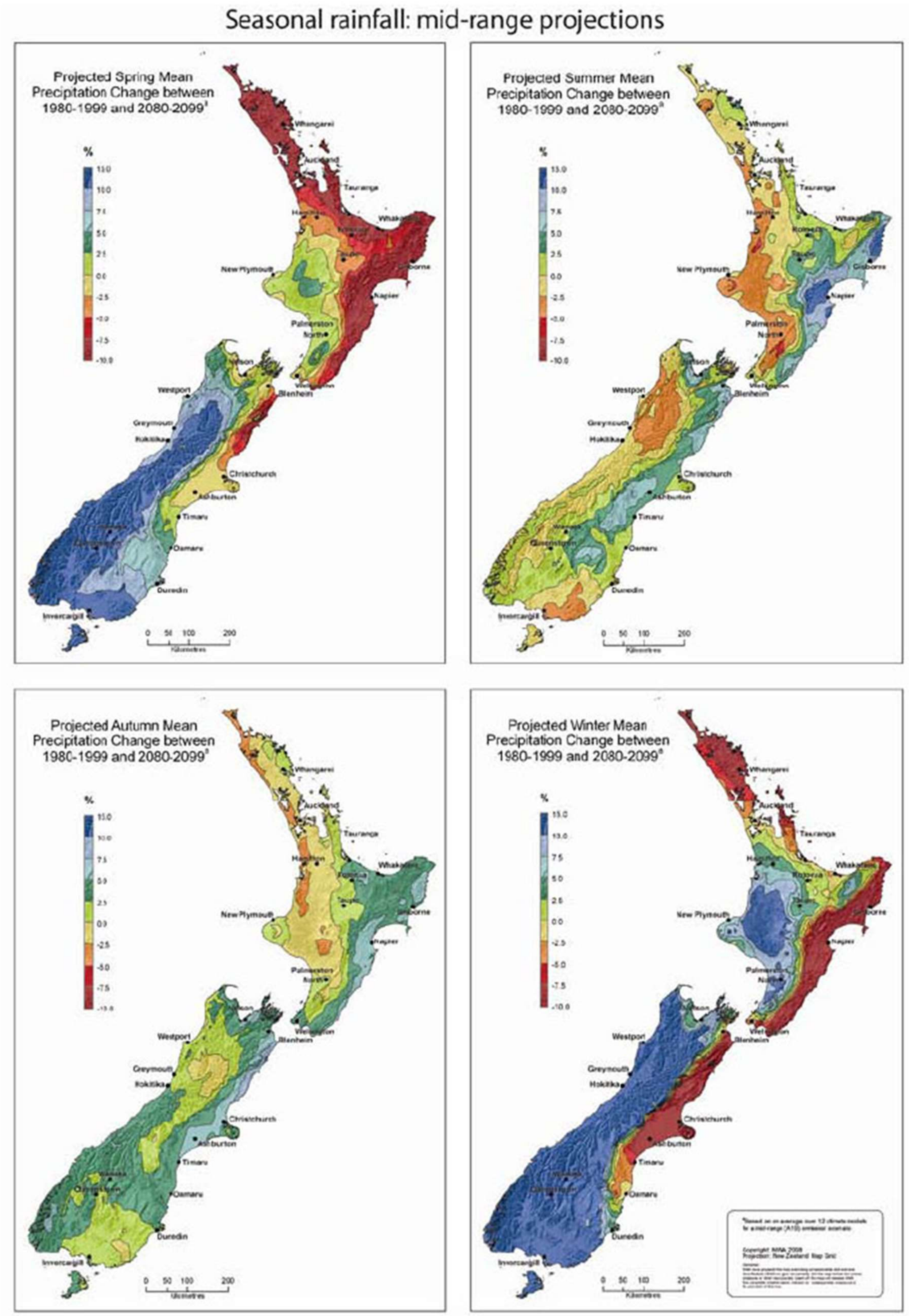

Figure 5.1.3 Projected mid-range changes in seasonal mean rainfall (in %) for 2090 relative to 1990
(Source: Ministry for the Environment, 2010).

All of these factors influence the relative value of ecosystem services in the coastal zone under analysis, and are thus factors that require consideration in the subsequent ecological economics research, where appropriate.

The report (ibid.) states that:

> "A sound risk assessment process is fundamental to ensuring climate change is appropriately factored into the planning and decision-making processes. The purpose of risk assessment, in the context of climate change, is to identify risks and hazards caused or exacerbated by climate change and to evaluate their effects and likelihood. Climate change risks and responses can then be prioritised with more confidence and compared equitably with other risks, resource availability and cost issues.
>
> A broad guide to risk management is presented in the international standard *ISO 31000:2009 Risk Management − Principles and Guidelines*[30]. This is the overarching risk management approach recommended by the Ministry for managing risks associated with climate change.
>
> A high-level, decision-making framework for flood risk management is set out in New Zealand standard *NZS 9401:2008Managing Flood Risk – A Process Standard*. This standard sets out a framework, based on accepted best practice, which users can work through as they seek to address their flood management issues. The standard was developed to give guidance on flood risk management, but it is not a detailed technical document."[31]

Proactive planning as required by the RMA and the CDEM Act, is the most effective means of minimising the risk to coastal communities such as that focussed upon in this research. The Resource Management Act 1991 (RMA) requires regional authorities to control the use of land for the avoidance or mitigation of natural hazards. Territorial authorities are required to control the actual or potential effects of the use, development or protection of land, including for the purpose of avoiding or remedying natural hazards. The Resource Management (Energy and Climate Change) Amendment Act 2004 further requires local authorities to have particular regard to the effects of climate change.

The Civil Defence Emergency Management Act (CDEM) 2002 primarily focuses on the sustainable management of hazards, resilient communities and on ensuring the safety of people, property and infrastructure in an emergency. The CDEM Act recommends an approach based on risk reduction, readiness, response and recovery.

Other relevant legislation for climate change and flood risk management includes the Building Act 2004, the Local Government Act 2002 and the Soil Conservation and Rivers Control Act 1941.

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[30] See: http://www.mfe.govt.nz/publications/climate-change/preparing-future-flooding-guide-local-government-new-zealand/part-three#footnote-6

[31] More detail on the risk assessment process is contained in sections 4.2.3 and 6.5 of the Climate Change Effects and Impacts Assessment manual (available at www.mfe.govt.nz/publications/climate/climate change-effect-impacts-assessments-may08).

Thus, the requirement for local and regional government to factor the impacts of climate change into their decision making and risk assessment is clearly stated. However, it is currently difficult to see that local government are indeed actively incorporating such factors into their annual or long term plans in any meaningful way, as can be seen from the review of the Horowhenua District Council Community Wellbeing Strategy and Action Plans (see Appendix C).

5.2 Projected Change in Landcover of Tahamata Farm to 2046, based on Projected Climate Change Impacts

The following analysis was completed by Dr Jane Richardson, in order to provide the required data for the subsequent ecological economics analysis of wetlands scenarios for Tahamata Farm, which is detailed in the following section.

<u>Tahamata Land Use (2016)</u>:

Currently the farm covers an area of 451.98 ha (Table 5.2.1). Surface water covers an area of 12.77 ha (3%) of the farm and comprises a small lake in the wetland area and the Ōhau river and river loop. In 2016 pine trees and scrub covered an area of 25.81 ha of the foredunes (6% of the farm area). The remaining 405.11 ha (90%) of the farm was classified as dairy pasture in 2016. Of the total area being used for dairy grazing 35.29 ha (8%) of the farm area had soils with a drainage class of 1 and 1-2 and can be described as puggy and/or very poorly drained – with a depth to the winter water table of less than 30 cm. Figure 1 shows the drainage class map for Tahamata farm. The analysis is based on data collected as part of the development of a soil health plan for the farm (Horizons Report No. 2011/INT/1401 Soil Health Plan No. 21).

Table 5.2.1 Landuse data for Tahamata

Landcover	**Current classification**		**No adaptation (do nothing)**		**Expand wetland to include DC 1, 1-2, 2-1,3-2 (Scenario 2b)**		**Expand wetland to include DC 1, 1-2 (scenario 2 a)**	
	2016		**2046**		**2046**		2046	
	Area (ha)	**% total farm area**	**Area (ha)**	**% total farm area**	**Area (ha)**	**% total farm area**	**Area (ha)**	**% total farm area**
Surface water	12.77	2.83	48.06	10.63				
Forestry/scrub	25.81	5.71	25.81	5.71	25.81	5.71	25.81	5.71
Wetland and flax	8.29	1.83	8.29	1.83	193.71	42.86	56.36	12.47
Dairy pasture	369.82	81.82	232.46	51.43	232.46	51.43	232.46	51.43
Dairy pasture - puggy and poorly drained	35.29	7.81	137.36	30.39			137.36	30.39
Total area	451.98	100.00	451.98	100	451.98	100	451.98	100

Scenario 1: Do nothing (no landuse change)

2046

Justification and assumptions

The trend for sea level rise around New Zealand has been about 5 mm/yr over the last thirty years and so significantly larger than the global average of about 3 mm/yr. But changes in regional sea level of up to 100 mm are occurring in less than a decade and over the last twenty years these increases have not been compensated for by a subsequent drop in sea level to the extent seen previously. Large variations in the rate of sea level rise around New Zealand make it harder to predict when a threshold for the sustainability of some current practice will be crossed, but at this **stage a rate of 200 mm/decade would be a reasonable approach** (Martin Manning – Science Summary, see sections 4.1-4.2). Projecting out to 2046 using this approach we could predict a sea level rise in the vicinity of 600 mm.

Of more relevance in terms of the impact of sea level rise on the farm out to 2046 is the change in groundwater levels. Sea level rise can cause a rise in groundwater over low lying land and an increase in the frequency and extent of flooding. An analysis from a Dunedin study indicates that **sea level rise will result in ponding of water at the surface** but that this does not just occur first on the lowest land, but **rather where the water table is currently closest to the surface** (Martin Manning – Science Summary; see sections 4.1-4.2).

The onset of climate change is expected to increase flood risk. Future floods are likely to be bigger. Modelling work on the Hutt River indicated the potential for a significant increase in flood frequencies over the 21st century under climate change scenarios (Ballinger et al., 2011). However, the magnitude of the change varied considerably depending on the emissions scenario and climate model used. The authors found that for the Hutt River under a high emissions scenario, flood return periods could reduce to a fifth of current-day values on average. It seems highly likely that with the projected change in climate variables the Ōhau River will experience larger and more frequent flooding.

The level of uncertainty around the magnitude and pace of sea level rise, frequency of flooding and water table response makes it difficult to predict what this will mean for the farm in 2046. However, the soil map can be used as a guide to identify the most vulnerable areas to change in sea level, groundwater levels and increased flooding. For the analysis of the farm in 2046 we have reclassified areas of the farm where the water table is currently less than 30 cm from the surface in winter (puggy and poorly drained dairy pasture –drainage class 1 and 1-2) as surface water. Areas of the farm which have a winter water table at less than 60 cm depth are reclassified in 2046 as puggy and poorly drained dairy pasture. The landcover area of wetland/flax and forestry/scrub remain the same in 2046 in this 'do nothing' scenario.

The farm in 2046 with no change in landuse

Based on the reclassification of the most vulnerable soils to sea level and water table rise, in 2046 surface water (at least in winter) is predicted to cover 48 ha (10.6% of the total farm area). Moderately to well drained dairy pasture is predicted to comprise 51.4% of the farm (232 ha). In 2046 30.4% of the farm area classified as puggy and poorly drained dairy pasture would rise to 137 ha (30%).

Scenario 2: Adaptation – expand wetland area

In Scenario 2 the adaptation response to rising sea level, increased river flooding and rising groundwater levels is active expansion of wetland areas. Under this Scenario 2a, areas where the winter water table is currently less than 30 cm below the surface and predicted to have standing water by 2046 (Drainage Class 1 and 1-2) are planted with wetland species. This would result in 56.36 ha of wetland (13% of farm area), 232 ha (51%) of pasture and 137 ha (30%) of dairy pasture on soils classified as puggy and poorly drained.

In Scenario 2 b In addition to these very wet areas (DC 1 and 1-2), the pasture areas predicted to be puggy and poorly drained in 2046 under a 600 mm sea level rise (soils that currently have a winter water table less than 60 cm deep) are also actively converted to wetlands. Under this scenario, of the total area of the Tahamata farm, 43% would be classified as actively managed wetlands, 51% would be dairy pasture with the remaining area in forestry/scrub (6%).

To summarise: the above research found that, currently, approximately 12% of Tahamata farm area has a winter water table less than 30 cm from the surface. Based on the classification of the most vulnerable soils to sea level and water table rise, in 2046 (and a possible 600 mm sea level rise) surface water (at least in winter) is predicted to cover 48 ha (10.6% of the total farm area). Moderately to well drained dairy pasture is predicted to comprise 51.4% of the farm (232 ha). And in 2046 the farm area classified as puggy and poorly drained dairy pasture would rise to 137 ha (30% of total area).

It is recommended that any decision to invest in drainage is reserved until the project team can present their findings and final report to Tahamata Inc.

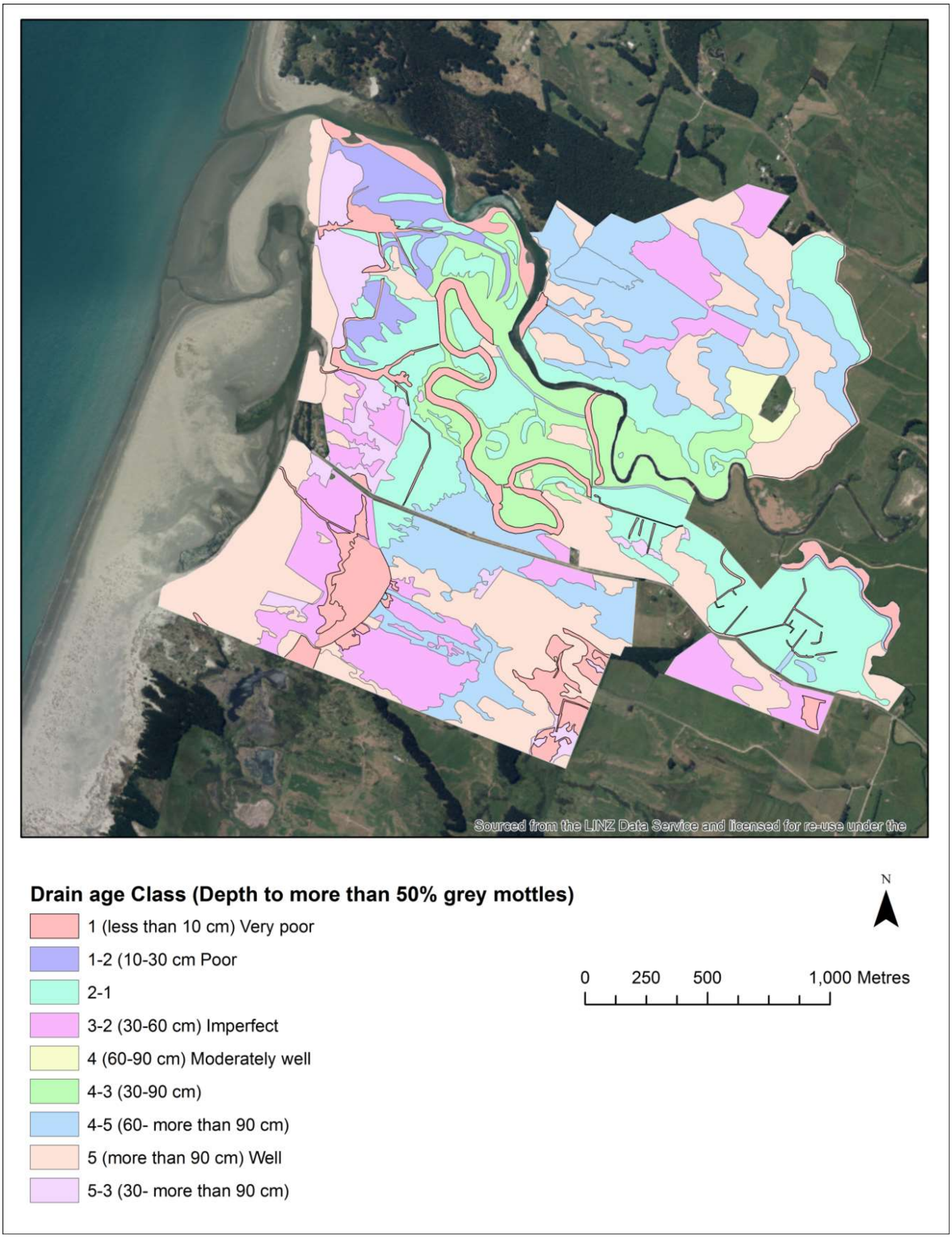

Figure 5.2.1 Drainage class map, Tahamata Inc.

Notes: Highest groundwater level and the water table can be estimated using the soil colour. Soils with high water table during the year exhibit grey colouration associated with a saturated and chemically reducing environment (mottling) at the depth of the high water mark and below. Soils are divided into drainage classes depending on the frequency and duration of periods of saturation or partial saturation during soil formation.

