.

The second important part of this project is to use biochar sacks to slow water during rain events, creating sediment traps that will slowly raise the narrow, deep bed of the stream into a more shallow and wider stream basin. The hope is that the biochar sediment basins (sacks with biochar) will filter the water in this small patch of the Waikōkopu stream, while simultaneously reducing erosion and restoring the river to a more natural shape that can better absorb rain events. This should create a natural, swampy stream surround, that allows for water to rise and fall, dissipating across a wide catchment area and provide habitat for freshwater plant and animal species. Freshwater fish needs streams with plenty of cover (plants, logs, rocky overhangs), as they spawn in the leaf litter at the edges of stream beds.

In European farming and paddock-draining practices, small streams are often dredged, creating narrow, steep-sided streams, and destroying the spawning ecosystems of the kōkopu. The sides of these dredged streams are too steep for plant growth and unless fenced, allow for cattle to graze right up to the stream edge. The **Kuku Biochar Project** will be one part of this ecosystem restoration, working towards a restored wetland/wildlife corridor in this coastal Māori farming community.

This part of the project will be installed on site[11] after Matariki and into the Māori New Year 2022, with additional expert guidance from Dr Rebecca Eivers.

[11] This Biochar text was written by Monique Jansen as part of the Biochar Blog within the Te Waituhi ā Nuku: Drawing Ecologies website.

D) High Value Nutrition He Rourou Whai Painga

This project aligns with HVN's Vision Mātauranga obligations (for further information, *He Rourou Whai Painga* takes a whānau wellbeing approach, including a study population enriched for Māori cultural context, and focus on effective engagement with Māori F&B stakeholders, which reflects a wider government commitment to partner with Māori in growing a more productive, innovative, and internationally connected Māori economic sector that will deliver prosperity to Māori and resilience and growth to the national economy.

By participating in this initiative, the Waikōkopu Grove and Orchard business acknowledges the importance of achieving impact for Māori in the design and implementation of *He Rourou Whai Painga* and recognises that the goals of this project extend beyond profit maximisation to include a focus on the intertwined wellbeing of culture, environment, people, and communities.

HVN acknowledges that each business participant is progressing at their own pace and may not have established connections to Māori stakeholders. Please know that this does not prevent participation in He Rourou Whai Painga.

https://www.highvaluenutrition.co.nz/about-us/vision-matauranga/

https://www.highvaluenutrition.co.nz/regulatory/).

E) Regenerative Agriculture

As part of a collaborative Strategic Research funding from Massey University, on 30 September 2021, Huhana Smith attended the Regenerative Agriculture hui with Taranaki farmers, Massey University's AgResearch team and Regenerative Agriculture School of People Environment and Planning's reseach team led by Sita Venkateswar.

Figures 2.3 and 2.4 Field Trip and Workshop, Regenerative Agriculture hui, Taranaki, 2021

Figure 2.5 Eve Armstrong presentation, Planetary boundaries, Regenerative Agriculture hui, Taranaki, 2021

Additionally, Huhana Smith has been in ongoing talks with former long-term collaborators Professor Penny Allan and Martin Bryant from the University of Technology, Sydney, which resulted in a co-authored chapter for a publication by reknowned artist duo COOKING SECTIONS from United Kingdom.

Their publication *Offsetted* traces the emergence of the valuation of nature. The book by the artist duo unpacks forms of dispossession that are becoming more common through the protection—not only destruction—of natural environments. Through a series of artistic and architectural interventions, *Offsetted* ties into current struggles for climate justice worldwide, contesting neoliberalism as a savior of its own ecological contradictions. It challenges conservation models based on “natural capital,” while proposing new spatial tactics to de-financialize the environment. Besides a photographic documentary and the works by COOKING SECTIONS, the book assembles numerous contributions by interdisciplinary artists and scientists. COOKING SECTIONS was established in London in 2013 by Daniel Fernández Pascual and Alon Schwabe. Their practice explores the overlapping boundaries between art, architecture, ecology and geopolitics. They were nominated for the 2021 Turner Prize in United Kingdom.[12]

[12] https://www.hatjecantz.de/cooking-sections-8152-1.html

3 HYDROLOGY

3.1 Introduction

The focus area of the Phase 3 Implementation Plan is the low-lying coastal land owned and administered by Tahamata Incorporated. The Phase 1 of this project focused on developing local information and subsequent transition plan organised around staged expansion of wetland habitats in preparation for, and response to, climate change impacts. The project's Phase 2 refined these recommendations to include specific areas for:

i. creation of native fish aquaculture ponds;
ii. extensive harakeke planting for future harvesting opportunities;
iii. restorative riparian planting to improve biodiversity and water quality; and
iv. restorative wetland planting to enhance existing habitat.

Chapter 3 of the report focuses on the development of climate and hydrological information and associated processing methodology supporting the creation of aquaculture ponds to enhance wetland habitat and support the lifecycle of native freshwater taonga species under climate change. The associated ecological work is presented in section 4. Following discussions with the project team, the following information is required:

- Ōhau river catchment climate projections;
- Climate change projection on flow regimes with a focus on flow regimes associated with īnanga life cycle;
- Due to the proposed geo-location of the aquaculture ponds, counpound effect of climate change induced Sea Level Rise (SLR) and associated hydrological regimes.

Chapter 3 of the report is organised as follow:

- Section 3.1 provides background informaiton on the climate change information available during this project and the methodology used for climate change impact assessment.
- Section 3.2 provide background information on IPCC5 climate change projections for New Zealand, a brief description of the hydrological model used to generate downstream impacts of climate change on flow regimes, a brief descrition on how to measure impact of climate change supporting investigation in flow regimes.
- Section 3.3 provides a summary of the required geospatial information specific to the Ōhau catchment used to develop the hydrological model.
- Section 3.4 provides an overview of the hydrological information available to develop the hydrological model supporting climate change investigations.
- Section 3.5 provides an overview of the climate model specific hydrological bias correction carried out to provide reliable information on change in hydrological regimes for the ecological investigations.
- Section 3.6 presents a summary of the expected climate change impact on the climate and associated hydrological regimes for the Ōhau catchment.
- Section 3.7 presents the methodology used to develop hydrological regime information specific to support ecological investigation and development of flotting wetland as īnanga nursery.

3.2 Hydro-climate background information

3.2.1 Climate Models

As part of the fifth IPCC assessment report (AR5) (IPCC 2014), NIWA assessed up to 41 GCMs from the AR5 model archive (referred hereafter as Coupled Model Intercomparison Project version 5- (CMIP5) for their suitability for the New Zealand region. Validation of those GCMs was carried out through comparison with large scale climatic and circulation characteristics across 62 metrics (Ministry for the Environment 2018). This analysis provided performance-based ranking based on New Zealand's historical climate. Six GCMs were chosen as being better at representing climatic dynamics around New Zealand and for spanning a useful range of climate change sensitivities to CO_2 projections. The six CMIP5 models selected were:

- HadGEM2-ES (Jones et al. 2011)
- CESM1-CAM5 (Meehl et al. 2013)
- NorESM1-M (Bentsen et al. 2013)
- GFDL-CM3 (Griffies et al. 2011)
- GISS-E2-R (Schmidt et al. 2014)
- BCC-CSM1.1 (Wu et al. 2014)

The GCMs were driven by four scenarios (Representative Concentration Pathways, RCPs) of future concentrations of greenhouse gases and aerosols, as well as by natural processes including solar irradiance and historical emissions. The GCM driven runs were otherwise free running in that they are not constrained by historical climate observations. GCM outputs (i.e., boundary condition and Sea Surface Temperatures) were then used to drive a Regional Climate Model (RCM) to refine the variables to a more useful spatial scale for the country. The output of the regional climate modelling became the input for the hydrological modelling analysed here after rudimentary bias correction. Further details on the validation and the GCM and RCM modelling can be found in Sood (2014) and Ministry for the Environment (2018).

The downscaled climate data used here run from 1971 to 2100. From 2006 onward, as per IPCC recommendations, each GCM is in turn driven by four RCPs that encapsulate alternative scenarios of radiative forcing and reflect alternative trajectories of global societal behaviour about greenhouse gas emissions and other activities. The range of RCPs used can help shed light on the utility of climate change mitigation. Descriptions and trajectories of the four RCPs are provided in Table 3-1 and Figure 3-1. By mid-century, the temperature trajectory of RCP2.6 is the least increase and RCP8.5 the greatest, with RCP4.5 and RCP6.0 producing intermediate warming. While RCP6.0 ends the century with more forcing than RCP4.5, early and mid-century it is RCP4.5 that has higher greenhouse gas concentrations and a stronger radiative forcing; this is somewhat reflected by the mid-century temperature change ranges for the New Zealand seven-station network (Table 3-1). RCP6.0 overtakes RCP4.5 after the middle of the century.

It is important to note that the climatic and hydrological effects of the RCPs are not simply a linear or monotonic progression from the lowest to highest RCP. Furthermore, the spatial patterns of climatic change across New Zealand vary across combinations of RCP-RCMs simulations.

Table 3-1: Descriptions of the Representative Concentration Pathways (RCPs). Temperature changes are the GCM mean (°C) and, in brackets, the likely ranges.

Representative Concentration Pathway	Description	Seven-station temperature change (Ministry for the Environment 2016)		Global surface temperature change for 2081-2100 (IPCC 2014, Table 2.1)
		2031-2050	2081-2100	
RCP2.6	The least change in radiative forcing considered, by the end of the century, with +2.6 W/m^2 by 2100 relative to pre-industrial levels.	0.7 (0.2- 1.3)	0.7 (0.1- 1.4)	1.0 (0.3- 1.7)
RCP4.5	Low-to-moderate change in radiative forcing by the end of the century, with +4.5 W/m^2 by 2100 relative to pre-industrial levels	0.8 (0.4- 1.3)	1.4 (0.7- 2.2)	1.8 (1.1- 2.6)
RCP6.0	Moderate-to-high change in radiative forcing by the end of the century, with +6.0 W/m^2 by 2100 relative to pre-industrial levels.	0.8 (0.3- 1.1)	1.8 (1.0- 2.8)	2.2 (1.4- 3.1)
RCP8.5	The largest change in radiative forcing considered, by the end of the century, with +8.5 W/m^2 by 2100 relative to pre-industrial levels.	1.0 (0.5- 1.7)	3.0 (2.0- 4.6)	3.7 (2.6- 4.8)

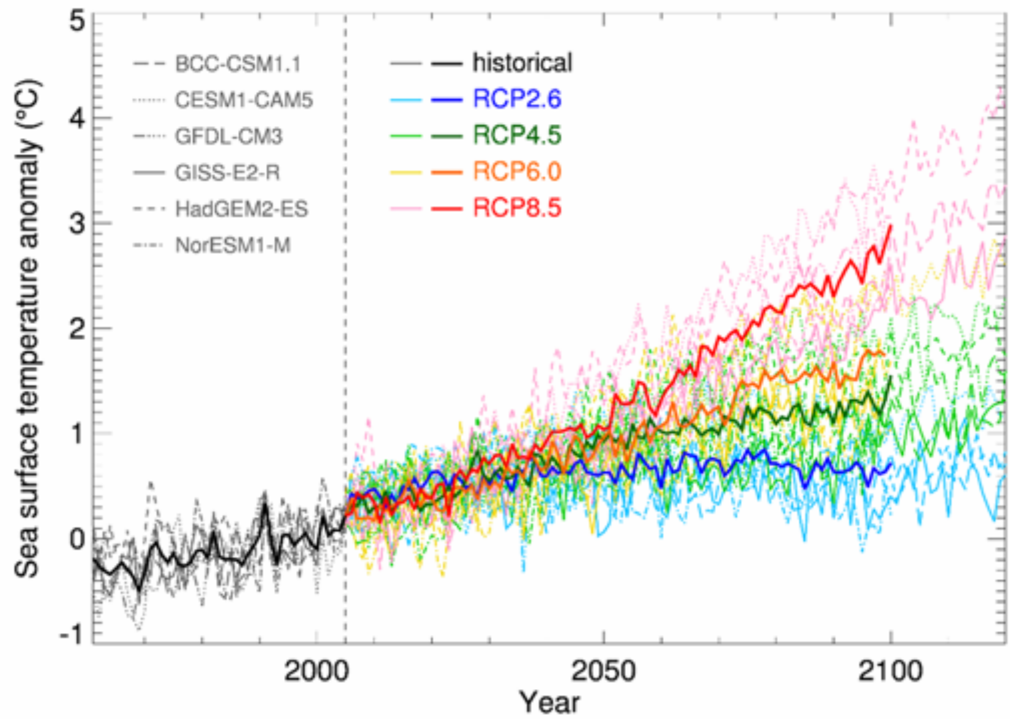

Figure 3-1: CMIP5 climate models (2006-2120), the historical simulations. Bias-adjusted sea surface temperatures, averaged over the RCM domain, for 6 (1960-2005), and four future simulations (RCPs 2.6, 4.5, 6.0 and 8.5), relative to 1986-2005. Individual models are shown by thin dotted or dashed or solid lines (shown in grey in the inset legend), and the 6-model ensemble-average by thicker solid lines, all of which are coloured according to the RCP pathway.

3.2.2 Hydrological model

The catchment hydrological model used in this study is NIWA's TopNet model (Clark et al. 2008), which is routinely used for surface water hydrological modelling applications in New Zealand. It is a spatially semi-distributed, time-stepping model of water balance. It is driven by time-series of precipitation and temperature, and additional weather elements where available. TopNet simulates water storage in the snowpack, plant canopy, rooting zone, shallow subsurface, lakes and rivers. It produces time-series of modelled river flow (without consideration of water abstraction, impoundments or discharges) throughout the modelled river network, as well as evapotranspiration (derived from weather/climate input information) but does not adjust river flows for effects of irrigation, water take and redistribution through hydro-electric canals. TopNet has two major components, namely a basin module and a flow routing module.

The model combines TOPMODEL hydrological model concepts (Beven et al. 1995) with a kinematic wave channel routing algorithm (Goring 1994) and a simple temperature-based empirical snow model (Clark et al. 2008). TopNet can be applied across a range of temporal and spatial scales over large watersheds using smaller sub-basins as model elements (Ibbitt and Woods 2002; Bandaragoda et al. 2004). Considerable effort has been made during the development of TopNet to ensure that the model has a strong physical basis and that the dominant rainfall-runoff dynamics are adequately represented in the model. TopNet model equations and information requirements are provided by Clark et al. (2008) and McMillan et al. (2013). The version of the model used in this project does not consider water transfers from river to river or water storage, nor does it model aquifer water balances.

For the development of the TopNet model used in this study, spatial information in TopNet was provided by national datasets as follows:

- Catchment topography based on a nationally available 8 m Digital Elevation Model (DEM) merged with existing LiDar information available inDecember 2016.
- Physiographical data based on the Land Cover Database version three and Land Resource Inventory (Newsome et al. 2000).
- Soil data based on the Fundamental Soil Layer information (Newsome et al. 2000).
- Hydrological properties (based on the River Environment Classification version three (REC3) (Snelder and Biggs 2010).

The method for deriving TopNet's parameters based on GIS data sources in New Zealand is given in Table 1 of Clark et al. (2008). Due to the paucity of some spatial information at national/regional scales, some soil parameters are set uniformly across New Zealand.

TopNet is currently configured to use LCDB3 (Newsome et al. 2000), reflecting 2008 land cover, rather than the latest version, version 5, which corresponds to 2016 land cover. There will be differences in land use between the two, and these may have hydrological consequences, although they are likely to be small in comparison with changes up to 2100. During the simulations from 1971 to 2100, however, land use is kept constant. The purpose of this is to isolate the effects of changing climate on the hydrological response; incorporating land use change scenarios would confound interpretation of the results.

To provide the best spatial resolution, hydrological simulations are based on the REC3 network Strahler[13] catchment order one (approximate average catchment area of 18.7 ha). Large surface water bodies present in the Ōhau river surface water catchment such as lakes, hydroelectric reservoirs, and wetlands (characterised by surface area larger than 1 ha) are not represented in the hydrological model (if present in the modelled domain). The simulation results comprise hourly time-series of various hydrological variables for each computational sub-catchment, and for each of the six GCMs and four RCPs considered. To manage the volume of output data, only river flow-precipitation and temperature information were preserved; all the other state variables and fluxes can be regenerated on demand.

Because of TopNet assumptions, soil and land use characteristics within each computational sub-catchment are homogenised. Essentially this means that the soil characteristics and physical properties of different land uses, such as pasture and forest, will be spatially averaged, and the hydrological model outputs will approximate conditions across land uses.

To carry out the simulations required for this study, TopNet was run continuously from 1971 to 2099, with the spin-up year 1971 excluded from the analysis. To represent high flow events, the climate inputs were stochastically disaggregated from daily to hourly time steps and the hydrological model was run in a "uncalibrated mode".

The hydrological model simulations were not tuned to match any hydrological time serie observations through post-processing bias correction or model calibration for the different areas of interest. As the GCM simulations are "free-running" (based only on initial conditions, not updated with observations), comparisons between present and future hydrological conditions can be made directly (as each GCM is characterised by specific physical assumptions and parameterisations), but this also means that simulated hydrological hindcasts do not track observational records.

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[13] Strahler order describes river size based on tributary hierarchy. Headwater streams with no tributaries are order 1; 2nd order streams develop at the confluence of two 1st order tributaries; stream order increases by 1 where two tributaries of the same order converge.

3.2.3 Measuring a climate change effect

To measure the effect of climate change on the chosen variable, simulated data from the baseline period from mid-1985 to mid-2006 (20 years) are compared to three future time periods: 2030-2049 (mid-century, referred as 2040s). 2040-2059 (referred as 2050s) and 2050-2069 (referred as 2060s). The numbered year indicates the calendar year of the hydrological year starting on 1 July. The magnitude of the effect is determined by the difference between the climate/hydrological characteristics or thresholds calculated over the baseline and future periods.

Results of this analysis are presented as

- Relative change in potential hydrological regimes and their ranges across the 6 GCMs.
- Relative change in projected climate change across the 6 GCMs.

3.2.4 Multi-model averaging versus median

One of the important elements of climate change projections is the use of multiple GCMs. Each GCM is in essence a plausible representation of the climate system as far as a particular research group is concerned. Using a suite of different GCMs allows us to compensate somewhat for uncertainties in climate science; the central tendency or 'multi-model average' of the suite of GCM results may be considered the most plausible climate change outcome. In statistics, however, there is no single definition of 'average' – it depends on how one defines the "centre". The most commonly used measure of average is the 'mean', calculated as the sum of a series of numbers divided by the number of numbers. The 'median' is another kind of average and describes the middle-most number (i.e., half of the numbers are above the median and half are below the median). Lastly, the 'mode' is the value that occurs most often. Each type of average has its place depending on the nature of the data and the insights being sought from the data.

In climate science multi-model averages have more often been represented as means, and this has been the case for the key studies in New Zealand (e.g., Ministry for the Environment 2018), but multi-model medians have also been used internationally (e.g., IPCC 2014). The mean is reasonable if the distribution of a dataset is normal (or Gaussian), but for hydrological variables (particularly for discharge) normal distributions may not be a good approximation. Furthermore, the median gives a truer indication of the central tendency when decisions are to be made based on likelihood (i.e., 50 per cent chance that the results will be greater than the median and 50 per cent chance they will be lower) as it is less affected by outliers, which is more appropriate when averaging across alternative representations of reality and aligns better with the IPCC's use of likelihood percentages. As a result, multi-model averages of hydropower generation capability will be represented in this report as medians.

3.3 Ōhau River catchment physiography

The study area is the surface water catchment of the Ōhau river, as illustrated in Figure 3-2 and Figure 3-3 , while Figure 3-4 presents land use information.

The digital elevation model (DEM) jointly with the location of the streamflow gauging stations were used to generate a stream network and an associated set of 913 Strahler 1 order surface water catchments (approximate subcatchment size of 18.7 ha). TopNet spatially distributed parameters were established for each sub-catchment using national information soil information from the Fundamental Soil Layer (FSL) and land use/land cover information (LCDB3).

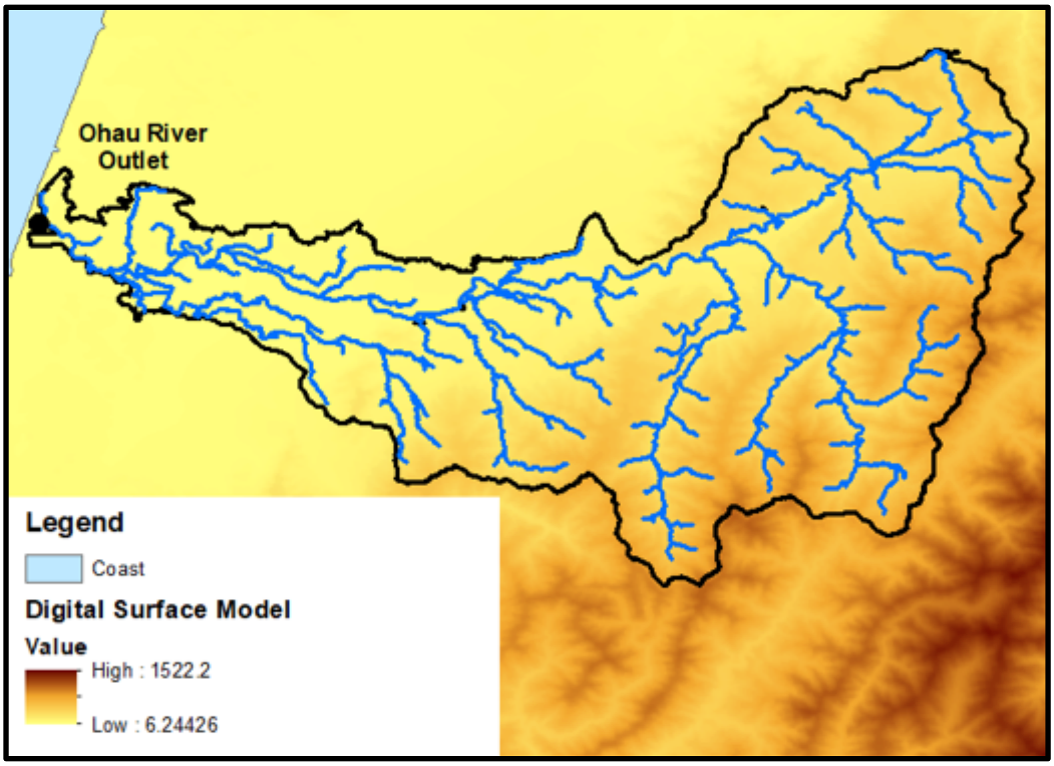


Figure 3-2: Ōhau river surface water catchment extent and land elevation (blue lines represent Strahler 2 streams from the DN3 version 1 coverage).

