Ngā Awa River Restoration Programme

Revegetation Options to Increase Climate Change Resilience and Support Restoration of the Awapoko, Oruru and Oruaiti Catchments in Doubtless Bay, Northland

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Cover photograph:

Whitebait spawning reach of the Oruru River at Barriball Road.

1. INTRODUCTION

1.1 Background

This report was commissioned by Te Papa Atawhai / Department of Conservation's (DOC) Ngā Awa River Restoration Programme. The Ngā Awa River Restoration Programme co-led by a Doubtless Bay hapū collective and DOC supports freshwater restoration initiatives in the Doubtless Bay catchment, that includes the Awapoko, Oruru and Oruaiti River sub-catchments (Fig. 1). Ngā Awa is a collaborative programme that is focused on co-design and co-leadership with mana whenua. In Doubtless Bay mana whenua are working as a hapū collective with DOC and requested planting planning advice for the catchment that takes into account climate change issues such as drought, coastal salinisation, increased flooding and wildfire risk.

The purpose of the work is to conduct a multi-catchment appraisal of revegetation options in Doubtless Bay to support freshwater restoration, incorporate climate change resilience, and provide nature-based solutions for climate adaptation with some context-specific advice.

1.2 Objectives

The objective of the project is to systematically evaluate revegetation and restoration options (to the level of context-specific restoration options) for land in the Awapoko, Oruru, and Oruaiti sub-catchments in a manner that recognises and considers expected climate change related impacts, and thus resilience to climate change. The intention is to provide context-specific advice on revegetation and restoration in terms of biotic and abiotic conditions, considering social and economic preferences and overtly incorporating climate change issues particularly as they affect freshwater ecosystems and values.

The project will provide advice to optimise revegetation planning across the project area to:

- Address regional climate change risks and work towards resilience,
- Protect marine and freshwater receiving environment quality,
- Restore wetland and terrestrial biodiversity.

Climate change projections for Northland and consequential risks are included in the project objectives as we consider nature-based solutions, such as appropriate revegetation, to be some of our most critical opportunities for addressing the adverse effects of climate change with co-benefits for both nature and people.

Four main consequences of climate change have been identified as relevant to the project area:

1. Drought – drought severity is projected to increase across northern New Zealand. Inland wetlands are at risk of impacts due to reduced moisture from reduced rainfall. Also, under this altered regime of drought disturbance, wetland ecosystems and species are at risk of enhanced spread, survival, and establishment of invasive species (Ministry for the Environment 2020). This issue can be exacerbated if the right plant is not planted, or weeds are not managed.
2. Sea level rise – coastal ecosystems (intertidal zones, estuaries, dunes, coastal lakes and wetlands) and groundwater are at risk of salination and increased disturbance due to sea level rise and extreme weather events (Ministry for the Environment 2020). For example, Whangarei has experienced c. 2.2 mm of sea level rise since the 1990s (Pearce, 2017) and some of our plant species on the riparian margins closer to the coast may not be saline tolerant.
3. Increased wildfire risk – rainfall is predicted to reduce during Northland's spring and winter seasons (MfE 2018) and some modelling suggests an increase in the number of days of very high and extreme forest fire danger (over the periods 2050 and 2080; MAF 2011). As a result, ecosystems and species are at risk of wildfires. In addition, disturbance from wildfire could provide opportunities for invasive species spread (Ministry for the Environment 2020). Recent large wildfires at Lake Ohia and Kaimaumau demonstrate this reality for locals.
4. Increased flooding – increased occurrence of high intensity rain events will result in increased occurrence of flooding. The future impact of ex-tropical cyclones is uncertain (Pearce, 2017). Anecdotal evidence suggests that flooding is already becoming more frequent within the project area. One of the drivers for the project is that several landowners have raised concerns or frustrations about losing plants and fencing due to flooding.

Variables relating to marine and freshwater receiving environment quality will be incorporated into the analyses to allow these factors to be considered through development of our advice. Opportunities to restore wetland and terrestrial biodiversity will be considered along with opportunities to directly address key ecosystems and species.

1.3 Scope and Structure

This report addresses the following scope and structure:

- Section 1: Background, objectives, scope and structure, sub-catchment descriptions, limitations,
- Section 2: Methods,

- Section 3: Spatial analysis results,
- Section 4: Representative revegetation options,
- Section 5: Conclusions and recommendations.

We note that treated effluent from the constructed wetlands of the East Coast Bays Wastewater Treatment Plant (WWTP)[1] is eventually discharged into a tributary of Te Wai o Te Parapara (Parapara Stream) in the Awapoko catchment. This awa has great significance for the mana whenua of the catchment. At the outset of the revegetation project DOC confirmed that the WWTP and constructed wetland is beyond the scope of this report and is being addressed via other avenues (e.g., the Taipā WWTP Working Group). Whilst the WWTP is out of scope of this project, the project team did visit the site to offer support to mana whenua and the working group around planting options that may complement their objective.

1.4 Sub-catchment Descriptions

The Awapoko, Oruru, and Oruaiti study sub-catchments provide a range of land cover types and land uses, with stream networks that span from upland 1st order source streams down to large 5th to 6th order streams in the lowland receiving areas of these catchments (Fig. 1). The designation of a given stream's 'order' is based on the Strahler stream network nomenclature system (Strahler 1957). In this system, the smallest permanent streams found in upland parts of a catchment that contribute to a waterway are considered '1st order streams'. Where two 1st order streams join, they form a 2nd order stream, and so forth.

The three sub-catchments together comprise an area of *c.* 39,007 hectares (Awapoko: 10,069-ha; Oruaiti: 18,749-ha; Oruru: 10,189-ha). Almost half (49.1%) of the total area of the three sub-catchments is covered by a combination of indigenous and exotic woody vegetation, with considerable areas of indigenous woody vegetation distributed extensively throughout the upland portions of the sub-catchments in particular, frequently with some level of protection (Fig. 1). The remaining portions of the catchments not covered in woody vegetation are comprised of production land used for a variety of purposes but dominated by beef cattle and dairy cattle farming (Fig. 2).

[1] Or the Taipā WWTP.

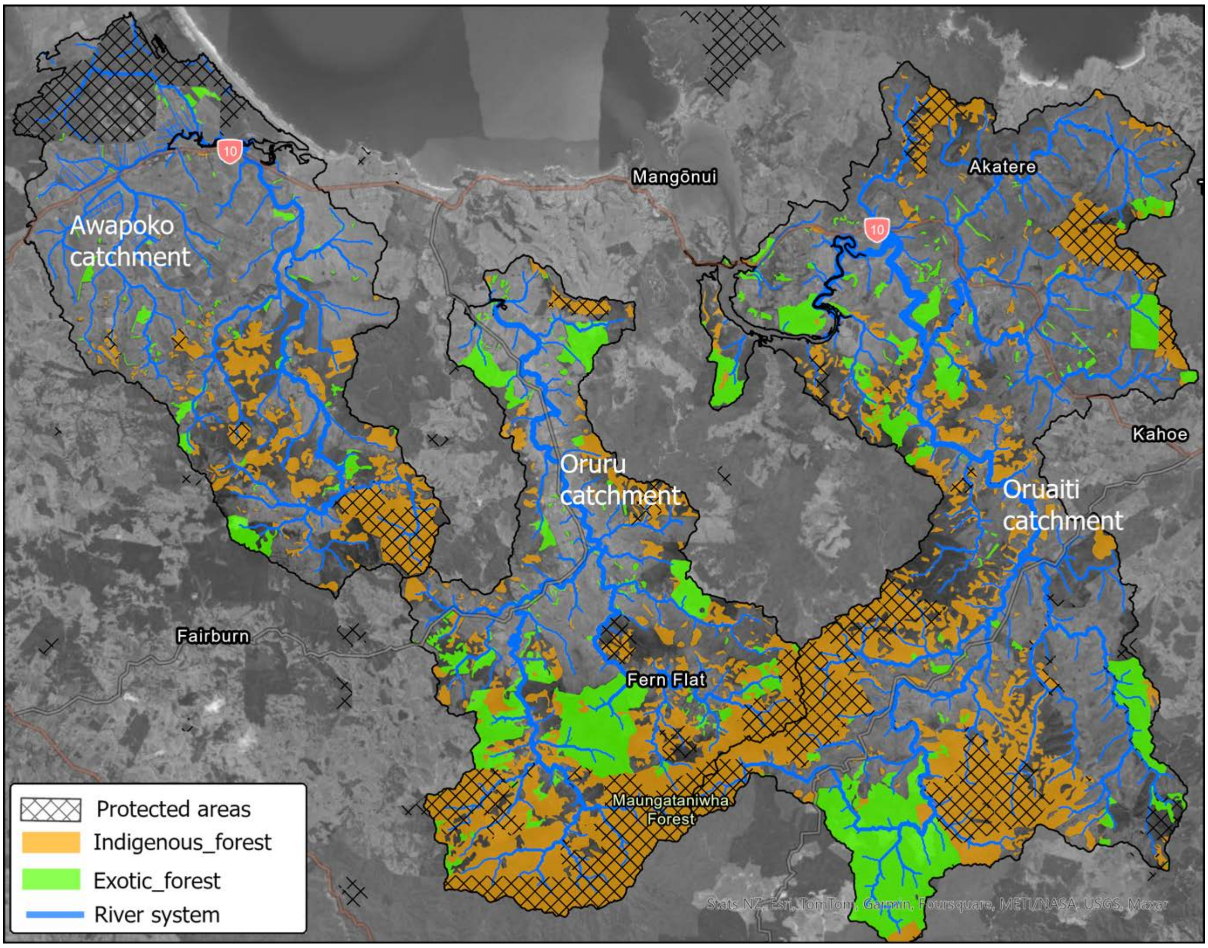

Figure 1: Distribution of indigenous and exotic forests, river systems, and catchment boundaries of the Awapoko, Oruru, Oruaiti sub-catchments, Doubtless Bay, Northland. These three focal sub-catchments for this study contain stream networks that start with 1st order source streams in upland headwater areas (thinnest blue lines on map) that connect progressively into larger streams (2nd, 3rd, etc.), ultimately ending in large 5th or 6th order streams located in the lowland areas of the catchment (thicker blue lines on map). The non-mapped areas in between the three focal sub-catchments comprise smaller stream networks that drain more directly to the sea.