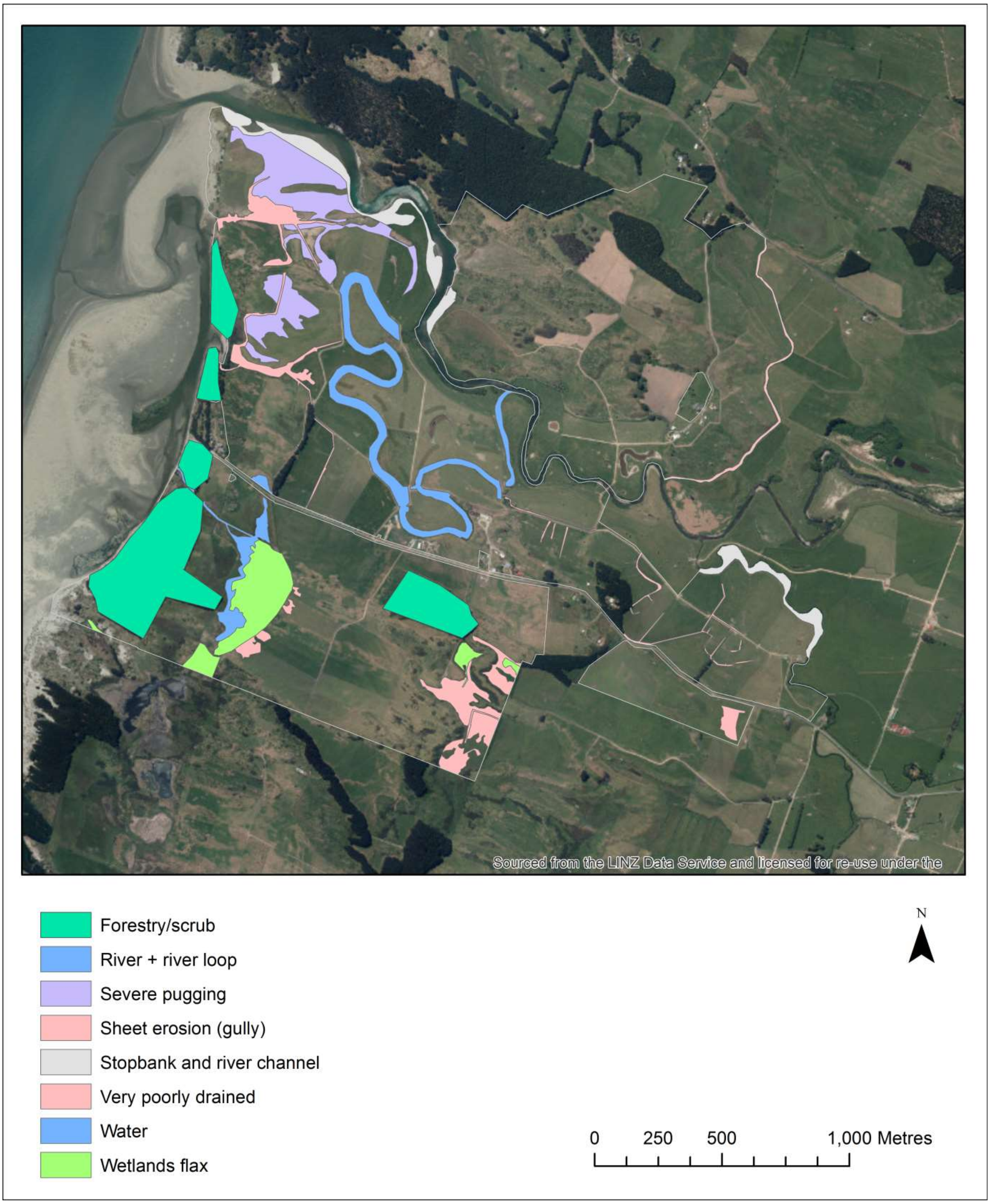

Figure 5.2.2 Forested areas and very poorly drained and wet areas (DC 1, 1-2)

5.3 Ecological Economics Analysis of Wetlands Scenarios for Tahamata

A separate report[32] documents the ecological economics research that was undertaken on various scenarios for wetlands on Tahamata Inc., a coastal dairy farm in the case study rohe. Readers are encouraged to read that report for greater detail about what is described here.

Tahamata is an iwi-owned 310 hectare dairy farm located on the Horowhenua coast, located on low lying, mainly sandy soils that are susceptible to water inundation, which is projected to happen with Climate Change, as early as within the next 30 years. Given this problem, our analysis focused on 3 scenarios that address how the dairy farm's management could adapt to this situation:

Scenario 1: (No Adaption) – this is essentially a 'do nothing scenario' where dairy production was adversely affected by the deterioration of the land and soil conditions due to water inundation;

Scenario 2 (Some Expansion of Wetlands) – this scenario considers expanding an existing wetland area to actively develop another 25 hectares of wetlands;

Scenario 3 (Full Expansion of Wetlands) – this scenario sees even more active development of wetlands so they now cover 194 hectares, which means the wetland covers more land than the dairy farming operations.

In all scenarios, the amount of land covered by commercial forestry (21.2 hectares) and scrub (64.4 hectares) remains constant throughout the 30 years of the scenario, which started from a base year of 2015/2016. Each of the 3 scenarios were assessed by using an ecosystem services approach where their economic valuation could be directly compared with an economic valuation of the dairy farming operations, with the intent of therefore integrating 'economic', 'ecological' and other values into the one analytical framework. All of these scenarios were based on an IPCC mid-range climate projection for sea-level rise over the next 30 years, which was modelled by Horizons Regional Council to produce projected water level and drainage patterns for the Tahamata farm.

The first phase of the research involved compiling comprehensive financial accounts for the dairy farm as well as the small forestry operation for the base year of 2015/2016, and compiling ecosystem services accounts, which covered 18 different ecosystem services, and attaching an economic value to each of these services. This involved GIS analysis of land cover areas so that a matrix was constructed of 18 ecosystem services by 8 different land use/land cover combinations. From this information, for each of the 8 land use/land cover combinations (which were mainly human modified ecosystems) we used our publicly available New Zealand data sources to determine an economic value ($/year) of each of their ecosystem services. For our assessment of the economic value of the wetland ecosystem services, we depended on the Economics of Ecosystems and Biodiversity (TEEB)[33] database, which covers 244 'inland wetlands' and a very useful regression equation

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[32] See: Patterson, M.G., Richardson, J., Hardy, D.J., Smith, H. (2017, temporarily embargoed*). Real Economics of the 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.

[33] See http://www.teebweb.org/

that summarises this data. We were thus able to use the TEEB data and regression equation, along with other information, to adapt TEEB ecosystem services valuation data to Tahamata. The ecosystem services accounts enabled us to compare ecosystem services value per hectare of the different land use/land cover combinations: Wetlands, dominated by Vegetation ($13,852/ha/yr); Wetlands, dominated by Open Water ($4,042/ha/yr); Surface Water on Ponding on Land; ($106/ha/yr); Forestry ($1,272/ha/yr), Scrub ($573/ha/yr), Stocked Dairy Pasture in Good Condition ($1,411/ha/yr), Dairy Stock on Poorly Drained and Puggy Soils ($704/yr/ha), and Poorly Drained and Puggy Soils with No Stock($395/ha/yr). These data underscored the very high comparative economic value of wetlands compared with other types of landcover/landuse.

The second phase of the research was to develop a scenario modelling tool (in the spreadsheet environment), to project the scenarios forward to 2045/2046, and then assess for that year the overall economic value of each scenario across each of the 18 ecosystem services and various financial information about the dairy farming and forestry activities.

Table 5.3.1 Commercial and Ecological Values Associated with Wetland Scenarios

Descriptors	Units	Base Year: 2014/15	Scenario 1: No Adaption 2045/46	Scenario 2: Some Expansion of Wetlands 2045/46	Scenario 3 Full Expansion of Wetlands 2045/46
Dairy Farm	Hectares	310.00	274.71	274.71	172.64
Forestry	Hectares	21.19	21.19	21.19	21.19
Wetlands	Hectares	21.06	21.06	56.36	193.71
Net Value	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial value of Dairy and Forestry Products	$\$NZ_{2015/16}$	328,844	241,173	241,173	189,342
Non-Commercial Value of Ecosystem Services	$\$NZ_{2015/16}$	352,735	322,360	597,587	1,648,974
Provisioning Ecosystem Services	$\$NZ_{2015/16}$	334,561	246,077	250,208	213,643
Cultural Ecosystem Services	$\$NZ_{2015/16}$	66,776	65,628	167,782	564,142
Regulating Ecosystem Services	$\$NZ_{2015/16}$	280,242	251,829	420,769	1,060,531
Supporting Ecosystem Services	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial Value Per Hectare	$\$NZ_{2015/16}$ / hectares (dairy +	993	815	815	977

In terms of the all-important ‘net value’ (value added), Scenario 1 (No Adaptation) had a net annual value of $563,533 for 2045/2046, which represents a decrease of 17.3% essentially because 35.3 hectares has become unavailable for dairy farming due to water inundation.

Scenario 2 (Some Expansion of Wetlands) had a net annual value of $838,759 for 2045/2046 which the same decrease dairy farm output as a first scenario, but this was more than compensated by the high economic value associated with the development of an expanded wetland area.

Scenario 3 (Full Expansion of Wetlands) had a net annual value of $1,838,316 for 2045/2046 which is considerably more than the first two scenarios. Although this scenario saw an even larger drop in the economic production of the dairy farm, this drop is greatly outweighed by the extra economic value generated by developing the wetlands essentially on areas which were no longer suitable or impossible to use for dairy farming. Other indicator variables for the scenarios are reported in the Table 5.3.1.

In all 3 scenarios, there was a decrease in the commercial (net) revenue of the Tahamata, decreasing as low as $189,342/yr in Scenario 3 compared with a base year figure of $328,844/yr. Although this is the case, it should be noted that, the Tahamata farm still remains viable and profitable, but just operating at lower level of production which is incidentally still at a higher level than the average New Zealand dairy farm or for that matter the average Lower North Island dairy farm.

There are a number of areas that require further research and stakeholder consultation, as explored further in Patterson et al. (2017). The economic analysis needs to be integrated into a full cost-benefit framework, which will require us to collect and process data on the costs of land use changes, particularly the active conversion of land to wetlands which includes such costs as planting, engineering works, fencing, pest control and so forth. Other adaption strategies, such draining the inundated land or planting grass species that are tolerant to the new high water table environment, also need to be considered in consultation with stakeholders. If any of the wetland conversion scenarios, or variants of them are to be implemented, as in most cases that seem to have a good economic justification, further research needs to be undertaken on how this conversion could be achieved. The ‘diffuse’ ecosystem services values, particularly for wetlands that benefit a large number of often ill-defined stakeholders across site-specific, local, regional, national and global scales, complicates and make difficult any concerted implementation aimed at capturing very significant ecosystem service values highlighted in some of the scenarios.

6 RESULTS – LANDSCAPE ARCHITECTURE DESIGNS, EXHIBITIONS

6.1 Design Approach

Exhibitions are an important adjunct to the design process and particularly important tools for communication and feedback of typically abstract or metric science based research. There were four public exhibitions between March 2016 and June 2017.

The research was framed around four exhibitions spanning 2016 and 2017. The exhibitions were part of an ongoing and iterative process which experimented with ways of communicating the research as it was happening, thereby encouraging communities to play an active role in developing long term climate change solutions.

The exhibitions were grounded in whakapapa thinking with the community which established the values and visions that would ensure the farmlands were always abundant and culture thrived, despite the uncertainty associated with climate change. The five visions: bringing whanau back to the whenua; ensuring healthy land and waterways; improving habitat for kai moana; teaching the next generations about their whakapapa and; keeping the farm economically viable[34] provided the basis for a series of long term design strategies to diversify the farm's activities, actively protect all waterways and encourage resettlement on the high ground thereby enhancing the connection between community, ancestral lands and production without compromising agricultural yield.

6.2 The First Two Exhibitions: Wai o Papa: Waterlands Exhibition

The first two exhibitions, called Wai o papa / Waterlands were held on 31 May and 21 June 2016 in the School of Architecture gallery: on a long wall that sits two metres behind a window next to Vivian Street, which is a major thoroughfare in Wellington. The narrative on the front wall explained the meaning of the title:

> *"Wai o Papa as a ground water flows beneath lands that will soon become water, or that may in some distant future become lands again. The flux has always been geological, but it's now overwhelmingly anthropological. Sea-level rise will inevitably affect most of the seven billion people in the world, in one way or another. We can wait for it to happen. But this may be too late. If we know it's going to happen, we need to act now.*
>
> *Wai o Papa is a research project in the Horowhenua to Kāpiti that explores how Māori coastal farming communities might anticipate and adapt to the impacts of climate change. It investigates, through design, ways to protect our lands in the face of sea level rise and how these might act as a catalyst for the restoration of well-being to the land, the water and its peoples.*

This is the first in a series of exhibitions communicating science through culture, art and design to the coastal communities of Aotearoa New Zealand."

34 These vision statements were forged by Moira Poutama and Aroha Spinks with shareholders at the wānanga held at Tukorehe marae, Kuku on 3 November 2016.

The first exhibition was attended by leaders of the Deep South National Science Challenge including Dr Dave Frame, Darren King and others; tangata whenua from the case study rohe as well as other areas throughout New Zealand, academia and members of the general public, as well as the research team.

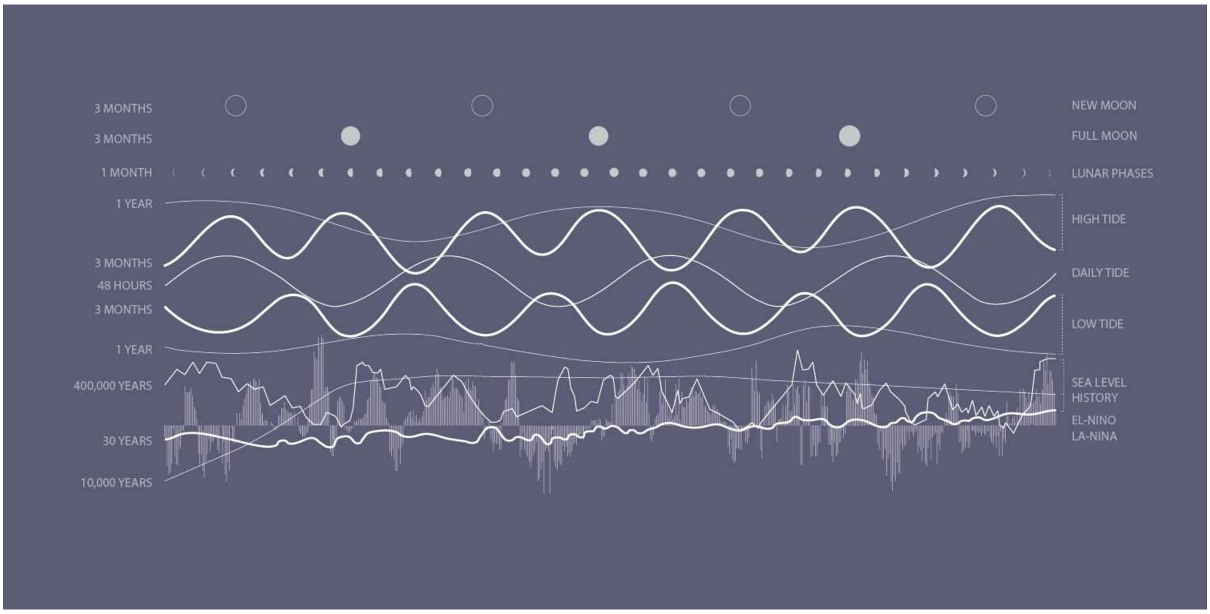


Figure 6.1 Overlay of weather cycles
(Compiled by Penny Allan and Abdallah Richards. Drawing on analysis conducted by wider research team).

It drew together data on geological time; geomorphology; ground water; current climate change science, and Māori understandings of water and tidal cycles. Graphs were depicted on the outer window of the building, against a background photo of the Ōhau River mouth, showing the range of cycles affecting the relationship between land and water in low lying coastal areas, from sea level rise over hundreds of thousands of years to the daily cycle of the tides.

The exhibition was extremely well received, particularly from a Vision Mātauranga perspective – the key component of this project. To this end, it was proposed by a leader within the Deep South NSC, Darren King (NIWA) that all current iwi and hapū projects in the current Deep South NSC Vision Mātauranga round national pool be brought together. It was noted by the Deep South NSC leadership team members who attended the exhibition that the research team had managed to transfer complex information in a clear and comprehensive way for audiences. Tikanga was also adhered to for the exhibition opening on 31 May with Derek Kawiti officiating on behalf of Victoria University. Notably, two whānau members who work in Wellington came to the Exhibition opening.

The second exhibition focused on the Maramataka, a lunar calendar based on oral narratives. It related to rituals associated with the rhythms of people, land and water, the abundance of resources and the phases of the moon.

Both exhibitions were foregrounded by the illuminated ‘Seas will Rise’ lightboxes[35]. Located on Vivian Street, a major thoroughfare in Wellington near the exhibition site, the graphics foreshadowed sea-level rise through some compellingly simple and direct maps and photographs.

Figure 6.2 The Maramataka in the second exhibition

At the same time, inside the School of Architecture, an exhibition of work from fifteen Masters students in architecture, landscape architecture and interior architecture showed adaptation strategies for the farm based on an understanding of Māori values developed through hīkoi. Students used this knowledge to envision how climate change might act as a catalyst for positive adaptation. For example: developing papa-kainga settlements to re-inhabit new waterfront land on higher ground; recognising the importance of re-establishing native ecologies; bringing back the birds as well as the whanau, hapū and iwi to their lands and; suggesting how farmland activities might diversify practice and still maintain productivity (see Figures 6.3-6.7). Two projects were selected by iwi researchers and professional designers to partner with professional firms—Isthmus and Studio Pacific— both based in Wellington, to develop and prepare the work for future exhibitions.