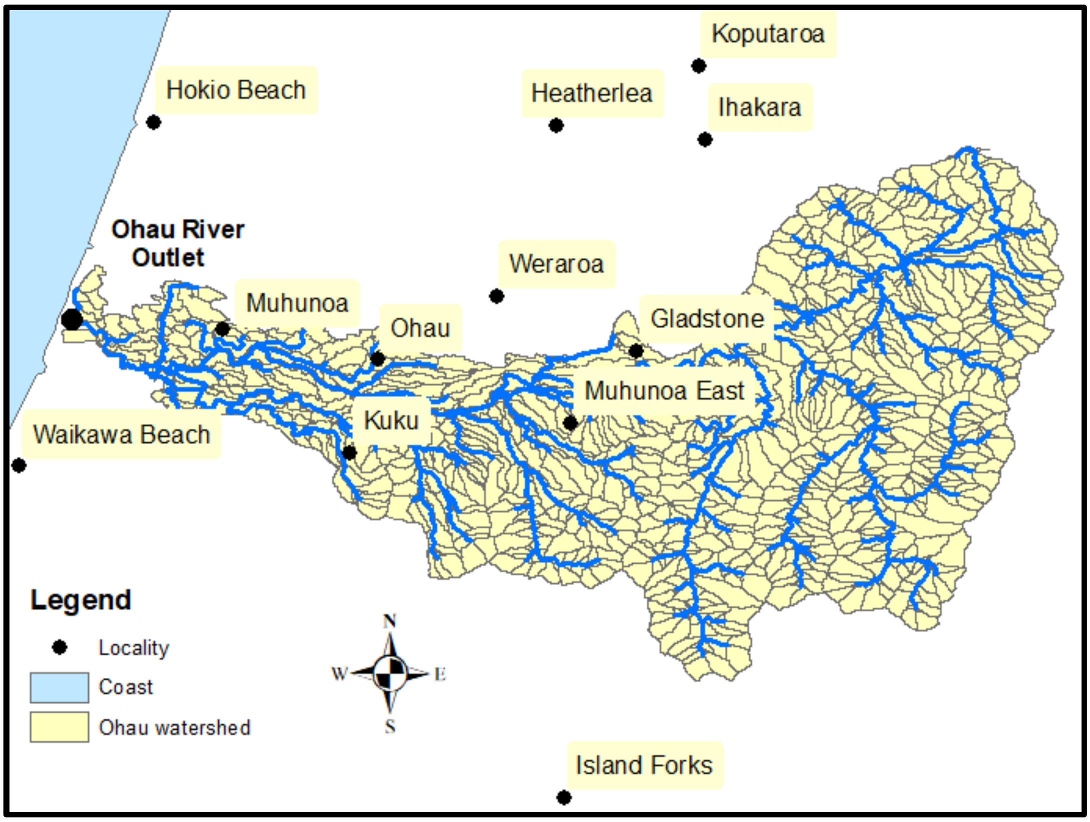


Figure 3-3: Ōhau river surface water catchment extent and modelled watersheds (blue lines represent Strahler 2 streams from the DN3 version 1 coverage).

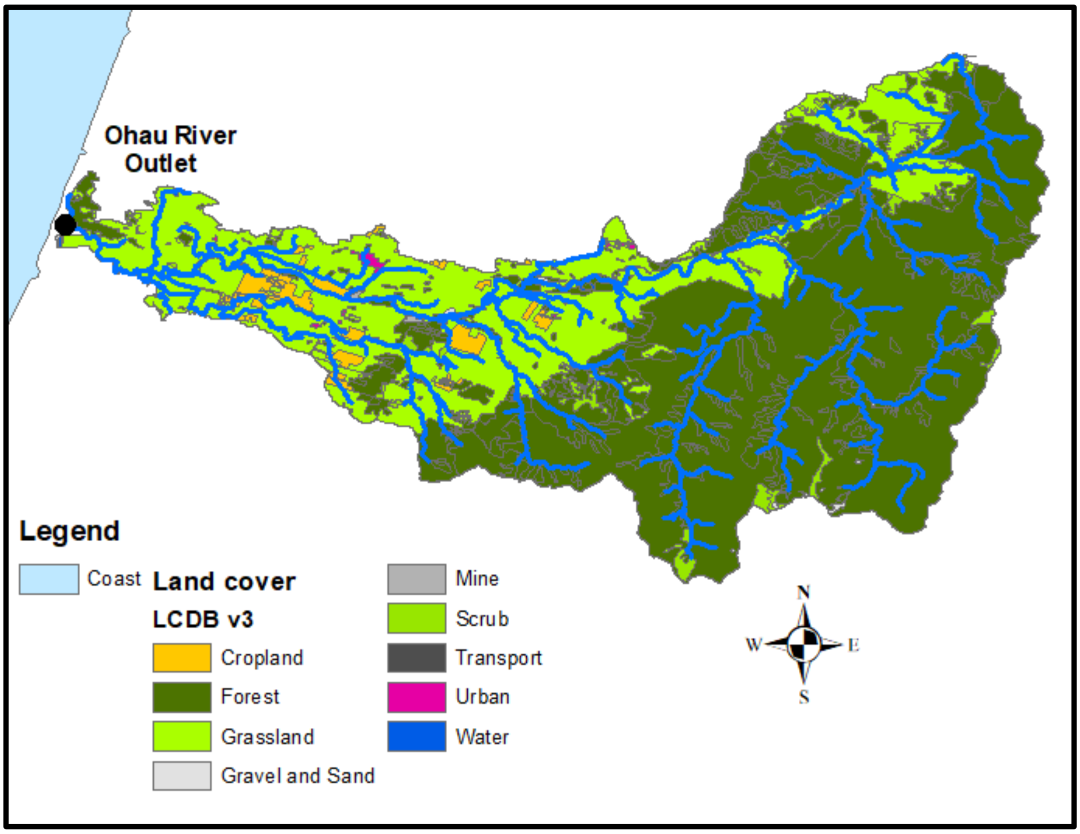


Figure 3-4: Land use.

3.4 Ōhau river hydrological observations

3.4.1 Observed streamflow

Review of the measured streamflow indicates that over the 4 streamflow gauges located within the Ōhau river surface water catchment, suitable discharge measurements are available at three locations located on the Ōhau river listed in Table 3-2 and mapped in Figure 3-5.

Table 3-2: Physiographic information for the three continuous streamflow observations.

Site	Tideda ID	DN3 reach ID	Period	Area (km²)
Ōhau at Muhonoa East Road	32104	7139361	1972-1976	111
Ōhau at Rongomatane	32106	7139215	1978-2011	105
Ōhau at Water Race	32105	7139129	1974-1979	104

Most of the flow sites are fully rated (for high and low flows) from at least the mid-1970s onwards and have reliably maintained rating curves, but only the Ōhau at Rongomatane has observation past 1980.

For the application presented hereafter TopNet hydrological models were built for the eight surface water catchments based on Strahler 1 catchments (typical size 18.7 ha). The total number of TopNet catchments in the Ōhau river surface water catchment at Strahler 1 is 913.

3.4.2 Water consenting

An interrogation of the Ministry for the Environment Water Consent database showed that there are 17 water allocation consents located within the Ōhau river surface water catchment (Figure 3-5). Primary use of the water consented is provided by Figure 3-6.

Analysis of MFE 2010 consent database indicates that:

- 47% of the water consents are associated with surface water resource;
- 100% of the water consents are associated with non-consumptive use;
- One water consent is associated with drinking water;
- 82% of the water consents are associated with irrigation us. 21% of the water consents are associated with pasture irrigation, and 79% associated with horticulture activities;
- One water consent is located upstream of the most downstream streamflow gauging station located on the Ōhau river.

As the version of the TopNet model used in the current application represents only natural discharge and the water consents are located upstream of any streamflow gauging station, observed flows are treated as natural flows. However, it is expected that due to the spatial distribution of the consents, the TopNet model streamflow simulations across low to mid-flow ranges might not be reliable for the lower reaches of the Ōhau river downstream of the Ōhau at Muhunoa Road (see Table 3-2 above).

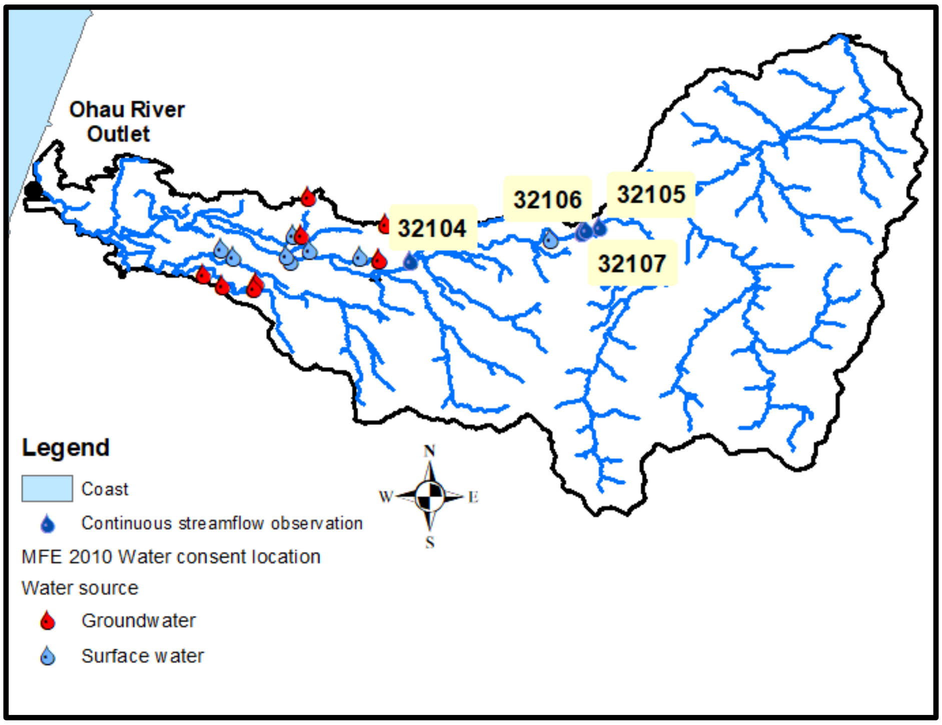


Figure 3-5: Location of surface water (light blue drop) and groundwater (red drop) water consent in the Ōhau surface water catchment. All uses are non-cimsumptive use (MfE 2010).

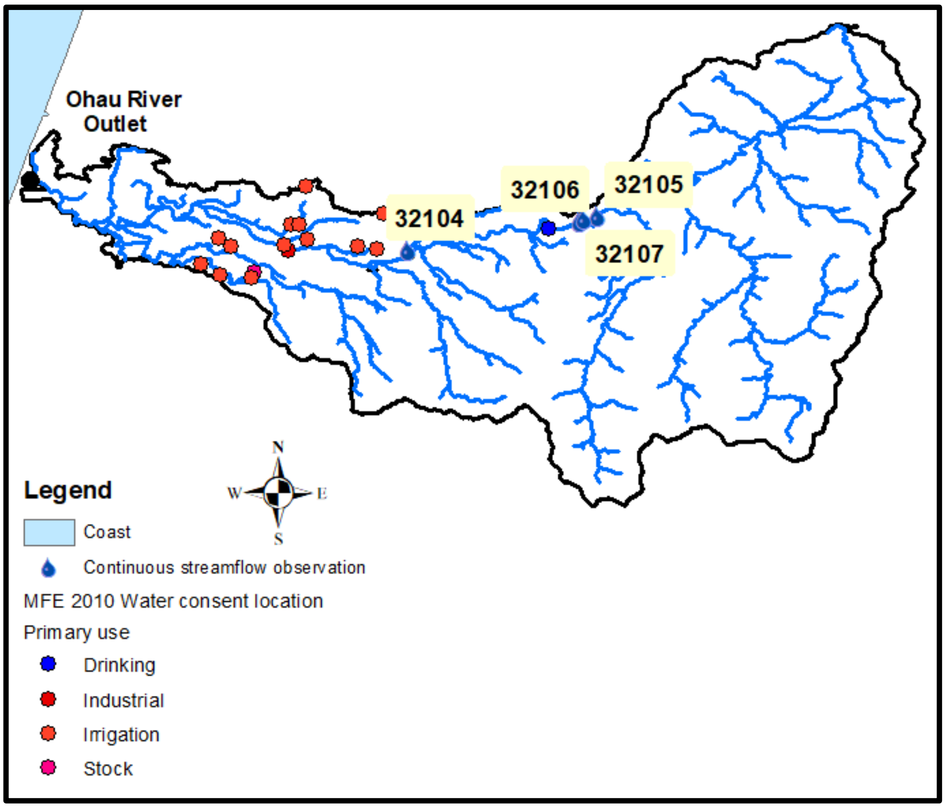


Figure 3-6: Location of water consent and associated primary use in the Ōhau surface water catchment. The colour of the consent is associated with the use of the water.

3.4.3 Groundwater

Analysis of MfE 2010's water consent database indicates that most of the water consent within the Ōhau river catchment is from groundwater. Figure 3-7 presents the location and extent of the hydrogeological units within the Ōhau surface water catchment (MfE 2019).

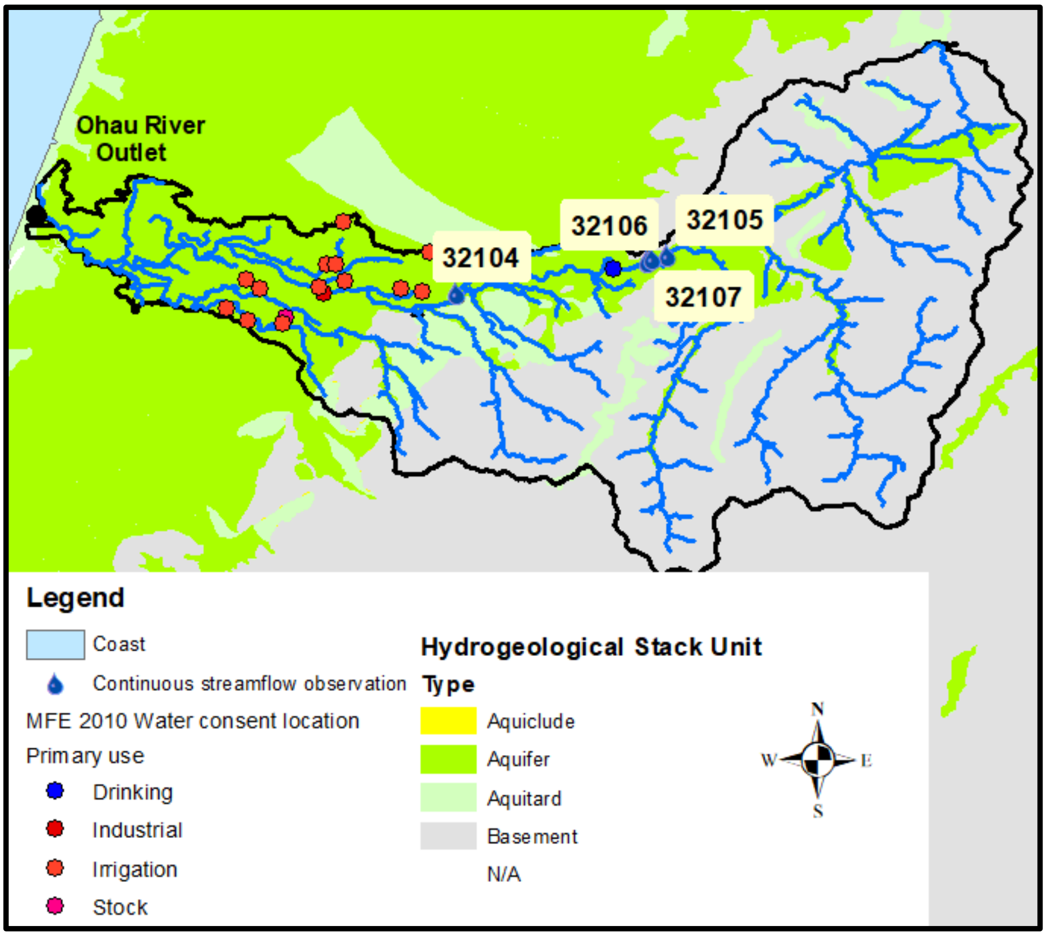


Figure 3-7: Hydrogeological units for the Ōhau surface water catchment. Water consented activities primary use use are represented.

Analysis of the hydrogeological units indicates that:

- The relative clustering of the groundwater consent in the lower reaches of the Ōhau river is consistent with the presence of substantial aquifer connected to the surface water network in this area.
- There is a potential groundwater connection between the Ōhau surface river catchment and the larger groundwater aquifer located on the southern boundary of the surface water catchment. This may result in an increase source of water to discharge to the lower reaches of the Ōhau river which could potentially be identified through water balance analysis.

3.5 Hydrological bias correction

TopNet parameterisation uses the concept of parameter multipliers, as one of the main assumptions of TopNet implementation is that the spatial distribution of the parameters is determined *a priori* from catchment physiographic information for the sources described above (see section **Error! Reference source not found.**). TopNet requires the determination of seven hydrological parameter multipliers and 10 snow-related parameters for each sub-catchment (see Table 3-3). The initial values of the parameter multipliers are set to a value of 1, while snow related parameters are initialised based on previous study results for the area.

Table 3-3: Range of TopNet parameter multipliers used during calibration process.

Parameter name	Parameter description	Calibrated range
Hydrological parameters		
Saturated store sensitivity (topmodf)	Describes exponential decrease of soil hydraulic conductivity with depth	[0.01-2] * default
Drainable soil water (swater1)	Range between saturation and field capacity	[0.05-10] * default
Plant available soil water (swater2)	Range between field capacity and wilting point	[0.05-10] * default
Hydraulic Conductivity at saturation (hydcond0)		[0.1-10000]*default
Ch_exp	Clapp-hornberger c exponent	[0.05-10] * default
Ga-psif	green-ampt wetting front suction	[0.05-10] * default
canscap	canopy storage capacity	[0.05-10] * default
canenh	canopy evaporation enhancement factor	[0.05-10] * default
Overland flow velocity (overvel)		[0.1-10]*default
Manning n	Characterises the roughness of each reach	[0.1-10] *default
Atmospheric lapse rate (atmlaps)	Change in temperature with elevation, used to adjust temperatures from climate data sites to basin centroid	[0.7-1.5] * default
Gauge Undercatch (gucatch)	Adjustment for non-representative precipitation	[0.5-1.5] * default
Snow parameters		
threshold for snow accumulation (th_accm)	Temperature threshold for snow accumulation	270.15-275.15 [K]
Threshold for snow melt (th_melt)	Temperature threshold for snow melt	269.15-274.15 [K]
snowddf	Degree-day factor for snow melt	1-10 [mm K-1 day-1]
Minddf	Calendar day of the minimum degree-day-factor day	1-366 [days]
Maxddf	Calendar day of the maximum degree-day-factor day	1-366 [days]
snowamp	Seasonal amplitude of degree-day factor for snow melt	0-5 mm K-1 day-1]
snowros	Addition in melt factor caused by rain-on-snow events	0-5 mm K-1 day-1]
decmelt	Decrease in melt due to higher albedo after fresh snow	0-5 mm K-1 day-1]
albdecy	Time decay of snow albedo	1-5 days

Parameter name	Parameter description	Calibrated range
Hydrological parameters		
cv_snow	Subgrid variability representing the distribution of the snowpack across the catchment	0-2 [-]

Due to the complex interaction between climate, landcover, and geomorphology, hydrological models generally require calibration for the model to reproduce observed hydrological behaviour and/or characteristics. Despite TopNet reproducing observed hydrological characteristics across New Zealand as a whole (see Booker and Woods 2012 and McMillan et al. 2016), model calibration is recommended to overcome catchment-specific hydrological behaviour (Zammit 2019).

The TopNet simulations used in this project leverage simmulations carried out as part of the Deep South National Hydrology project (Climate impacts on the national water cycle | Deep South Challenge) to provide surface water time series information under climate change. As a result, calibration of the hydrological model for all surface water gauging stations was not implemented as part of the project.

To assess if calibration is needed, we compared simulated observed hydrological characteristics over the period 1986-2005 (Figure 3-8) with non- bias corrected CMIP5 GCM-driven simulated hydrological characteristics for the Ōhau river at Rogomatane (station ID 32106). This was carried out by comparing the daily observed and predicted flow time series (to identify potential mismatches in the flow regime), flow duration curve (to identify potential mismatches in the statistical distribution of the flows) and cumulative flow (to identify potential issues related to systematic bias in the simulation process). Analysis of the simulated flow regimes using the uncalibrated model indicates that : i) the uncalibrated model is able to represent the range of hydrological regimes observed at Rogomatane stream flow station; ii) the uncalibrated model suffers of a consistent ater balance error over the period 1986-2005; iii) the hydrological model is able to represent the seasonal hydrological behaviour observed at Rogomatane but is not able to represent the magnitude nor timing of the high flow events over the period September to December; and iv) based on the analysis carried out a calibration of the topNet model at Rogomatane is recommended.

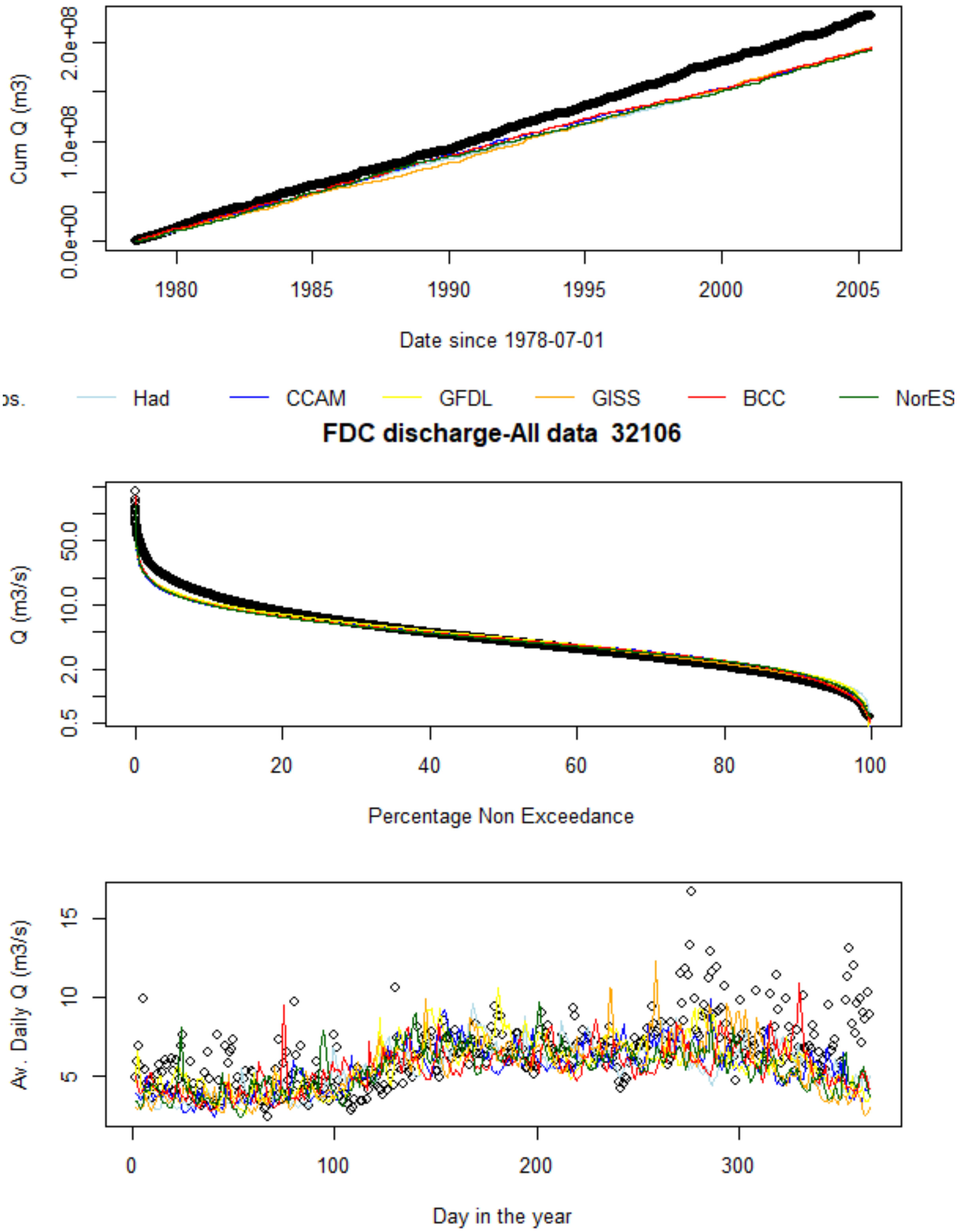


Figure 3-8: Uncalibrated cumulated hydrographs, flow duration curve and daily average hydrograph for the Ōhau River at Rongomatane (station ID 3216) over the period 1985-2006). Observations (black diamonds) are compared with unclaibrated TopNet flows driven by GCMs; HadGEM-ES (light blue) , CESM1-CAM5 (blue), GFDL-CM3 (yellow), GISS-E2-R (orange), BCC-CSM1.1 (red), and NorESM1-M (dark-green).