2 METHODS

2.1 GIS based vulnerability analysis methods

A GIS-based 'multicriteria analysis' (MCA) approach was used to rank and combine spatial factors that together provided a representation of ecosystem vulnerability within the three focal sub-catchments in the context of the desired study outcomes (e.g., as per Case et al. 2023), with freshwater health and biodiversity considered of particular importance. Vulnerability refers to how susceptible or sensitive (or, conversely, how resilient) an ecosystem might be to existing and/or future stressors or disturbances, such as the impacts of climate change (droughts, increased floods, fires, etc; e.g., Yoshikawa et al. 2023).

The vulnerability factors selected for inclusion in the analysis (Table 1) was based primarily on the availability of spatial (GIS) datasets that were credible (i.e., had an associated publication, report, or documented metadata) and that comprised variables which reasonably reflected the condition or state of the contemporary biophysical environment across the sub-catchments (see Appendix A).

The analysis was carried out for two spatial scales: for 1st-order[2] headwater catchments and for larger '3rd-order planning unit' catchments (sensu Freshwater Ecosystems of New Zealand spatial framework; Leathwick et al., 2010). The latter units comprise a spatial combination of 3rd to 6th order catchments. The rationale for the two-scale approach recognised the importance of both the water source (headwater) and receiving zones (higher order rivers) of the three focal sub-catchments for overall water quality and biodiversity, and that different factors would likely influence the vulnerability of these two zones. Thus, the approach was to first assess headwater (source) catchment vulnerability, which could then become a contributing factor itself in the evaluation of receiving catchment vulnerability.

The headwater (source) catchment analysis focused on spatial factors that would reflect the relative vulnerability of headwater zones to sediment, nutrient and/or pathogen runoff into upland waterways, and the rate at which this might occur, due to overland water flow. Five spatial datasets were used for this purpose (Table 1). For the receiving catchments analysis, the objective was to assess the vulnerability of lowland stream environments in terms of

[2] The smallest permanent streams that contribute to a waterway are 'first order streams'. When two first order streams join they form a second order stream. The largest waterways in Doubtless Bay are sixth order streams.

existing riparian vegetation, the level of ecosystem protection/representation, and the potential for ongoing disturbance impacts to these riverine systems (Table 1).

The MCA procedure involved assessing the GIS data for each vulnerability factor (Table 1) and ranking the data values along an ordinal scale of 1 (low) through to 4 (high) in terms of their relative impact on catchment vulnerability. For example, slope gradients, which affect the likelihood that rainfall will cause rapid overland runoff, ranged from almost flat (0 degrees) to steep (38 degrees) across the headwater catchments, and were reclassified into four vulnerability classes (1 to 4, flat-to-steep) based on decisions about the relative impact of slope steepness on possible runoff processes. Data for each vulnerability factor, in turn, was given a 1 to 4 rank in this way. Ranked data layers were then spatially overlaid in the GIS with source/receiving catchment boundaries and an area-weighted mean rank average was computed for each vulnerability factor within each catchment polygon. These average rank scores were subsequently re-scaled to be distributed fully along the ordinal 1 to 4, low-to-high, scale.

For headwater catchments, vulnerability scores across four vulnerability factors were averaged and then multiplied by a scaling modifier related to the percentage of exotic forest present in each catchment. This latter scalar was used to reflect the known potential for exotic forest harvesting to cause periodic increased vulnerability for downstream impacts (Wright et al. 2019). We do recognise that the impacts of plantation forest operations can vary depending on management standards applied in each location; our approach here should be interpreted as conservative but should be evaluated on a case-by-case basis. For the receiving catchment analysis, vulnerability scores were summed for the five factors, resulting in a final vulnerability score in the range of five (low) to 20 (high).

Table 1. Description of vulnerability factors used in the GIS-based multi-criterion analysis.

Analysis focus	Vulnerabilities	GIS data layers[1]	Project objectives informed
Source areas (headwaters)	• Soil and biomass loss downslope due to erosion and exotic forest harvesting • Potential for abrupt overland water flow: nutrient/pathogen & sediment transport downstream • Lack of upland-lowland stream network riparian vegetation connectivity (biodiversity/habitats)	1. Erosion rates 2. Slope gradient 3. Soil drainage 4. Percent exotic plantation forest 5. Percent unvegetated gully riparian zones	Protection of receiving environment quality Flooding mitigation Terrestrial ecosystem restoration (contributing to river water quality, biodiversity, and upland-lowland connectivity) Flammability/fire risk mitigation Socio-cultural and economic preferences
Receiving areas (downstream zones)	• Condition of 1st order source catchments within receiving catchments • Bank erosion, sediment, nutrient, pathogen inputs, weed transport caused by frequent and extensive flooding • Current (baseline) status of stream water quality • Stream water quality and habitat/biodiversity effects of under-vegetated riparian zones • Under-representation and protection of key ecosystem types in each catchment • Originally classified as wetland ecosystems	1. Results from 1st order catchment analysis 2. Modelled flooding extents 3. Macroinvertebrate community index (MCI) for stream sections 4. Percentage of riparian zones with woody vegetation 5. Threatened environments rankings	Protection of receiving environment (stream) quality Flooding (and stream erosion) mitigation Terrestrial ecosystem restoration (wetlands, riparian zones) and habitat connectivity Flammability/fire risk mitigation

[1] See Appendix A for a description of GIS datasets, their sources/derivations.

2.2 Site Visits

Site visits were undertaken over the 4-6 March 2024 by Adam Forbes and Brad Case, representatives of DOC and the Ngā Awa project, the hapū collective (Mana whenua), Northland Regional Council, landowners and other interested parties including industry. The purpose of the site visits was to explore restoration issues relating to the Awapoko, Oruru and Oruaiti as they relate to the project objectives.

2.3 Representative Revegetation Option Development

Each option was covered as applicable using the following set of considerations and structure as a starting point. Examples of the scope of considerations are given in Table 2. Content was adapted to suit the style and content of each option:

- Objective(s),
- Context,
- Option description,
- Implementation:
  - Risks,
  - Key advice points,
  - Resources needed,
  - Avenues of support.

Table 2. Typical scope of considerations applied to representative revegetation option development.

Objectives

Objectives	Set clear objectives defining what management seeks to achieve. Examples include: conserve soil, sequester carbon, increase biodiversity, restore cultural values. These are critical as they will help shape and define the management approaches that are implemented.

Context

Pests	Identify the plant and animal pests threatening revegetation. Consider plant and animal pests both within the site and in the larger landscape as the latter will require a different management approach. Whilst out of scope, it is worth noting some invasive species can be more tolerant of increasing temperatures and extreme conditions, potentially out competing our native species for limited resources. Tackling pests and vegetation purposes may indirectly support our native species ability to be more resilient against pressures that might occur as a result of climate change.
Seed sources & dispersers	Assess the amount and proximity of seed sources (exotic and native) to the site. Which species are present (seral[3]

[3] An intermediate stage of ecological succession.

	species or canopy species?) and how important will managing a source of propagules (e.g., enrichment planting) be? How abundant are seed dispersing birds? What is the role of the soil seed bank?
Site factors	How might site factors (e.g., aspect, soils) influence revegetation and how does management need to anticipate and respond to these influences?
Existing vegetation cover	What is the composition, structure, age, management history? What is the level of desirable regeneration? By which species? What interventions would revegetation benefit from (e.g., canopy gaps, enrichment planting)?
Land stability	What is the likelihood of land instability? Can this issue be managed (and if so how)?
Disturbance from stream/river flows	What is the likelihood of flooding/inundation? Can this issue be accommodated (and if so how)?
Climate change risks	What are the specific climate change risks predicted for the area?

Revegetation description

Overview
Site preparation
Specific interventions
Composition and structure
Management and maintenance

Implementation

Risks	What risks need to be accommodated through the option?
Key advice points	Which are the most important aspects of advice
Resources needed	State specific resources
Avenues of support	State specific sources of support

2.4 Illustrative case studies

Two case studies were developed to illustrate how the GIS-based vulnerability analysis results and possible local intervention options could be combined with other spatial and non-spatial information and possible options outlined in this report to underpin a planning and design approach to climate adaptation by improving ecosystem resilience.

3. SPATIAL ANALYSIS RESULTS

3.1 GIS-based vulnerability analysis

A total of 446 source (1st order) catchments across the three larger study catchments were included in the GIS-based MCA ranking and spatial vulnerability analysis. Of the 446 source catchments analysed, 4% (18/446) fell into the highest vulnerability category (red areas in Fig. 2), with another 41.2% (184/446) ranked in the moderately-highly vulnerable category (orange areas in Fig. 2). The remaining 55% of the catchments (244/446) were assessed as of lower vulnerability. Mapping of these catchment vulnerabilities indicated that there are particular hotspots of upland catchment vulnerability, particularly in the upper Oruaiti and lower Awapoko watersheds.