35 By Massey University Master’s student, Kevin Cartwright.

Figure 6.3 The student work in the second exhibition

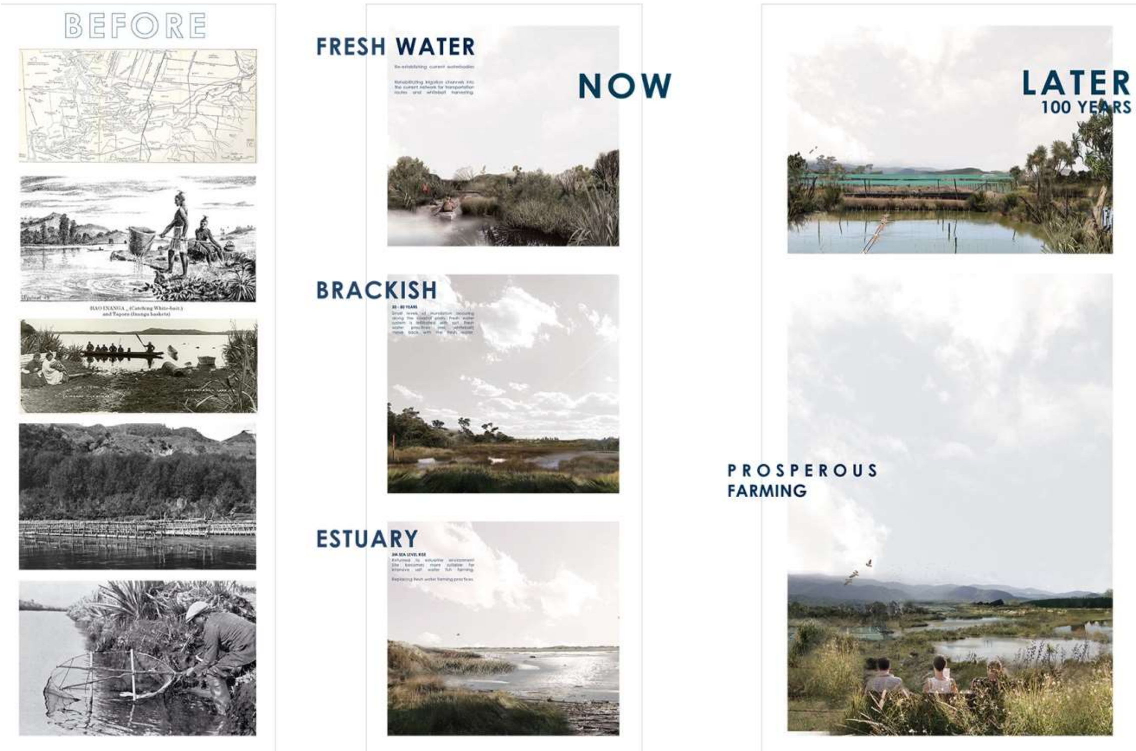


Figure 6.4 Student work by Alexandra Jackson and Ryan McCully

Figure 6.5 Student work by Alexandra Jackson and Ryan McCully

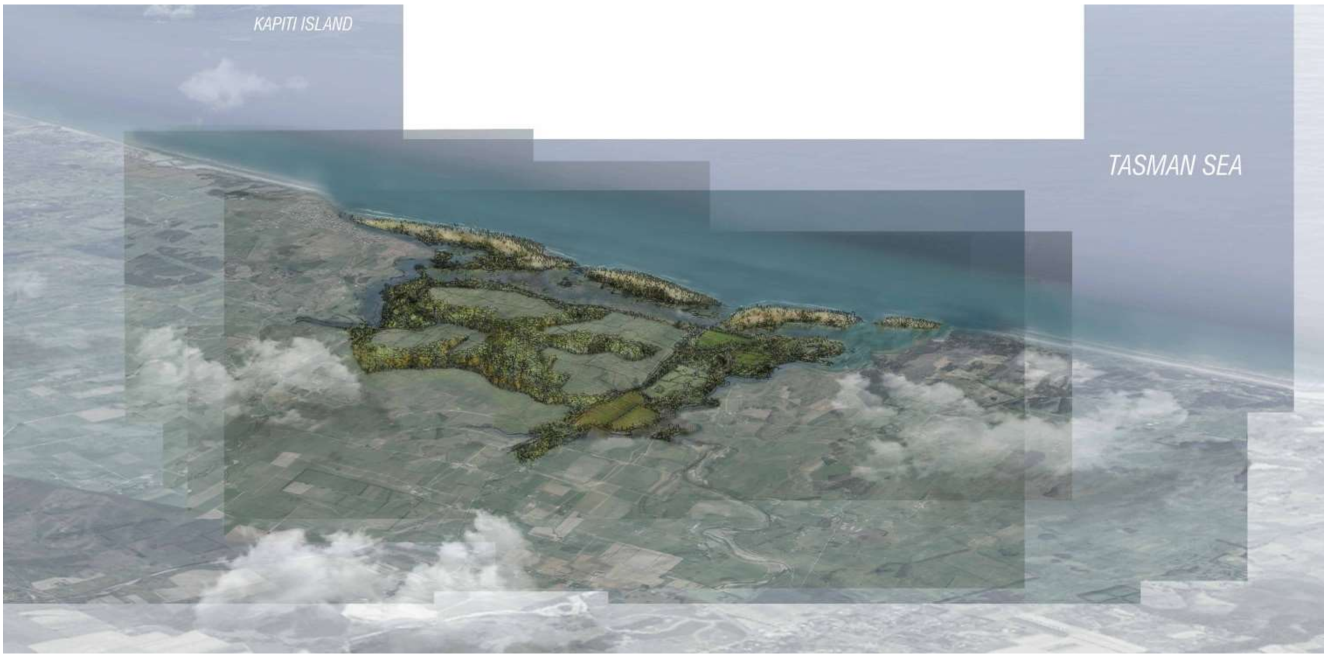


Figure 6.6 Birds eye view of the farm by student Yota Kojima

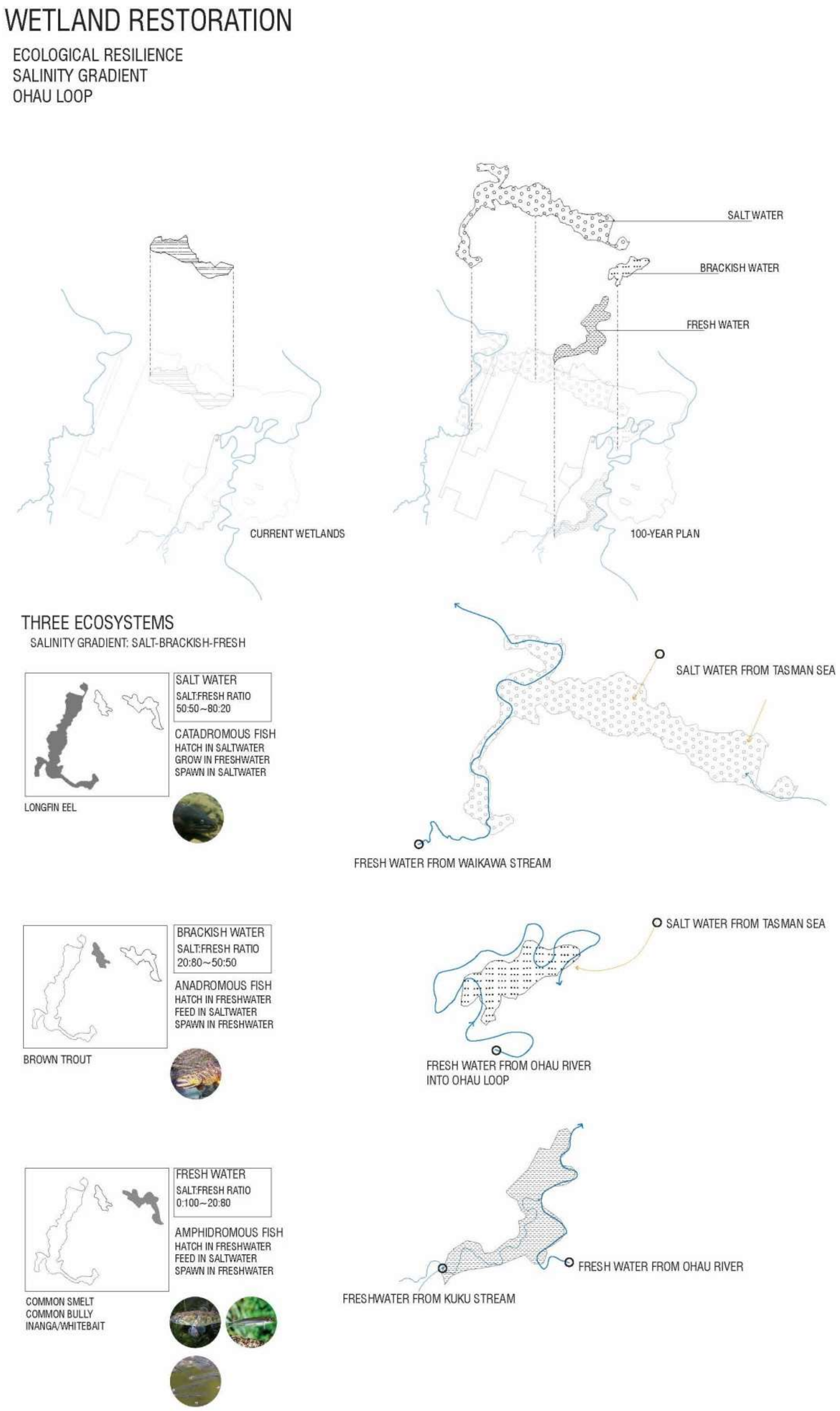


Figure 6.7 Student work by Yota Kojima showing potential restoration of wetlands for a food producing venture of the farm

6.3 The Third and Fourth Exhibitions

The third and fourth exhibitions events, *Whakatairangitia - Rere ki uta, rere ki tai! — Proclaim it to the sea, proclaim it to the land*', were held in a collection of disused dairy sheds on the farm (see Figures 6.8-6.18) and the Dowse Art Museum in Wellington (see Figure 6.19).

The dairy sheds exhibition, designed to encourage a full immersion in the site and its whakapapa connections, brought the research together from an indigenous and interdisciplinary perspective. The three sheds by the Kuku Stream were thematically grounded by the concepts of whakapapa (interconnected genealogy), hīkoi (walking/talking hui) and kōrero tuku iho (oral narratives of place).

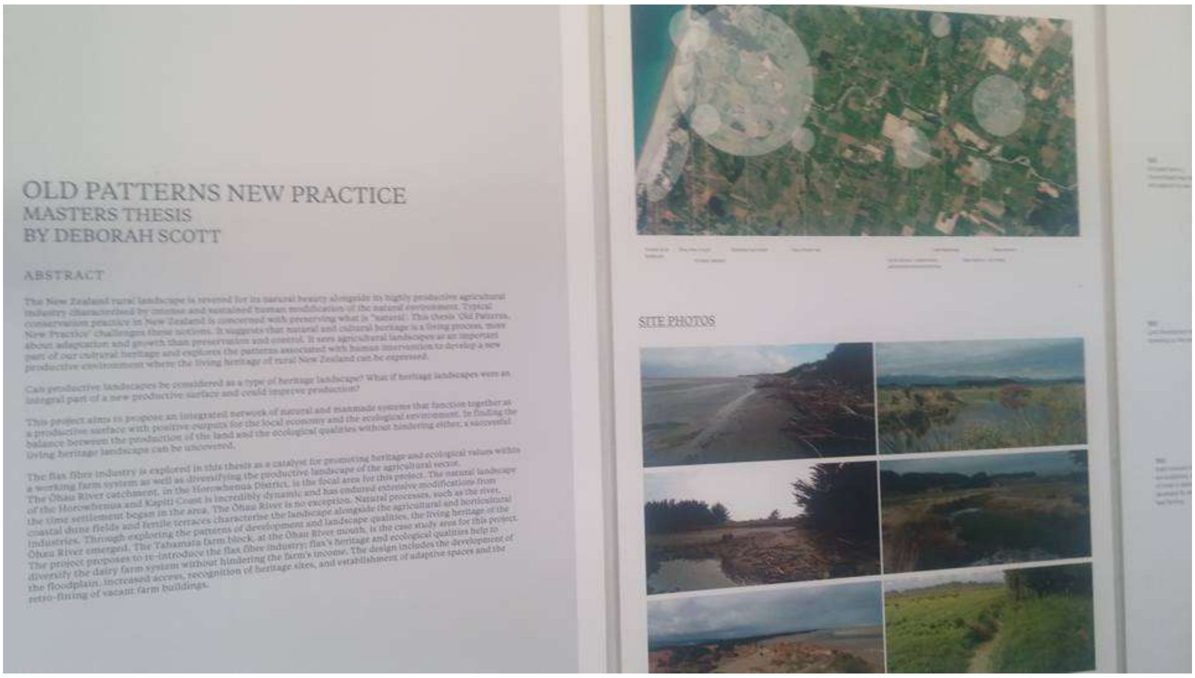
The whakapapa shed grounded visitors in the site and the vision (see Figure 6.8).

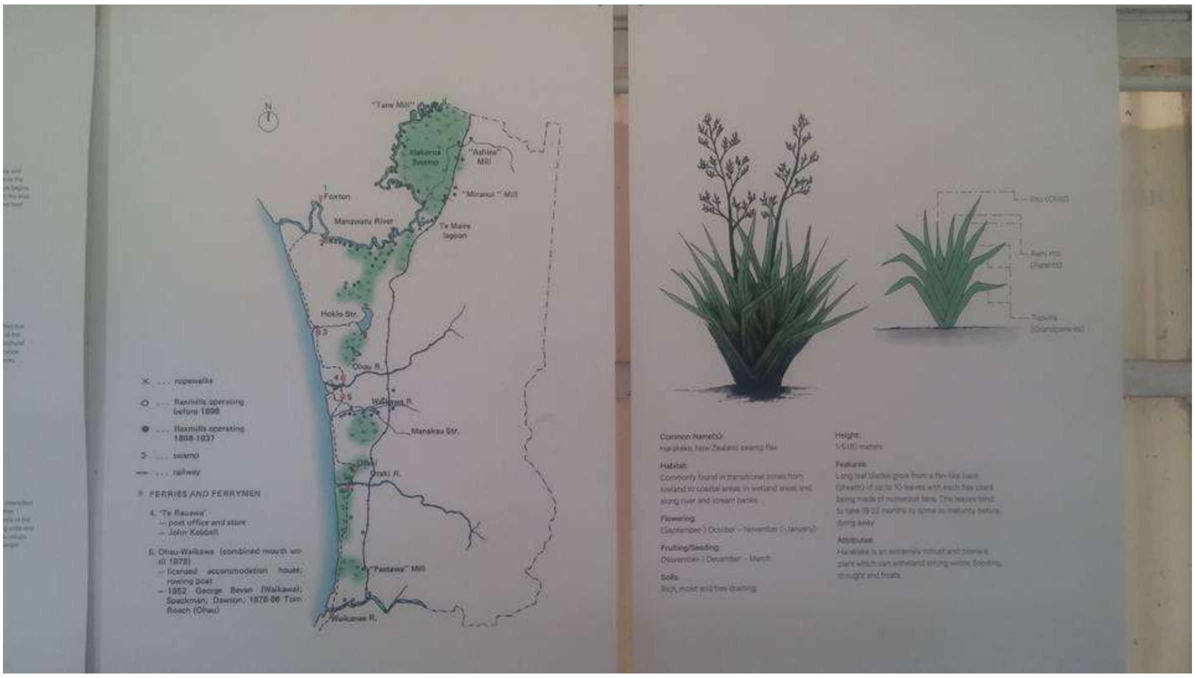
Figure 6.8 Whakapapa shed

The hīkoi shed expressed the journey of the research through an exhibition of art and design and included the students' proposals.

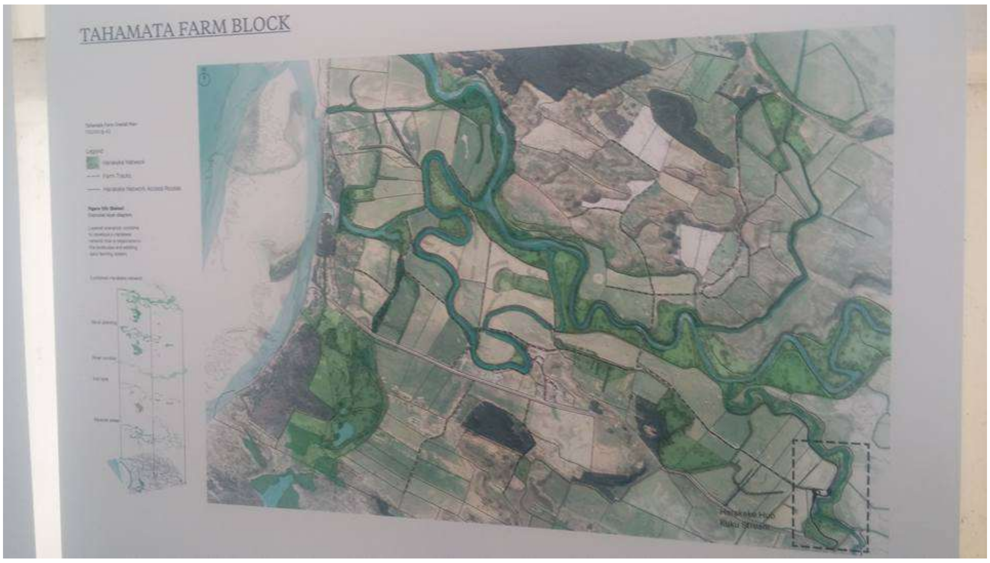
Figure 6.9 The 'hīkoi' shed

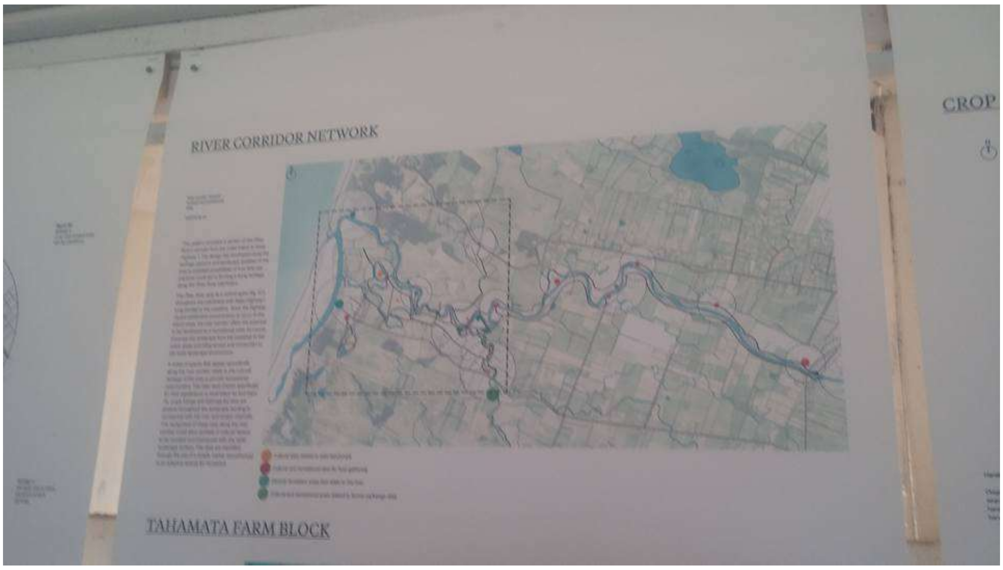
The hīkoi shed featured a design proposal, by Masters student Deborah Scott, to revitalise the harakeke industry (NZ flax), planting the farm's waterways and wetland fringes with harekeke whilst prioritising dairying on higher ground (see Fig. 6.10a-e). A revitalized harakeke industry works with Māori cultural traditions: in the 19th century, local iwi and hapū harvested it from the margins of wetlands and waterways to develop a significant and sustainable industry around its fibre. Re-establishing harakeke also has significant environmental benefits: cleaning polluted waters; encouraging biodiversity; minimising the effect of erosion and land loss; slowing down flood waters, and mitigating coastal impacts of higher or more salinised water tables. Particular emphasis is given to how such changes could be implemented on the Tahamata farm block, on which the exhibition was held.