An alternative to the calibration process is the bias correction process, which aims to correct the hydrological model parametrisation using a simple water balance approach for a surface water catchment. The bias correction is designed to reproduce the average annual precipitation, evapotranspiration, and mean discharge hydrological characteristics under the assumption that the upstream catchment associated with any gauging station is a surface water catchment. Due to its simple design, the bias correction aims to correct i) systematic bias in the simulation process (see cumulative discharge traces in Figure 3-8); ii) potential mismatches in the statistical distribution of the flows (see flow duration curve in Figure 3-8); and iii) but does not provide any correction on the timing of events. Figure 3-9 presents simulated observed hydrological characteristics over the period 1986-2005 with bias corrected CMIP5 GCM-driven simulated hydrological characteristics for the Ōhau river at Rogomatane (station ID 32106), while Table 3-4 presents the observed and simulated hydrological characteristics used for the bias correction and Table 3-5 presents the GCM specific TopNet parameters values used as part of the bias correction process.

Table 3-4: Observed and simulated bias corrected hydrological characteristics for the Ōhau river at Rongomatane.

Simulation name	Mean annual precipitation [mm/yr]	Mean annual evapotranspiration [mm/yr]	Mean annual runoff [mm/yr]
Observation Ōhau at Rogomatane	2651	725	1926
HadGEM2-ES	2652	759	1892
CESM1-CAM5	2651	755	1896
GFDL-CM3	2652	760	1891
GISS-E2-R	2652	744	1908
BCC-CSM1.1	2651	761	1889
NorESM1-M	2650	761	1889

Table 3-5: GCM specific TopNet parameter multipliers used during bias correction process.

GCM name	Parameter description	
	Gaugecatch (gauge undercatch)	Swater2 (plant available water)
HadGEM2-ES	1.125* default	1.200* default
CESM1-CAM5	1.131* default	1.200* default
GFDL-CM3	1.091* default	1.200* default
GISS-E2-R	1.133* default	1.200* default
BCC-CSM1.1	1.124* default	1.200* default
NorESM1-M	1.135* default	1.200* default

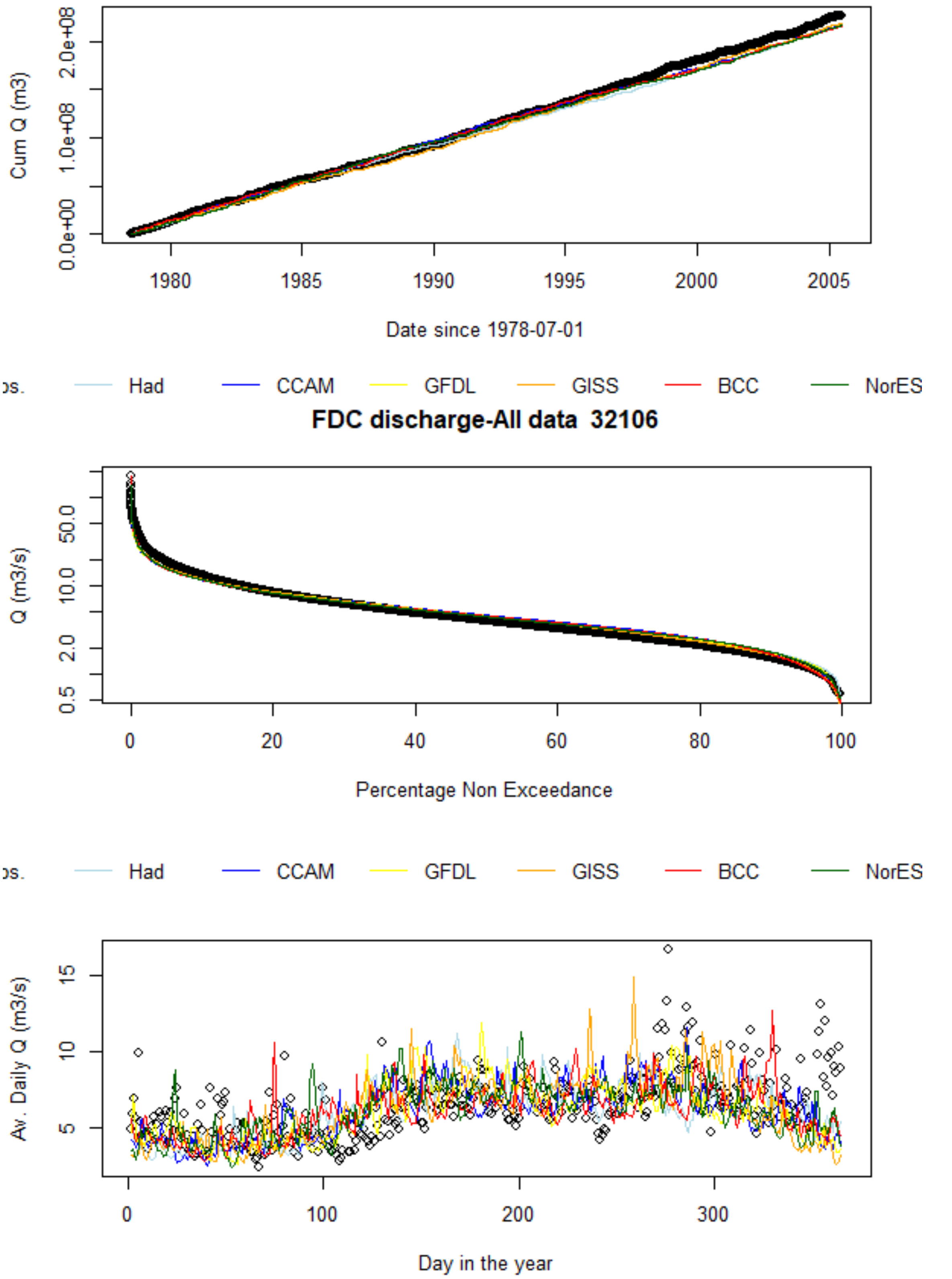


Figure 3-9: Bias corrected cumulated hydrographs, flow duration curve and daily average hydrograph for the Ōhau River at Rongomatane (station ID 3216) over the period 1985-2006). Observations (black diamonds) are compared with uncalibrated bias corrected TopNet flows driven by GCMs; HadGEM-ES (light blue) , CESM1-CAM5 (blue), GFDL-CM3 (yellow), GISS-E2-R (orange), BCC-CSM1.1 (red), and NorESM1-M (dark-green).

Analysis of the bias correction indicates that:

- For the bias correction purpose, precipitation has to increase between 9 and 14%, slieghlty larger than the conventional precipitation measurement error (10%), while plant available water has to increase by 20% independantly of the climate model. The later seems to indicate a potential issue with the soil information used to develop the hydrologicla model.
- GCM specific bias corrected precipitation match calculated catchment scale precipitation, while long term evapotranspiration and runoff compensate each other.

3.6 Climate change analysis

In association with the project team (see Section 5), seven locations/river transects have been selected for information extraction in the low reaches of the Ōhau river. Those transects, presented in Figure 3-10 with the corresponding DN3 river network nzsegment, were chosen as:

- Control point location for the flotting wetlands inlet and discharge in regards of īnanga recruitment
- Current location of īnanga spawning identified through on-going annual survey of riverbanks
- Potential future īnanga spawning due to the change of location of sweater-freshwater interface expected due to sea level rise.

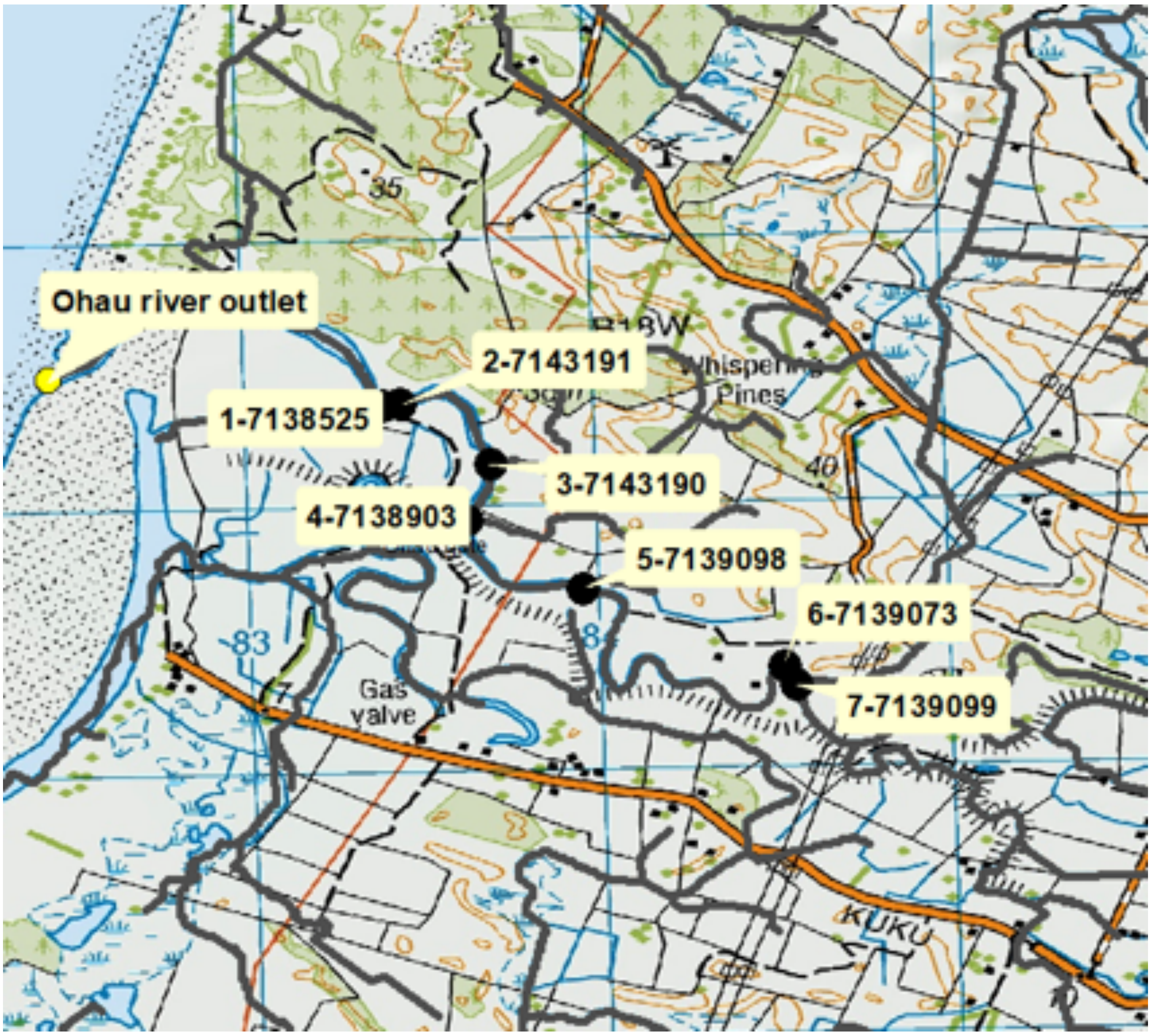


Figure 3-10: Location of investigation for climate change impact assessment along the Ōhau River. Location ID and DN3 nzsegment presented.

On the seven river-transect locations, location 4 is of particular interest as water level loggers were installed (at the onset of the project) to monitor water levels and tidal effect in the low reaches of the Ōhau river. Rating analysis was developed at that location for two occasion dring the project (see Section 4 'Freshwater Ecology' for further information). A comparison of observed and simulated discharge is presented in Figure 3-11 for the period of observation (2021 calendar year) across the simulated flow regime. The analysis indicates that the observed flow regime is within the range of flow regimes simulated for all RCP scenarios.

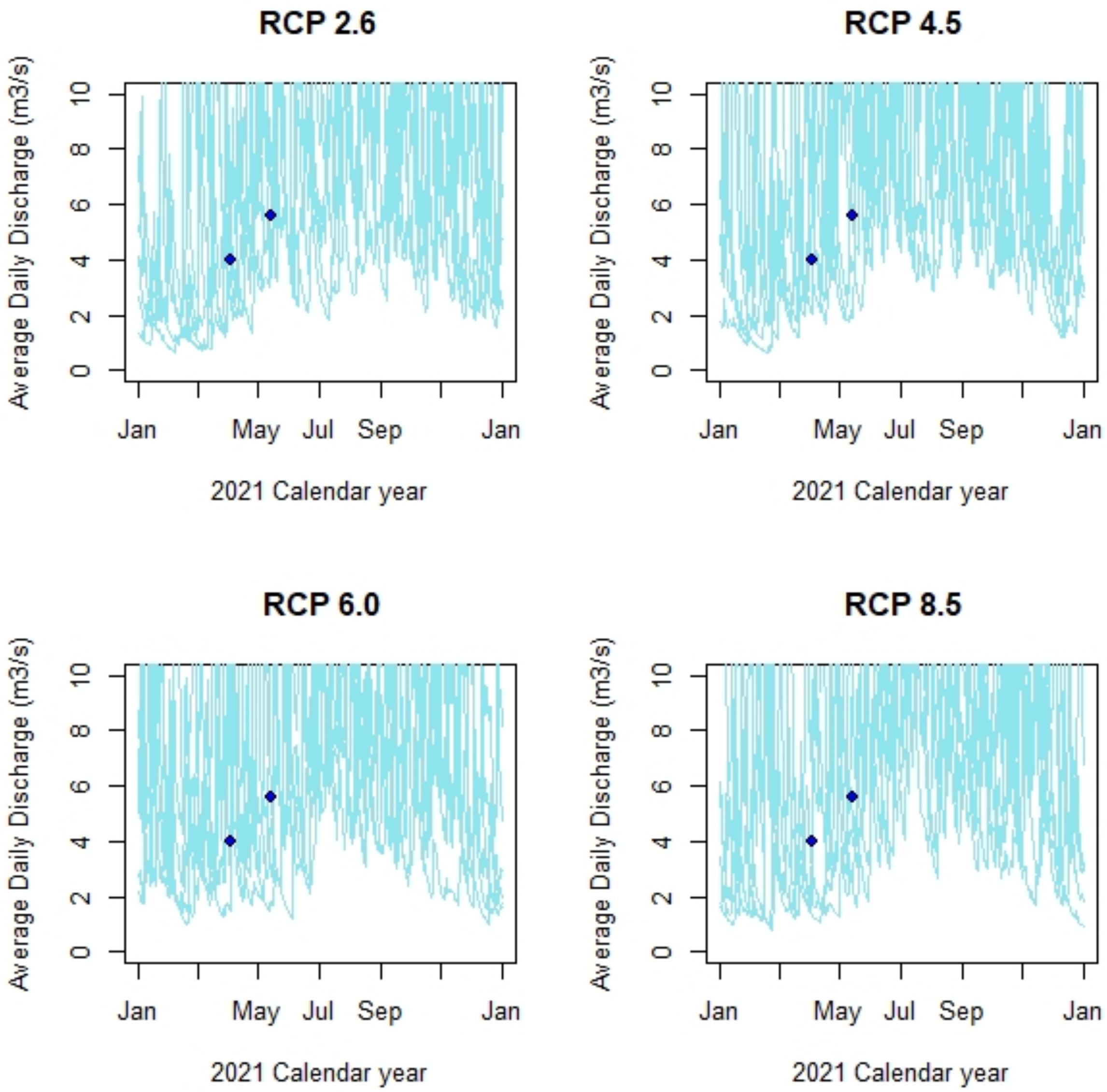


Figure 3-11: Comparison of bias corrected hydrological time series (blue lines) with observed discharge measured on two occassions at Location 4 (blue dot) alongside the installed waterlevel logger on the True Left Bank (TLB) of the Ōhau River. Each hydrological trace represents a GCM driven simulation generating an 6 member ensemble trace.

To measure the effect of climate change on the chosen variable, simulated data from the baseline period from mid-1986 to mid-2006 (20 years) are compared to seven future time periods: 2021-2041 (2030s), 2031-2051 (2040s), 2041-2061 (2050s), 2051-2071 (2060s), 2061-2081 (2070s), 2071-2091 (2080s) and 2081-2099 (2090s). The numbered year indicates the calendar year of the hydrological year starting on 1 July. The magnitude of the effect is determined by the difference between the climate/hydrological characteristics or thresholds calculated over the baseline and future periods. For clarity only results for 2030s-2050s-2070s and 2090s are presented hereafter for the Ōhau river outlet for change in precipitation (Figure 3-12), temperature (Figure 3-13), evapotranspiration (Figure 3-14) and river flow (Figure 3-15).

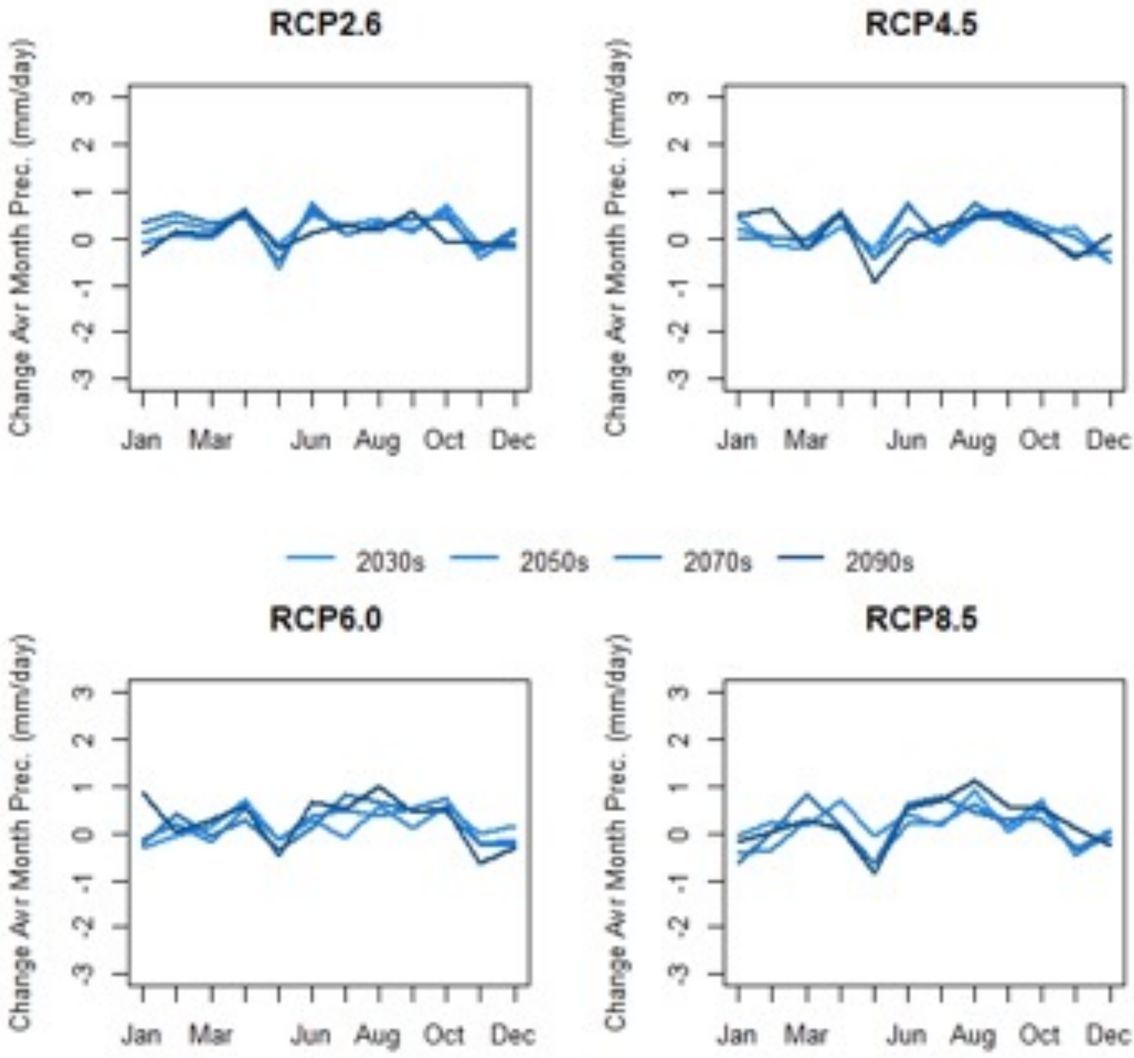


Figure 3-12: Simulated change in average monthly precipitation under RCP 2.6 (topleft), RCP4.5 (topright), RCP6.0 (bottom left) and RCP8.5 (bottom right) projections for the Ōhau river outlet for four 20year centred periods. Change are provided as the median change (in mm/day) across the 6 GCMs.