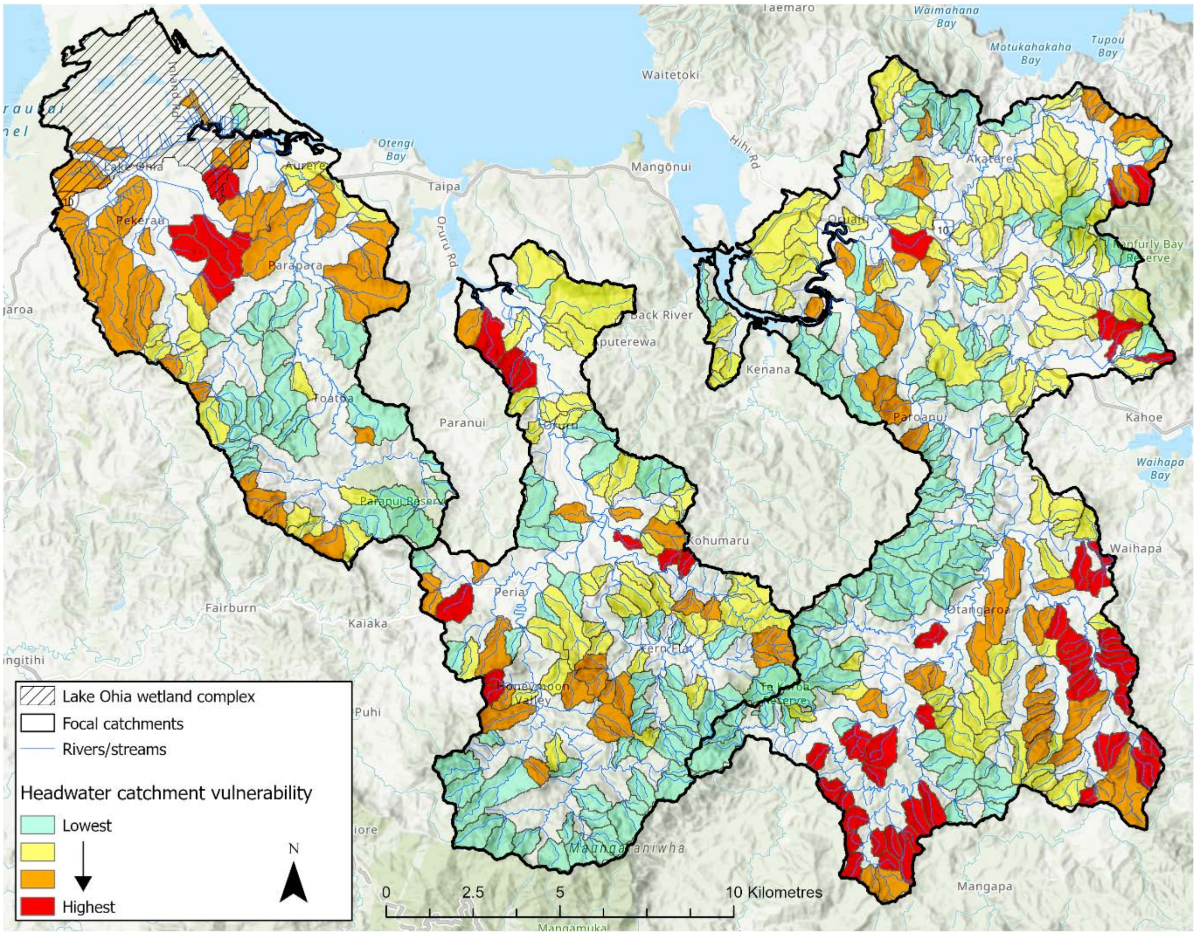

Figure 2: Mapped results of a GIS-based vulnerability analysis for 448, 1st order headwater catchments within the three focal sub-catchments. The analysis involved a spatial overlay of four data layers ranked on an ordinal scale of 1 to 4 (low to high) and combined as a mean vulnerability; a fifth layer, quantifying the percentage of exotic forest present in each source catchment, was used as a multiplier, assuming that harvesting of large portions of these catchments on a rotational basis increases vulnerability.

There was a total of 33 receiving areas that comprised of larger, higher-order (3rd to 6th order) streams. These receiving areas are subject to both potential effects from upland source catchments in addition to other broader land use/land cover pressures on the overall ecological condition in streams and in the receiving areas as a whole. The MCA analysis at the receiving area scale highlighted seven areas of most concern (red and orange polygons in Fig 3), including four of seven receiving areas within the larger Awapoko watershed and the lowland areas of the Oruru watershed.

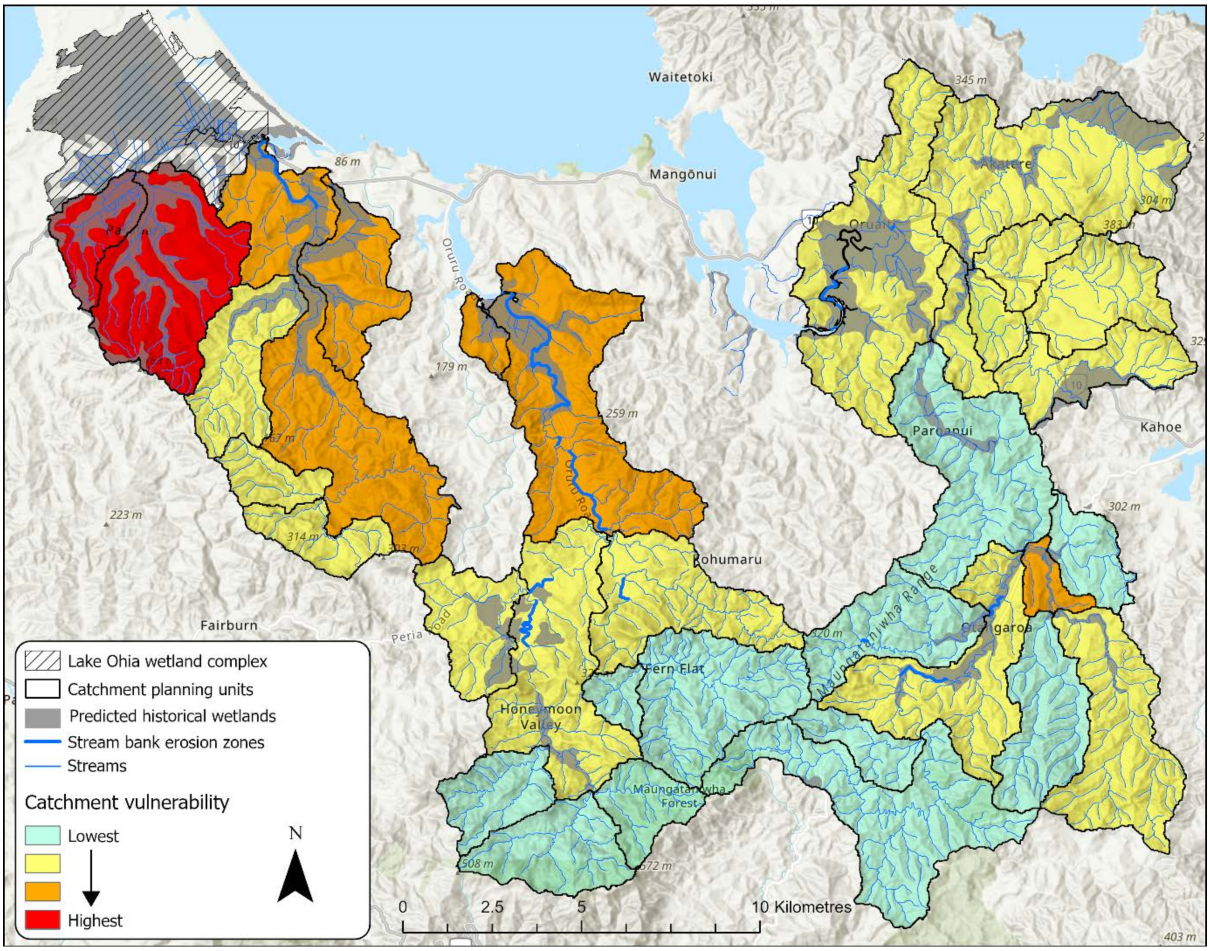

Figure 3: Mapped results of a GIS-based vulnerability analysis for 33 catchment planning units comprising a spatial combination of 3rd to 5th order catchments within the Doubtless Bay study area. The vulnerability analysis involved an overlay of five spatial data layers ranked on an ordinal scale of 1 to 4 (low to high) and combined as a sum of vulnerabilities with each planning unit. The data layers used are described in Table 1. Also shown as thick blue lines are the stream sections that have predicted high susceptibility for stream bank erosion and, in grey, the distribution of historical wetlands; these data are correlated with factors used in the analysis (e.g., flooding extents) but are presented here to illustrate the compounding of critical considerations for particular river zones.

3.2 Attributes of underying vulnerability

Drivers of source catchment vulnerabilities varied in different zones but, generally, the most vulnerable source areas were those having largely unvegetated stream gullies, higher natural erosion rates, and higher aerial proportions of exotic plantation forestry. The latter factor was treated as a 'modifier' in the analysis, recognising that plantation forestry layers an additional vulnerability on top of a catchment's underlying vulnerability due to periodic and significant disturbances (harvesting), leading to potential sediment and material loss downstream.

The factors contributing to receiving area vulnerabilities involved combinations of low levels of existing riparian vegetation, low stream water quality (Macroinvertebrate Community Index), high ecological importance with minimal representation/protection, considerable pressure from extensive and frequent flooding, and greater input from vulnerable source catchments. Figure 3 also emphasises the spatial co-occurrence of other correlated factors in lowland riverine areas, such as known high stream bank erosion rates and the almost complete loss of historical wetlands that would have offered a buffering effect and provided critical biodiversity and habitat (Clarkson et al. 2013).

4. REPRESENTATIVE REVEGETATION OPTIONS

4.1 Overview

The revegetation options relate to 11 specific locations across the three sub-catchments (Fig 4). Locations were selected as being representative examples relevant to other locations within the sub-catchments. Option 5 (making a total of 12 options) is strategic weed control and is study area wide, not a particular example point.

Table 3 shows how the 12 revegetation options align with the range of project objectives.