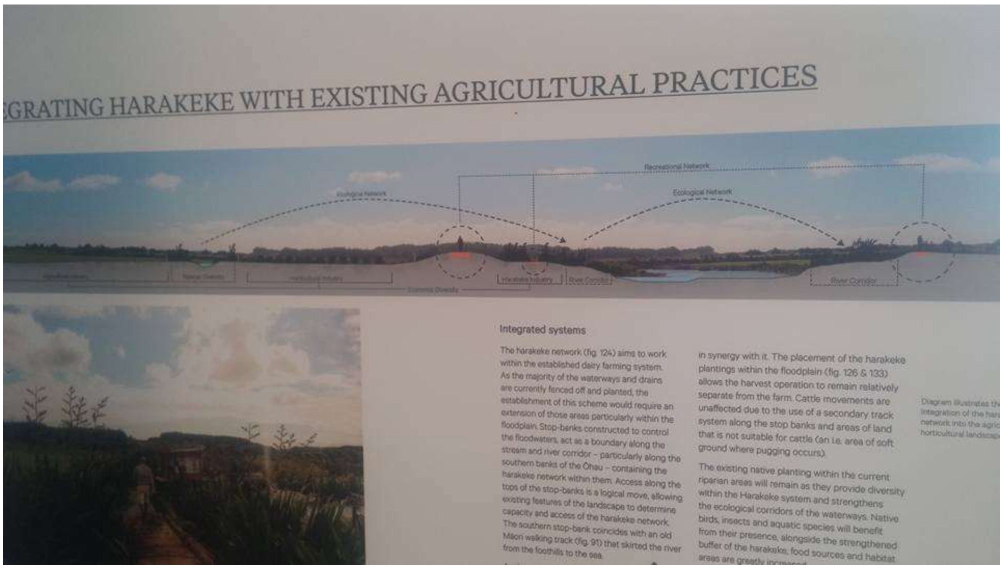




Figures 6.10a-b Old Patterns New Practice, Harakeke Industry, by Deborah Scott







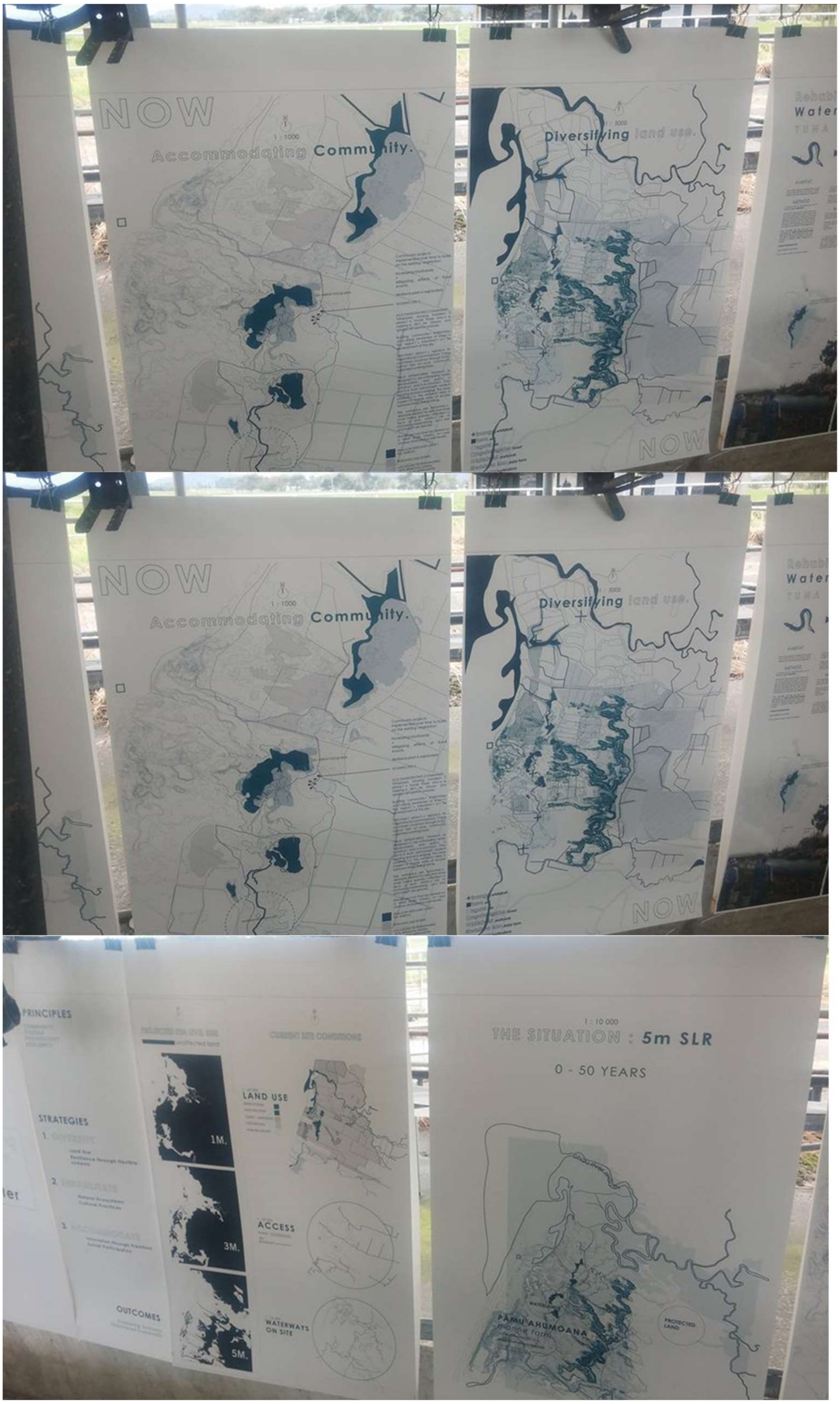
Figures 6.10c-e Revitalising the Harakeke Industry, by Deborah Scott

Art photography by Ann Shelton highlighted the significance of harakeke and other native plants as rongoā with healing properties used by Māori.

These exhibition also included large visual maps, which depicted the impacts of the 3m sea level rise (see Figure 6.11a-c). This starkly revealed how significant sea level rise will potentially be in the case study rohe.

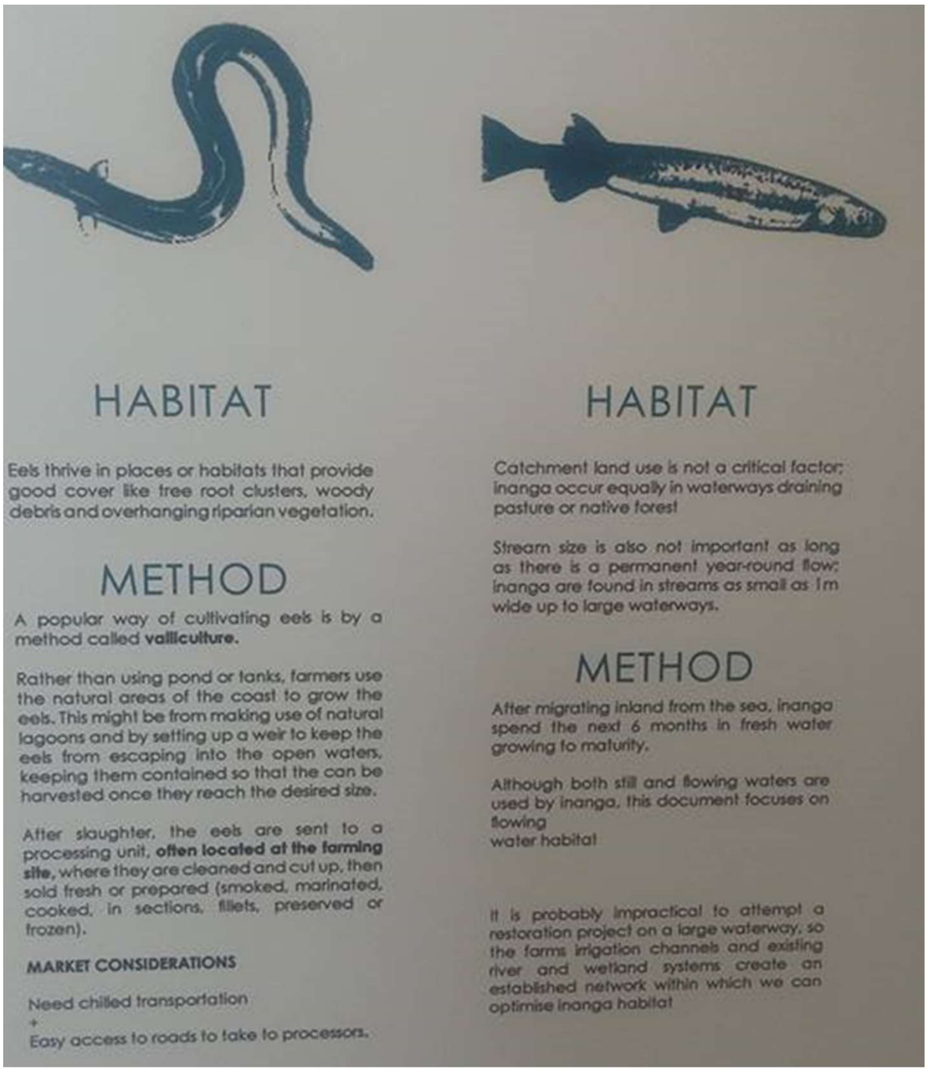
Figures 6.11a-b Impacts of a 3m sea level rise

Team work by Master's students from Victoria University, as depicted in Figures 6.12a-c, was kaupapa about adapting to water inundation over time, including various land use changes that could be implemented over time.



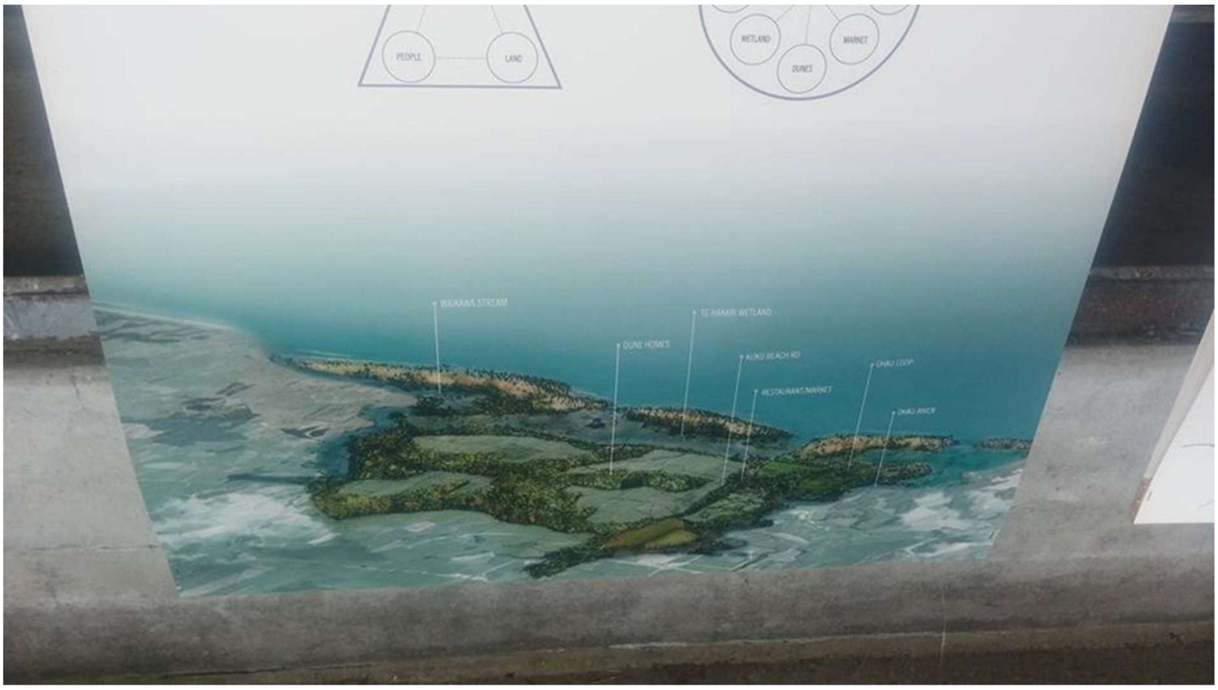
Figures 6.12a-c Adapting to Water Inundation over Time

One such strategy is the use of tuna inanga to rehabilitate waterways (see Figures 6.13a-b).

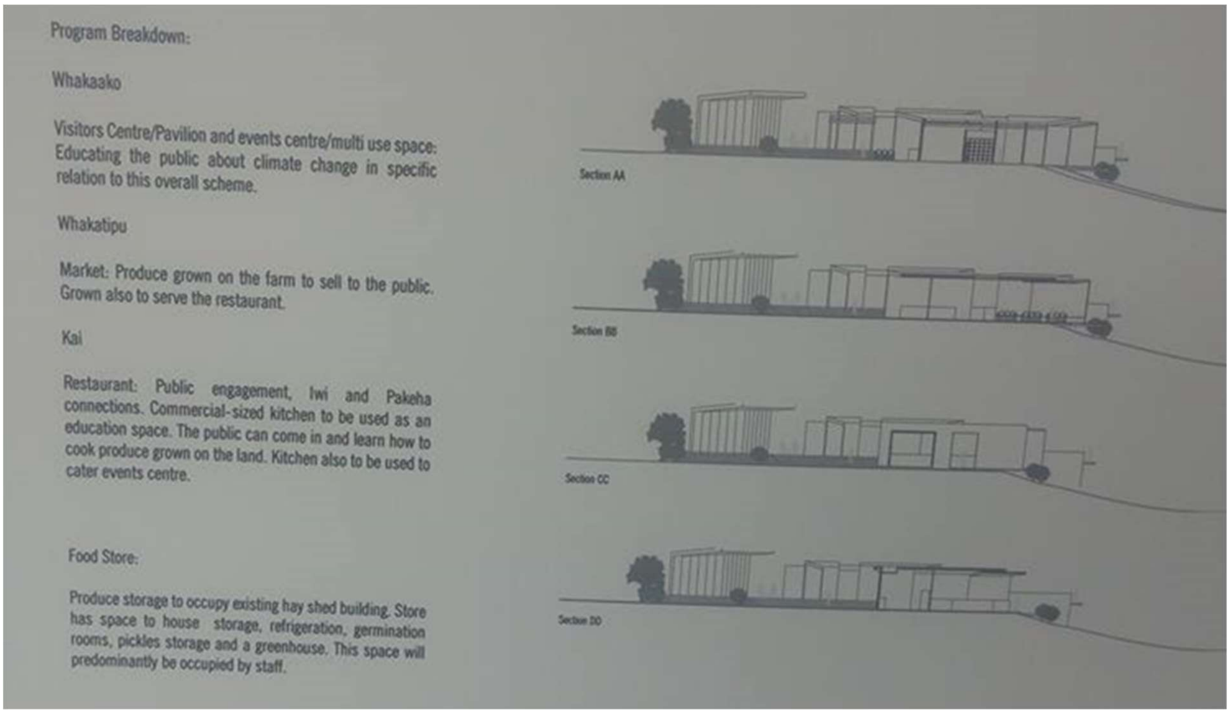


Figures 6.13a-b Tuna Inanga to Rehabilitate Waterways

Likewise, alternate housing using prefab housing suited to changed environmental conditions, was explored by Victoria University students. The kaupapa exhibited here (see Figures 6.14a-d) explored returning whanau to the land via papa kāinga that could adapt to living on higher ground and also the return of the harakeke industry (see also Figure 6.10).



Figures 6.14a-b Papa kāinga and the inter-relationships between people and the land and waterways



Figures 6.14c-d Papa kāinga options for the future

As shown in the visual displays shown above, all work exhibited explored the interconnections between the people, the land and the waterways, with examples provided of ways in which innovative landscape designs could enable people better adapt to an increasingly wet landscape. They included visual depictions of the possible projected sea level rise over time in the case study area and explored ways in which the natural environment could be utilised to best protect local communities from the impacts of climate change, and the ways in which built structures could help people live in such a changed environment. This encouraged local communities to consider potential changes that will likely occur in the rohe, offering them a range of options and enabling them to plan.

One of the important outcomes of the research was the identification of thresholds, critical ecological signals of the gradual but irreversible shift of the Ōhau River from a river mouth system to an estuary. The erosion and ultimate breach of coastal dunes, an elevated water table, flooding, and failure of vegetation to thrive are thresholds that will herald the shift with wide ranging impacts on the long-term viability of the farm. The kōrero tuku iho or oral narrative shed (see Figure 6.15) reflected on the nature of these climate change-related thresholds, expressing them visually and asking the question “what would you do if…?” to establish a very clear, time-based relationship in climate change terms, between ‘what might happen’ and ‘what needs to be done’ (see Figures 6.16a-c).

Figure 6.15 The ‘oral narrative’ shed

This linking of thresholds (see Figure 6.17) with adaptive responses has resonances with the codified knowledge system of the Maramataka. However, instead of relating narratives describing past and present relationships between people land and water, our intent was to create new narratives, new rituals and new practices, connecting climate change related phenomenon with specific actions and embedding these in cultural practice. We framed the thresholds as catalysts for action and linked them to a toolbox of relatively low cost adaptation strategies that were tailored to respond to thresholds *as they occurred*. The first strategies related to protection of arable land from salt water inundation and included revegetation of the coastal dunes and protection of wetlands. The second set of strategies were about accommodating the environmental shift: allowing for flooding in targeted ways, diversifying farming practices and preparing infrastructure for an eventual shift to high ground. A third set of strategies related to resettlement.

Figures 6.16a-b What would you do if…?