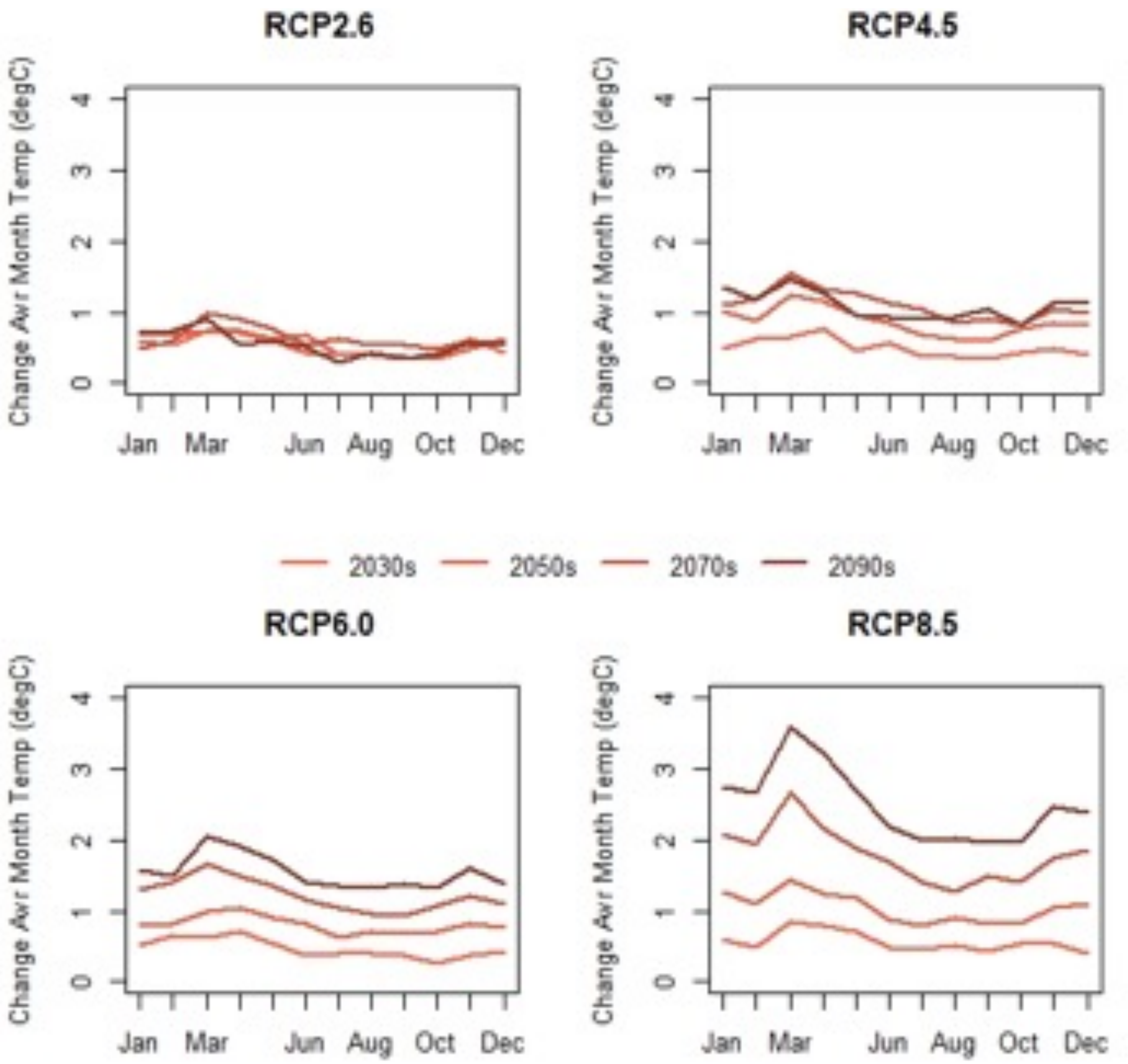


Figure 3-13: Simulated change in average monthly temperature under RCP 2.6 (topleft), RCP4.5 (topright), RCP6.0 (bottom left) and RCP8.5 (bottom right) projections for the Ōhau river outlet for four 20year centred periods. Change are provided as the median change (in deg C/day) across the 6 GCMs.

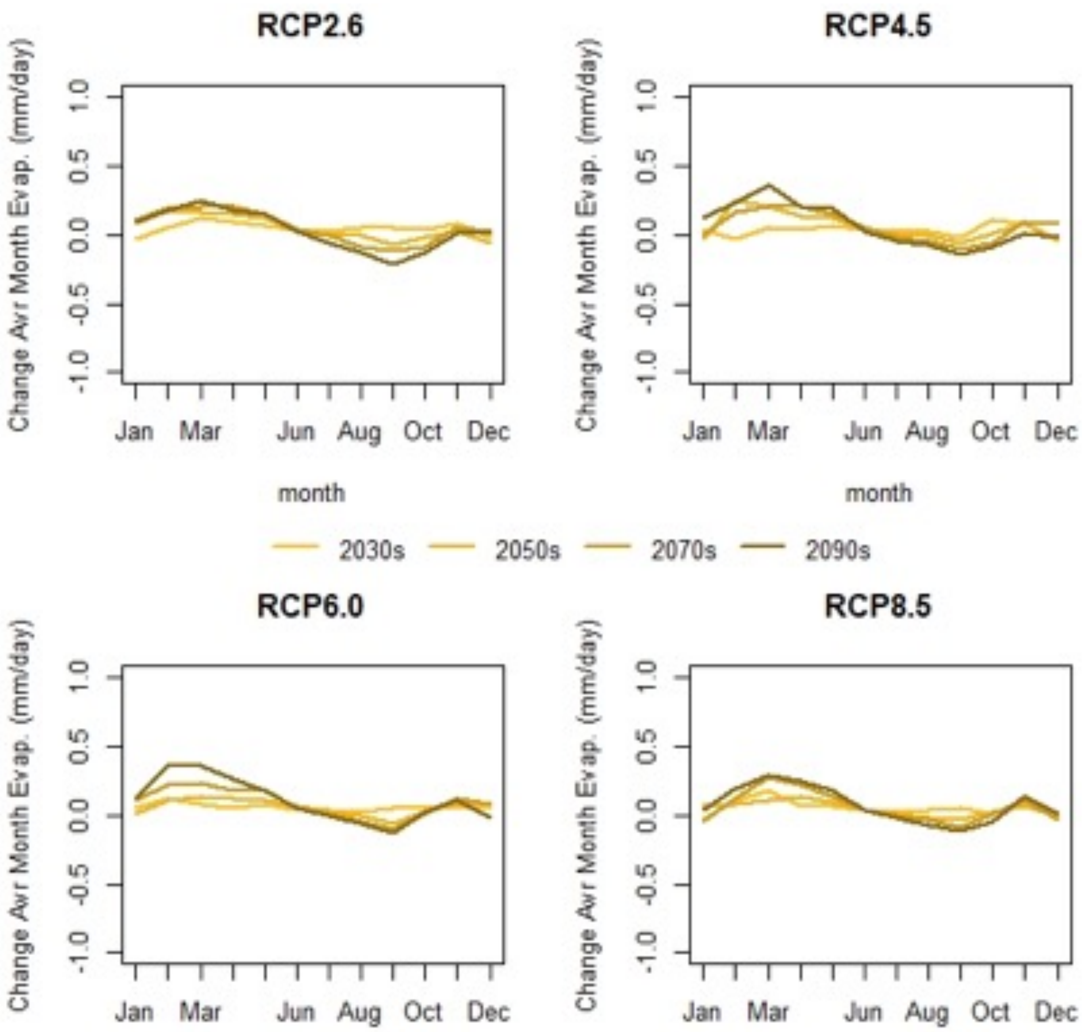


Figure 3-14: Simulated change in average monthly evaporation under RCP 2.6 (topleft), RCP4.5 (topright), RCP6.0 (bottom left) and RCP8.5 (bottom right) projections for the Ōhau river outlet for four 20year centred periods. Change are provided as the median change (in mm/day) across the 6 GCMs.

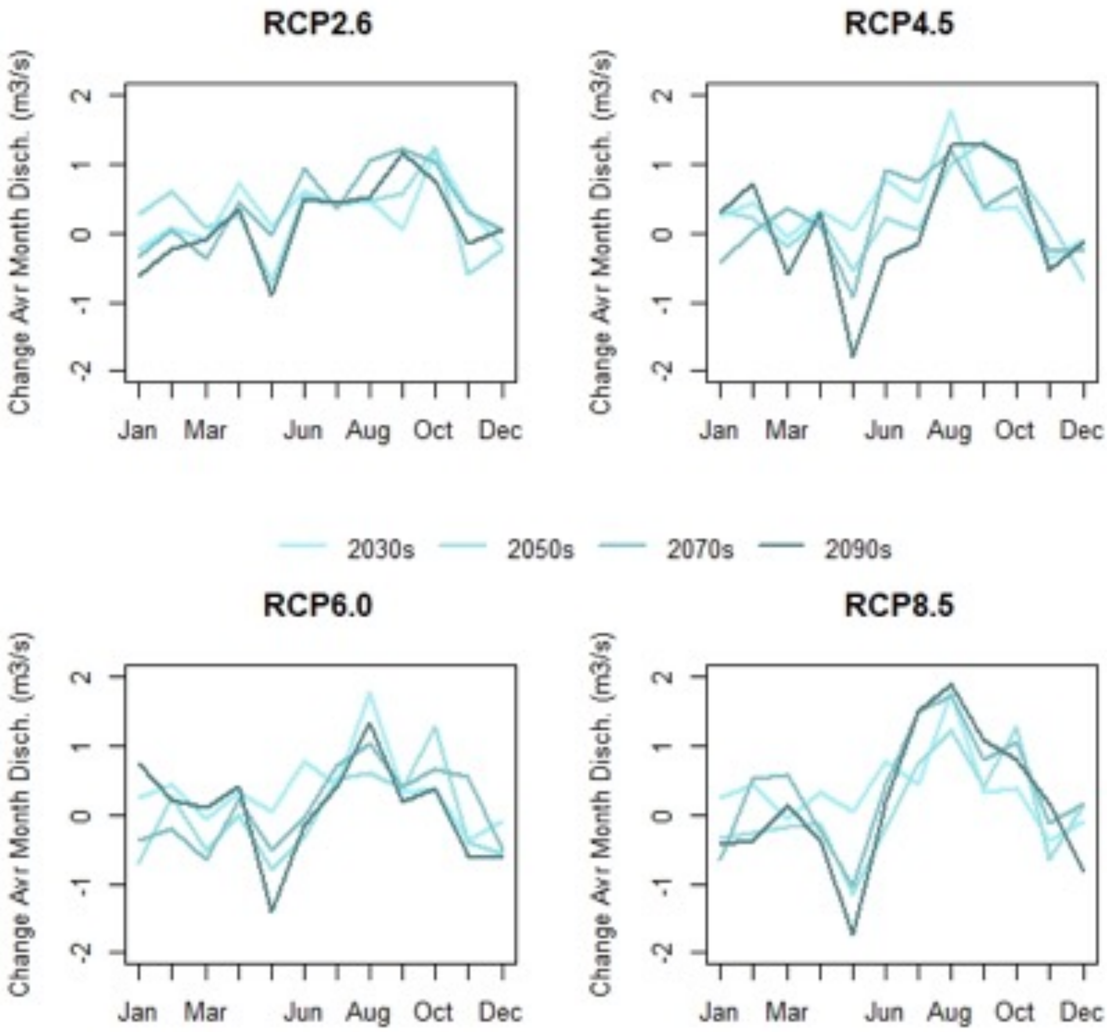


Figure 3-15: Simulated change in average monthly discharge (river flow) under RCP 2.6 (topleft), RCP4.5 (topright), RCP6.0 (bottom left) and RCP8.5 (bottom right) projections for the Ōhau river outlet for four 20year centred periods. Change are provided as the median change (in mm/day) across the 6 GCMs.

Analysis of the expected climate change for the Ōhau River catchment indicates that:

- Temeperatures are expected to increase between 1 and 3 degrees (annual average) by the end of the century under the highest radiative forcing scenario. Summer temperatures are expected a larger increase than winter temperature.
- On annual basis, precipitation is expected to remain stable across time and radiative forcing. Winter precipitation is expected to slightly increase while summer precipitation is expected to slightly decrease (under the largest radiative forcing scenario).
- Despite the large temperature increase, evapotranspiration is expected to remain stable across radiative forcing and time. On a seasonal basis, summer evapotranspiration is expected to be slightly higher than currently experienced, while winter evapotranspiration is expected to slightly decrease with time and radiative forcing.
- Monthly hydrological regimes are expected to experience more seasnal variation. Summer discharge is expected to decrease with the largest decrease being in May across all radiative forcing scenarios and time. Winter discharge is expected to increase with radiative forcing

and time. On annual basis, discharge is expected to increase along the Ōhau River, with winter increase in discharge overcompensating summer decrease.

3.7 Hydrological information supporting ecological investigation

The aim of the project is to develop the methodology required for the creation of aquaculture ponds to enhance wetland habitat and support the lifecycle of native freshwater taonga species under climate change. Following discussion with the ecological modelling team, it was identified that īnanga life cycle is driven by :

- Spawning on vegetation at high tide at the seawater/freshwater interface around March;
- Fish egg development in the vegetation during March/April to August/September (depending on the moon cycle). This stage requires that the eggs remains in the vegetation and not flushed at sea following flood event. If such an event is to occur, the īnanga generation is lost.
- Release to the sea for the next stage of īnanga life cycle.

To answer those questions the following information is required from the hydrological model:

- River water level at the seven location of interest during the critical time period for īnanga life cycle. This is required to estimate the risk of streambank overtopping that could results in the eggs being flushed at sea.
- Impact of sea level rise on river level as location of interest are all located in coastal Ōhau river.

3.7.1 Converting stream discharge to water level

The conversion of the river discharge (produced by the topNet hydrological model) to river height is carried out using Uniform Flow theory (Neal et al 2021) that assumes that I) discharge is uniform across the river profile, ii) bed friction and bed slope are identical, iii) hydraulic radius is taken as water depth (using rectangular channel conceptualisation), and iv) bankfull discharge (i.e. the discharge corresponding to a river close to bursting its bank) is provided by the 1 in 2.33 ARI flood.

$$\boldsymbol{h} = \left(\frac{\boldsymbol{nQ}}{\boldsymbol{wS}^{1/2}}\right)^{3/5}$$

Equation 1: Water level equation based on Uniform Flow Theory

With ***h*** representing the river water level, ***n*** Mannig's bed friction coefficient, ***Q*** the river discharge at the location of the trasnect, ***S*** the slope of the river bed, and ***w*** the width of the transect.

To calculate water level and streambank discharge the following process was carried out at each of the seven river-transect locations for each GCM driven simulations:

- Extract the annual time series of discharge for each GCM over the period 1985-2006
- Calculate the 1:2.33 ARI using Gumbel distribution to estimate the bankfull discharge for each GCM at the location of interest

- Calculate streambank full water level
- Using rectangular channel approximation (Equation 1), calculate time series of water level

Figure 3-16 illustrates the the conversion of stream discharge to water level and streambank full discharge water level. For the sake of clarity, it is is provided only at location 1.

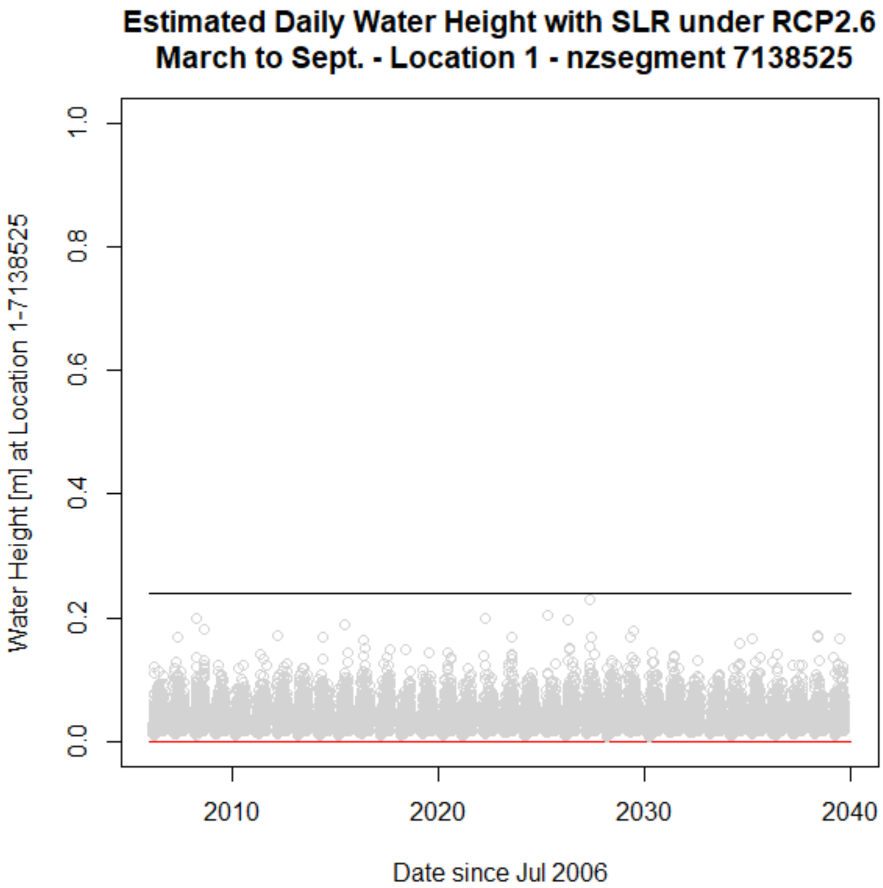


Figure 3-16: Ensemble theoritical uniform flow March to September water level time series (grey dots) and streambank full discharge water height (black line) under RCP2.6 over the period 2006-2040 at location 1. Theoritical water height (grey dots) generated over the period March to September for each hindcast GCM driven simulation.

3.7.2 Simulation of Sea Level Rise on water level

Hydrodynamic models are usually used to represent the effect of mean sea level rise on riverine water level under different weather/climate conditions. Due to the fact that no hydrodynamic model was available for the Ōhau river coastal area, a simple approach was developed to conceptualise the combined effect of sea level rise with change in hydrological regimes due to climate change.

The resulting conceptual model has the following assumptions:

- The model is based on a simple bath-tub concept resulting in river water level being added.
- No hydrostatic correction (due to difference in density between sea water and freshwater) is applied to water level. This means that we consider that seawater, brackish water and freshwater have the same density.
- Instantaneous mixing between seawater and freshwater.

- The model represents only the effect of Mean Sea Level Rise (MSLR) on river water level and ignores tidal, wave height, and strom surge impact.
- River bathymetry is considered to be rectangular.
- No calculations are made about the potential extent of land flooding as a result of the combined effect of MSLR and climate change induce riverine discharge.

Mean Sea Level projections are taken from Ministry for the Environment 2017 coastal guidance and are interpolated to daily time step as per Figure 3-17.

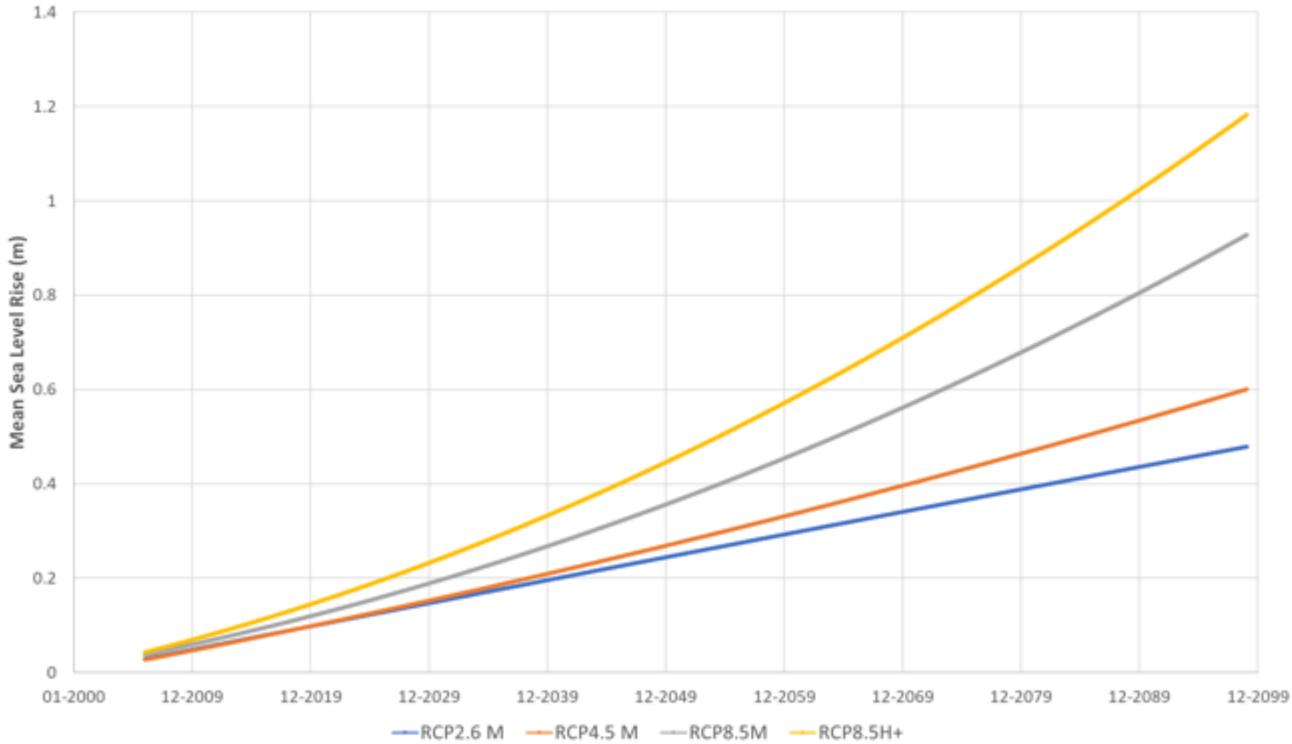


Figure 3-17: Mean seal level rise scenarios for New Zealand (MfE 2017). For modelling purpose, RCP8.5M is taken as RCP6.0.

The impact of MSLR on river level are determined as follow:

- MSLR time series is compared to reach specific hydraulic characteristics such as bed elevation of the reach and reach width to determine the time when MSLR is expected to impact local water level.
- Once the reach is impacted by MSLR, MSLR are added to the local water level assuming bath- tub approach.

Figure 3-18 presents the outcomes of the use of the simple conceptual model at location 1.