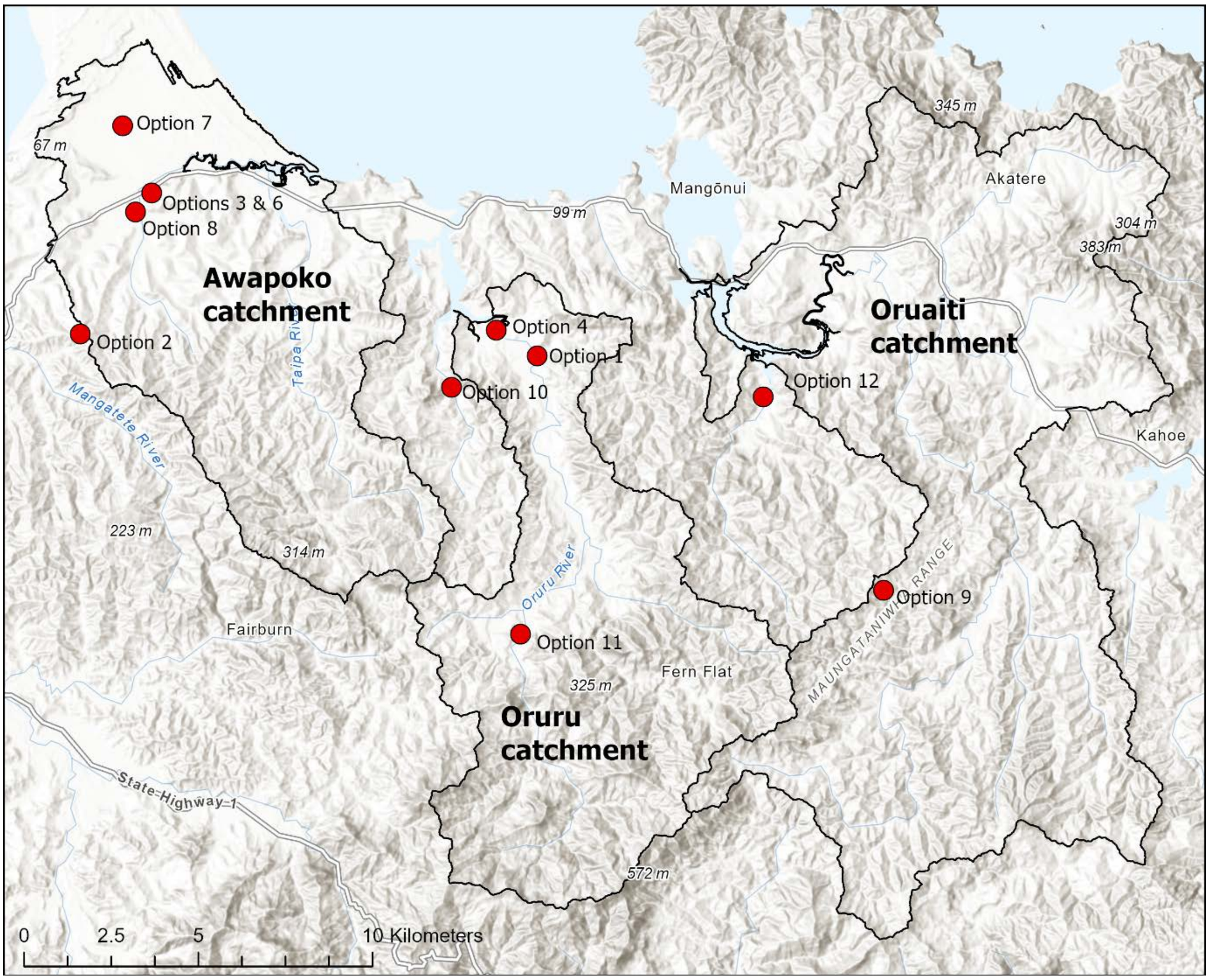

Figure 4: The study area (Awapoko, Oruru and Oruaiti sub-catchments) and the specific option case study locations indicated by option number used in this report.

Table 3. Scenarios identified and upon which representative restoration options are based. Locations and alignment with project objectives are indicated.

#	Scenario	From	To	Local examples	Project objectives							
					Climate change				Protection	Restoration		Humans
					Effects of drought, particularly on wetlands	Effects of sea level rise on coastal freshwater ecosystems	Effects of wildfires on ecosystems, species, and invasions	Effects of flooding	Coastal and freshwater receiving environment quality	Wetland restoration	Terrestrial ecosystem restoration	Social, Cultural and economic preferences
1	Appropriate riparian cover (inc. for īnanga spawning) lowland floodable/erodible sites.	Open, willows, grasses, weeds	Light native forest and spawning species	Saltwater Wedge (Oruru)		Y	Y	Y	Y		Y	Y
2	Appropriate vegetation cover steeplands (retirement, pastoral management)	Slips and soil loss	Appropriately vegetated stabilised soils	Pekarau Road			Y	Y	Y		Y	Y
3	Revegetation to mitigate drought and manage wildfire	Flammable	Less flammable	Lake Ohia/SH10 Hillside land planted site	Y	Y	Y	Y		Y	Y	Y
4	Enrichment planting to promote successional development	Earlier successional	Later successional	Pariri Road			Y		Y	Y	Y	Y
5	Strategically addressing weed hotspots and transitioning to favourable cover	High propagule biomass	Low weed biomass and stable desirable cover	Dangen Road and others			Y		Y	Y	Y	Y
6	Tree establishment on silica pan soils	Grassland	Appropriate vegetation cover	Farm at Pekerau Road							Y	Y
7	Rewetting wetlands (e.g. lake Ohia)	Drained wetland	Restored wetland	Lake Ohia	Y	Y	Y	Y	Y	Y	Y	Y

8	Naturalising drainage networks and legacy riparian cover to increase detention (via constructed wetlands) and create aquatic habitat diversity	Linear network shaped by agriculture and historical decisions	Functioning waterways which increase detention and provide habitats	Pekerau Road	Y	Y		Y	Y	Y	Y	Y
9	Management of existing native forests	Existing forest with threats	Long term forest health through management	Crown land at Tipatipa Road	Y		Y	Y	Y	Y	Y	Y
10	Working with available incentives (ETS, others?)	Financially unsupported projects	Financial support for projects	Honeymoon Valley					Y		Y	Y
11	Management of retired land (e.g. forestry non-replant areas)	Uncertain trajectory	Tangible trajectory	Summit/Adamsons Forest Honeymoon Valley riparian			Y	Y	Y		Y	Y
12	Culturally/socially centred riparian restoration	Weedy grazed floodplain	Attractive area with native forest elements	Kenana marae bridge area				Y	Y		Y	Y

4.2 Option 1 - Appropriate riparian cover to support īnanga spawning, on floodable/erodible sites

Objective

1. To establish grasses, shrubs and light native forest cover that encourage īnanga spawning by providing favourable spawning habitat on riverbanks, reduce water and bank temperatures whilst avoiding further bank erosion or woody debris that could become hazardous with flooding.

4.2.1 Site photograph(s)

Figure 5: (Top) Riparian conditions in the Oruru River reach currently used by īnanga for spawning. (Bottom) Broader floodplain environment with pastural grazing beyond the riparian zone.

4.2.2 Context

Pre-human cover	Podocarp forest
Pests	Crack willow, rank grass
Seed sources and dispersers	>1.5-2 km to nearest substantial native seed source. Depleted soil seed bank. Planting required.
Site factors	Flat alluvial surface with steep bank slope.
Existing vegetation cover	Rank grass with crack willow and poplar. Marginal vegetation is raupo and rank grass.
Land stability	Possible bank instability.
Disturbance from stream/river flows	Frequent flooding. Floodwaters leave channel spreading across adjacent floodplain.
Climate change issues	20 to 30 more hot days (>25ºC) by 2040, increased rainfall intensity and thus flooding, during rare extreme events and possible salinisation of the coastal aquifer at Taipa (Pearce, 2017). Increased salinity in freshwater habitat due to sea level rise. Increased variation in saltwater wedge/habitat spawning areas – but generally moving inland over time.

4.2.3 Option description

Overview

Īnanga are reliant on riparian vegetation and leaf litter to protect eggs on banks during spawning season (Hickford et al., 2018). Increasing temperatures, moisture loss and predation are increasing pressure on īnanga populations.

The example location is on the saltwater wedge[4] reach of the Oruru River accessed at the lower reaches downstream from Peria.

The option involves removing problematic trees occurring within the riparian zone and planting native tree species to achieve a riparian forest cover while allowing for marginal vegetation suitable for īnanga spawning at and near the saltwater wedge.

[4] A saltwater wedge is essentially a layer of saltwater below a layer of freshwater, which is pushed into an estuary/channel by tides.

Site preparation

1. Fell and remove existing crack willow and poplar trees and also other large trees which will eventually topple causing coarse woody debris to enter the watercourse.
2. Treat problem weed infestations, such as wild ginger.
3. Stock proof fence along the landward side of the riparian zone where not already fenced.

Specific interventions

1. Planting pioneer (year 1) with native trees and shrubs followed by enrichment species (year 3-5 as determined by attainment of canopy closure). Limit native planting to outside of channel (on the surrounding floodplain surface) so as not to shade out marginal īnanga spawning vegetation (such as raupo or rank sward).
2. Plant native sedges and grasses along the wetted margin and banks to provide habitat for īnanga spawning and contribute to bank stabilisation, and some riparian cover/shading (i.e., shelter for fish) while not impeding floodwaters. Avoid planting flax close to flowing water, as floodwaters tend to flow around the plants, carving out chunks of riverbank that slump into the water (with the flax plant). Do not plant flax too close to the edge of high bank margins (3m) as this can also cause slumping. This is particularly important in this subcatchment as it is prone to high bank margins (>3 m) which are prone to erosion and in particular slumping.

Target composition and structure

The composition would be initially formed from native shrub and tree species which tolerate open conditions and help to form a closed canopy (left hand portion of tables below). Once canopy closure is achieved, a second wave of longer-lived, taller-statured species would be introduced through enrichment planting (right hand portion of tables below).

For the lower banks and wetted margins, choose from the species listed in the Whitebait Connection's restoration lists[5] for īnanga spawning[6]. This list includes species which have some tolerance of saline conditions.

[5] See https://www.whitebaitconnection.co.nz/images/wbc/resources/īnanga/WBC-NISP_Plants_for_Restoration_FINAL_LowRes.pdf
[6] Īnanga can spawn in both exotic and native species (e.g., grasses; Hickford et al., 2018) but the īnanga spawning work in this catchment has primarily focused on native ecosourced plants.