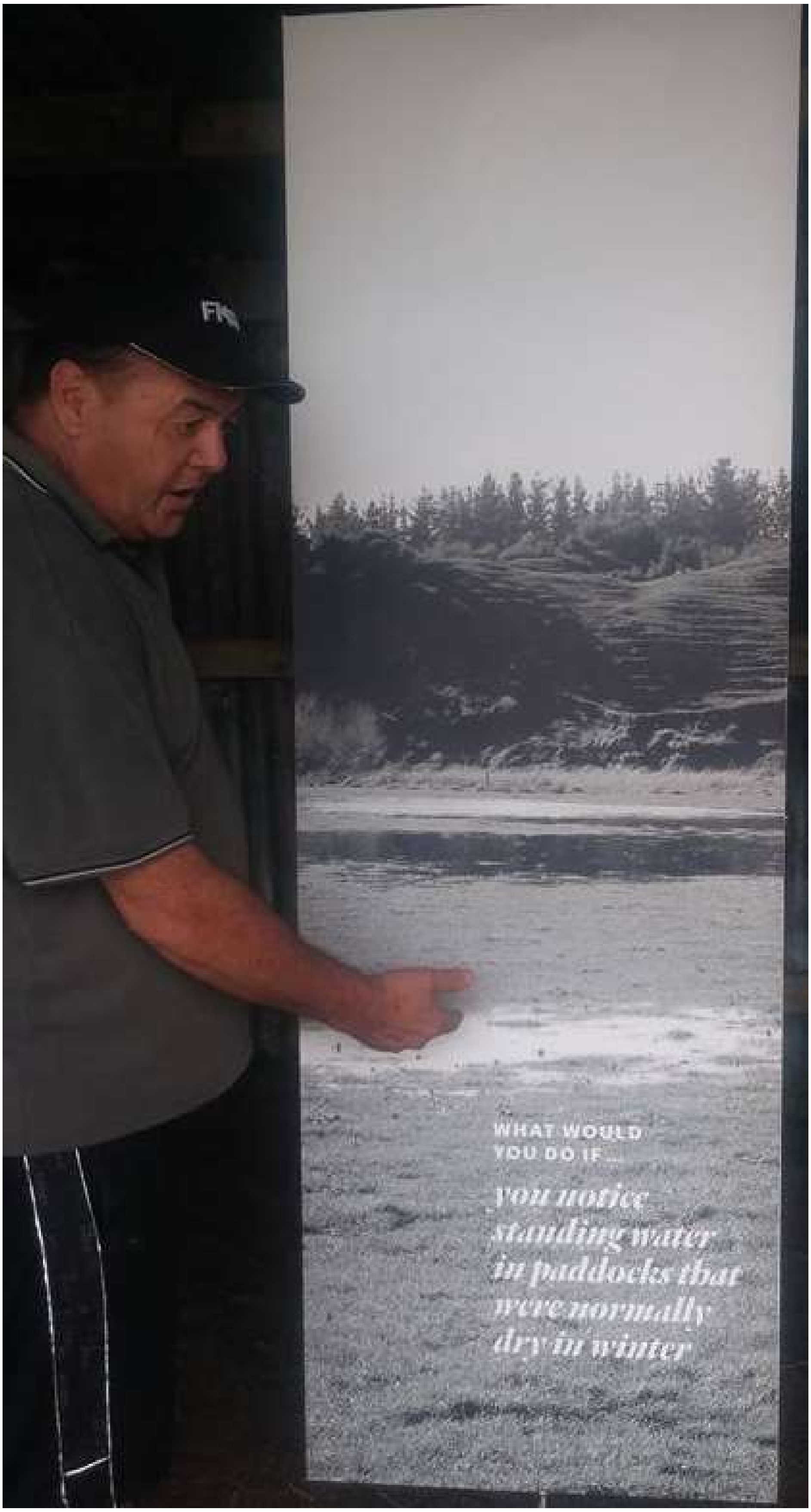
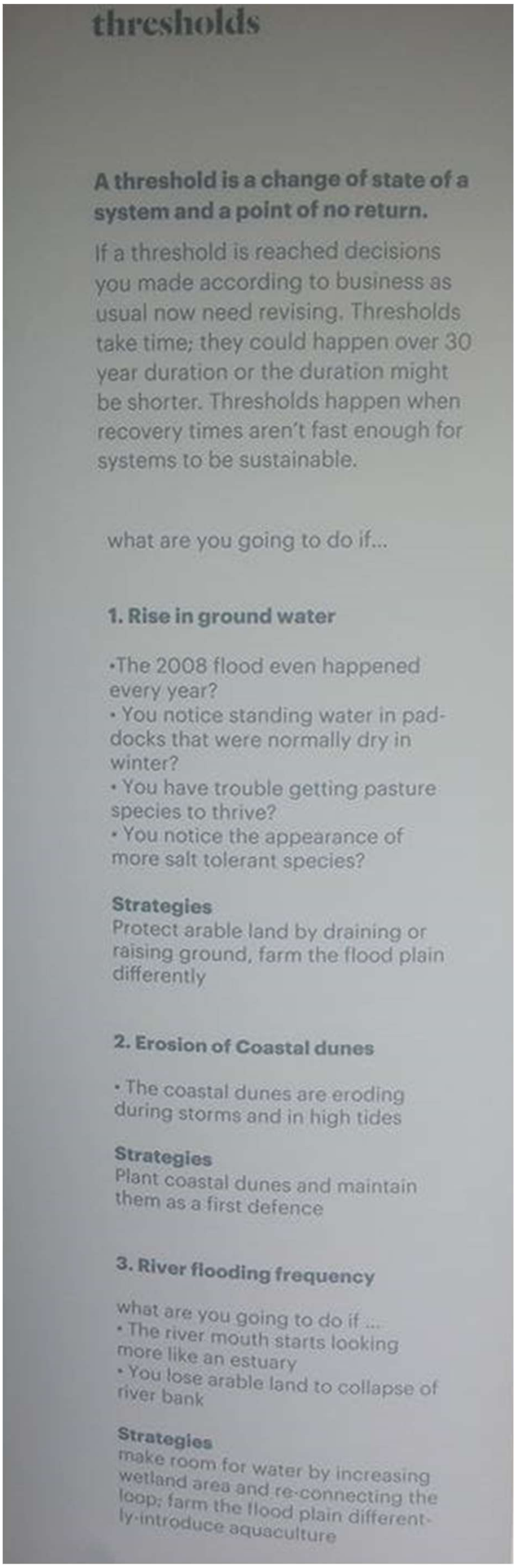


Figure 6.16c Dave Seymour in the 'oral narrative' shed, pointing to the standing water threshold


thresholds

A threshold is a change of state of a system and a point of no return.

If a threshold is reached decisions you made according to business as usual now need revising. Thresholds take time; they could happen over 30 year duration or the duration might be shorter. Thresholds happen when recovery times aren't fast enough for systems to be sustainable.

what are you going to do if...

1. Rise in ground water

•The 2008 flood even happened every year?
• You notice standing water in paddocks that were normally dry in winter?
• You have trouble getting pasture species to thrive?
• You notice the appearance of more salt tolerant species?

Strategies
Protect arable land by draining or raising ground, farm the flood plain differently

2. Erosion of Coastal dunes

• The coastal dunes are eroding during storms and in high tides

Strategies
Plant coastal dunes and maintain them as a first defence

3. River flooding frequency

what are you going to do if ...
• The river mouth starts looking more like an estuary
• You lose arable land to collapse of river bank

Strategies
make room for water by increasing wetland area and re-connecting the loop; farm the flood plain differently-introduce aquaculture

Figure 6.17 Thresholds

All the strategies and tactics were designed to be combined in a variety of ways over time to give farmers multiple options, empowering them to make small incremental changes based on the daily, experiential observations of land and water relationships rather than having to rely on scientific monitoring or policy related government interventions.

The fourth exhibition, and the culmination of the research, was part of a group exhibition in 2017 - 'This Time of Useful Consciousness: Political Ecology Now'- curated by Senior Curator Melanie Oliver at the Dowse Art Museum in Wellington, featuring a range of artists from Aotearoa New Zealand. While the dairy sheds exhibition took the issues to the local communities, the Dowse exhibition portrayed the intensity of the work in an art gallery, along with other art works.

Figure 6.18 The Whakapapa shed showing the vision banners

Figure 6.19 The exhibition at the Dowse Museum

7 ADAPTATION STRATEGIES TO ADDRESS THE PROJECTED CLIMATE CHANGE IMPACTS IN THE CASE STUDY ROHE

7.1 Adaptation Strategies to Address Climate Change Impacts in the Rohe

A toolbox of eight adaptive strategies was formulated based on the research findings which indicated nine key strategies that (if implemented over time) the research team envisages will maximise economic productivity and protect coastal farms from the variability of climate change impacts. The toolbox is intended to be a guide to the choices farm managers, trustees and shareholders might make over time, based on the most current research about climate change and its potential impact on the coast. Our research has shown that coastal ecosystems are vital and important for stabilising the coastline, improving groundwater management, and acting as a buffer for the more intensively managed areas further inland. More resilient approaches to coastal stabilisation should involve maintaining a sequence of plant species starting with saltmarsh plants and salt tolerant grasses by the high tide level and then going back in stages using species such as harakeke, cabbage trees, kahikatea, manuka, and many more.

The strategies are based on three over-arching steps, with specific activities for each, as listed below. The strategy is explored further below, with maps depicting where such strategies are likely to be most relevant in the rohe.

<u>PROTECT:</u>

1. Protect coastal dunes
   Protect and establish dunes as the first line of defence.

2. Protect wetlands
   Establish wetlands as a buffer against sea level rise and flooding.

3. Protect the most arable land.
   Establish and plant embankments to protect the most arable land

4. Protect habitat and biodiversity
   Restore existing and regenerate new habitats with links between ecosystems; e.g., salty, brackish, freshwater wetlands; dune habitats, terrestrial vegetation).

<u>ADAPT/ANTICIPATE:</u>

5. Make room for water
   Anticipating areas for expansion of water will reduce ecological disturbance and protect arable land from inundation. Activating the Ōhau loop will prevent erosion, slow the river down and improve hydrology.

6. Diversify farming practices
   Minimise economic risk by maximising diversity using culturally specific farming practices, e.g., harakeke, forestry, manuka, aquaculture.

7. Develop adaptive infrastructure
   Adapt existing farm buildings for an extra revenue stream.

   Establish robust all weather connections: (bridges, boardwalks, roads connecting high ground) to serve as the foundational infrastructure for all future development.

8. Celebrate the high ground
   Provide infrastructure for cultural festivals that might eventually be the basis for new settlement.

RETREAT:

9. Settle the high ground.
   Establish plans for existing whare and new papakainga to be re-sited on flat, unproductive, north facing high ground, above the 5m level

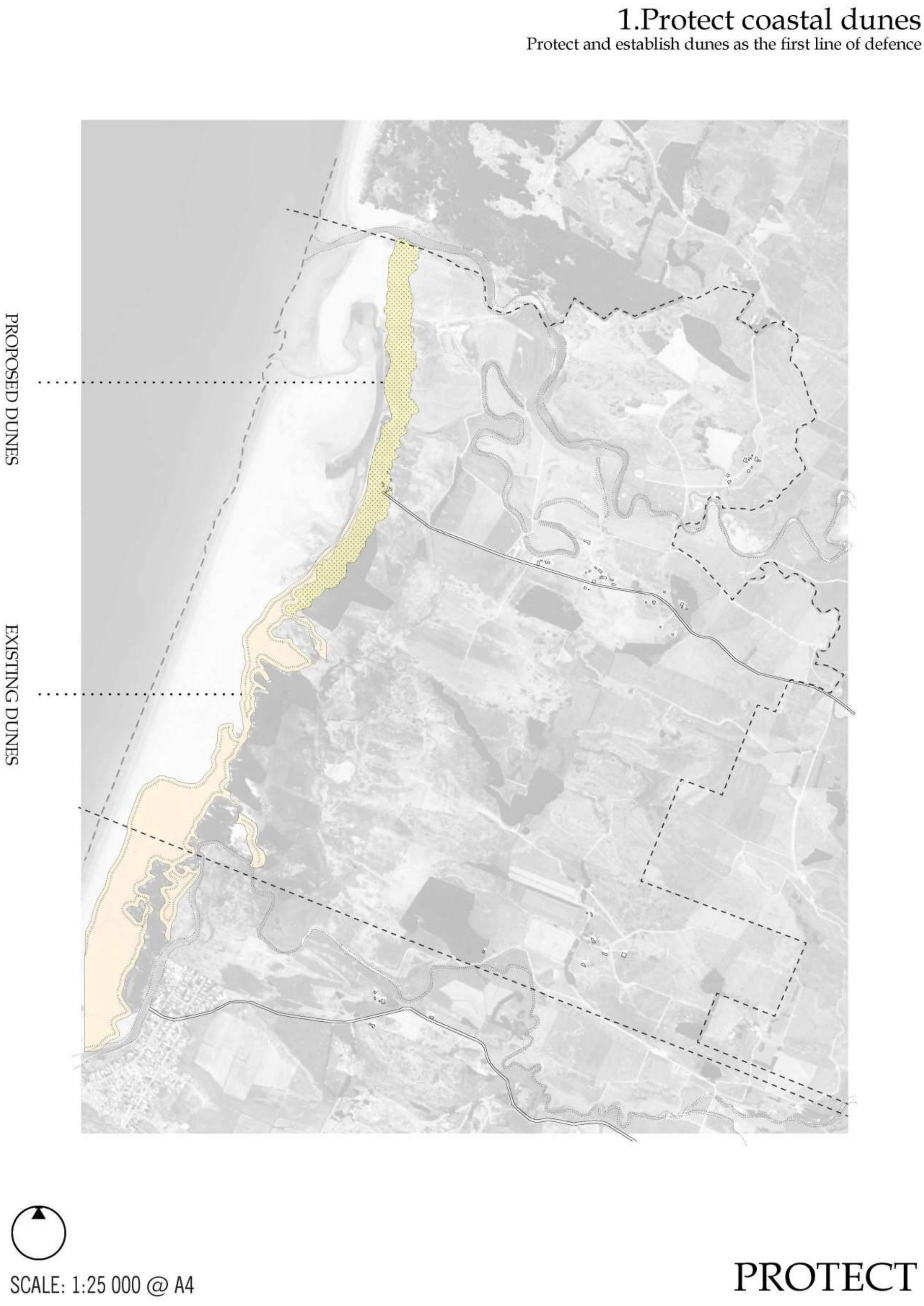


Figure 7.1 Protect Coastal Dunes

Figure 7.1 shows the location of existing coastal dunes (in pink) and where these might be supplemented to protect the farm in the short term (in yellow). The darker green depicts pine plantations, some of which have recently been removed.

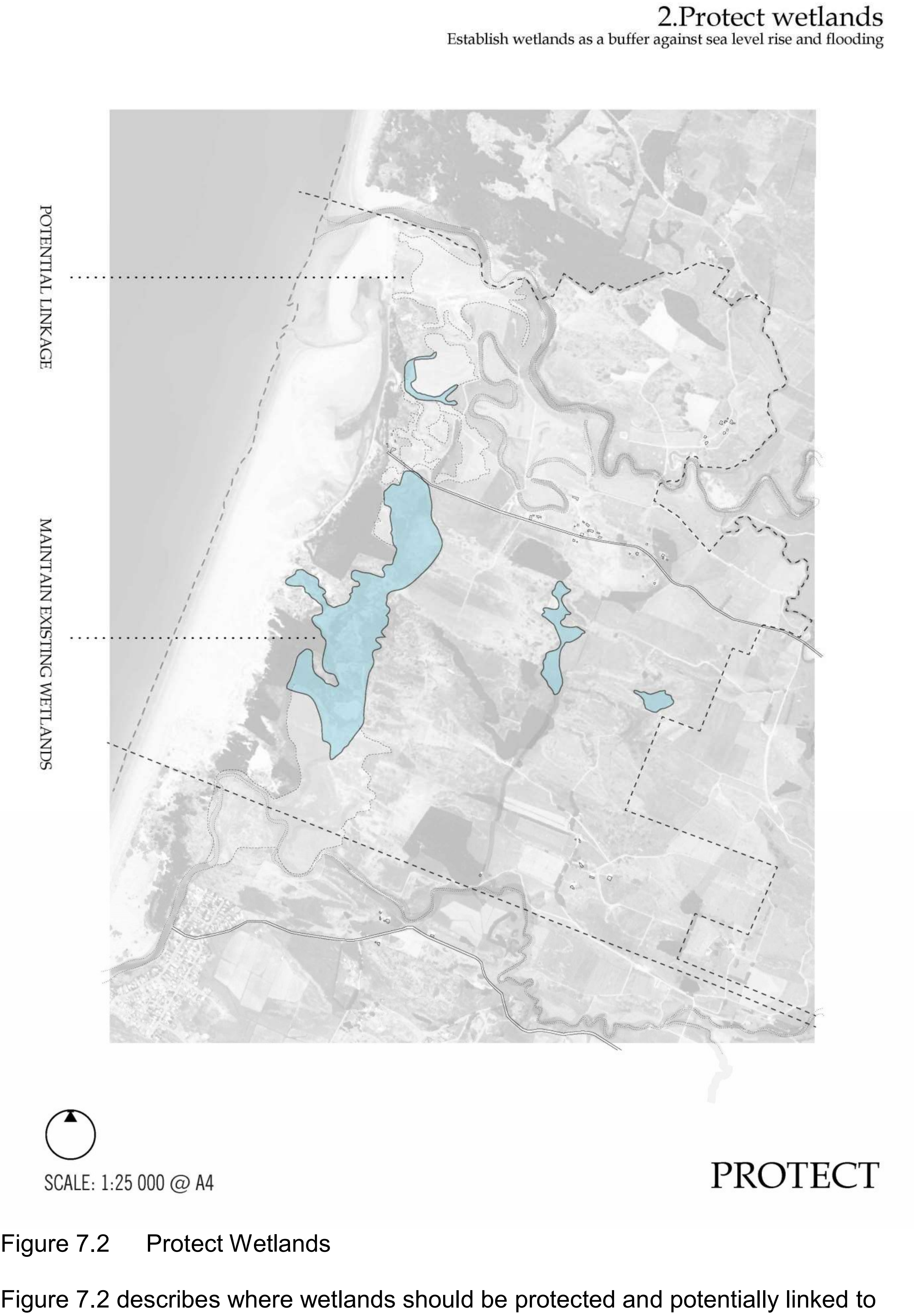


Figure 7.2 Protect Wetlands

Figure 7.2 describes where wetlands should be protected and potentially linked to the Ohau River network to act as a buffer against storm surge and rising salinated ground water.