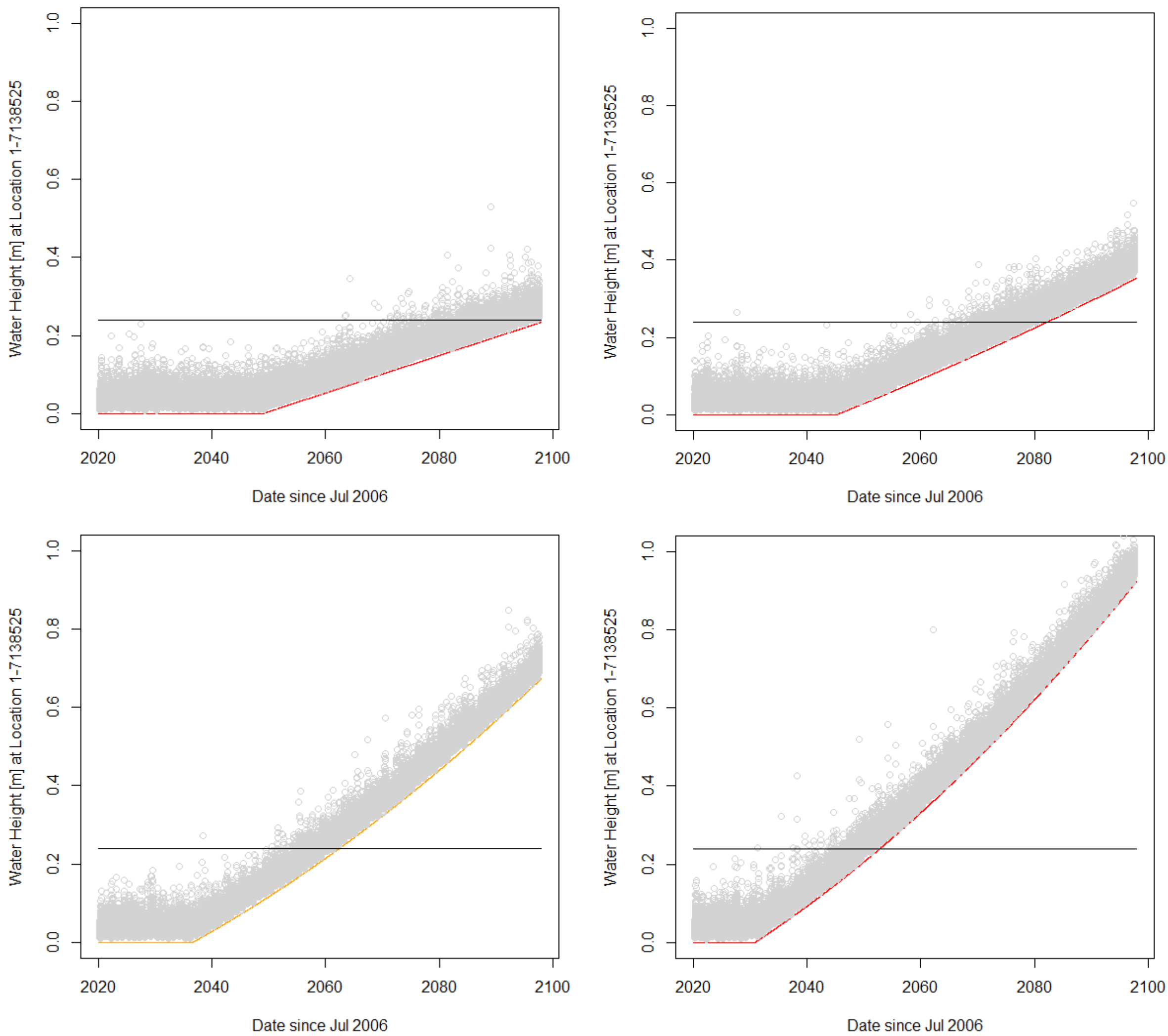


Figure 3-18: Ensemble theoritical uniform flow March to September water level time series (grey dots), streambank full discharge water height (black line) and Mean Sea Level Rise (red line) under RCP2.6 (top left), RCP4.5 (top right), RCP6.0 (bottom left) and RCP8.5 (bottom right) over the period 2006-2100 at location 1. Theoritical water height (grey dots) generated over the period March to September for each hindcast GCM driven simulation.

Analysis of the use of the conceptual model at location 1 indicates the following regarding the combined risk of sea level rise and riverine discharge flooding:

- SLR should not impact permantent water levels at location 1 under RCP2.6, however it starts to impact local water level around 2050. Bank overtopping is expected from 2070 onward and location is expected to be regularly flooded by 2099. Under this scenario the risk of land surface flooding during critical period of īnanga life cycle is considered to be low and nusery could be established at location 1 up to 2070.
- SLR should start to impact local water level around 2045 under RCP4.5. Bank overtopping is expected from 2065 onward and location is expected to be regularly flooded by 2080. Under this scenario the risk of land surface flooding during critical period of īnanga life cycle is

considered to be low up to 2060 and nusery could be established at location 1 up to that time.

- SLR should starts to impact local water level around 2035 under RCP6.0. Bank overtopping is expected from 2050 onward and location is expected to be regularly flooded by 2060. Under this scenario the risk of land surface flooding during critical period of īnanga life cycle is considered to be low up to 2050 and nusery could be established at location 1 up to that time.
- SLR should starts to impact local water level around 2035 under RCP8.5. Bank overtopping is expected from 2030 onward and location is expected to be regularly flooded by 2040. Under this scenario the risk of land surface flooding during critical period of īnanga life cycle is considered to be low up to 2040 and nusery could be established at location 1 up to that time.

4 FRESHWATER ECOLOGY

4.1 Introduction

The focus area of the Phase 3 Implementation Plan was the low-lying coastal land owned and administered by Tahamata Incorporation extending from the southern banks of the Ōhau River to the Ōhau River Loop in the south, and to the coast in the west (Figure 4.1).

Figure 4.1 Location of the Phase 3 Focus Area for identifying sites to create the proposed aquaculture wetland habitat pond

Outputs from Phase 1 of this project included a Transition Plan, which contained recommendations for staged expansion of wetland habitats in preparation for, and response to, climate change impacts. Phase 2 refined these recommendations to include specific areas for:

i. creation of native fish aquaculture ponds
ii. extensive harakeke planting for future harvesting opportunities
iii. restorative riparian planting to improve biodiversity and water quality
iv. restorative wetland planting to enhance existing habitat.

The creation of aquaculture ponds to enhance wetland habitat and support the lifecycle of native freshwater taonga species was chosen as the focus for Phase 3 freshwater ecology work.

4.1.1 Native fish aquaculture feasibility

At the wānanga held in November 2020 a presentation was given to the wider research group and hapū members titled '*Constructed Treatment Wetlands, Whitebait & Tuna: Building farm-scale climate change resilience*' (Eivers, R.S. 2020). This presentation introduced constructed treatment wetlands (CTW) and their various design parameters for water quality treatment, including open-water flow, subsurface horizontal flow, and subsurface vertical flow models. The presentation also described more recent works by Eivers (2018) to integrate biodiversity values into CTW designs to achieve improvements in both water quality and aquatic ecosystem values. The presentation additionally introduced the native fish aquaculture ponds of Jan and Charles Mitchell, created on the banks of the Waitetuna River on Ōhautira Road, Raglan. The opportunities, intricacies, complexities, and risks of running a native fish aquaculture system commercially were then discussed.

Discussions during the wānanga revealed that there was not yet capacity within the local hapū to oversee a commercial native fish aquaculture enterprise, nor was there yet licence to do so on Tahamata land. It was therefore decided to focus the Phase 3 freshwater ecological works on creating passive (i.e. systems that do not require active hydrological management) wetland habitat pond systems to support and sustain whitebait and tuna taonga species. Īnanga (*Galaxias maculatus*) were described as especially important for mana whenua due to the high value of their whitebait (juvenile life stage of the fish) as kai moana.

4.2 Wetland Habitat Ponds

To effectively support and enhance the lifecycle of īnanga, particularly spawning, the wetland habitat ponds must be carefully (i) located and (ii) designed to emulate the natural hydrology of the Ōhau River. Specifically, to retain the hydrological influence of the tide, as well as a constant flow of freshwater from the awa to serve as a "lure" to īnanga and other whitebait species to swim upstream into the recreated wetland habitat.

4.1.2 Location

To locate a feasible site for the proposed wetland habitat pond system, accurate site-specific data was needed regarding water levels in the awa in relation to river flows (discharge) and the tides throughout the marama/lunar cycle. It is essential that the 'saltwater wedge' created between the brackish water pushed upstream on the incoming taitai nunui/king tides during autumn and the downstream flowing freshwater of the awa occurs within the wetland pond system to initiate īnanga spawning within the recreated habitat.

During the hīkoi on 20th November 2020, a suitable location on the Ōhau River was identified for hydrological monitoring of water levels. Key considerations for choosing the location were proximity to the mainstem of the awa and an existing small backwater wetland, and the safety of the location for installing water-level data loggers, both for personnel accessing the loggers, and for the loggers themselves when exposed to flooding flows of the awa.

4.1.3 Site Hydrology

Two 'Solinst Levelogger Edge' pressure sensor and temperature dataloggers were installed on 31st March 2021 to record water level fluctuations in the backwater wetland (WL) and the main stem of the Ōhau River (True Left Bank, TLB) over the study period (Figure 4.2). A 'Solinst Barologger Edge' was simultaneously installed to compensate the Levelogger Edge data for atmospheric pressure fluctuations. This was installed at a nearby outdoor shed, ensuring the logger was in the open air whilst being protected from the weather. The loggers measured water level (meters), temperature (° C), and atmospheric pressure (kPa) every 5 minutes.

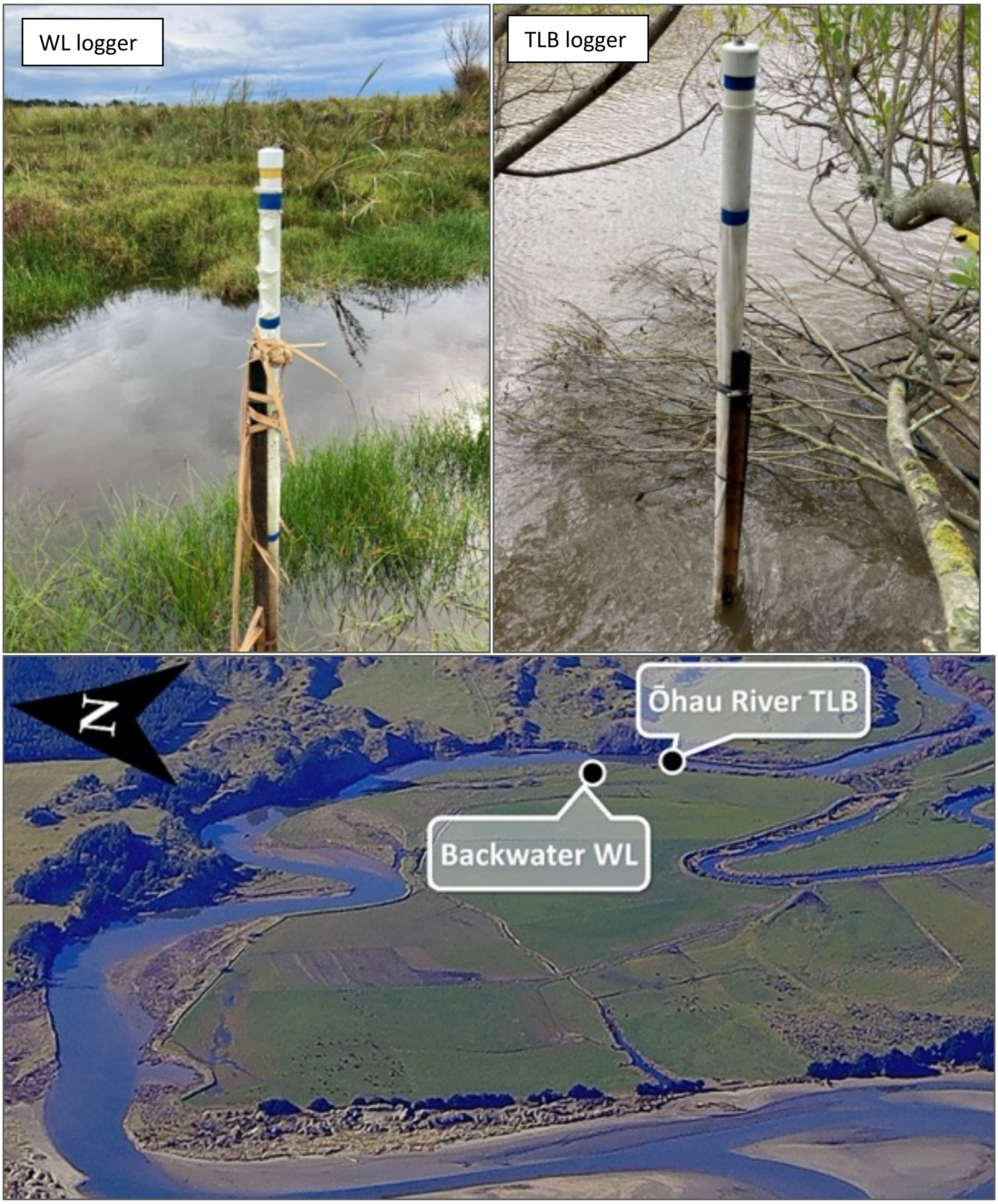


Figure 4.2 Images and approximate location of the Solinst Edge Water-level loggers on the True Left Bank (TLB) of the Ōhau River, and nearby Backwater Wetland (WL)

Data was downloaded from the loggers to a laptop using the Solinst Levelogger Software 4.4.0 on 3rd April 2021 and 14th May 2021. Note, due to Covid-19 lockdown restrictions, the loggers were not able to be downloaded in October 2021 as planned therefore the data presented does not represent the entire monitoring period as intended.

The ‘Data Wizard’ function of the Solinst Levelogger Software was used to compensate the raw water level data for atmospheric pressure fluctuations. Finally, the ‘water pressure’ water levels were calibrated with 12 physical water depth measurements.

Flow gauging and measurements of discharge in the mainstem of the awa were undertaken using a SonTek Flowtracker® (2006 Handheld ADV®, SonTek/YSI, San Diego, USA) employing the ‘Mid-Section Discharge Method’ (SonTek/YSI 2009) on two occasions when flows were considered representative of low to moderate river levels, 3rd April and 14th May 2021. Unfortunately planned additional discharge measurements were prevented due to Covid-19 travel restrictions.

4.1.4 Water level data

Water level patterns were similar between the backwater wetland site (WL, Figure 4.3) and the mainstem site (TLB, Figure 4.4) but differed in magnitude and during low tides. Water levels dropped completely leaving only damp ground in the WL site while the TLB retained water depth due to flow from the awa. Depths ranged from 0 to 1.20 m (mean 0.21 m, median 0.10 m) and from 0 to 1.54 m (mean 0.41 m, median 0.32 m) for the WL and TLB sites, respectively.

4.1.5 River Discharge

The results from the two flow gauging events are given in Table 4.1. The water depth in April was close to the mean depth for the monitoring period derived from TLB water level logger, suggesting the discharge measurement is closely representative of mean discharge during autumn (Gaugin #1). The flow gauging in May was close to the 70th percentile of the range from the logger data (0.55 m) and is therefore representative of moderate-high flows (Guaging #2).

Table 4.1 Measured discharge in the Ōhau River at the location of the TLB water logger

	Date	Mean Depth m	Velocity m s^{-1}	Q m^3 s^{-1}	Q m^3 day^{-1}
Gauging #1	3-Apr-21	0.46	0.27	3.97	343155
Gauging #2	14-May-21	0.53	0.31	5.60	483762

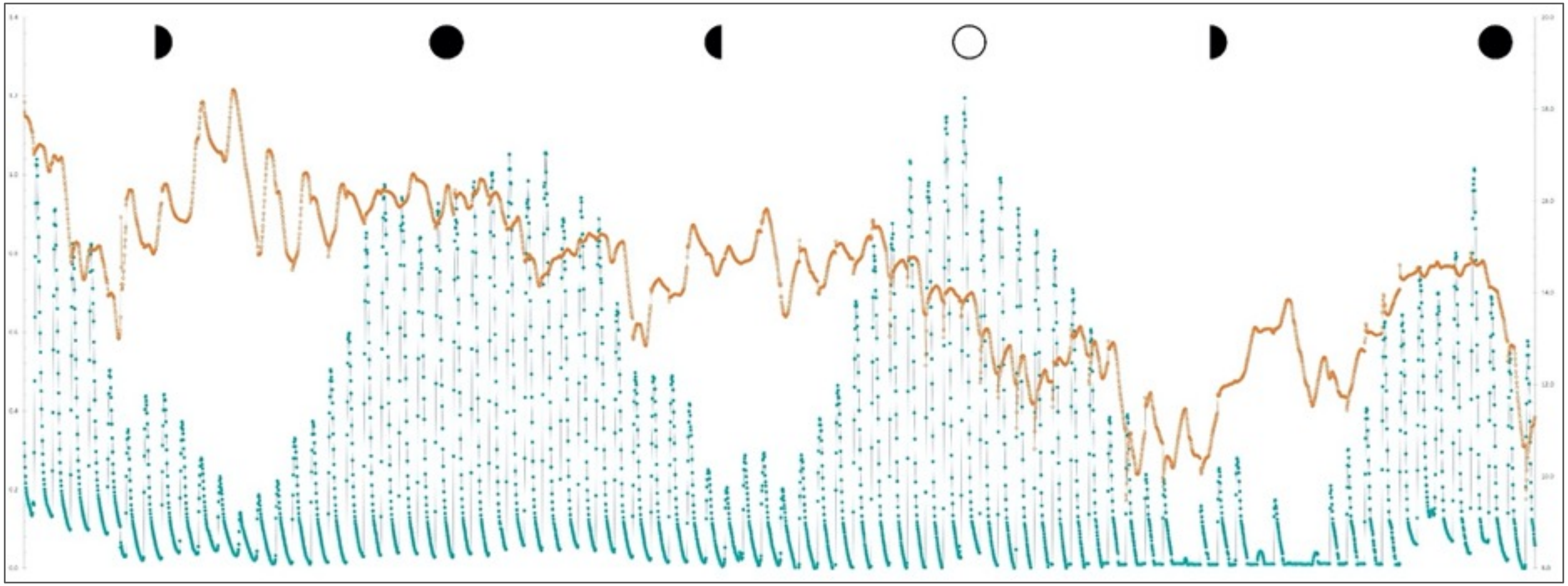


Figure 4.3 Water levels (m) (green line, primary Y-axis, 0.0-1.4 m) and temperature (°C) (orange line, secondary Y-axis, 8.0-20.0 °C) in the backwater wetland (WL) of the Ōhau River from March to May 2021

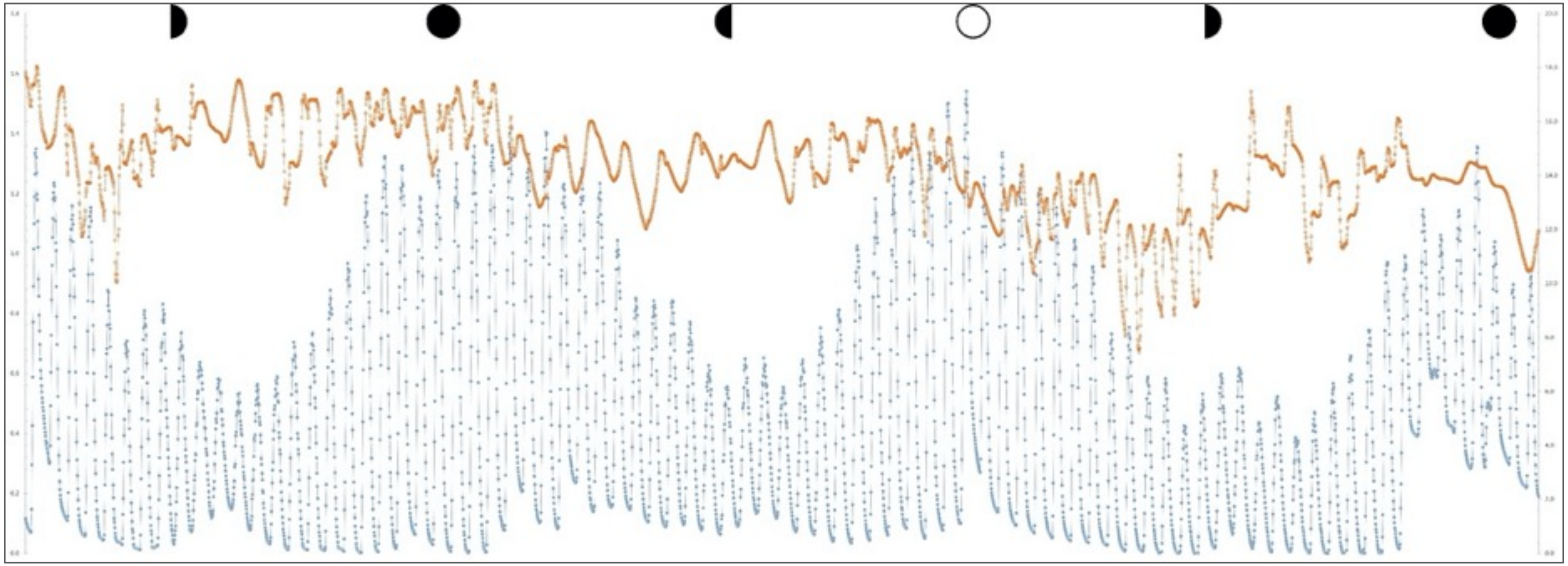


Figure 4.4 Water levels (m) (blue line, primary Y-axis, 0.0-1.8 m) and temperature (°C) (orange line, secondary Y-axis) on the True Left Bank (TLB) of the Ōhau River from March to May 2021

4.1.6 Saltwater Wedge – the īnanga 'love zone'

Knowledge of the location(s) of the saltwater wedge in the Ōhau River relative to the WL and TLB water level loggers is an essential consideration for the placement and design of the proposed wetland habitat ponds. Once thought to occur in a relatively fixed location, where the upper tidal limit of the salty or brackish water from the sea or estuary meets the freshwater of the awa, it is now understood the location of the saltwater wedge can vary longitudinally from a few hundred meters to several kilometres (Suren & Sykes 2021). The range in locations of the saltwater wedge is driven by variability in river flows and the size of the tides (influenced by both the moon phases and atmospheric pressure).

An attempt was made to measure the location of the saltwater wedge of the Ōhau River on 13th May 2021 following standard New Zealand protocols[14]. Unfortunately, this was not successful due to equipment failure.

It is recommended that repeat measurements of the saltwater wedge are undertaken from February to the end of May, coinciding with the īnanga spawning season, to accurately map the various longitudinal locations of the predicted 'love zone' under different river flows and full/new moon cycles. Installing *in situ* conductivity loggers on the bed of the awa would additionally provide detailed data that could be used to define movement of the saltwater wedge between manual measurements.

Once accurate data describing the location(s) of the saltwater wedge has been collated for the Ōhau River and scrutinised alongside the water level and river discharge data, the most robust and appropriate site for the wetland habitat pond system can be finalised.

4.2 Design of the Wetland Habitat Pond System

The design of the wetland habitat pond system incorporates the open water surface flow and horizontal subsurface flow principles introduced at the wetland restoration wānanga (Eivers 2020). Critical components of the design include:

i. Variable depths to accommodate fluctuating water levels associated with the different tidal heights
ii. Gently sloping bank edges of the ponds for optimal īnanga spawning habitat (7 – 20°)
iii. Dense planting of native wetland grasses, rushes and sedges on sloped edges for spawning habitat
iv. Wide shallow channels connecting the pond system to the upstream freshwater reach of the Ōhau River, and the downstream brackish reaches of the Ōhau Estuary
v. Bunds on the river-side of the ponds to provide flood protection during īnanga egg gestation;
vi. Native riparian planting with species strategically selected and placed to optimise flood protection, allow light for wetland grasses and sedges, and shade over open water.

The proposed design concept is presented with suggested dimensions in plan view (Figure 4.5), and cross sectional views (Figure 4.6).