Table 4. Light riparian native forest species lists – Priority species

Pioneer planting

Name	NVS Code
Horoeka	PSECRA
Houhere	HOHPOP
Kānuka	KUNERI
Kāpuka	GRILIT
Karamū	COPROB
Kōhūhū	PITTEN
Koromiko	VERSTR
Kōwhai	SOPMIC
Kumarahou	POMKUM
Māhoe	MELRAM
Makomako	ARISER
Mānuka	LETSCO
Ngaio	MYOLAE
Pittosporium ellipticum	PITELL
Pōhutukawa	METEXC
Porokaiwhiri	HEDARB
Poroporo	SOLAVI
Pūriri	VITLUC
Putaputawētā	CARSER
Red mapou	MYRAUS
Rewarewa	KNIEXC
Tauhinu	OZOLEP
Tōtara	PODTOT
Whau	ENTARB
Whauwhaupaku	PSEARB

Enrichment planting

Name	NVS Code
Kahikatea	DACDAC
Mataī	PRUTAX
Rimu	DACCUP
Tānekaha	PHYTRI
Taraire	BEITAR
Tawa	BEITAW
Titoki	ALEEXC
Toro	MYRSAL

Table 5. Light riparian native forest species lists – Other species options

Pioneer planting	
Name	NVS Code
Akeake	DODVIS
Hangehange	GENLIG
Kanono	COPGRA
Makamaka	ACKROS
Neinei	DRALAT
Poataniwha	MELSIM
Puka	GRILUC
Ramarama	LOPBUL
Tamingi	EPAPAU
Taurepo	RHASCA
Tī kōuka	CORAUS
Towai	PTESYL
Wharangi	MELTER

Enrichment planting	
Name	NVS Code
Kawakawa	PIPEXC
Kohekohe	DIDSPE
Pukatea	LAUNOV
Tūrepo	STRHET

Management and maintenance

Post-planting management would include blanking[7] and pest control (i.e., weedy plants and browsing animals that may eat seedlings, preventing plants from establishing).

Enrichment planting would need to occur across the planted area once canopy closure has been achieved (c. 3-5 years). Species would ideally be ecosourced but as a minimum need to be matched to suitable microclimates (soil conditions, topographic shelter, etc).

4.2.4 Implementation

Risks	• Invasion or reinvasion of the planting site by aggressive weed species. One main avenue for weed propagules reaching the site is dispersal via flood waters from upstream locations. Also weed species might be represented in the soil or could be spread by birds, wind or gravity from adjacent sources. • Disturbance from flooding. Planting is limited to the high floodplain however flooding of this zone does occur. As well as disturbance of planted seedlings, fencing could be compromised thereby putting

[7] Replacing dead seedlings to help achieve even canopy cover in the early stages of planted stand development.

	the planted area at risk of browsing by stock and increased cost to landowners for fencing replacement. • Bank erosion and instability. • Shading and degradation of īnanga spawning habitat.
Key advice points	• Plant to achieve canopy closure rapidly. • Strive to eradicate aggressive weeds from the site before planting (herbicide/control method advice). • Locate species according to any particular microsite preferences regarding light availability and soil moisture conditions. • Effective enrichment planting may require physical modification of the pioneer stand by pruning or localised felling. • Fences tailored to flooding (i.e., minimal resource and cost inputs). • Consider riparian margin width and plant species performance/influence to prevent increasing erosion. For example, heavy established species such as flax can trigger bank slumping if on unstable ground too close to the waters edge.
Resources needed	• Arborist skills to remove existing willow and other problematic riparian trees. • Materials and labour for site preparation, planting and maintenance. • Fencing materials and labour.
Avenues of support	• Arborists. • Likeminded community members. • Nurseries. Some local nurseries can ecosource plants. • Biodiversity/landscaping contractors. • Whitebait Connections resources[8] for īnanga spawning habitat. • NRC land advisors and planting resources. • DOCs Nga awa programme and local hapu have partnered with Mountains to Sea (Whitebait Connections) Northland Īnanga Spawning Habitat Restoration Project (NISHRP) to survey and restore Inanga Spawning sites in Doubtless Bay. The restoration of Inanga habitat may be eligible for NISHRP funding (confirmed until 2025) or Native Freshwater species habitat in Doubtless Bay may be eligible for funding via DOCs Nga awa Programme.

[8] See the Whitebait Connections resources page on their website: https://www.whitebaitconnection.co.nz/what-we-do/education/īnanga-spawning.html

4.3 Option 2 – Appropriate vegetation cover on unstable steeplands

Objective

1. To stabilise erodible soils through appropriate woody vegetation cover.

4.3.1 Site photograph(s)

Figure 6: (Top) example of land instability where a slip has occurred on sloping ground (Middle) closer view of the slip (Bottom) adjacent hill slope areas stabilised by native forest.

4.3.2 Context

Pre-human cover	Kauri/taraire-kohekohe-tawa forest.
Pests	Rank grass. Possums. Browsing stock are a threat where not excluded by fencing.
Seed sources and dispersers	Adjacent native seed source. Presumed to be adequate disperser availability. Depleted soil seed bank.
Site factors	Southern facing slope aspect. Sloping face.
Existing vegetation cover	Pasture and rank grass.
Land stability	These faces are susceptible to slipping. Modelling suggests that the area has a high erosion rate.
Disturbance from stream/river flows	Not applicable to these faces.
Climate change issues	20 to 30 more hot days (>25°C) by 2040, increased drought risk and also increased rainfall intensity and thus increased slip and erosion risk during rare extreme events (Pearce, 2017).

4.3.3 Revegetation option description

Overview

The example location is east of Kaingaroa, north of Duncan and Churton Roads. The site has a coastal element to its climate.

The option involves revegetating erosion prone land[9] with woody species to increase land stabilisation. The option is based on the permanent retirement of the erosion prone land from pastural grazing. Retirement of the entire face has the additional benefit of retiring existing native forest areas which would otherwise gradually breakdown under the existing regime of understorey grazing.

The initial planting would comprise a mix of traditional erosion control planting (poplar poles) to achieve rapid slope stabilisation in higher risk areas coupled with fast growing exotic and native species. A later phase of planting would help ensure successional species are incorporated into the composition.

This strategy relies in part on natural regeneration from adjacent forest seed sources and it is therefore important that barriers to regeneration such as browsers and aggressive plant pests are effectively managed on an ongoing basis.

Site preparation

1. Stock proof fence one or several large blocks along the top and bottom of hill slopes. Install connecting fence to enclose sides of slope. Utilise existing fencing where possible.
2. Spot spray planting locations on a 3 × 3 m interval.

Specific interventions

1. Plant poplar poles on existing slips and on sites at high risk of mobilising. These can be poisoned or left to senesce naturally over the course of several decades.
2. Plant ngaio and the other listed natives at 3 × 3 m (1,111 stems ha^{-1}) spacing in the relative proportions given below.
3. Once canopy closure has occurred, carry out a phase of enrichment planting.

[9] There are formal and informal methods of determining erosion susceptibility and we leave it with landowners to choose the most appropriate method. Northland Regional Council is one source of information about the distribution of erosion prone land and also provides grants to support appropriate management of erodible land.

Target composition and structure

Poplar will be planted on an as-required basis to provide rapid stabilisation.

Ngaio grows rapidly (both above and below ground) and is a relatively low-cost component of a planted forest canopy. It is also easy to strike and grow seedlings that could be raised by the landowner further reducing costs. The species forms a canopy quickly and casts shade rapidly building a forest microclimate. The flowers attract insect pollinators and therefore provide some ecosystem function.

The remaining native species are included in the planted composition at a lower level (the composition is bulked by ngaio) on the basis that overall, the planted stand would build a microclimate suitable to facilitate natural establishment from the adjacent native forest seed sources.

Once canopy closure has been established there is the option of securing successional development through enrichment planting with long-lived canopy species, especially those that are in low numbers or missing from adjacent forest seed sources.

Table 6. Stabilising erodible steep lands species lists.

Pioneer planting	
Name	NVS Code
Kānuka	KUNERI
Karamū	COPROB
Kawaka	LIBPLU
Koromiko	VERSTR
Māhoe	MELRAM
Ngaio	MYOLAE
Pittosporium ellipticum	PITELL
Rewarewa	KNIEXC
Tōtara	PODTOT
Whau	ENTARB

Enrichment planting	
Name	NVS Code
Kahikatea	DACDAC
Mataī	PRUTAX
Miro	PECFER
Porokaiwhiri	HEDARB
Tānekaha	PHYTRI
Titoki	ALEEXC

Management and maintenance

Post-planting management would include blanking and pest control (particularly browsers).

Enrichment planting would need to be timed across the planted area once canopy closure has been achieved. Species would need to be matched to suitable microclimates (soil conditions, topographic shelter, etc).

Ngaio should be thought of as a component that can be pruned or felled to optimise microclimate conditions for the planted native species.

4.3.4 Implementation

Risks	• Land erosion and instability. • Invasion of the planting site by aggressive weed species. • Stock accessing planting sites. • Possum browsing.
Key advice points	• Use of poplars aims to achieve ground stability rapidly. Poplar is only a temporary component of the option and can be removed once the planted composition has matured. Probably 20 years would be the timeframe for their removal. • Ngaio is incorporated due to its rapid growth which will help bulk the planted structure supporting planted natives and assisting with microclimate development. • Incorporate existing native forest in the option area as these are the sources for native forest seed in the longer term, once a suitable microclimate has developed.
Resources needed	• Fencing materials and labour. • Site specific poplar planting/locating advice. • Materials and labour for site preparation, planting and maintenance.
Avenues of support	• Northland Regional Council regarding poplar planting. • Northland Regional Council Hill County Erosion Fund.[10] • Likeminded community members. • Nurseries. • Biodiversity/landscaping contractors. • If >1 ha and meeting Ministry of Primary Industries (MPI) Forest Land definition at completion of planting the New Zealand Emissions Trading Scheme (NZETS) could potentially provide an avenue of support[11].

[10] Offered through the NRC Land Management Team. Owners of properties over 4 ha can apply to access this fund, which will reimburse a set amount of the per metre costs (approximately 2/3rd cost) of fencing off any amount of highly-erodible land for retirement from grazing including grazed bush blocks with permanent electric fence, and/or for retiring and planting 2 ha or more of highly-erodible grazing land in native establishment species. This funding targets the most erodible land. See https://www.nrc.govt.nz/your-council/work-with-us/funding-and-awards/for-landowners/grants-for-fencing-andor-planting-natives-on-erosion-prone-land/

[11] Landowners looking to retire land and offset costs with funding support, should check there are not plant species specific requirements for eligibility for funding (e.g., NZETS).

4.4 Option 3 – Revegetation to mitigate drought and help manage wildfire

Objective

1. To revegetate a site in a manner that meets biodiversity restoration objectives while mitigating risks of drought and wildfire.

4.4.1 Site photograph(s)

Figure 7: (Top) a face that was previously in radiata pine has been planted in predominantly kānuka. State Highway 10 is visible, and a residential dwelling is located on the terrace above the face. (Middle) Kānuka planted in rows across the face. (Bottom) Flax was planted in shallow gully heads. Lake Ohia is out-of-frame at the downslope side of the site.