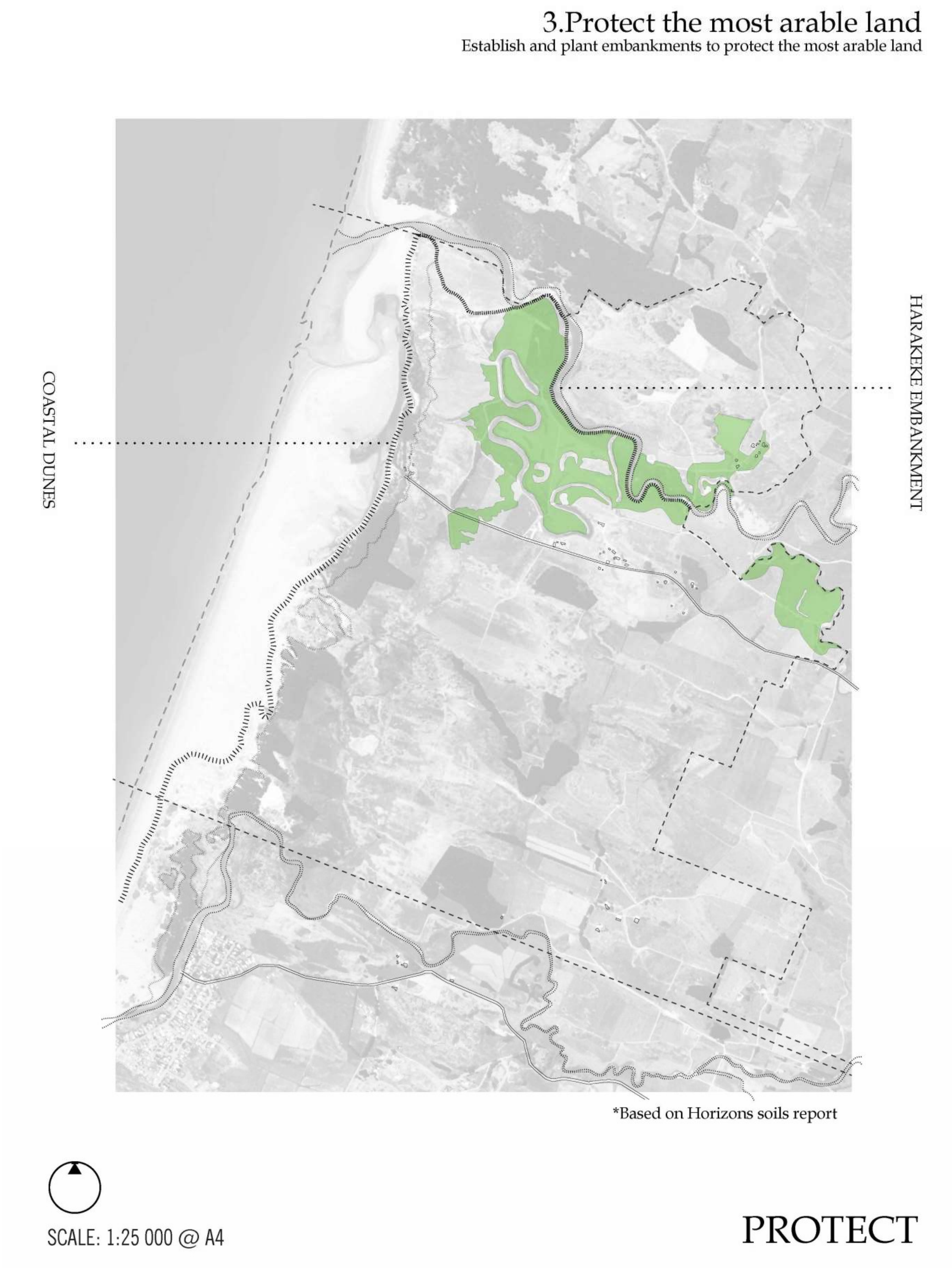


Figure 7.3 Protect Most Arable Land

Figure 7.3 shows the most arable land suggesting it might be protected with harakeke embankments along the river and by building up coastal dunes.

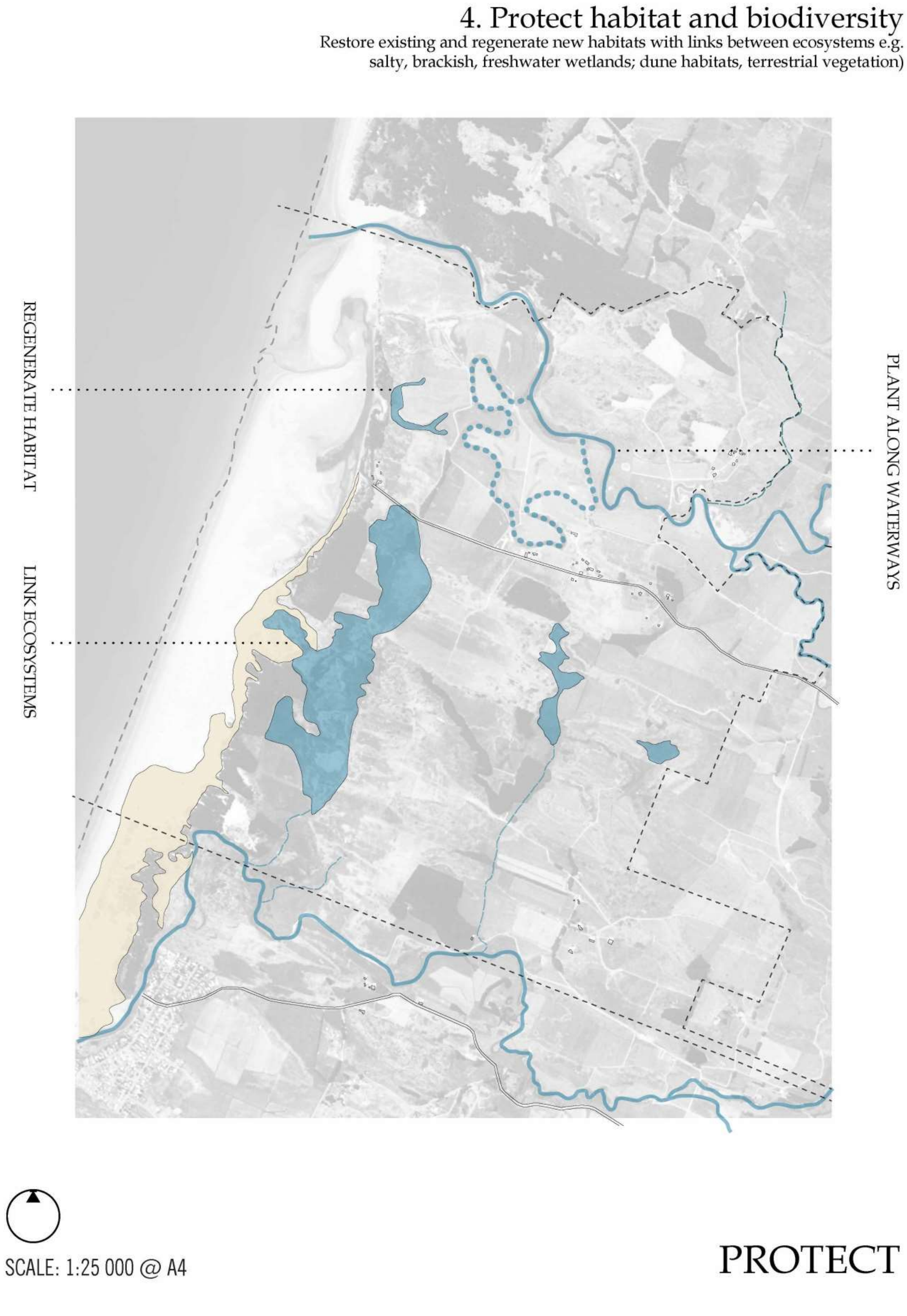


Figure 7.4 Protect Critical Habitat

Figure 7.4 shows the critical habitat and where it might be protected.

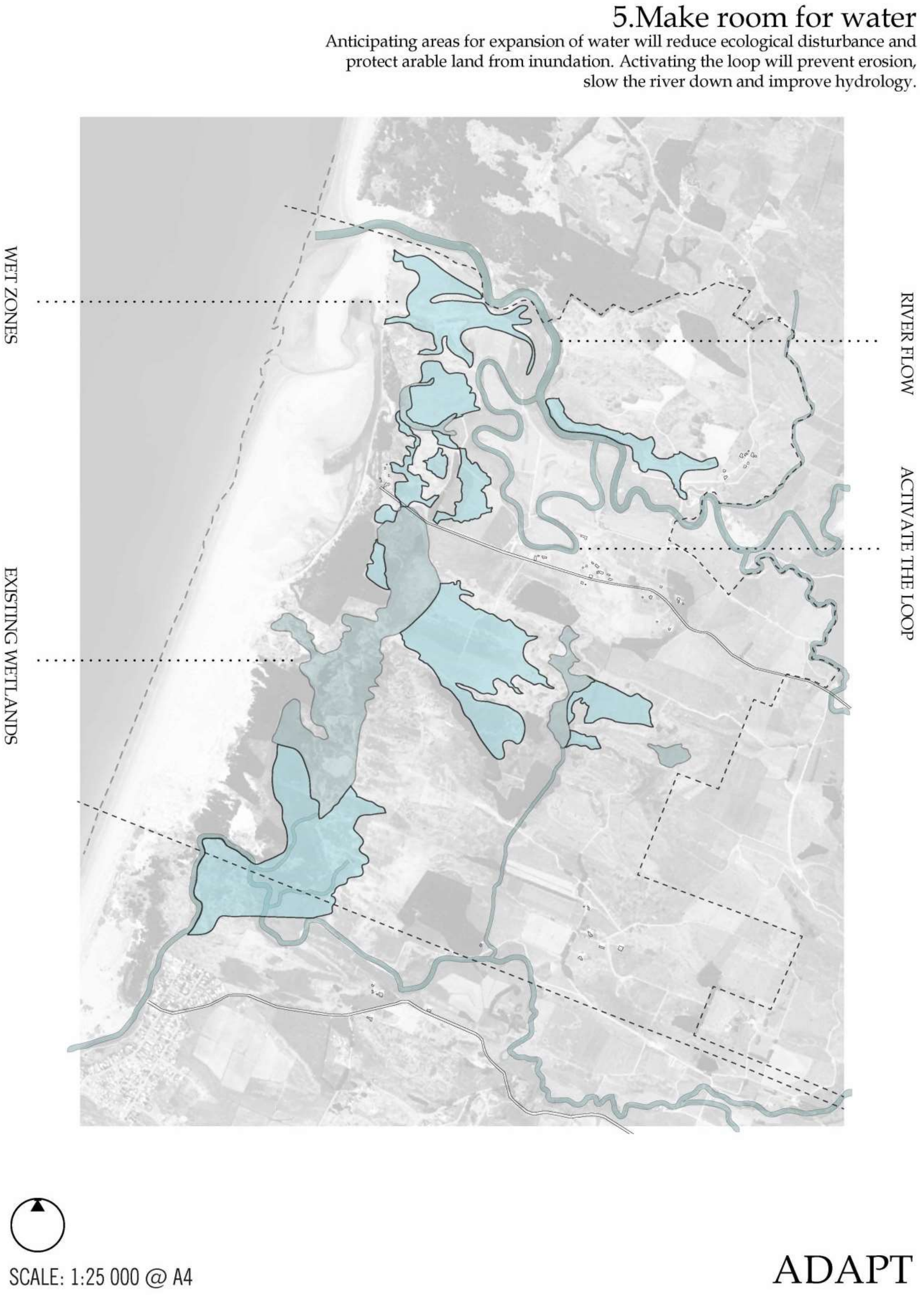


Figure 7.5 Adapt – Make Room for Water

Figure 7.5 suggests that designating more low lying areas as permanent and ephemeral wetlands will not only protect habitat but also direct flood waters away from valuable farmland. It could also provide the basis for a diversification of farm practices to include aquaculture (see following).

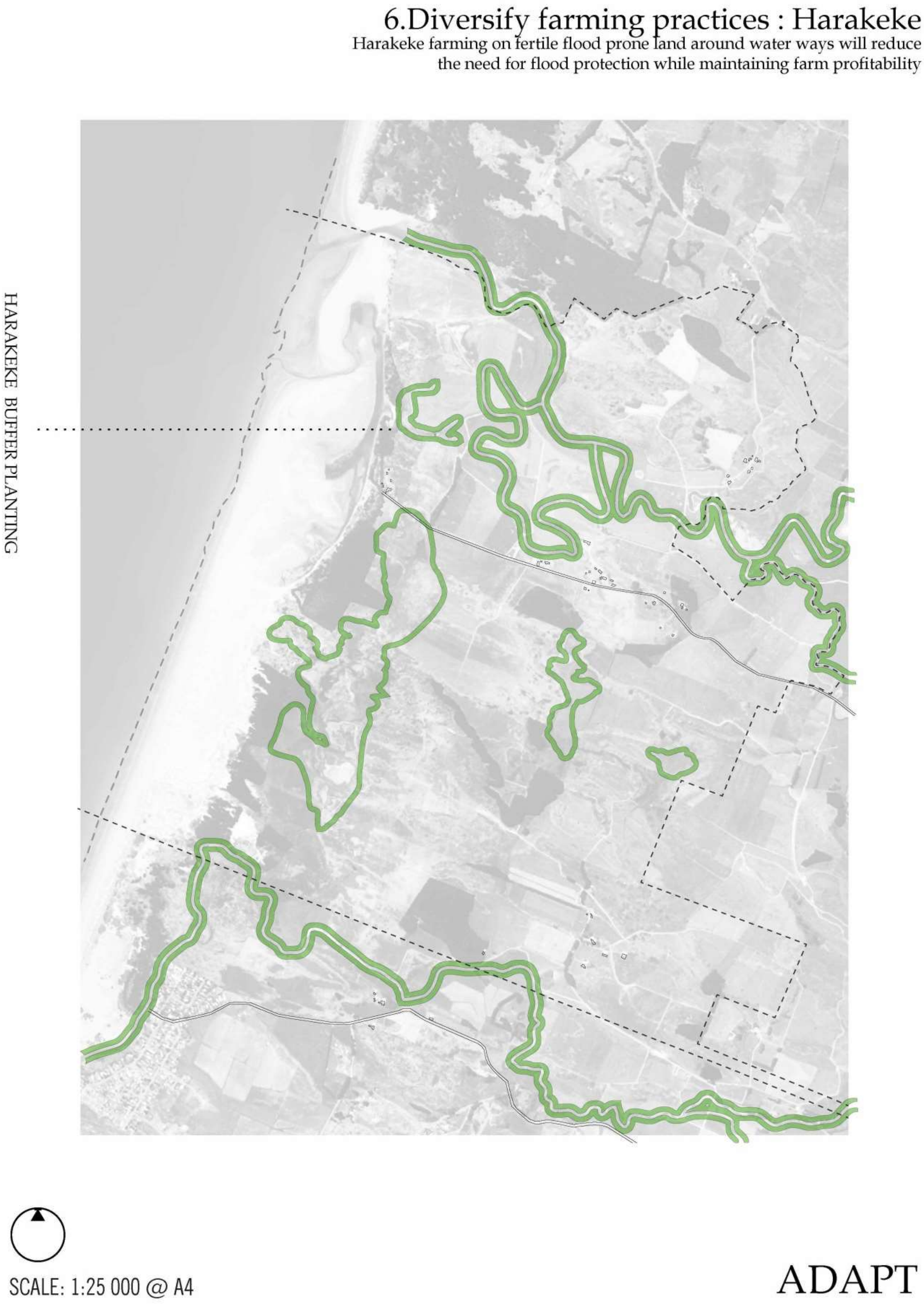


Figure 7.6 Adapt – Plant Harakeke

Figure 7.6 to Figure 7.9 depict the location of a range of possible appropriate farm practices that might supplement and ultimately replace dairying. Figure 7.6 depicts the location of potential harakeke planting, as one possible appropriate farm practice that might supplement and ultimately replace dairying.

Figure 7.7 Adapt – Plant Forests behind Dunes

Figure 7.7 identifies the location of potential new forestry as an alternative future farming land use.