[14] Resource 2B – Locating the saltwater wedge, accessed from https://www.whitebaitconnection.co.nz/curriculum/īnanga-spawning.html

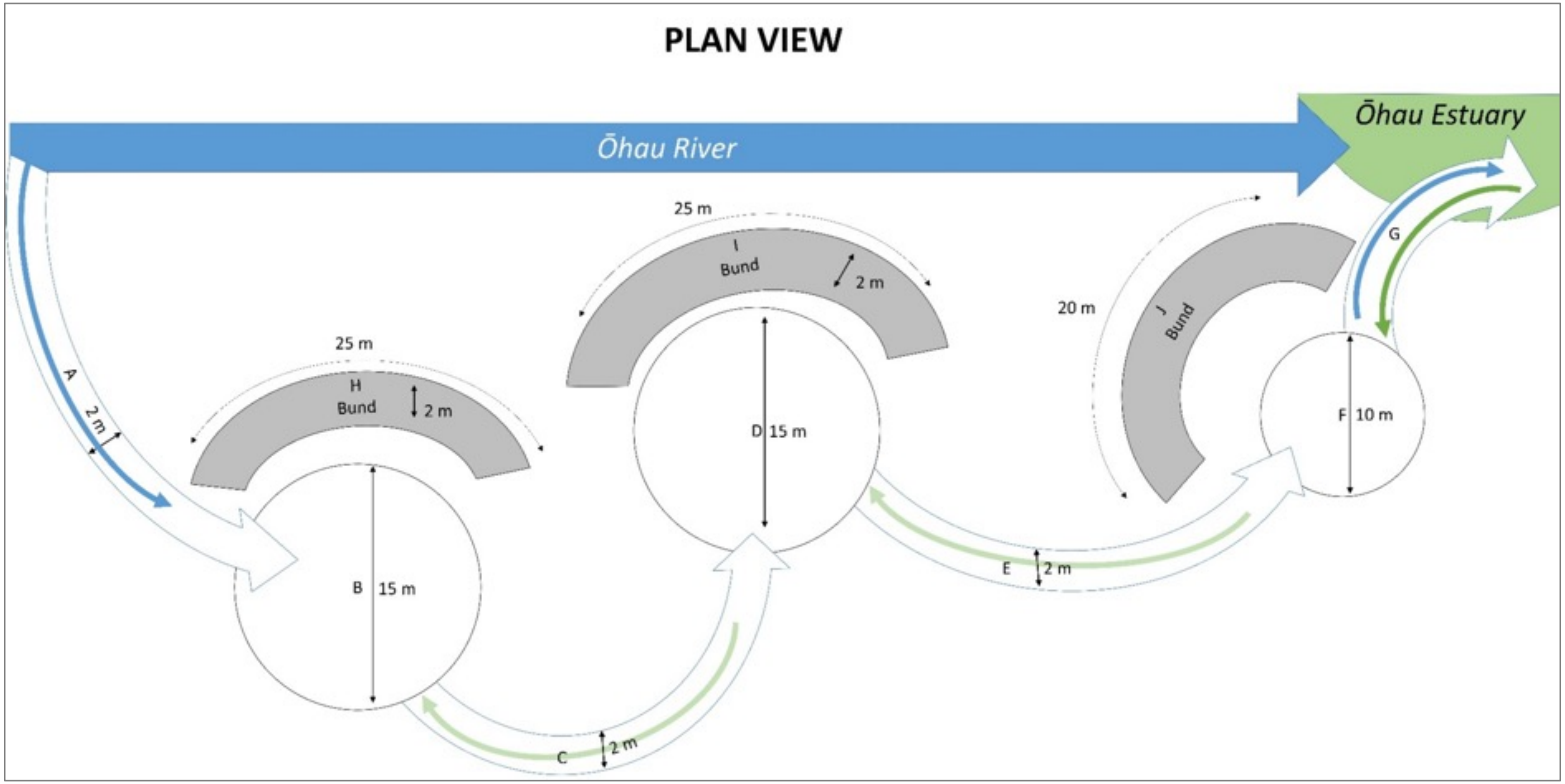


Figure 4.5 Plan view schematic diagram of the proposed wetland habitat pond system displaying various pond areas connected by sinuous channels, protected from flooding by strategically placed bunds. The upstream inlet connects to the purely freshwater reaches of the Ōhau River (blue arrow) to maintain freshwater flows while the downstream outlet connects to the tidal reaches of the Ōhau Estuary (green arrow) to ensure natural tidal influences occur.

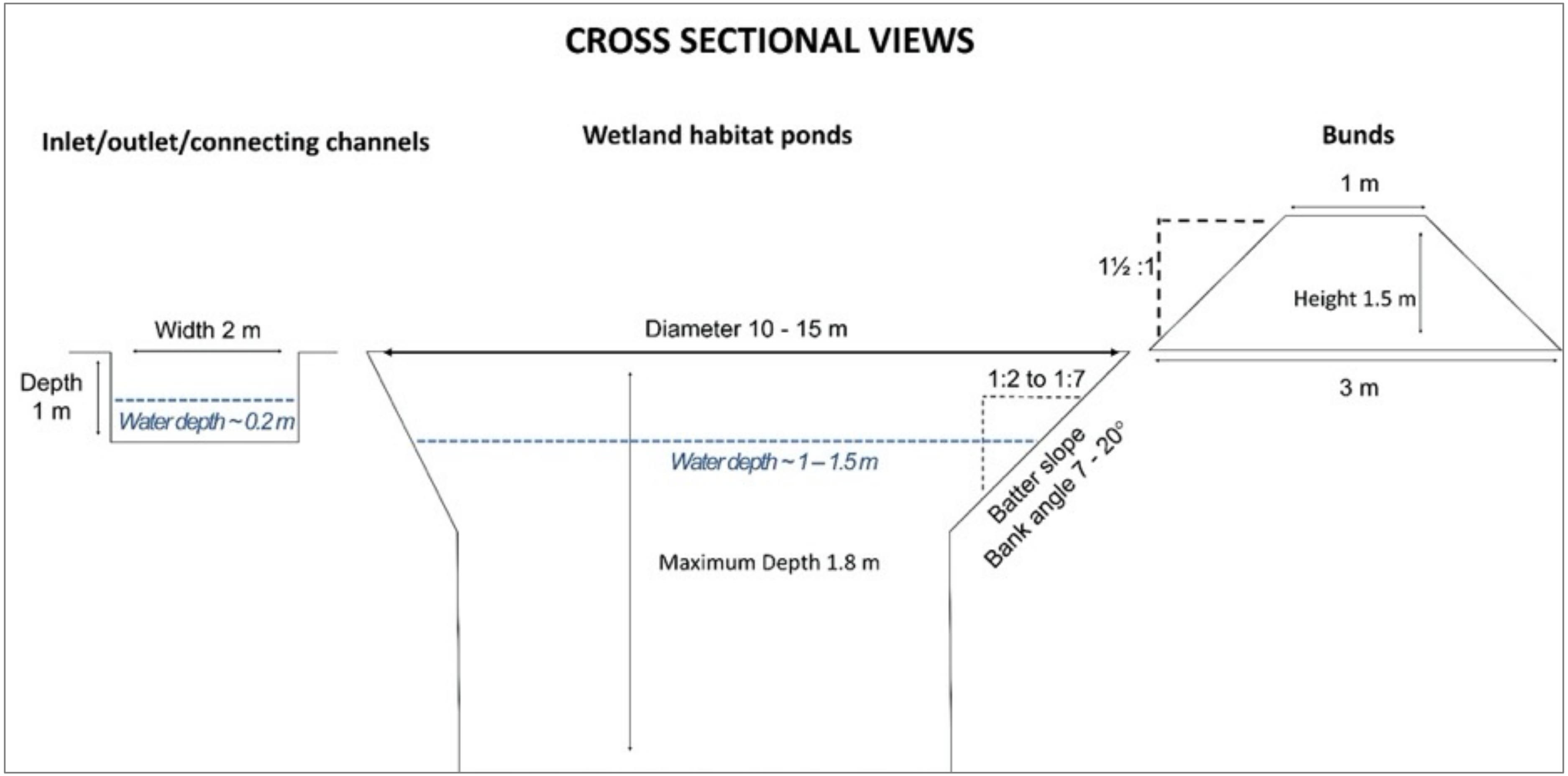


Figure 4.6 Cross sectional schematic diagrams of each section of the proposed wetland habitat pond system design with approximate dimensions

4.2.1 Future Proofing Design & Implementation

Estimating future changes to the location of the saltwater wedge and requisite īnanga spawning habitat, due to the anticipated impacts of climate change, can be extrapolated from the measured data collated for the focus area on the southern banks of the Ōhau River using hydrological modelling. Specifically, sea level rise, which will influence the upper tidal limit of saline water from the ocean, and water levels in the awa, driven by changes in rainfall intensity and duration.

A hydrological model of the Ōhau catchment coupled with various global and national climate change model scenarios is described in Chapter 3. The outputs from numerous model scenarios gives an indication of future changes in flooding flows, as well as flood frequency and duration, due to climate change. This data additionally informs the placement of the proposed wetland habitat pond system as large flood events during the gestation period of īnanga eggs can significantly reduce hatching success. It is therefore important that the recreated wetland pond habitat is located, designed, oriented, and planted to minimise flooding impacts.

As an example, a brief sketch in Figure 4.7 demonstrates how the wetland habitat pond system can be created progressively upstream through time in response to sea level rise to maintain habitat for īnanga and other galaxiid species and cultivate ecosystem resilience.

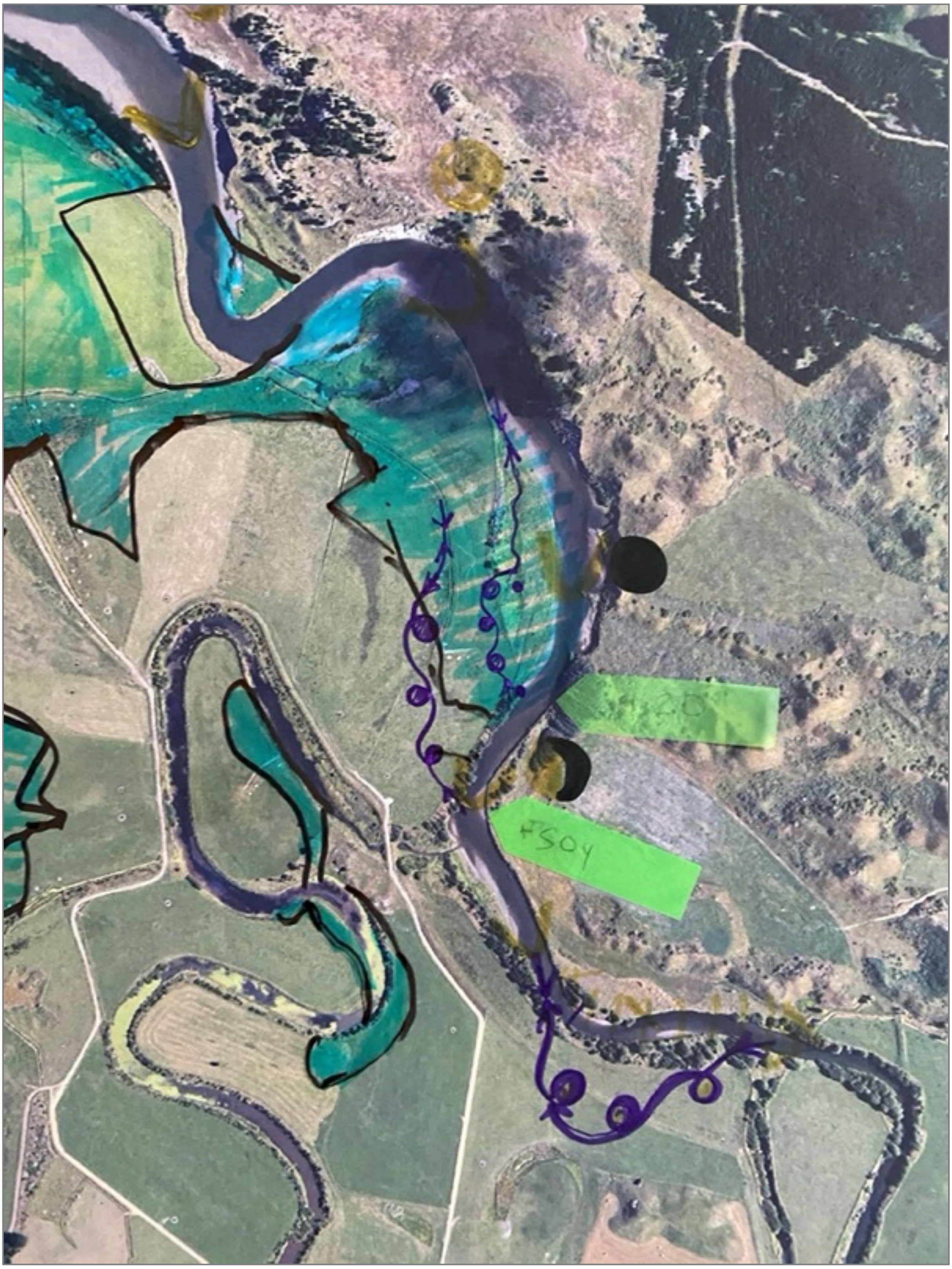


Figure 4.7 A working sketch of the wetland habitat pond systems in various locations along the southern bank of the Ōhau River (purple), placed so to accommodate sea level rise. Blue shading represents the rise in sea level by 0.5 m (+20 years from present)

5 LANDSCAPE SPATIAL DESIGNS

5.1 Overview

An important aspect of the research design underpinning this project was the use of visual and other artistic forms to communicate complex science and culturally important knowledge relevant to climate change transitions for Māori coastal communities.

During the research period COVID disruptions made facilitated face to face and meaningful engagement difficult, especially when trying to share visuals with stakeholders through the use of such designs. Despite this, the following chapter summarises the work of Masters student, Mercia Abbott.

Mercia's research aim sought to answer the following: *How can spatial design be used to weave multiple narratives, climate change science, ecologies and mātauranga Māori knowledge, to produce meaningful kaupapa that enhances cultural understanding, taonga species and environmental wellbeing within the Kuku rohe in Horowhenua?*

As Mercia highlighted,

> "Spatial design is driven by a rich understanding of spatial experience, which can create, shape, alter, visualise, and communicate people's experiences, knowledge, stories, and lives, from our everyday rituals and moments to the extraordinary ones.
>
> I came into this project to utilise my diverse toolkit of visualisation skills and techniques, including the use of 3D spatial modelling technologies, AR, and VR capabilities, to communicate the needs of this rohe. To work within a kete of people committed to understanding future scenarios of climate change and implementing adaptation strategies that seek to protect these local treasured ecologies. To understand the complexities intertwined in this mahi including the tangible and intangible, I have tried to translate this work in meaningful ways."

Figure 5.1 See link to Mercia's thesis *The Woven Narratives.*

https://drive.google.com/file/d/1Okm_ih9dRnUv6FTwP3lkSRhoKzONXrfU/view

Note that all collaborative work with Drs Eivers and Zammit is clearly explained in her thesis and is not repeated here for this report. Please also see Mercia's examination presentation attached below that clearly overviews the work she conducted with iwi researchers for the benefit of Tahamata Incorporated coastal farm.

https://drive.google.com/file/d/1O94YlmjMtBbFCHk2MfdFO9kEr4GsT3nD/view

Please also look at the final edited online wānanga link for a very fulsome overview of the whole research process and its findings, and as led by Mercia and Huhana.

Figure 5.2 Historic aerial photograph 1942, showing the connectivity between estuarine areas, back washes, and Blind Creek region around the Ōhau River long before the cut was made.

6 IMPLEMENTATION PLAN: CONCLUSIONS, RECOMMENDATIONS & FUTURE RESEARCH

6.1 DEVELOPING TRANSITION ACTION PLANS FOR COASTAL CLIMATE CHANGE ADAPTATION: OVERVIEW

The hapū of Ngāti Tukorehe and the ancestral coast contains significant knowledge of place due to our hapū living between the mountains to sea for many generations, with known papa kāinga, wāhi tapu, wāhi tupuna and many other areas of diverse resource use. Since 1996, active kaitiaki have been harnessing korero tuku iho or narrtives of place from many kaumatua no longer with us, and whose expertise was based on ancestors'. These combined voices underpin all our research and actions, which has now developed into mātauranga Māori-led, trans-disciplinary research at the interface, alongside action-orientated projects underpinned by whakapapa, korero tuku iho and hīkoi (walking talking hui) methods.

Since the first wetland plantings from September 2002 (funded by Ngā Whenua Rahui and Mātauranga Kura Taiao/Department of Conservation) the dreams and aspirations of iwi and hapū researchers have been to reconnect more generations of whānau/shareholders to their Tahamata Incorporated coastal farm, to its former high natural integrity and to its once celebrated abundance of taonga species. While the research team and others are aware of all water quality decline issues, the whānau of shareholders are now more deeply attuned to sharing intergenerational knowledge about the ancestral Kuku coastline. We continue to face a series of stressors due to neighbouring land tenure changes to the farm's holdings and the fragmentation to protection of cultural significance this causes. This refers to a Ngāti Tukorehe working party acting decisively against a proposed 18 hole golf course that also encompasses our most sacred area Tirotirowhetu papa kāinga as a wāhi tapu, wāhi tupuna and wāhi karakia.

Despite such ongoing challenges opposite Tahamata Incorporation farm and our finalising our Takutai Moana connections to the coastal estauary and coastline through law, the series of interrelated research endeavours with multiple actions for the coastline between Waiwiri and Waitohu Streams, Horowhenua to Kāpiti region, remain transformative. To date in Kuku, there is a revegetated coastal dune wetland forest re-establishing and waterways and wetlands that are returning rare indigenous biodiversity such as the mātātā (fernbird). Mauri, health, and well-being for our hapū/shareholders and their whānau and our kin natural world remains the key to all actions taken.

Despite the lower tidal reaches of the Ōhau River, the former estuary and adjacent lands still being used for intensite agriculture, the farm board and farm management are now far more aware and active in helping to protect the farm from climate change impacts. Identified impacts include sea level rise, associated saltwater intrusion inland of shallow groundwater aquifers, and an increase in the magnitude and frequency of flood events. These were well witnessed during this third phase of research. More regular flooding and bursting/breaching of stopbanks are affecting the productive potential of current agricultural landholdings at the coast. Such events are also impacting on the lifecycle and mauri of taonga whitebait species including īnanga, kōkopu, and kōaro, some already classified as 'At Risk of being Threatened'.

Therefore, the implementation plans as devised, described, and illustrated are for the most vulnerable low lying agricultural land on the true left bank of the lower Ōhau River. It is recommended that present dairy farming land use in its current footprint be reduced to make way for a series of recreated wetland habitat ponds (as detailed in Chapter 4).

The research team conceptually designed and created diverse wetland habitat areas to support īnanga (and likely kōkopu) spawning, critical to completing the lifecycle of these taonga whitebait species. As pictured earlier (Figure 4.5 and Figure 4.7), the outcome for now is to start a sequence of wetland habitat pond systems that are connected to the Ōhau River in two places; via an upstream connection facilitating freshwater flow through the wetland, and via a downstream connection allowing brackish water to enter the wetland system during high tide phases. Tidal influence is critical to īnanga as they spawn in the riparian vegetation at, or just above, the saltwater wedge (the point where the freshwater meets the saltwater from the sea) during the king tides of autumn. The wetland habitat pond system(s) will be strategically placed in the most unproductive areas of farmland, whilst maintaining connection to the awa and the moana to ensure the full tidal cycle occurs throughout them. They will be practically maintained and adapted to accommodate changes in sea level and associated changes in the location and the extent of saltwater wedge, influenced by tidal fluctuations driven by lunar cycles and weather pressure systems. Pond systems will also be strategically placed to give the best possible protection from the destructive forces of high flows in the Ōhau River during flood events. The anticipated lateral extent of flood waters, the height of flood flows, and the frequency of flood events has been informed by climate change modelling carried out in the earlier phases of this project. Protection of the wetland pond system(s) from flood events will be most critical during spawning and egg gestation for īnanga from around March to the end of May.

The final design for the wetland pond system(s) needs to ensure bank and bed levels are accurately created to allow flows from the upstream awa and the brackish water tides to reach riparian areas. Construction of the ponds will be relatively straightforward given they will be dug into an existing paddock, with no, or minor effects on the environment.

The creation of the wetland habitat pond systems will be activated by tikanga, building on the mahi we have been doing for the past 24 years of kei uta/hinterland revitalisation. As sea levels continue to rise, our aim is to ensure sustained mahinga kai values of our hapū/shareholder community into the future, with design concepts and models recreated further upstream or inland of the Ōhau River to ensure continued adaptation and survival of taonga whitebait species. Following the success of these wetland habitat pond system(s), we share this knowledge and experience with other hapū facing similar climate change challenges.

6.2 KEY FINDINGS AND RECOMMENDATIONS FOR RESEARCHERS CONDUCTING CLIMATE CHANGE ADAPTATION RESEARCH WITH MĀORI COMMUNITIES

The aim of this research phase was to investigate implementable plans for alternative land use options based on aspirations as identified and prioritised by the landowners in previous two phases, especially the Phase 2 Risk Assessments. The combined three stages of climate change research since 2015 has identified the following factors as being important to successful research with Māori communities who are grappling with the impacts of climate change.

We attempt to work through the relevant issues to make sound and evidence-based decisions about appropriate adaptations. These points are not considered to be a comprehensive assessment of how to conduct research with Māori but are learnings that have come from our research and things that we found helpful may help other transdisciplinary, bicultural researcher–community teams who are collaborating to address complex issues.

6.2.1 Culturally-Appropriate Engagement Processes

Since 2000, Ngāti Tukorehe has championed a tikanga-led research process whereby all research collaborators are manuwhiri or visitors to our whenua. They are therefore welcomed through the marae via ceremonies of pōwhiri and whakanoa, to ensure that they are always safe and well whilst on the whenua or by awa and moana with us. This also includes research that might be conducted on private lands that are not part of the iwi or hapū holdings anymore. The iwi researchers invite all researchers into a Māori cultural paradigm and ask then to transform themselves into our spaces, whether as a freshwater ecologist, fluvial geomorphologist, ecological economist, climate change modeller or internaitonal artist or designer. Whoever you are, Ngāti Tukorehe excercised tikanga of ceremony ever since Te Hākari/Te Hakiri wetland’s first trees were planted in 2002.

Figure 6.1 Masters student hīkoi to dune wetland restoration project as part of dissemination of climate change action-orientated research findings with budding artists. Photograph by DS grant recipient Maija Stephens, 5 July 2021

Figure 6.2 A flourishing puriri tree at dune wetland restoration project, Kuku Ōhau Estuary, Horowhenua. Photograph by Deep South grant recipient Maija Stephens, 5 July 2021.

Ngāti Tukorehe researchers have developed a reputation across the Raukawa ki te Tonga region for taking the lead in action according to an exercise of mana. Our call to be guided by ancestral prestige and their authority, with collective empowerment to lead in contemporary times. Mana taonga is the principle that acknowledges the value of connections between everything, human and all non-humans; Mana whenua recognises the ahi kaa and those home-based hapū who keep the home fires alive for next generations. Mana tangata is the influence of all that collective self-worth, whilst attuning to the spiritual dimensions of Mana atua or propitiation to all environmental entities, including climatic, stellar, lunar and other cosmological dimensions. Additionally we are guided by our rights as enshrined in Whakakpapa, to exercise those rights as current acts of Tinorangatiratanga, binding them together through transformative acts of Kaitiakitanga.

6.3 Next Steps and Future Research

Based on the work that has been done to date as outlined in this report, the following recommendations are given, going from modelling recommendations to implementation and upscaling.