4.4.2 Context

Pre-human cover	Kauri/taraire-kohekohe-tawa forest.
Pests	Rank grass. Possums. Browsing stock are a threat where not excluded by fencing. Pine regrowth appears not to be an issue.
Seed sources and dispersers	Limited adjacent native seed source. Likely to be a limited frugivore disperser availability. Depleted soil seed bank.
Site factors	Northern facing slope aspect. Sloping face.
Existing vegetation cover	Pasture and rank grass. Planted kānuka and localised flax.
Land stability	Potential instability with some localised gully erosion.
Disturbance from stream/river flows	Not applicable to these faces.
Climate change issues	20 to 30 more hot days (>25°C) by 2040, increased drought and thus wildfire risk, and also increased rainfall intensity and thus increased slip and erosion risk during rare extreme events (Pearce, 2017).

4.4.3 Option description

Overview

The example location is the face immediately south of State Highway 10, between the intersections of Pekerau and Inland Road. The site is at the base of the Karikari Peninsula and approximately 0.5 km from the edge of Lake Ohia.

The site was formerly radiata pine plantation and has recently been planted in native trees. The main species planted is kānuka. The transition from radiata pine to kānuka is positive in terms of biodiversity values however both species are highly flammable.

There are potential fire ignition sources to the north of the face. One main potential source of fire is Lake Ohia, where there is a history of human induced fires. The second potential source of fire is State Highway 10, where fire sources from vehicles using the highway is immediately adjacent to the toe of the face.

The option involves incorporating low flammability species to provide green breaks and somewhat mitigate the wildfire risk presented by kānuka dominance. The science of fire behaviour is not well developed for New Zealand's forests, so this advice follows what is available from Fire and Emergency New Zealand.

Extended dry periods are predicted to increase in Doubtless Bay with climate change. Therefore, where species are planted on exposed north-facing sites such as this one they need to be resilient to extended periods of low soil moisture.

The challenge for restoration is to select species that perform well for both low flammability and high drought tolerance, while also being ecologically relevant and suitable for the exposed conditions of early-stage native tree planting. For instance, Innes and Kelly (1992) found kānuka and tōtara to be more resilient to drought than māhoe, however the former two species are high and moderate/high flammability whereas māhoe is less flammable (low/moderate) so would be a preferable choice from the perspective of fire but not necessarily drought.

Figure 2. Determination of final flammability classes for 42 native New Zealand shrubs and trees.

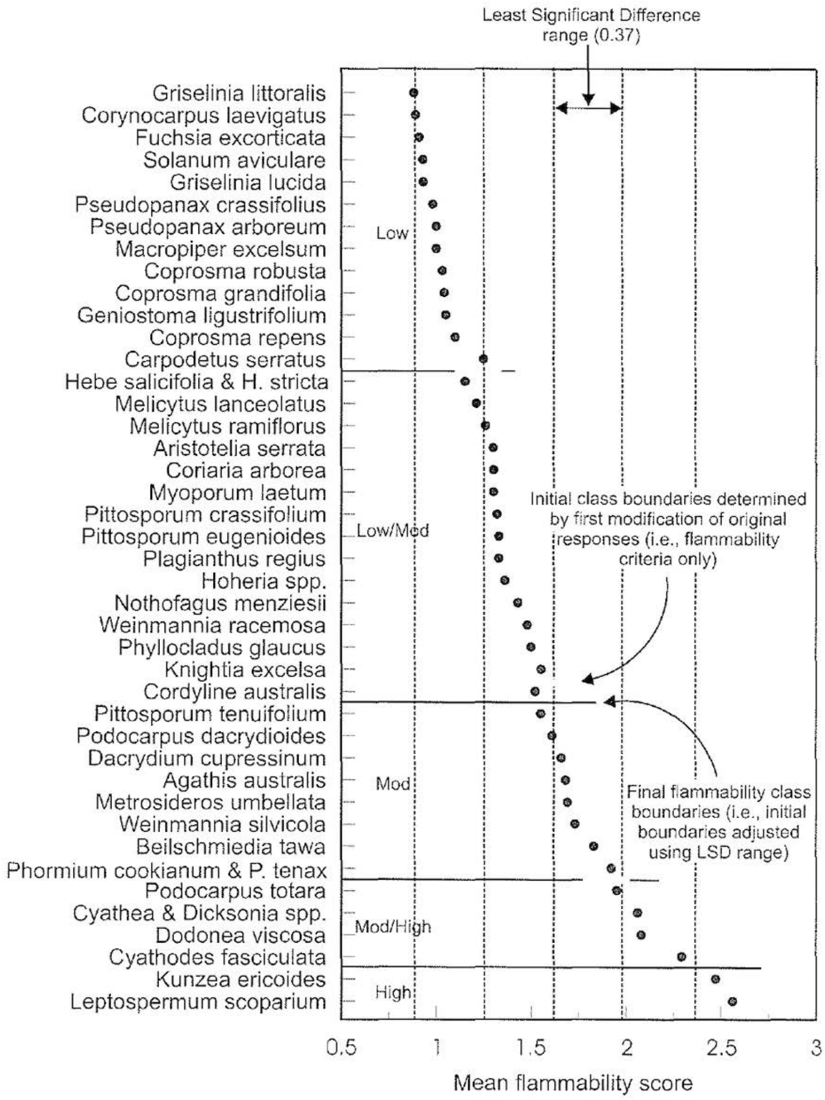

Figure 8: Flammability classes for 42 native shrubs and trees according to Fire and Emergency New Zealand.

The next consideration of the option is configuration of planted species according to their flammability. At the example site, we apply Fire Emergency New Zealand’s advice and recommend bands of species of low flammability planted along the toe of the slope so that the mature crowns have >4 m spacing between rows. This aims to provide a green break between ignition sources (the lake and the State Highway) and the high flammability kānuka planting on the slope above. We recommend the same option at the top of slope where a dwelling is located c. 20 m back from the edge of the planted kānuka stand.

Land areas within green breaks should be maintained in short grass year round by stock grazing.

Site preparation

1. The site is already fenced to a stock proof standard. Install additional fencing (could be temporary/seasonal) to allow green breaks to be subject to periodic stock grazing.
2. Spot spray planting locations on a 1.5 × 1.5 m interval (4,444 stems ha^{-1}).

Specific interventions

1. Establish green breaks at the top and bottom of the slope spaced 8 m apart (upslope) to create and maintain gaps between tree crowns. These areas should be grazed with stock to keep weed invasions at bay and maintain lower vegetation biomass within the green breaks.
2. Enrichment plant low and low/medium flammability species amongst existing kānuka to reduce the overall flammability of the planted composition. Ideally these species would be planted in conjunction with the initial planting.

Target composition and structure

The following species are of low or low/moderate flammability status and of a resilience sufficient to cope with droughts and the exposed nature of the planted stand and site.

Table 7. Species suitable for green break planting and enrichment planting.

Green break planting		Enrichment planting	
Name	NVS Code	Name	NVS Code
Horoeka	PSECRA	Houhere	HOUPOP
Houhere	HOUPOP	Māhoe	MELRAM
Kāpuka	GRILIT	Putaputawētā	CARSER
Karamū	COPROB	Rewarewa	KNIEXC
Koromiko	VERSTR	Whauwhaupaku	PSEARB
Māhoe	MELRAM		
Makomako	ARISER		
Ngaio	MYOLAE		
Poroporo	SOLAVI		
Putaputawētā	CARSER		
Rewarewa	KNIEXC		
Tī kōuka	CORAUS		
Whauwhaupaku	PSEARB		

Management and maintenance

Post-planting management would include blanking and plant pest control.

Enrichment planting would need to be timed across the planted area once canopy closure has been achieved. Species would need to be matched to suitable microclimates (soil conditions, topographic shelter).

The pre-existing kānuka should be thought of as a component that can be trimmed or felled to optimise microclimate conditions for the planted native species (see Tulod & Norton, 2020).

Graze green breaks with stock to keep vegetation biomass low in these areas.

4.4.4 Implementation

Risks	• Land erosion and instability. • Invasion of the planting site by aggressive weed species. • Stock accessing planting sites. • Possum browsing.
Key advice points	• Use species of low or low/moderate flammability which are suitable for both the dry north facing site and prolonged dry periods to provide a green break at the top and bottom of the face. • Graze the green breaks to keep vegetative biomass at low volumes. • Enrichment plant the existing kānuka stand to increase biomass of low or low/moderate flammability species.
Resources needed	• Fencing materials and labour. • Materials and labour for site preparation, planting and maintenance.
Avenues of support	• Likeminded community members. • Nurseries. • Biodiversity/landscaping contractors. • Emissions Trading Scheme.

4.5 Option 4 – Enrichment planting to promote successional forest development

1. To accelerate and direct successional development in a young planted native forest.

4.5.1 Site photograph(s)

Figure 9: (Top) Planted natives forming a microclimate sufficient to shade out the light-demanding grass sward. (Middle) Example of spacing and understorey of planted native tree stand. (Bottom) Natural establishment of ngaio within the planted native tree stand.

4.5.2 Context

Pre-human cover	Podocarp forest.
Pests	Possums. Browsing stock are a threat where not excluded by fencing.
Seed sources and dispersers	Isolated from native seed source. Likely to be a limited frugivore disperser availablity. Depleted soil seed bank.
Site factors	Riparian to Oruru River. East facing river bank. Mainly sloping face.
Existing vegetation cover	Planted natives, mainly mānuka/kānuka.
Land stability	No apparent instability.
Disturbance from stream/river flows	Parts of the site might flood in very large flood events in the Oruru River.
Climate change issues	20 to 30 more hot days (>25ºC) by 2040, increased drought risk, increased rainfall intensity and thus flooding, during rare extreme events and possible salinisation of the coastal aquifer at Taipa (Pearce 2017).

4.5.3 Option description

Overview

The example location is on the true left/west side of the Oruru River near Pariri Road.

The planted stand has established well, and in less than a decade a distinct forest microclimate has developed. Evidence of this is found in the native trees outcompeting light demanding grasses. The understorey features a largely bare soil substrate with a native leaf litter layer.