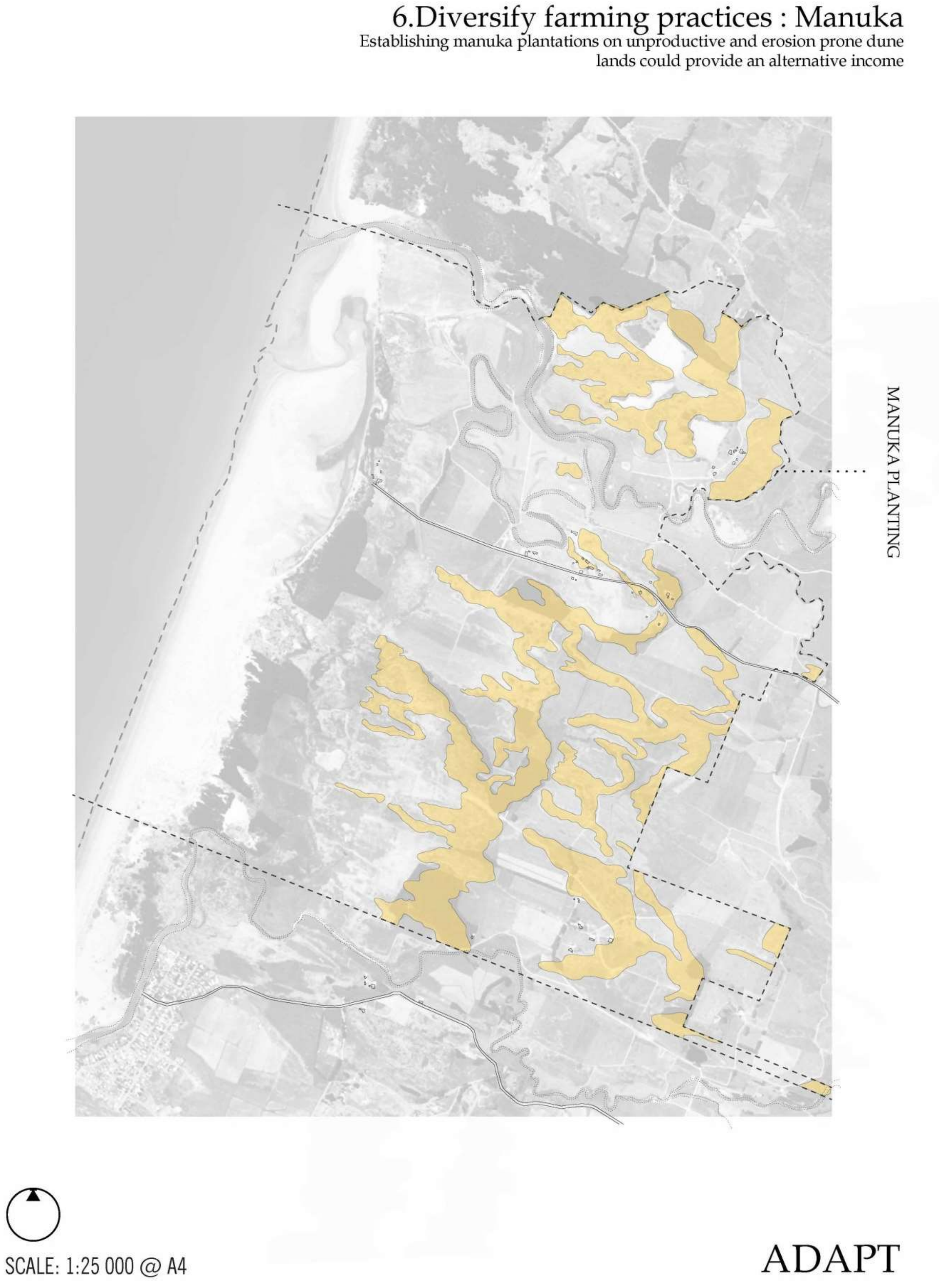


Figure 7.8 Adapt – Plant Manuka Plantations

Figure 7.8 identifies potential location of manuka forests as a potential future alternative land use.

6.Diversify farming practices : aquaculture
Increase fish populations for recreational or commercial fishing

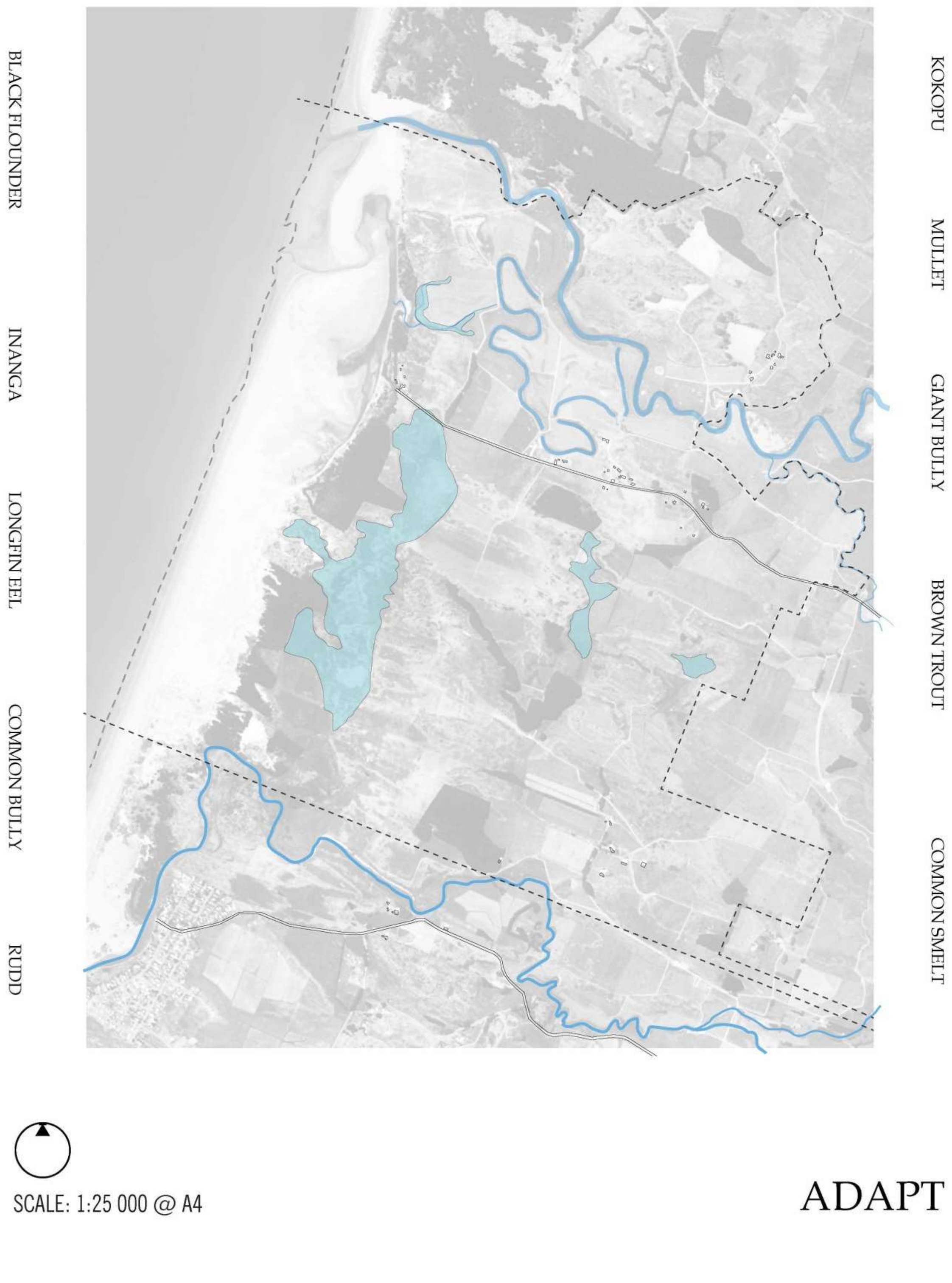


Figure 7.9 Adapt – Aquaculture

Figure 7.9 depicts aquaculture as an alternative future land use.

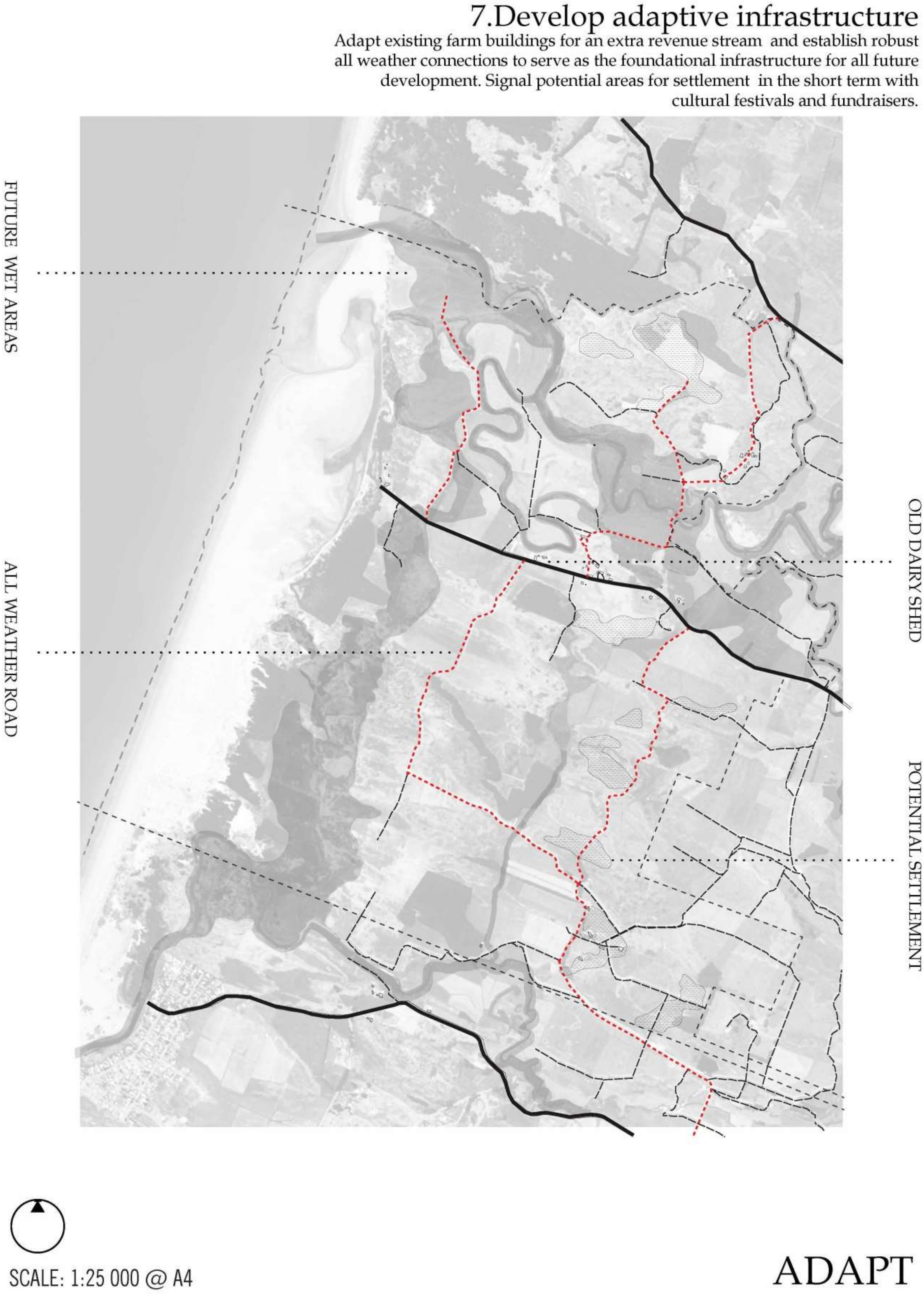


Figure 7.10 Adapt – Build Adaptive Infrastructure

Figure 7.10 suggests that identifying locations for, and then building, new all-weather roads that anticipate climate change can signal the need for long term adaptive strategies like shifting settlements to high ground, well before they need to happen.

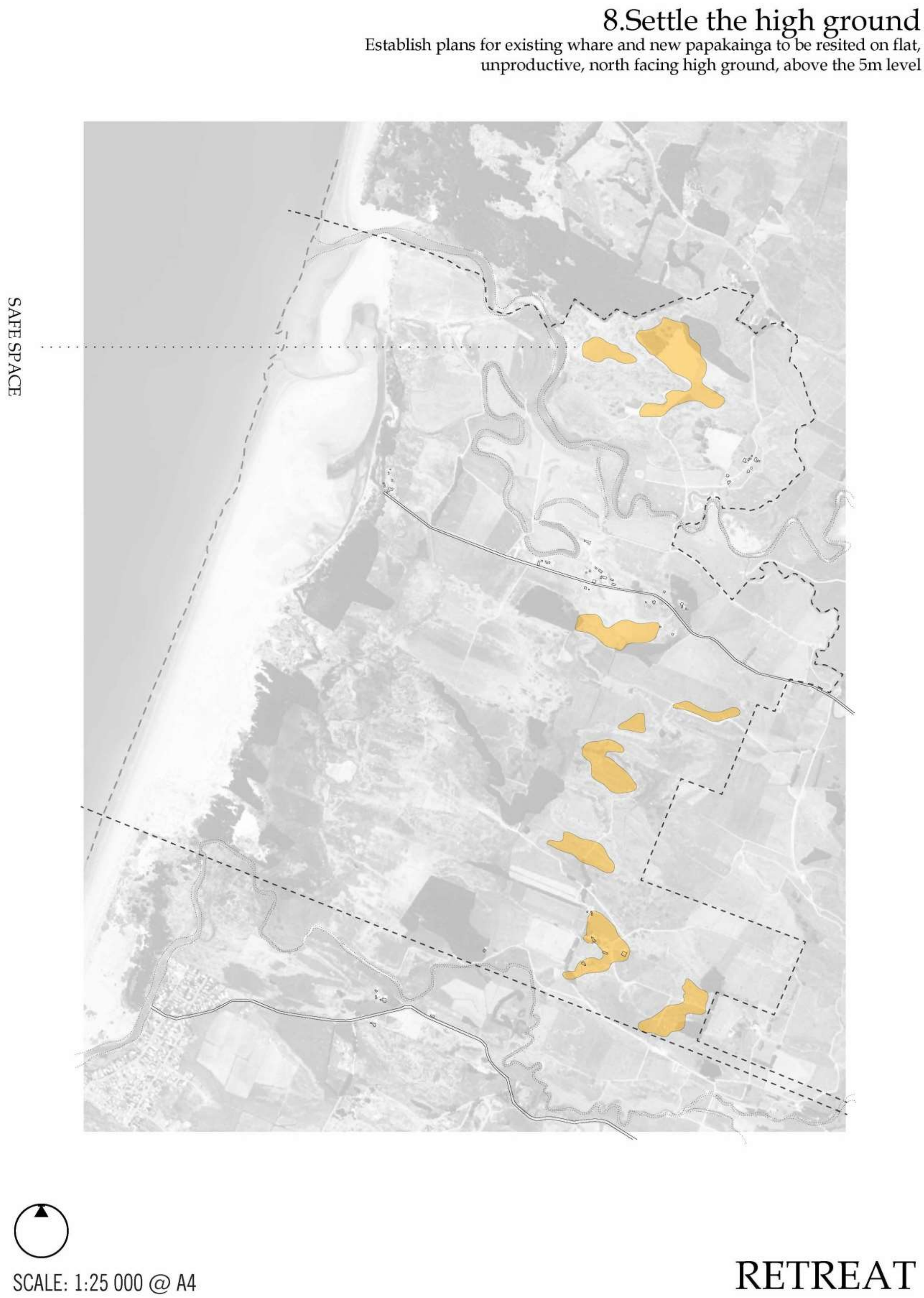


Figure 7.11 Retreat – Settle the High Ground

Figure 7.11 suggests that identifying locations for and then building new all-weather roads that anticipate climate change can signal the need for long term adaptive strategies like shifting settlements to high ground, well before they need to happen.

7.2 Potential Impacts for Tahamata Incorporation Shareholder Farm

On 17 October 2016, the research team presented a report to Tahamata Farm Board (see minutes from this hui in Appendix B). This included an overview of the research conducted to date, and a summary of the main research findings, as set out above.

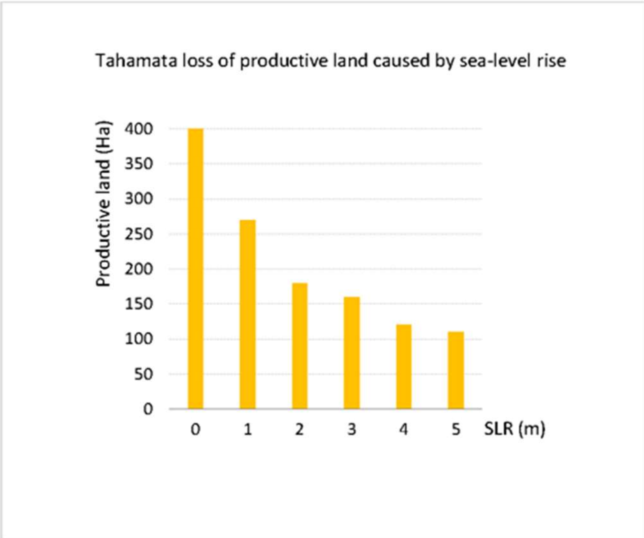
The research team identified potential climate change related impacts on the farm over the next 100 years, visually depicted in Figure 7.12 below, how these changes might be measured, and also what these changes might look like on the ground. The impacts will be economic (loss of arable land, damage to property) and environmental (loss of habitat and biodiversity), and are likely to be a result of:

- Inundation
- Coastal erosion
- Increased salinity
- Rising water table

Figure 7.12 Impacts of Sea Level Rise on Coastal Areas

Furthermore, there will be a potential loss of productive land due to a rise in sea level of 0.5 to 5 metres, as depicted in Figure 7.13 below. This was determined using a topographical LiDAR dataset made available by Horizons Regional Council.

SLR (m)	Lost total (ha)	Productive land (ha)	Lost total (%)	Productive land (%)
0	0	400	0%	100%
1	130	270	32%	68%
2	220	180	55%	45%
3	240	160	60%	40%
4	280	120	70%	30%
5	290	110	72%	28%



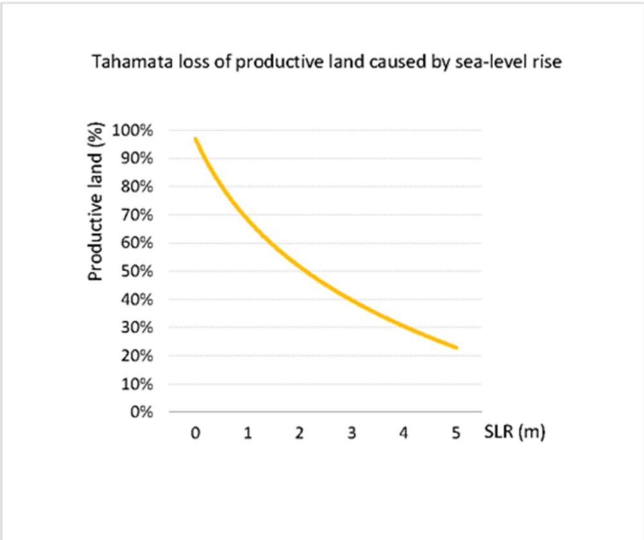


Figure 7.13 Tahamata land loss from sea level rise

7.3 Ecological Economics Analysis for Tahamata

This section is a summary of the main findings for this ecological economics assessment of various scenarios for wetlands for Tahamata Incorporation. The full report contains much greater information and readers are referred to that for more information (see Patterson et al., 2017).