6.3.1 Recommendations for Ongoing Hydrological Research for Climate Change Adaptation Planning

- Based on the 7 river-transet locations of interest, implement a surface water/groundwater model (such as the one being developed as part of the New Zealand Water Modelling framework) to better represent the impact of climate change on regional groundwater system and river flow.
- Leverage new Sea Level rise projection and land subsidence data provided by NZSeaRise programme led by Victoria University (ending in March 2022)
- Develop a collaboration with the NZFuture coast research programme (lead by NIWA and funded over the period 2021-2026) to refine current estimation of river salinisation, land surface inundation and groundwater SLR induced salinisation
- Improve river bathymetry in the hydrological model (from the simple rectangle 'bath-tub') to a more detailed and realistic river bathymetry across the 7 river transects. This will enable a better representation of river hydrology, discharge, stream bank elevation, stream bank over-topping (i.e. flooding), and adjacent farmland and/or wetland habitat pond inundation frequency and intensity.
- Improve hydrodynamic interaction between tidal movement and freshwater hydrology to better represent SLR-tidal-freshwater interface, its impact on local water levels and most importantly the location(s) of the saltwater wedge required for īnanga spawning.
- As part of modelling chain improvement (Climate-hydrology-ecology), refine current projections to develop through location specific bias correction, to more accurately inform the placement of the proposed wetland habitat pond systems.
- Potentially roll out the methodology across the catchment to look at other fish species.
- Potentially roll out the methodology to other locations as part of future funding opportunities.

6.3.2 Recommendations for ongoing data collection

- Carry out repeat measurements of the saltwater wedge in the Ōhau River from February to the end of May, coinciding with the īnanga spawning season, to accurately map the various longitudinal locations of the predicted 'love zone' under different river flows and full/new moon cycles. Feed this data back to hydrological modelling improvements outlined above.
- Analyse the locations of the saltwater wedge, water level (from loggers) and river discharge data to

identify the most robust and appropriate site for the wetland habitat pond system(s). Cross-check this data and the outcomes with modelled guidance produced from above to ensure the highest level of accuracy and critique of risk.

- In 2022, stocktake data, including images and observations, and imbed into an arcGIS mapping system as an ongoing resource and working model.

- Quantify riverbank and streambank areas already fenced but unplanted riparian zones. This would give information on areas that could be acted on as soon as plantings were organised. Initial estimations are that less than 50% of possible areas are currently planted, so this could have a significant impact on the systems ecological diversity and water quality into the future.

- Quantify riverbank and streambank areas requiring riparian fencing (both new and improved fencing where current fencing is inadequate). Modelling a range of options for doing this including the prioritising of protection for specific waterways; modelling different widths of riparian zones; using novel and cost-effective riparian plant species such as *Carex spp.*; and options for incorporating culturally significant sites and trees into these protected zones. Modelling a range of scenarios that could then be shared with stakeholders which would provide accurate calculations of land areas and fencing lengths for each option.

- Identify specific features and projects across the system for further investigation and potential research. For example: upgrading flood gates to facilitate fish movement and breeding between the river/estuary and internal waterways; further investigation into the now degraded Lagoon 1 and potential to reform it into a tidal/estuarine habitat to support native birds and fish; further research into the ecological functions of the prolific native aquatic grass(es) present throughout the waterways including nutrient removal and fish breeding habitat; research into habitat provisions for native wetland birds within the loop system to encourage habitation and potential development of breeding sites.

- Simultaneously reviewing and incorporating the previously completed science at each site across the system.

APPENDIX A: ONLINE MATERIAL RELATING TO WHITEBAIT RESEARCH

Compiled by Moira Poutama

https://poriruaharbourtrust.org.nz/onepoto-arm/#onepotoarm

https://raglaneels.com/

https://www.stuff.co.nz/environment/75922680/raglan-whitebait-pioneer-charles-mitchell-dies-age-64

file:///Users/moirapoutamalive.com/Desktop/Deep%20South%202021%20Whitebait%20Website/(7)%20Watch%20%7C%20Facebook.webarchive

https://www.alamy.com/stock-photo/whitebait-new-zealand.html

https://bullerdc.govt.nz/new-zealand-whitebait-farm-project-all-go/

https://thefishsite.com/articles/new-zealand-startup-launches-7-million-whitebait-farming-project

https://www.sciencelearn.org.nz/resources/442-whitebait

https://en.wikipedia.org/wiki/File:Gianchetti_and_poutine.jpg

https://teara.govt.nz/en/diagram/11692/inanga-life-cycle

https://niwa.co.nz/our-science/freshwater/tools/kaitiaki_tools/species/inanga

https://www.whitebaitconnection.co.nz

https://rarespecies.nzfoa.org.nz/species/inanga/

http://www.gw.govt.nz/assets/council-publications/Inanga_Part_2.pdf

https://www.scoop.co.nz/stories/AK2108/S00206/restoring-inanga-spawning-habitat-in-pawowhai-stream.htm

https://www.mpi.govt.nz/dmsdocument/7992/direct

https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=3230

https://www.manawaturiver.co.nz/wp-content/uploads/2020/01/Manawatu-Catchment-native-Fish-Factsheet.pdf

https://www.nmtt.co.nz/education/he-awa-ora-healthy-rivers/inanga-restoration-project/

https://www.fonterra.com/nz/en/our-stories/articles/how-one-community-has-rallied-to-protect-whitebait.html

https://www.facebook.com/permalink.php?story_fbid=2319791661650084&id=2005736099722310

APPENDIX B: INITIAL STAKEHOLDER WĀNANGA, KUKU, 2020

AGENDA: Deep South Climate Change National Science Challenge – Vision Mātauranga Wānanga and Hīkoi at Kuku, Horowhenua, Thursday 19th November 2020

10.30 am	Pōwhiri (Please arrive early to gather – a haukainga representative will show you where.
11.00 - 12.30	Enjoy a substantial morning tea with introductions to Deep South Phase 3 team, marae housekeeping, what to expect from wānanga, followed by Kōrerorero led by Rebecca Eivers and her work (30 mins).
1.00 - 4.00pm	Leave at 12.50 pm to drive to carpark at Kuku Ōhau estuary and then take Hīkoi to lower reaches of Ōhau River and coastal sites – meet at carpark again at 4.00pm to get back to marae.
4.15 – 5.00pm	Back at marae – feedback on Hīkoi, key aspects and laying out agenda for Friday.

For those staying at marae overnight or those wanting to come - a convoy is heading to the opening of *Mana Moana* in Wellington for the evening and returning to pā again afterwards. It's a free outdoor projection on water screen event! We shall have kai and refreshments in each vehicle. We need to be at Te Whare Waka by 6.30pm, so we shall be leaving Kuku pā at 5.00 pm. *Mana Moana* is a collaboration between Māori and Pasifika musicians, artists, writers, and choreographers. It is a series of five short art films, fusing poetry, dance, song, painting, photography and animation. This must see for the climate change kaupapa that we are engaging with.
Check out https://www.manamoana.co.nz for more details.

Friday 20 November 2020

7.30 - 8.30 am	Breakfast for marae stayers
8.30am - 9.25am	Pack cars and tidy whare tupuna for marae stayers
9.30 am	Ready to start feedback session with all participants on highlights of Hīkoi and Thursday conversations, and identify any gaps in data collated.
10.30 -12.30pm	Kōrerorero led by Christian Zammit on Climate Change Modelling and his work (30 mins). Then work with break out groups on the 5 key themes, which include: determine how well your organsiation might help Māori coastal communities address each theme, and in general how might all entities enhance relationships with Māori landholders, fund and accelerate solutions-focussed activities for coastal Māori comunities particularly between the Ōhau, Horowhenua to Ōtaki, Kāpiti regions, with ability to be shared elsewhere around Aotearoa too.
12.30pm	LUNCH
1.30 – 2.45 pm	Resume conversations break out group leader's wrapping up dialogue.
3.00pm	Whakawatea – permission granted by hosts for manawhiri to leave for collective safe journeys home.

APPENDIX C – PRELIMINARY ECOLOGICAL AND HYDROLOGICAL SYSTEMS 'STOCKTAKE' REPORT, 2021.

Prepared by Moira Poutama and Hadyn Fowler, for Tahamata Farm

Figure A.1 Outline of the *Stocktake Area*, 2021. Image credit: Google Earth 6/4/2016.

The following stocktake work was conducted across days in July 2021. Hadyn Fowler is a Berlin Based Australian artist who worked closely with iwi researcher Moira Poutama to collate this stocktake report. It is an ongoing discussion document to be consulted over, with hapū shareholders and Tahamata Board of Directors. Again, COVID disruptions delayed the dissemination of this work at the time, but it has been compelted to a standard that can be shared digitally with groups.

Hadyn walked this observational and photographic stocktake of ecological and hydrological conditions across an 165 Hectare area of Tahamata farm (see Image A1). The area is bounded by the Ōhau River (North), Kuku Beach Road (South), the coastal estuary (West), and extends East past the current cowshed, with the Ōhau Loop lying centrally within this zone. *The Ōhau Loop phase 1 - existing status and recommendations for improvement* (Allan et al, 2011) and the earlier. *Kuku-Ōhau: situation and opportunities in the lower river, preliminary notes (Lucas Associates 1998)* were used as key comparative references for this 2021 stocktake. In November 2021, a preliminary drone flyover was also undertaken, focusing on documenting the interconnectivity of waterways, hydrological obstructions and other other systems of interest identified in the stocktake.

The stocktake was developed and undertaken from a *whole-of-landscape* approach. Taking into

consideration eco-systemic, cultural, and hydrological interconnectivity across the system, with a range of potential planning, protection, economic and restoration outcomes envisaged.
These include:

The creation of an observational record of the current ecological and hydrological status of the stocktake area, as an ongoing comparison to historical and future records and data.

- To build on and utilise the previously undertaken science including Alan et el (2011) and Lucas Associates (1998).

- To better understand the interplay of natural and constructed hydrological systems and the existing ecologies that these may support, in particular the physical obstructions, vegetation cover and agricultural pollution flows impacting both water quality and native fish movement and breeding across the system.

- To quantify riparian, aquatic and other vegetation cover and substandard or absent riparian fencing of streams, springs and drains.

- To serve as a blueprint for thinking around how interventions in one area may impact positively (or negatively) across the whole system.

- To re-look at historical and ongoing hydrological engineering works, including the Loop, stop banks, flood gates and farm drainage ditches. Understanding these as part of the current ecological and hydrological system and exploring possibilities for adapting and capitalising on these features towards improved ecological health and diversity, climate change mitigation, farm sustainability and economic diversification.

- Identify and prioritise areas within the system for immediate action, further research and/or comprehensive long term planning.

- Identify interventions or strategies that may produce shared benefits between enhanced ecosystem values and long-term economic sustainability of Tahamata farm in response to climate change and sea level inundation.

- To build on the findings of this stocktake to develop a comprehensive range of proposals to improve ecological health and diversity, water quality, sustainability and climate change resilience across the system.

The stocktake focused on the network of waterways across this zone, including springs, streams, constructed drainage ditches, the Ōhau Loop, the Ōhau River and the estuarine inlets recognised as or likely to be potential/ remaining Īnanga breeding sites. Principal observations focussed on understanding the water flow through these interconnected bodies of water; impacts on water quality including the state of riparian fencing and planting; flood gates, culverts, and other potential blockages; observed vegetation and animal life; and the interaction of these water systems with the engineered stop banks and accompanying flood gates which inhibit flow between the 'internal' hydrological systems and the outer river and estuarine system.

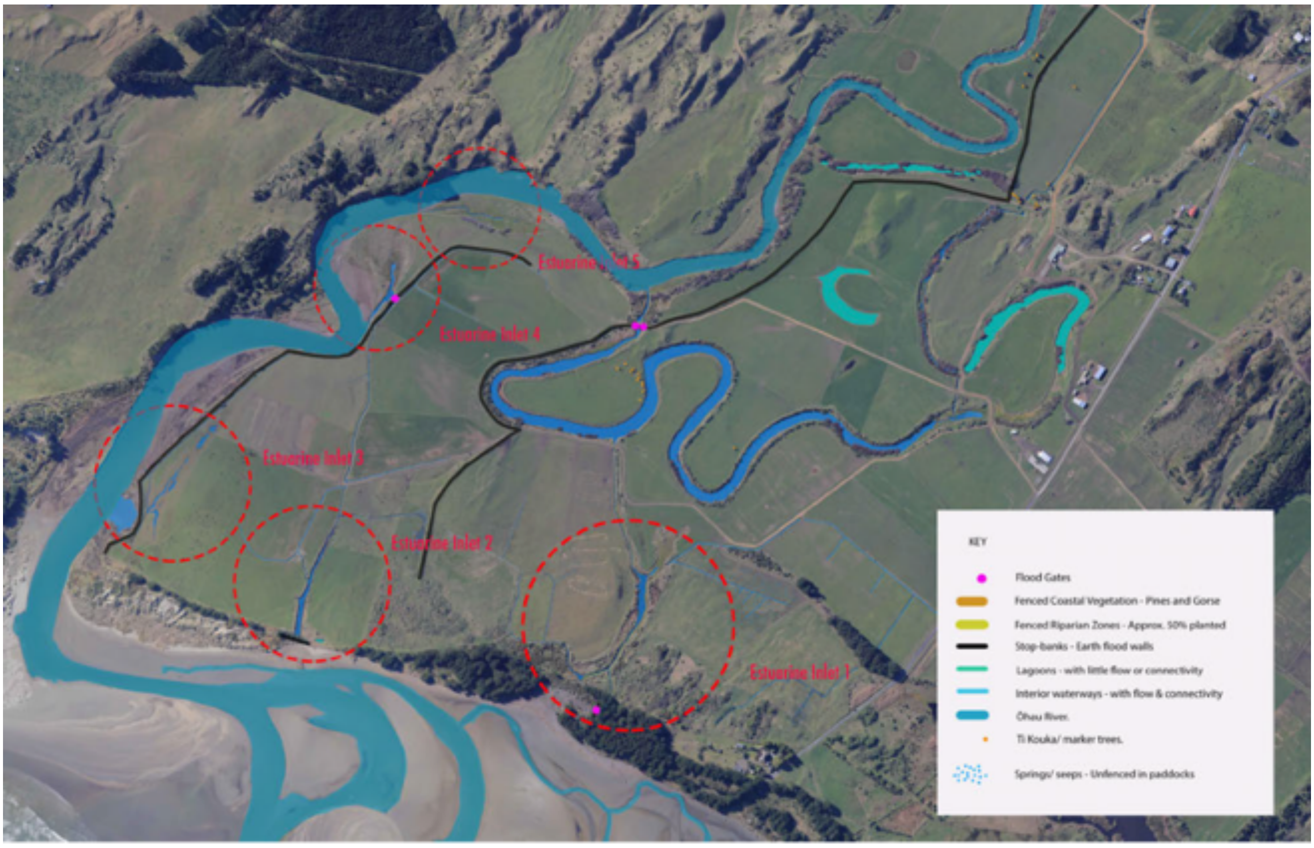
<u>Connectivity of Inland waterways</u>.

Within the Stocktake area, a large and fascinating diversity of permanent water bodies and waterways exist, many of which have uniquely individual characteristics. A few of these water bodies are isolated, although the majority have some connection with each other including a major section of the Loop. Others are connected via one-way flows including raised pipes, culverts in a major section of the Loop and whilst a fish friendly floodgate was installed in 2013, it is still limiting fish and water movement across the whole system.

<u>Estuarine inlets</u>

Figure A.2 Estuarine inlets and water connectivity throughout the stocktake system. Image, Hayden Fowler 2021.

Five estuarine inlets were identified within the stock take zone two of which are located near the current Īnanga study area (See Image A2). These have a particular importance within the larger system as the, now largely impeded, interfaces between salt and freshwater environments and their significance as habitats for native fish migration and breeding.



EI 1 (Estuarine Inlet 1) known locally as 'the Backwash' or 'the Blind Creek', is the largest of the five inlets. It is significantly restricted by a stop bank, culvert and flood gate now buried under large deposits of driftwood - however, freshwater seepage can be observed draining through into the outer estuary. Forming a large, elongated lagoon behind the stop bank and flood gate, EI 1 is partially fed by pugged areas of unfenced springs/wetland areas and farm ditches, both fenced and unfenced. EI 1 is also directly connected to a lower section of the loop via an extended drainage ditch, with water able to flow in either direction between these water bodies.

EI 2, (Image 3) is separate water system and significantly restricted by a stop bank. There is no flood gate visible, but freshwater seepage can again be observed draining under the stop bank and into the estuary. It appears as an elongated lagoon behind the stop bank and is fed by drainage ditches and unfenced springs within dairy pasture. At this point the farmland is at a lower elevation than the beach and previous ocean incursions can be seen in the driftwood that has washed over or around the stop bank, into a small lagoon next to EI 2. EI 2 tapers off to the East along a drainage ditch, where its outlet through a flood gate near the mouth of EI 4 on the Ōhau River. EI 2 is significantly less vegetated than EI 1, and it appears to have, visually at least, poorer water quality that the EI 1 system.

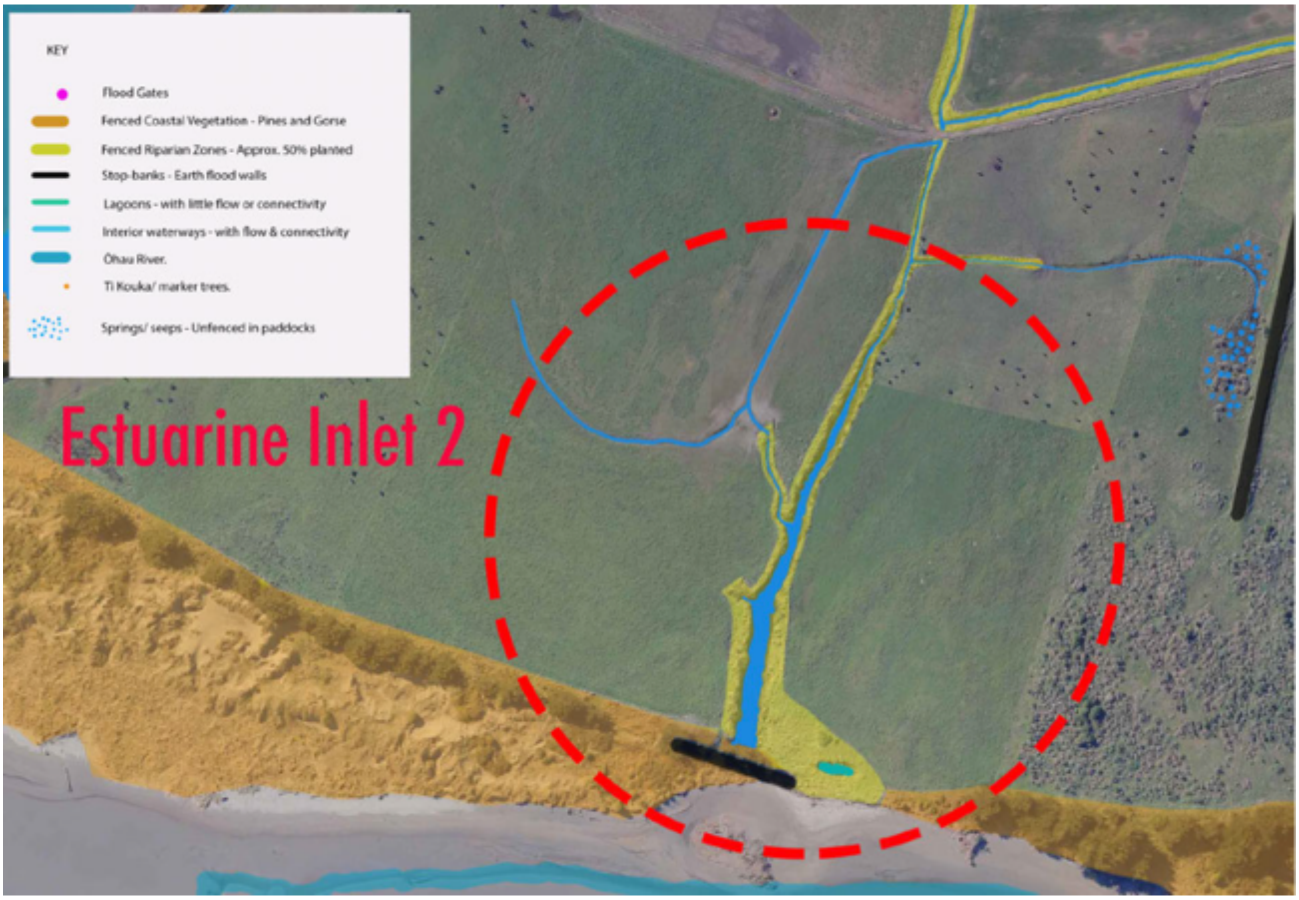


Figure A.3 Estuarine Inlet 2. Note unfenced drain and spring tributaries. Image, Hayden Fowler 2021.

EI 3, a large historical inlet located near the Ōhau River mouth has been completely cut off by a stop bank, though the form of its extensive tail remains visible in the landscape.

EI 4 runs in a SE direction off the Ōhau River and sits outside the stop banks. It has unimpeded flow, natural form and is thickly vegetated with aquatic grasses.

EI 5, the smallest of the inlets, also runs in a SE direction off the Ōhau River and sits outside the flood walls. It has unimpeded flow, natural form and is thickly vegetated with aquatic grasses

Figure A.4 Evidence of ocean incursion in the small lagoon next to EI 2. Image, Hayden Fowler 2021.

Figure A.5 A section of Estuarine Inlet 1. Image, Hayden Fowler 2021

Figure A.6 Estuarine Inlet 5, situated in the current Īnanga study zone. Note the prolific native aquatic grasses. Image, Hayden Fowler 2021

<u>The Ōhau Loop</u>

The Loop is an approximately 3km meandering stretch, cut off the river as flood protection measures in 1972. It has since existed as a series of lagoons of variable water quality. An approximately 2km stretch of The Loop remains connected to water flow, fed by a long ditch which channels water from a network of unfenced and un-vegetated springs, streams and drainage ditches to the East. This long section of flowing Loop connects directly with the EI 1 system and outflows to the Ōhau River, via two flood gates at the Loop's terminus. The flowing sections of the Loop appear visually in a reasonable state of health, although it should be noted that these observations were taken in winter, so summer may be quite different with algal blooms and less freshwater inflow. The Loop, however, has the widest, best fenced, and most planted riparian zone of almost any site in the stocktake zone and better than the Ōhau river itself. Around 50% of its riparian zone is planted. The loop was also observed to support small breeding colonies of Pukeko, black swans and mallard ducks and areas with some diversity of riparian vegetation, aquatic, and marsh plants. Considered interventions could significantly enhance the development of this extensive ecological zone.

Figure A.7 The Ōhau Loop, swampy Eastern terminus with incoming flow downstream. Image, Hayden Fowler 2021.

Figure A.8 The Ōhau Loop, open section. Image, Hayden Fowler 2021

Figure A.9 The Ōhau Loop, open section. Note the typical level of riparian vegetation. Image, Hayden Fowler 2021.