The site lacks diverse native forest seed sources, and the planted stand does not contain the diversity to direct successional development towards representative forest compositions. The site would naturally have been native conifer forest with broadleaved components.

The option involves siting large grade native tree seedlings (>60 cm height at planting) in suitable microsites. The concept is for the enrichment phase seedlings to join the canopy and assist in providing stable, long-term, native forest cover.

Site preparation

1. The site is already fenced to a stock proof standard.
2. Minor felling or pruning of the existing native tree stand might be required to optimise the microclimate for enrichment phase seedling survival and growth. As a guide, created gap diameters should be 0.25-1 times the height of the canopy. Interventions should not create gap diameters any larger than the height of the stand at the manipulation location. For instance, creating a gap in a 3 m tall stand should aim for a 0.75 – 3 m wide canopy gap.
3. Gap size should be matched to species-specific shade tolerance of enrichment phase species. Larger gaps can be planted with multiple individuals of the same or different species. Within-gap zonation (e.g., southern or northern edge of gap) may produce slightly different microclimates (e.g., different levels of light transmission based on the path of the sun) and this can be considered in siting species based on their requirement for shelter and shade. Be conservative with canopy opening treatments. Often a small amount of vegetation removal can create a surprisingly large increase in light transmission. Better to start small with canopy opening and increase openings in small increments. Creating too larger gaps can open up stands to invasion by light-demanding weeds.
4. Stand edges can have gap microclimate qualities and depending on their aspect are valuable sites for targeted enrichment planting.

Specific interventions

1. Gap creation as required.
2. Planting enrichment phase species.

Target composition and structure

The following species are representative of natural forests of the site and or relevant to supporting successional development. Most would be unlikely to re-establish at the site in the foreseeable future without enrichment planting.

Table 8. Species suitable for enrichment planting low diversity planted riparian forest.

Enrichment planting		Gap creation scale[1]
Name	NVS Code	
Hīnau	ELADEN	Small/nil
Horoeka	PSECRA	Moderate
Houhere	HOHPOP	Large
Kahikatea	DACDAC	Large
Kohekohe	DIDSPE	Moderate
Kōwhai	SOPMIC	Large
Mangeao	LITCAL	Small
Mataī	LITCAL	Moderate
Miro	PECFER	Small
Nīkau	RHOSAP	Small/nil
Northern rātā	METROB	Moderate
Pūriri	VITLUC	Large
Rewarewa	KNIEXC	Large
Rimu	DACCUP	Moderate
Tānekaha	PHYTRI	Moderate
Taraire	BEITAR	Small/nil
Tawa	BEITAW	Small
Titoki	ALEEXC	Large
Tōtara	PODTOT	Large
Towai	PTESYL	Large

Notes: [1] This describes recommended scales of canopy opening to suit light requirements for species within the planted native forest which this option is based on. Nil = no canopy opening, small = gap ratio 0.25:1, moderate = gap ratio 0.6:1, large = gap ratio 1.0:1.

Management and maintenance

Post-planting management would include blanking and plant pest control.

The pre-existing planted natives should be thought of as a component that can be trimmed or felled to optimise microclimate conditions for the planted native species (see Forbes et al., 2020).

4.5.4 Implementation

Risks	• Flooding and inundation. • Invasion of the planting site by aggressive weed species. • Stock accessing planting sites. • Possum browsing.
Key advice points	• Match species planting locations with existing canopy cover. Consider opportunities to use existing gaps or trim/prune existing trees to create optimal conditions for species. • Use canopy height to gap diameter ratios to judge gap sizes and the need for canopy interventions. • Start small with interventions and gradually increase as required. • Retain trimmed vegetation in the stand so it can be reincorporated into the forest ecosystem.
Resources needed	• Materials and labour for site preparation, planting and maintenance. • Tools and a level of competency to safely trim or fell planted native seedlings.
Avenues of support	• Likeminded community members. • Nurseries. • Biodiversity/landscaping contractors. • Publications (see references). • Some restoration projects may be eligible for Ngā Awa habitat restoration support.

4.6 Option 5 – Strategically addressing weed hotspots and transitioning to favourable native cover

1. To strategically reduce biomass and adverse ecological effects of problem weeds at the whole-of-catchment scale starting at the top of the catchment.

4.6.1 Site photograph(s)

Figure 10: Examples of problem weed hotspots on waterway margins at three locations in the Oruru catchment (Top, Middle, & Bottom photos).

4.6.2 Option description

Overview

Plant pests in Northland are a principal threat to biodiversity. A number of serious plant pests are present in the environment and our study area is an example of the diversity and severity of plant pest threats. Northland Regional Council gives a list[12] of 12 particularly problematic plant pests. Plant pests are categorised as either Exclusion, Eradication, Progressive Containment, or Sustained Control. Within our study area there are a number of problem areas or hotspots where infestations are particularly intense.

Landowners report significant expansion of some plant pests over their time on a given area of land. One landowner stated she wished she could have known how significantly the wild ginger infestation would grow over the 10 years on her land, and that now it has expanded to a point where removing it is unmanageable without support. This is representative of other landowners' experiences regarding expansion and spread of plant pests over time.

[12] See https://www.nrc.govt.nz/resource-library-archive/environmental-monitoring-archive2/state-of-the-environment-report-archive/2011/state-of-the-environment-monitoring/our-land-our-air/pest-plants-and-animals/

Other landowners reported the role that waterways are having in dispersing plant pest seeds and vegetative material downstream. A number of sites visited contained stands of highly aggressive weeds on stream banks where floodwaters or base flows can transport seed to downstream establishment sites. We note that climate change means increases in temperatures that are predicted to increase some invasive/pest species, both plants and invertebrates (including freshwater species).

A main problem is there is no coordinated catchment level control efforts. We also noted a lack of awareness of landowners to the potential accelerating weed problems. Controlling such serious weeds is demanding in both time and money which puts it beyond some landowners' capabilities and others have been forced to accept the lack of resources as a barrier to addressing such plant pests on their land.

Specific interventions

1. Establish a body to serve as a vehicle for coordination and knowledge-sharing regarding plant pest distribution and control efforts. Northland Regional Council is responsible for pest biosecurity and would make a logical component of any such body. Far North District Council is responsible for roadside weed management so their involvement could be relevant also. The weed management plan should be incorporated into the community led catchment plan (which is currently under development) to utilize and leverage resources and funding opportunities as they arise.
2. Compile a map from local and expert knowledge on which to base a strategy for control. The map should include known hotspots/infestations and also catchment position and likely modes of dispersal. Infestations near waterways and roads should be a particular focus of the map.
3. Develop a prioritised weed control catchment plan incorporating input from landowners and plant pest experts.
4. Part of the control plan should include remediation options to transition the weed infested land to a favourable vegetation cover.

Useful resources

- Species-specific information on weed biology and control techniques – https://www.weedbusters.org.nz/what-are-weeds/weed-list/c/
- Northland Regional Council review of riparian setbacks science – https://www.nrc.govt.nz/media/yoxonnvq/riparian-setbacks-summary-of-the-science.pdf
- Northland Regional Council's guide to Northland's plant pests – https://www.nrc.govt.nz/environment/weed-and-pest-control/strategies-and-resources/a-guide-to-northlands-pest-plants/

- Northland Regional Council's Plant Pests information for schools – https://www.nrc.govt.nz/for-schools/school-information-packs/pest-plants/
- Northland Regional Council Pest Plants and Animals – https://www.nrc.govt.nz/resource-library-archive/environmental-monitoring-archive2/state-of-the-environment-report-archive/2011/state-of-the-environment-monitoring/our-land-our-air/pest-plants-and-animals/#What%20are%20the%20main%20pest%20species%20in%20Northland?
- Northland Regional Council's Regional Pest Strategy – https://www.nrc.govt.nz/media/uhudlio4/northlandregionalpestandmarinepathwaymanagementplan20172027.pdf

4.7 Option 6 – Tree establishment on podzol soils

1. To increase tree establishment success through species choice.

4.7.1 Site photograph(s)

Figure 11: Example of silica pan extracted from ridgeline podzol soils at the example location.

4.7.2 Context

Pre-human cover	Kauri forest.
Pests	Possums. Browsing stock are a threat where not excluded by fencing.
Seed sources and dispersers	Isolated from native seed source. Likely to be a limited frugivore disperser availability. Depleted soil seed bank.
Site factors	Podzol soils of the qualities: infertile, poorly drained including silica pan, variable moisture status. Exposed elevated coastal position.
Existing vegetation cover	Pastoral grazing. Landowner has struggled to establish trees.
Land stability	No apparent instability.

Disturbance from stream/river flows	Not relevant to this elevated site.
Climate change issues	20 to 30 more hot days (>25°C) by 2040, increased drought and thus wildfire risk, and also increased rainfall intensity and thus increased slip and erosion risk during rare extreme events (Pearce, 2017).

4.7.3 Option description

Overview

The example location is on the elevated pastoral hill country south of the intersection between State Highway 10 and Pekerau Road.

The landowner has struggled to establish and grow trees for amenity around their farm. The farm includes upper headwaters of the Lake Ohia and Aurere Stream catchments.

National scale mapping (New Zealand Soil Classification) indicates the soils of the example site are Densipan Podzols. Podzols are an order of soils (also known as gumland soils) which have formed under long-term kauri forest cover. Podzol soils form by leaching of the mild acid solution draining from acid leaves and bark of kauri trees. This acidic leachate has the effect of leaching nutrients and finer clay particles from the soil.

What remains from the leaching process are fine textured silica sands and silts which form a consolidated pan structure (Fig. 11). Topsoil is likely to be only 25-40 cm deep. The poorly drained, acidic soils have their own adapted plant community. One way of recognising members of this community is to look at which species commonly occur with kauri on their characteristically podzolized soils.

The approach for this option is to identify and prescribe trees and shrubs which are common kauri associates, and which are suitable for tree establishment in a pastoral setting.

Site preparation

1. Apply standard preparation for tree planting:
    - Appropriate site,
    - Appropriate grade,
    - Spot spray to reduce early competition.

Specific interventions

1. Select suitable shrub and tree species for podzol soils.
2. Monitoring progress and success and adapt establishment practices.