Tahamata Incorporation is an iwi-owned 310 hectare dairy farm located on the Horowhenua coast on low-lying mainly sandy soils that are susceptible to water inundation, which is projected to happen due to Climate Change, as early as within the next 30 years. Given this problem, our analysis focused on 3 scenarios for how the dairy farm's management could adapt to those situations:

Scenario 1: (No Adaptation) is essentially a 'do nothing scenario' where dairy production was adversely affected by the deterioration of the land and soil conditions due to water inundation;

Scenario 2 (Some Expansion of Wetlands) considers expanding an existing wetland area to actively develop another 25 hectares of wetlands;

Scenario 3 (Full Expansion of Wetlands) sees even more active development of wetlands so they now covered 194 hectares, which meant the wetland covered more land than the dairy farming operations. In all scenarios, the amount of land covered by commercial forestry (21.2 hectares) and scrub (64.4 hectares) remains constant throughout the 30 years of the scenario that started from a base year of 2015/2016.

Each of these scenarios were assessed using an **ecosystem services approach** where their economic valuation could be directly compared with an economic valuation of the dairy farming operations, with the intent of integrating 'economic', 'ecological' and other values into one analytical framework. All of these scenarios were based in an IPCC mid-range climate projection for sea-level rise over the next 30 years, which was modelled by Horizons Regional Council, to produce projected water level and drainage patterns for the Tahamata farm.

The first phase of the research involved compiling comprehensive **financial accounts** for the dairy farm and the small forestry operation, for the base year of 2015/2016, as well as **ecosystem services accounts** that covered 18 different ecosystem services and attached an economic value to each of these services. This involved GIS analysis of land cover areas in a matrix of 18 ecosystem services by 8 different land use/land cover combinations. From this information, for each of the 8 land use/land cover combinations (which were mainly human modified ecosystems), we used our New Zealand data sources to determine an economic value ($/year) of each of their ecosystem services. For our assessment of the economic value of the wetland ecosystem services, we depended on the TEEB database, which covers 244 'inland wetlands'. Also included is a very useful regression equation that summarises this data, which enabled us to use it, along with other information, to adapt the TEEB ecosystem services valuation data to Tahamata. The ecosystem services account enables us to compare ecosystem services value per hectare of various different land use/land cover combinations:

Wetlands, dominated by Vegetation ($13,852/ha/yr);
Wetlands, dominated by Open Water ($4,042/ha/yr);
Surface Water or Ponding on Land; ($106/ha/yr);
Forestry ($1,272/ha/yr); Scrub ($573/ha/yr);
Stocked Dairy Pasture in Good Condition ($1,411/ha/yr);
Dairy Stock on Poorly Drained and Puggy Soils ($704/yr/ha); and
Poorly Drained and Puggy Soils with No Stock($395/ha/yr).
These data underscored the very high comparative economic value of wetlands compared with other types of landcover/landuse.

The second phase of the research was to develop a **scenario modelling tool** (in the spreadsheet environment), to project the scenarios forward to 2045/2046, and then assess for that year the overall economic value of each scenario across each of the 18 ecosystem services and various financial information about the dairy farming and forestry activities. In terms of the all-important 'net value' (value added):

Scenario 1 (No Adaptation) had a net annual value of $563,533 for 2045/2046, which represents a decrease of 17.3%, essentially because 35.3 hectares became unavailable for dairy farming due to water inundation.

Scenario 2 (Some Expansion of Wetlands) had a net annual value of $838,759 for 2045/2046, which had the same decrease in dairy farm output as the first scenario, but this was more than compensated for by the high economic value associated with the development of an expanded wetland area.

Scenario 3 (Full Expansion of Wetlands) had a net annual value of $1,838,316 for 2045/2046, which is considerably more than the first two scenarios. Although this scenario saw an even larger drop in the economic production of the dairy farm, this is greatly outweighed by the extra economic value generated by developing the wetlands, essentially on areas that were no longer suitable or impossible to use for dairy farming.

In all 3 scenarios, there was a decrease in the commercial (net) revenue of the Tahamata farm, decreasing as low as $189,342/yr in Scenario 3 compared with a base year figure of $328,844/yr. Although this is the case, it should be noted that the Tahamata farm still remains viable and profitable, but just operating at lower level of production, which incidentally is still at a higher level than the average New Zealand dairy farm or for that matter the average Lower North Island dairy farm.

Other indicator variables for the scenarios are reported in the following table:

Descriptors	Units	Base Year: 2014/15	Scenario 1: No Adaption 2045/46	Scenario 2: Some Expansion of Wetlands 2045/46	Scenario 3 Full Expansion of Wetlands 2045/46
Dairy Farm	Hectares	310.00	274.71	274.71	172.64
Forestry	Hectares	21.19	21.19	21.19	21.19
Wetlands	Hectares	21.06	21.06	56.36	193.71
Net Value	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial value of Dairy and Forestry Products	$\$NZ_{2015/16}$	328,844	241,173	241,173	189,342
Non-Commercial Value of Ecosystem Services	$\$NZ_{2015/16}$	352,735	322,360	597,587	1,648,974
Provisioning Ecosystem Services	$\$NZ_{2015/16}$	334,561	246,077	250,208	213,643
Cultural Ecosystem Services	$\$NZ_{2015/16}$	66,776	65,628	167,782	564,142
Regulating Ecosystem Services	$\$NZ_{2015/16}$	280,242	251,829	420,769	1,060,531
Supporting Ecosystem Services	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial Value Per Hectare	$\$NZ_{2015/16}$ / hectares (dairy +	993	815	815	977

Table 7.1.1 Summary of Changes in Key Indicators Associated with Different Scenarios for Wetlands on Tahamata Farm, to 2045/46

The full report by Patterson et al. (2017) concludes by identifying a number of areas that require further research and stakeholder consultation. In brief, the economic analysis needs integrated into a full cost-benefit framework, which will require us to collect and process data on the costs of land use changes, particularly the active conversion of land to wetlands; this includes costs such as planting, engineering works, fencing, pest control and so forth. Other adaptation strategies, such as draining the inundated land or planting grass species that will be tolerant to the new high water table environment, need to be considered in consultation with stakeholders. If any of the wetland conversion scenarios, or variants of them, are to be implemented, for cases that seem to have a good economic justification, further research investigation needs to be undertaken on how this is to be achieved. The fact that ecosystem services values are 'diffuse' – particularly for wetlands that benefit a large number of often ill-defined stakeholders across site-specific, local, regional, national and global scales – complicates and makes difficult any concerted implementation aimed at capturing those very significant ecosystem services values that are highlighted in some of the scenarios.

8 IMPLICATIONS, CONCLUSIONS, RECOMMENDATIONS & FUTURE RESEARCH

8.1 Climate Change Issues for New Zealand Coastal Areas, with a Focus on the Horowhenua – Kāpiti Rohe

- The trend for sea level rise around New Zealand has been about 5 mm/yr over the last 30 years, which is significantly larger than the global average of about 3 mm/yr. Large variations in the rate of sea level rise around New Zealand make it hard to predict when a threshold for the sustainability of some current practice will be crossed; however, at this stage, planning for a rate of 200 mm of sea level rise per decade would be a reasonable approach.
- Many international studies have shown that natural processes can keep ahead of sea level rise at rates of up to 5 mm/year, but questions remain about what happens for larger rates.
- Sea level around New Zealand is now alternating between rising much faster than the global average or going down slightly.
- Wellington's storm event in July 2016 showed that coastal development in the Kāpiti region is more vulnerable than natural sand dunes.
- Current tidal cycles in groundwater show it has a wide range of responses to sea level with cycles in some places being more than 2.5 km from the coastline.
- Groundwater levels can rise by more than a meter as a result of rainfall.
- Sea level rise can cause a rise in groundwater over low lying land and an increase in the frequency and extent of flooding. An analysis from a Dunedin study indicates that sea level rise will result in ponding of water at the surface but that this does not just occur first on the lowest land, but rather where the water table is currently closest to the surface.
- Sensitivity of coastal land and water systems:

This research highlighted the importance of developing geomorphologically-grounded adaptive strategies by working with the natural function of the coastal catchment to absorb change. We combined data from soil surveys, flood mapping and modelling, GIS and LiDAR and fluvial sediment budgets with estimates of sea level rise rates and magnitudes and changes in river flood frequencies to identify coastal farming areas most vulnerable to sea level rise and climate change. We used an interdisciplinary approach to identify indicators and thresholds and associated strategies for adaptation. Future research is required to extend this approach to cover physical processes such as future change in groundwater levels, a wider range of options for management of wetlands and landscapes and their sensitivity to change.

8.2 The Role of "Design"

The research also shows how qualitative methods like art and design can act concurrently and collectively with scientific research to deliver specific benefits relating to the integration of nature-based and socio-cultural influences, acknowledging risks, vulnerabilities and the adaptive capacity of a place. Exhibitions enhance these methods by grounding knowledge in place and integrating the many threads of scientific and design research to make interdisciplinary knowledge immediately accessible to communities. They act as the basis for transformative change by transferring complex environmental science data and interpretations, enhanced by mātauranga Māori and local knowledge of place, to achieve a step change in the public's understanding of environmental science.

Each exhibition speculated on what the past means for the future and how hapū, shareholders or whanau might adapt their activities for the land and waterways in their regions. The exhibitions highlighted specific climate change scenarios for the farm, exploring through a range of scales, strategies that defer to the specificity of place and culture. The work exhibited shows that adaptation is going to be slow and incremental, but will need to continue across generations. Importantly, it reinforces the need to engage with climate change adaptation strategies, plan for them, and act now.

8.3 Adaptation Strategies for the Coastal Zone

A toolbox of various adaptation strategies aligned to three key themes was developed – Protect, Adapt/Anticipate, and Retreat. These strategies can be implemented over time as the localised climate change impacts are increasing felt. The toolbox is flexible enough that stakeholders might decide themselves what is most suitable for their farms, or combine them in a variety of ways. There is now a very clear relationship between 'what might happen' and 'what needs to be done'. *'When'* these adaptation strategies need to happen is much harder to establish. Identifying thresholds might be the key.

Future research should seek to identify the link between thresholds and adaptation, thus marking a trigger for action. Thresholds and triggers, as indicators of key ecological relationships, are part of both western science and Mātauranga Māori knowledge frameworks. This project considered thresholds relating to issues such as aggradation, flooding, salination and wetlands. If further research could flesh out what these thresholds might 'look like', we could better communicate these to local iwi, in culturally appropriate ways so they might be in a better position to adapt.

8.4 The Role of Wetlands in Adaptation to Climate Change

Coastal adaptation strategies for climate change must inevitably consider the use of wetlands, particularly how farms, other land-based commercial entities and wider communities along the coast decide to utilise land that will increasingly revert back to a 'wet' state. This research explored multiple ways of considering and utilising wetlands as part of adaptation strategies for climate change, which is a national and international issue. This is a challenging space, given that historically and even currently, wetlands continue to be perceived to be of little or no productive use, despite their significant benefit in terms of biodiversity richness, flood protection, groundwater protection.

The wetland water levels that prevent sea water intruding into groundwater are being considered as a way of identifying thresholds for sustainability. Pine trees are vulnerable to sea water, reducing or preventing the uptake of groundwater by osmosis and so the effective lifetimes for current pine plantations close to the high tide line, or their future use as indicators, are being developed.

8.4.1 *Adaptation Strategy for Tahamata*

The most detailed analysis was undertaken for Tahamata Farm, due to the greater level of engagement this entity had with the research team, and the availability of data from sources such as Horizons Regional Council. A report with detailed information was prepared for the Board of Tahamata (see Patterson et al., 2017), which referenced confidential information that cannot be included in this public report, at this time.

Further information and analysis of the risks, costs and benefits in ecological and socio-economic terms, is required to help local communities manage their land. The research team would like to continue working with Tahamata Farm to develop a decision-making tool (that takes into account specific soil types, hydrology, and different land management decisions) to assist land owners and local communities to assess their risks associated with climate change impacts on their coastal ecosystems and economies.

8.5 Community Engagement to Address Scepticism around Climate Change

A reticence is present in some sectors of the wider community about whether there is a current need to consider the impacts of climate change, and in some cases even to acknowledge that it is happening at all.

The review of media reports about climate change impacts for the case study rohe revealed similar scepticism around the accuracy of climate change science, sometimes due to the inability of scientists and authors of reports on this topic to give categorical assurances of what is happening, and to provide specific timelines. One of the cited reasons for the apparent scepticism regarding the climate change science in the KCDC-commission report in 2012 was that the report's author was not able to answer all questions posed regarding the science. The research team, similarly, encountered such scepticism and resistance to the need to consider climate change at this time.

Encouraging local communities to engage in future planning to address climate change is not straight forward. Innovative mechanisms are required to iteratively communicate the inherently complex and uncertain dimensions of climate change science. There is a tendency by some to ignore climate change because there is no clear consensus as to the rate and magnitude of sea level rise and climate change. Very little available detail regarding the local impacts promulgates resistance. In Phase 2 of the research, we will take time to present the findings of this research, as depicted in this report and in the visual images presented here, to Tangata whenua, and to carefully consider what transition plans can be developed to ensure the local community is better prepared to face such changes as they occur.

8.6 Integrated, Decision Making Tool that Considers the Risks, Costs and Benefits of Adaptation Options

A critical issue faced by local communities making land management decisions in the face of changing climatic conditions is, "What should we do about increasingly wet coastal land that has historically been drained and converted for dairy farms or horticulture?" Given expected climatic changes, these lands will tend to convert back a to wetland ecosystem, which has major implications for feasibility of farming operations. Substantial and ongoing drainage schemes are cost prohibitive. The prototype tool developed in this research analysed the ecological and economic costs and benefits associated with wetlands for Māori coastal dairy farm land use, for 3 scenarios: Business as Usual, Groundwater Rise associated with Climate Change, and Purposeful Expansion of Wetlands. Future research is required to greatly expand the national applicability of this tool, enabling it to consider different soil types, hydrology, alternative land uses, and different coastal conditions. Such an integrative decision making tool would assist land owners and local communities to assess their risks and benefits associated with climate change impacts on their coastal ecosystems and economies.

8.7 Innovative, Collaborative Decision Making

When making decisions about land use, farming practice and so forth, decision makers must take into consideration the wider range of perspectives of tangata whenua, including their environmental, cultural, social and economic well-being in relation to these coastal lands and waterways.

Likewise, local communities must liaise with local and regional government whereby possible to clarify resourcing that is available to help implement Adaptation Strategies, and develop a Transition Action Plan, accordingly.

For example, an issue that needs to be considered in conjunction with local councils is this: Climate change adaptation strategies designed with consideration of the geomorphology of a site, geomorphic processes and geomorphic concepts, work with the inherent diversity and dynamics of the coast, river and catchment, consider the capacity of the natural system to absorb change, enhance the natural resilience and fit within the evolutionary trajectory of the landscape. Integration of a geomorphic perspective when designing adaptation strategies to address the adverse impacts of climate change ensures that effective adaptation responses are developed.

Decision makers often use past solutions to solve current and even future problems (i.e. tendency to drain land that becomes wet). They also tend to assume that past institutional responses to events such as major floods will continue in the future; e.g., that regional councils will continue to maintain costly river management and drainage infrastructure. However, given regional demographics, a declining rating base, user pays political ideology and increased competition for local government resources to address climate change impacts, Councils are unlikely to be able to readily resource drainage schemes on individual farms at the rate at which extreme flooding events will occur into the future. Purposeful engagement with local government is thus now required to determine how communities can develop adaptive pathways that align with local and national government planning and resources.

Future research is required to identify financial, economic, policy and local government information, resourcing/support, infrastructure and incentives that may be required to enable effective land use management and adaptation decisions. It is imperative that we engage with all decision makers, including local government and other influencers, who will play a significant role in how well coastal communities can adapt and transition to a resilient and sustainable future.

8.8 "Enduring Solutions" for Adaptive Management

The Adaptation Strategy options identified in this report allow for an incremental implementation of stepped changes over time, as the impacts of climate change become increasingly felt. Building on the need to take a precautionary approach to decision making and investment, small steps taken in the immediate or near future can buy time, enabling decision makers to respond to new information and adjust management approaches gradually, rather than having to make large changes all at once. Building flexibility into decision making allows you to implement adaptation options in phases, over time. Monitoring is an important part of these approaches and they are good for handling uncertainty, but where monitoring is not feasible, decision makers need a qualitative understanding of critical threshold tipping points where the land and water systems they depend on irreversibly shift. Armed with this knowledge they can make appropriate changes if and when it is necessary. This will result in cost effective and enduring adaptive change.

Future research should identify those agencies/kaumatua/research groups that can provide the types of information needed by local communities to enable them to make meaningful land use management and adaptation decisions. Local communities benefit from enduring research that will "live on" beyond the research and can incorporate updated knowledge about climate change. We will identify available institutional, economic and socio-cultural supports that can be accessed to help communities transition from "Business and Usual" to "Preferred Futures" in coastal zone management.

For example, in our case study area, it has become apparent that the stability of the coastal foredune is critical for buffering the impacts of sea level rise and inundation. However, evidence from Nelson suggests that pine plantations in the coastal zone are vulnerable to saltwater intrusion, which increases the risk that such coastal pine forests will not be able to survive in salty waters. Furthermore, after coastal plantations have been harvested, they are not usually replanted for a period of time, sometimes a year; unplanted foredunes are then at a greater risk of erosion, which is worsened during periods of wind and drought, or storm surges. So land owners need information about what species should be planted in these areas, given the likely change in future climate and soil conditions which will need to take into account increased salinity. To gather the type of information required to make best decisions about such issues, where would local communities or land owners go? What Mātauranga Māori is relevant to such decision making?

8.9 A Precautionary Approach to Decision Making and Farm Investments

It is recommended that a precautionary approach to decision-making and investment be taken. This means that farm trustees, managers, stakeholders, local and regional government and local communities acknowledge their social responsibility to minimise the exposure of their community to harm as much as possible when scientific investigation has found a plausible risk, as has been identified in this report. Such a precautionary approach should be taken when considering new developments or infrastructure changes, as well as maintenance activities. This is particularly important when costly investment in farming activities is being considered.

With limited resources, it is important to ensure that investment decisions made today do not lock farming communities into practices that become increasingly unsustainable into the future, whereby future investment will be required to implement adaptation strategies. Avoiding making decisions that will make it more difficult to manage climate change flood risks in the future involves not locking in options that limit further adaptation in the future. New developments should not be exposed to, nor increase, flood risk over their intended lifetime. For existing developments the level of risk should be progressively reduced.