Figure A.10 The Ōhau Loop, towards NW terminus and outflow to river. Image, Image, Hayden Fowler

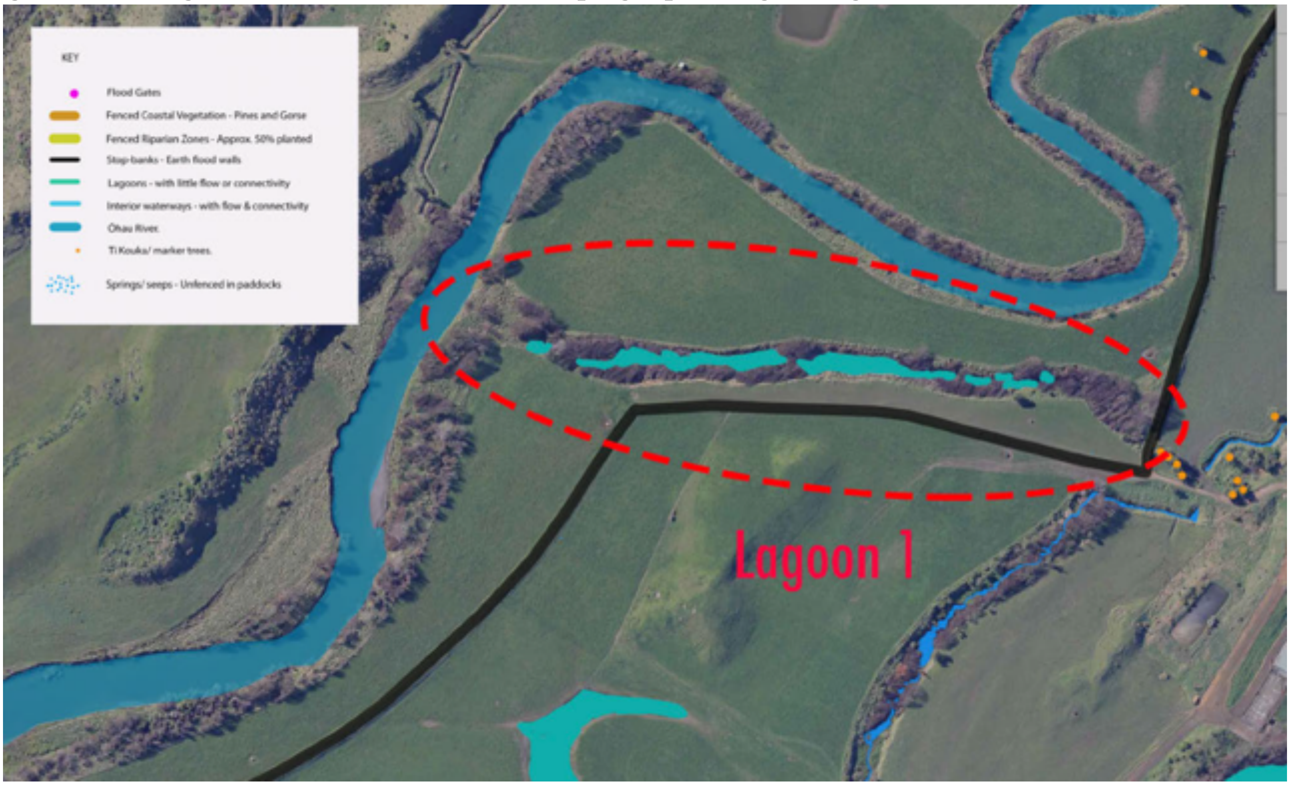
Figure A.11 Stock near Ōhau Loop

Orphaned Lagoons

Two sections of the loop are partially or completely orphaned from the flow.

Lagoon 1 is the most eastern section at the top of ‘the cut’ which appears to be only filled when the river tops the stop banks during flooding. Containing muddy, stagnant water, is crowded with willow growth and its connection to the river is currently blocked. However, it sits outside of the stop banks and aligns at an angle to the Ōhau and in many respects emulates the shape of the Estuarine Inlets 3, 4 & 5 further down the river. After further research, it could for example, be opened to the river to form a large tidal or estuarine inlet and has been identified for further investigation of its potential adaptation to Īnanga breeding habitat. As it lies outside of the stop banks, this would have no effect on flood risks to the farm. Lucas associates calculated that the upstream limit of the saline / freshwater interface (an important factor regarding īnanga breeding habitat). Was near the Lagoon 1 and according to the report īnanga were observed breeding in long grass at this site. This also suggests that much of the Loop would also provide good breeding habitat for īnanga, if there was access.

Figure A.12: Lagoon 1 (the cut). Note the earth plug separating the lagoon from the river.



Suggested investigation into the removal of this plug for example, to create a new tidal estuarine inlet - creating habitat and restoring health to a currently degraded water body. Image, Hayden Fowler 2021. Lagoon 2 is the second orphaned section of the loop, adjacent to the western side of the cowshed. The water level here appeared higher (circa 1m) than the adjacent sections of the loop, and it overflows, via a raised pipe, into the flowing section of the loop. There was no water visibly flowing into this Lagoon, but because of its location next to a hill and former pā site, it is suspected to be spring fed. The water quality here appears poorer than the flowing section of the loop, and there may also be muddy run off from the adjacent farm tracks and yards. Historically this section of the loop received the effluent outflow from the cowshed, reportedly for decades.

Lagoon 3 is a large crescent shaped lagoon, which when viewed from above, appears to be a remnant of an earlier river course. It is located between the loop and the river, it is poorly/ partially fenced, but contains some aquatic vegetation. 2-3 smaller lagoons also exist within the stocktake site.

Figure A.13: Lagoon 3, partial riparian fencing and remnant vegetation. Image Hayden Fowler 2021.

Figure A.14: Lagoon 3, partial riparian fencing. Image Hayden Fowler 2021.

Figure A.15: Lagoon 1, muddy waters from recent overland flood inflow. Image Hayden Fowler 2021.

Figure A.16: Lagoon 1, debris from recent river flooding inflow, across pastureland outside of stop banks. Image Hayden Fowler 2021.

Flood Gates

These control all the connection points between the internal water systems and the outer river and estuary, which are divided by stop banks. *The Ōhau Loop phase 1 - existing status and recommendations for improvement* (Allan et al, 2011) recognised these as a defining issue for fish movement, migration, and breeding. The gates specially inhibit movement of fish coming from the river and estuary trying to enter the internal on-farm hydrologycal system. Allan et al recommended the retrofitting of these gates to more fish friendly versions, and this certainly should be investigated further as a relatively simple way to improve connectivity between internal and external hydrological systems.

Figure A.17: Flood Gate exiting via culvert, under stop bank and into the Ōhau River from the Loop terminus. Image Hayden Fowler 2021.

Figure A.18: Opposite view - Loop terminus with culverts exiting through to flood gates. Image Hayden Fowler 2021.

Riparian Fencing

All the major water bodies have some form of riparian fencing, although the fenced riparian zones are often narrow. The widest, best fenced, and most planted riparian zone is around the flowing section of the Loop. Most of the tributaries (streams/ ditches/ springs), which feed into the broader network of waterways have poor, narrow, or no riparian fencing and little riparian planting. Several unfenced puna/spring areas occur at the head of these tributaries. When cows are grazed in these areas, they become deeply pugged, muddy and contaminated with urine and effluent- further depleting the ecological integrity, water quality and Mana of these ecological and hydrological systems. It seems highly likely that the condition of these tributary waters would be having an ongoing negative impact on the water quality across the system including the loop and estuarine inlets.

Figure A.19: Unfenced wetland flow, tributary to the Estuarine Inlet 1 system. Note grazed remnant native wetland grasses. Image Hayden Fowler 2021.

Figure A.20: Typical condition of tributary creeks and farm drains. Main tributary to the Loop system. Image Hayden Fowler 2021.

Figure A.21: Typical condition of tributary creeks and farm drains. Main tributaries to the Loop system. Image Hayden Fowler 2021.

Figure A.22: Broken fences around wetland drainage. Feeds into main tributary of the Loop system. Image Hayden Fowler 2021.

Figure A.23: Unfenced wetland flow, tributary to the Estuarine Inlet 2 system. Image Hayden Fowler 2021.

Vegetation

Throughout the extended network of waterways, including farm ditches, areas of the loop and the estuarine inlets (possible īnanga zones), there are extensive dense mats of native aquatic grass, which are suspected as ideal egg laying grasses for īnanga. These may be an existing resource for expanding fish breeding habitat across the system into the future. The aquatic grasses are also likely to be responding to and processing Nitrogen run-off from paddocks, particularly in the farm drainage ditches. As such, the functions and further potential of this plant in the system is recognised as deserving of further investigation.

Throughout the farm there are clusters of unprotected large tī kōuka/ cabbage trees (cultural 'marker' trees). Cattle have free access to these and use them as rubbing posts, which is damaging their trunks and likely affecting their long-term survival. They are striking, culturally and ecologically significant trees and by far the most mature native vegetation throughout the stocktake area. They generally exist in groups, so fencing them off and underplanting with companion species is a reasonable proposition. Some clusters could be incorporated into existing riparian zones by expanding/moving relatively short sections of fencing.

Willows were present throughout the area but seemed only problematic in two or three places. Selective ringbarking may be a valuable strategy in these areas as it opens the waterways and provides valuable roosting habitat for a number of desirable wetland bird species.

Gorse was rare throughout the survey area, except for a large established area on the eastern side of the dunes behind the pines. Here, it is providing protection against erosion, habitat for large groups of small birds, and a potential nursery for regrowth of native vegetation beneath them.

Both Lucas Associates (1996) and Alan et al recommended similar riparian planting. Lucas associates undertook an extensive botanical survey of the Loop and developed comprehensive planting plans and species lists.

Wildlife

During the survey several animals were observed. A large colony of rabbits in the section just behind the the dunes and adjacent to Kuku beach Road. Mallard ducks at several locations including a group of around 30 on the loop. An estimated 40 Black swans who are successfully breeding on the Loop, one pair had approx 10 larger adolescent signets and another nest was observed with an adult sitting on a full clutch of eggs. The most western section of the loop has a Pukeko colony, and within the established riparian bush, several small bush birds including fantails. Colonies of chaffinches and other small birds were common on the gorse covered dunes. A large feral cat was also seen near the Loop and over the 3-day period 4-5 preyed upon bird carcasses were observed ranging from an unidentified small bush bird, up to a black swan. Paradise ducks and Kotuku were also seen in the area. The breeding colonies of aquatic birds, and other observations on the Loop suggest a level of aquatic and ecological health. A range of considered interventions could be further investigated here to attract further native bird species, such as Kotuku, bittern, white faced heron etc. Predator control should also be a considered option.

Figure A.24: Predated swan carcass. Image Hayden Fowler 2021

APPENDIX D: PANUI FOR FINAL WĀNANGA TO CO-DESIGN IMPLEMENTATION PLAN, 2021

(Originally planned to be held at at Tukorehe Marae; held online due to Covid)

[NB: Due to the pandemic across 2021 and into 2022, this significantly delayed face to face opportunities and closer ways to disseminate information on findings and designs to hapū and whānau and communities of interest. The Final wānanga was postponed from its August date to September at the marae, then again to an online delivery on 7 October 2021. A planned hīkoi with participants to sites for potential īnanga ponding systems for 11 November was also cancelled due to country wide COVID disruptions to travel and general health safety.]

Example of email:

> Nau mai, piki mai, haere mai ki tēnei *Wānanga Tirohanga Whakamua,* ki Tukorehe Marae, 8 o ngā ra o Hepetema 2021.
>
> Welcome one and all to our Wānanga. Our research team look forward to sharing with you what we have been working on as part of our action orientated implementation planning research project, Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating action-orientated climate change transitions to water-based land uses thatenhance taonga species, funded for 2020-2021 by the Deep South National Science Challenge. Please see the attached panui and executive summary.
>
> We will also share a dovetailed Massey-funded regenerative agriculture project that is underway, and other potential convergences, during the presentations from the team.
> We also look forward to hearing from you about your insights into climate change adaptation strategies and opportunities to assist coastal communities such as ours who are grappling with such issues on the ground.
>
> Many of you have been to our marae before so please arrive before the 11.00am sharp start of hui. Park in our new carpark.
>
> For those waewaetapu (not been to marae before) please signal back to me if you have not been formally welcomed and a powhiri shall be arranged for you at 10.30am sharp. Let me know how you might be placed with kaikorero, kaikaranga and waiata. Please arrive before 10.15am to 612 State Highway One and park in our new carpark. You will be stewarded to the more internal waharoa, not the one on SH1.
>
> Don’t hesitate to contact us if you have any questions.
> Please RSVP by 1 September to Moira Poutama (moirapoutama@icloud.com), indicating numbers attending from your organisation, and any dietary needs.
>
> Ngā mihi atu anō

ONLINE
Wānanga with
Research team
7 OCTOBER 2021
1.00 - 3.30pm

He Wānanga Tirohanga Whakamua

Deep South National Science Challenge Vision Mātauranga

Phase 3 Research Project to benefit Tahamata Incorporation, Shareholders, iwi and hapū.

This panui is to draw iwi/hapu leaders' and entities' attention to an ONLINE tirohanga whakamua (visioning session for futures) followed by Q and A on **Thursday 7 October 2021 from 1.00 - 3.30pm.**

[This presentation will inform a later hīkoi (walking/talking hui) on site with iwi, entities, shareholders, and board members in Kuku on afternoon of 11 November 2021 (FINAL times TBC).]

Phase 3 Research: ***Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating action-orientated climate change transitions to water-based land uses that enhance taonga species***

Given cumulative climate change impacts, this third project is about enhancing taonga species for our mokopuna and te taiao (wellbeing of future generations and the environment). The research team are currently exploring the connections between socio-cultural, economic and environmental wellbeing, whilst determining key adaptations for climate change in our rohe. Based on Phase 1 and 2 Climate Change and Manaaki Taha Moana research for the lower Ōhau River loop region, we are consolidating all available climate/hydrological variables that foster or inhibit revitalization of coastal taonga species. With Waikōkopu Consulting of Raglan, a climate change modeller from NIWA, a Māori design Masters student from Massey, Wellington and iwi researchers, we have been flow tracking and recording Ōhau River levels via data loggers to gather the intricacies of tides and moon phases. Together, we are co-designing sedimentation ponding systems by the Ōhau River for increasing tuna and galaxiid nurseries, with a focus on inanga or whitebait.

The panui below is for originally planned wānanga to be held at Tukorehe Marae, Kuku, which was emailed out to a wide range of iwi/hapū/whanau stakeholders on 30 August 2021 (cancelled due to Covid, and replaced with ONLINE wānanga – see previous slides).

The event was originally scheduled for 8 September 2021 (see 1st panui below), rescheduled due to covid (2nd panui below), then eventually cancelled again from an in-person event, to online (see above).

Tukorehe Marae | 612 State Highway One, Kuku
8 September 2021 from 11.00 - 2.00pm.

He Wānanga Tirohanga Whakamua

Deep South National Science Challenge Vision Mātauranga

Phase 3 Research Project to benefit Tahamata Incorporation, Shareholders, iwi and hapū.

This panui is to draw entities attention to a wānanga tirohanga whakamua (visioning session for futures) on **8 September 2021.**

Phase 3 Research: *Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating action-orientated climate change transitions to water-based land uses that enhance taonga species*

Given cumulative climate change impacts, this third project is about enhancing taonga species for our mokopuna and te taiao (wellbeing of future generations and the environment). The research team are currently exploring the connections between socio-cultural, economic and environmental wellbeing, whilst determining key adaptations for climate change in our rohe. Based on Phase 1 and 2 Climate Change and Manaaki Taha Moana research for the lower Ōhau River loop region, we are consolidating all available climate/hydrological variables that foster or inhibit revitalization of coastal taonga species. With Waikōkopu Consulting of Raglan, a climate change modeller from NIWA, a Māori design Masters student from Massey, Wellington and iwi researchers, we have been flow tracking and recording Ōhau River levels via data loggers to gather the intricacies of tides and moon phases. Together, we are codesigning sedimentation ponding systems by the Ōhau River for increasing tuna and galaxiid nurseries, including inanga.

Tukorehe Marae | 612 State Highway One, Kuku

6 OCTOBER 2021

11.00am – 2.00pm

He Wānanga Tirohanga Whakamua

Deep South National Science Challenge Vision Mātauranga

Phase 3 Research Project to benefit Tahamata Incorporation and the Shareholders

This panui is to draw shareholders to a wānanga tirohanga whakamua (visioning session for futures) on **6 October 2021.**

Phase 3 Research: *Manaaki i ngā taonga i tukua mai e ngā tupuna: Investigating action-orientated climate change transitions to water-based land uses that enhance taonga species*

Given cumulative climate change impacts, this third project is about enhancing taonga species for our mokopuna and te taiao (wellbeing of future generations and the environment). The research team are currently exploring the connections between socio-cultural, economic and environmental wellbeing, whilst determining key adaptations for climate change in our rohe. Based on Phase 1 and 2 climate change and Manaaki Taha Moana research for the lower Ōhau River loop region, we are consolidating all available climate/hydrological variables that foster or inhibit revitalization of coastal taonga species. With Waikōkopu Consulting of Raglan, a climate change modeller from NIWA, a Māori design Masters student from Massey, Wellington and iwi researchers, we have been flow tracking and recording Ōhau River levels via data loggers to gather the intricacies of tides and moon phases. Together, we are co-designing sedimentation ponding systems by the Ōhau River for increasing tuna and galaxiid nurseries, with a focus on enhancing inanga or whitebait fisheries.

Deep South National Science Challenge Vision Mātauranga

Phase 3 Research Project to benefit Tahamata Incorporation and the Shareholders

Nau mai, haere mai e ngā whānaunga tini o Tahamata

As a shareholder of Tahamata Incorporation, we are inviting you to work with us on how to adjust and adapt to more water due to climate change upon our coastal farm. We want you to know about our work, what we need to envisage from now, and into the future. We need your help to take the farm to where it needs to be.

AGENDA TO DATE

He Whakatau ki te whanau o Tahamata: Rangimarkus Heke

Karakia: Rangimarkus Heke

Overview presentations from Research team: Huhana Smith, Moira Poutama, Rebecca Eivers, Mercia Abbott, Christian Zammit.

Workshops with whanau followed by drive/hīkoi to site

Contact for all details

Moira Poutama: 021 922 161 or moirapoutama@icloud.com
Huhana Smith: 021 2448711 or Huhana.smith@massey.ac.nz

APPENDIX E: PROJECT OUTPUTS

The following is a list of presentations and other outputs by members of the research team. Covid has prevented us from extensive dissemination at conferences. Despite that, we have achieved the following:

Smith, H. (2022). "Harnessing creative potential of major transformative indigenous and non-indigenous contemporary art/design exhibition, events, conversations and engagements based on sustained research about uncertain futures on the west coast from Horowhenua to Taranaki." Presentation as part of intial Te Waituhi ā Nuku: Drawing Ecologies with Taranaki iwi leaders and hui at Govett Brewster Art Gallery, 9 Feburary 2022.

Allan, P., Bryant, M. & **Smith H.** 2021, "Knowing Through Harakeke", in Daniel Fernández Pascual & Alon Schwabe (eds.) OFFSETTED, Hatje Cantz: Berlin. Published in 2022

https://www.hatjecantz.de/cooking-sections-8152-1.html

Smith, H. (2021). "Ko te tiakitanga me te whakaoranga – protection and restoration in the age of changing with our climate", Climate Crisis Special Issue, #26 (November 1, 2021)

Online version

https://shuddhashar.com/ko-te-tiakitanga-me-te-whakaoranga-protection-and-restoration-in-the-age-of-changing-with-our-climate/

Smith H. (2021). Invited by Gillian Blythe CEO Water New Zealand, Hamilton to present a keynote presentation at their Water Conference. Date were changed three times to the final dates 24-26 February 2022, due to ongoing COVID 19/Delta outbreaks in 2021.

Smith H. (2021). Invited by Public Programs team at the Queensland Art Gallery | Gallery of Modern Art (QAGOMA) to host a pre-recorded virtual conversation with Alex Monteith, Ron Bull Jnr, Gerard O'Regan and Aunty Dale Chapman, presented in conjunction with the opening weekend celebrations for the 10th Asia Pacific Triennial of Contemporary Art (APT10), 4-5 December 2021.

Smith H. (2021). Invited to present 'The heat is on…a Māori response to climate change' for Nui Te Korero conference. Changed to a digital conference due to COVID 19, 29 June 2020.

Smith H. (2021). Invited Panellist to speak on the Wendy Michener Event on Art, Design, and Climate Justice, 29 March 2021, York University, Toronto, Canada.

Smith H. (2021). Te Ipu Taiao: The Climate Crucible conference on Saturday 13 March 2021. 10:30am-12pm: Panel: Huhana Smith, James Renwick, Rick Williment, Paris Williams - Te Ipu Taiao - The Climate Crucible in Aotearoa. Panel Chair: John O'Connor.

Smith H. (2021). "E Tata Tope e Roa Whakatipu", a chapter in Susette Goldsmith's (ed.), Treesense, Massey University Press, Auckland.

Smith, H. (2021). Invited to participate in Ditchley Foundation conference

"Climate judo": how can the impact of the pandemic and ensuing economic crisis be turned into effective action on climate change? 25-26 February 2021. My main points in this global online conference were:

Engagement with indigenous knowledge systems is key. Indigenous knowledge systems are often overlooked but may provide solutions to many climate challenges, particularly at a local level. The Maori Whakapapa highlights their relation to all life forces, a very community orientated, sustainable and inter-connected approach to life. We should underpin our climate discussions with indigenous knowledge systems in addition to science for long-term gain.

Visual mediums as the most powerful educational tool. At a local level, visual technologies – combined with science – might be used as an effective tool of communication to show people what climate change and conversely, effective climate change action, might look like in their local communities.

Smith, H. (2021). What if the City was A Theatre: A Symposium on Performance and Urban Space. 12 February 2021, Matiu Room, Te Whare Waka o Pōneke, Wellington. Panel discussion: "What about spatial justice? Kaitiakitanga, Performance, and Collaboration". With Dorita Hannah, Emalani Case, Huhana Smith, Sean Coyle, Sophie Jerram.

Smith, H. (2021). What if the City was A Theatre: A Symposium on Performance and Urban Space. 14 February 2021, City Gallery Adam Auditorium, Wellington. Panel discussion: "The City in the Anthropocene: Performing Urban Geology and Te Taiao". With Angela Kilford, Huhana Smith, Ingrid Horrocks, Maibritt Pederson Zari.

Smith, H. (2020). Keynote online for conference Mapping the Anthropocene in Ōtepoti/Dunedin: Climate Change, Otago Polytechnic, 29 September 2020.

Smith, H. (2020). Invited to speak for Monica Brewster talks at Govett-Brewster Art Gallery Len Lye Centre, 8 September 2020.

Spinks, A. (2021). Climate change adaptation projects with Māori communities. Presentation at Climate Sensitive Towns & Communities Conference, October 2021.

Spinks, A., Te Aomarere, A. (2021). Restoration of Lake Waiorongomai. Abstract accepted for presentation at International Wetlands Conference, October 2021.

Other:
-Related co-funding: **Dr Aroha Spinks** of WWF-NZ granted $50,000 for a case study on the Te Hatete Waikawa blocks – as part of the WWF Oceania First Voices project, which is an indigenous led Climate Change advocacy and adaptation project involving Australia, NZ, Fiji, Solomon Islands, Papua New Guinea.
- Deep South Vision Mātauranga Te Kahui support grant ($10,000) for **Maija Stephens** to visually document the project.
- **Huhana Smith** was elected by iwi and hapū group to be co-chair with Cr Rachel Keedwell for Horzions Regional Council's Climate Action Joint Committee.