Target composition and structure

The following species are commonly found on podzol soils in association with kauri and are likely to be suitable to positions within the example location which have an element of exposure and are lacking forest interior microclimate.

Table 9. Species suitable for establishment and growth on podzolized soils.

Identity		Comments
Name	NVS Code	
Akeake	DODVIS	Widely distributed including coastal scrub
Gumland grass tree	DRASIN	Gumland scrub, seral vegetation, ridgelines
Halocarpus kirkii	HALKIR	With kauri, ridgelines, swampy hollows, gully heads
Kānuka	KUNERI	Widely distributed and can occur with kauri
Kauri	AGAAUS	Primary tree responsible for current soil conditions
Pittosporium ellipticum	PITELL	With kauri, ridges, slip scars, secondary forest
Pittosporium virgatum	PITVIR	With kauri, ridges, slip scars, secondary forest
Tall mingimingi	LEUFAS	Widely distributed and can occur with kauri
Tānekaha	PHYTRI	Can occur with kauri
Toru	TORTOR	Infertile soils, gumland scrub, ridges, slip scars
White maire	NESLAN	Slopes and ridges, riparian but not floodable sites

Management and maintenance

Post-planting management would include blanking and plant pest control. Monitor success and adapt management as necessary.

4.7.4 Implementation

Risks	• Challenging soil conditions for tree establishment and growth (acidic, poorly drained, infertile). • Invasion of the planting site by aggressive weed species. • Stock accessing planting sites. • Possum browsing.
Key advice points	• Select shrub and tree species which are naturally adapted to podzol soils and are normally associated with kauri forest. • Plant as normal but monitor success and adapt practice.
Resources needed	• Access to a range of kauri associate species as seedlings. • Resources for site preparation, planting and maintenance.
Avenues of support	• Likeminded community members. • Nurseries. • Biodiversity/landscaping contractors.

4.8 Option 7 – Rewetting wetlands and increasing wetland extent

Objective

1. To restore wetland hydrology and enable restoration of wetland extent and integrity.

4.8.1 Site photograph

Figure 12: View of Lake Ohia looking north from State Highway 10.

4.8.2 Context

Pre-human cover	Initially kauri forest (hence podzol/gumland) then lake/wetland with change in sea level. Drained in European times to current extent.
Pests	Possums. Wetland plant pests.
Seed sources and dispersers	Unclear over representativeness of existing cover as seed source.
Site factors	Peat and podzol soils. Hydrology altered by draining. Wetland extent altered in space and time. Human induced fires.

	Roading. Fringing pastural farming. Potential flooding.
Existing vegetation cover	Mānuka and gumland species.
Land stability	No apparent instability.
Disturbance from stream/river flows	Parts of the land are seasonally flooded.
Climate change issues	20 to 30 more hot days (>25ºC) by 2040 and thus increased drought and wildfire risk. Increased rainfall intensity and thus flooding, during rare extreme events and possible salinisation of the coastal aquifer at Taipa (Pearce, 2017).

4.8.3 Option description

The case study site Lake Ohia[13] is located at the base on the Karikari Peninsula and receives water in part from the Pekerau Valley to the south.

Prior to the end of the last ice age the site supported kauri forest. With the end of the ice age sea levels increased and the site formed into a shallow lake. With European arrival and the rise of the kauri gum trade, pressure came on Lake Ohia for its historical kauri resources. The lake was drained around 1900 for harvesting of kauri gum. The site has repeatedly burned from human-induced fires. Two public roads have been constructed near the site (Inland Road and Lake Ohia Road) and pastoral farming is the adjacent land use. Harakeke was extensively harvested historically.

The wetland hydrology has been impacted through drainage and standing water only occurs for approximately 2 months of the year. Today Lake Ohia supports several threatened plant and animal species, making the site ecologically sensitive.

The option proposes restoration (either partly or fully) of Lake Ohia's wetland hydrology. This is a complex proposal needing to be more fully investigated. Some factors needing investigation are:

- Restoration potential,

[13] We note however that there are existing and drained (historical) wetlands located throughout the catchment in a range of sizes. These wetlands would be considerably less challenging to restore than Lake Ohia but nonetheless offer a significant suite of 'ecosystem services' (e.g., increased biodiversity, water quality improvement) that contribute to increased resilience to climate change. Having restored wetlands dispersed and functioning throughout the catchment (from the headwaters to the sea) in itself contributes to resilience by providing numerous small-scale interventions that are a feature of Nature-based Solutions.

- Cultural perspectives,
- Land use perspectives,
- Wildlife vulnerability and benefits,
- Hydrology assessment,
- Infrastructure assessment (e.g., roads, drainage networks, other).

Wetland ecosystems present critical opportunities to mitigate the adverse effects of climate change, such as buffering floods and coastal inundation, sequestering and storing atmospheric carbon while supporting biodiversity. Draining wetlands, particularly peat wetlands, results in the release of carbon to the atmosphere. Re-wetting wetlands is an aspect of wetland restoration which when carried out correctly yields a range of climate and nature benefits (RAMSAR, 2021).

The Ministry for the Environment's National Policy Statement for Freshwater Management (NPS-FM) requires Regional Councils to amend their plans to provide for and promote the restoration of natural inland wetlands with a particular focus on restoring the values of ecosystem health, indigenous biodiversity, hydrological functioning, Māori freshwater values and amenity values (MfE, 2024, p. 27). The National Policy Statement for Indigenous Biodiversity (NPS-IB) requires local authorities to promote the restoration of 1) threatened and rare ecosystems representative of naturally occurring and formerly present ecosystems, and 2) natural inland wetlands whose ecological integrity is degraded (NPS-IB 2023, p. 28). These national policies show this proposal to re-wet Lake Ohia is consistent with national policy direction regarding wetland and indigenous biodiversity management.

Two critical factors in wetland restoration are 1. understanding the hydrology of the site and 2. establishing clear goals for the restoration. As described above, Lake Ohia offers many opportunities including addressing different goals in different parts of the complex. For example, flood mitigation, water treatment, native species restoration (e.g., rare bird habitat), and carbon sequestration could be prioritised in different sections. Often multiple goals can be addressed at once. Establishing goals for the site will require a well-planned, collaborative, deliberative process involving all relevant stakeholders.

<u>Specific interventions</u>

There are a wide range of long-term interventions that could be undertaken guided by restoration goals for example:

- Hydrological interventions to support flood mitigation and keep roads safe during storms.

- Wetland engineering to support water quality treatment for the lower Awapoko, and water storage in some areas to improve wetland habitat, particularly during hot and dry weather – thus improving resilience to climate change.
- Wetland plantings that reflect climate projections (e.g., salinisation, drought) and address cultural, environmental and economic aspirations as much as possible.
- Recreation of natural habitats based on locally relevant plant communities (e.g., kauri, raupo, harakeke),
- Create economic opportunities which fit with restoration interventions.

Understanding management needs and long-term maintenance costs needs to be part of the deliberative process.

4.8.4 Implementation

Risks	• Need to negotiate multiple interests, collaboratively develop a long-term plan, including approaches for management and governance. • Invasion of the planting sites by aggressive weed species. • Grazers/birds accessing planting sites (need to plant with pukekos etc. in mind). • Fire risk. • Coastal salinisation.
Key advice points	• Plant to achieve goals (e.g., water treatment/open water/flood mitigation). • Plant with understanding of long-term predictions for water quality (e.g., saline?) and quantity.
Resources needed	• Hydrological expertise. • Wetland restoration expertise. • Fencing/boardwalk materials and labour. • Materials and labour for site preparation, planting and maintenance.
Avenues of support	• Likeminded community members. • Ecologist(s) and researchers for information about known ecological values and advice on options and considerations. • Nurseries. • Biodiversity/landscaping contractors. • Manaaki Whenua Wetland Restoration expertise & resources[A].

[A] https://www.landcareresearch.co.nz/publications/wetland-handbook-series/

4.9 Option 8 – Naturalising drainage networks and riparian habitat

1. To naturalise drainage networks and legacy riparian cover to increase water retention and create aquatic habitat diversity.

4.9.1 Site photograph(s)

Figure 13: (Top) View of channelised drainage network with exotic vegetation in the riparian zone, (Bottom) channelised drainage network lacking valuable wetland and riparian habitats.

4.9.2 Context

Pre-human cover	Podocarp forest.
Pests	Possums. Tobacco weed.
Seed sources and dispersers	Both seed sources and dispersers are limited in their occurrance.
Site factors	Potential bank instability. Potential soil compaction from channelisation and grazing.
Existing vegetation cover	Exotic pasture grasses, poplar, tobacco weed.
Land stability	Potential bank instability.
Disturbance from stream/river flows	Suffers from inundation and flooding.

4.9.3 Option description

Overview

The example location for this option is the lower Pekerau valley, on the flats south of the intersection of State Highway 10 and Pekerau Road.

Local residents report flooding in the unnamed streams of the area. Often flood waters rise rapidly and vehicle access could be cut off to properties for a day or more.

Along much of the valley the natural drainage network has been channelised to allow for pastural farming. Flows have been diverted from wetlands to drains which has reduced water retention in the landscape.

The current vegetation cover is a function of forest clearance, pastural land use and historical decisions over tree species planting. The main tree species along drains are planted poplar, pines, and eucalyptus. These species appear to have been a popular choice on the flats as they occur throughout many parts of the study area. The combined effect of removing original forest cover, modifying the drainage network, and planting a small diversity of exotic trees at low densities has had the effect of homogenising these waterway habitats.

The site would once have supported biologically diverse podocarp forest, most likely with strong swamp forest components such as kahikatea, mātai, pukatea, and maire tawake.

Figure 13: Example of a multi-cell wetland prior to planting. By creating multiple cells with a serpentine design, the bund height between cells is kept to a minimum. The design allows treatment of three major drain/stream inputs as well as runoff from the raceways. Use of curved edges to the wetland cells creates a natural appearance. Note also Figure 14.

Figure 14: The same wetland shown in Figure 13 after four years of plant establishment. The landowners have also done extensive planting around the wetland margins.

Figure 14: Example of constructed wetland creating hydrological functioning and indigenous habitat. Reproduced from Tanner et al. (2021).

The option is to reshape the drainage network to rebuild sinuous waterway alignments, liven and reconnect former wetlands, and create new wetlands (see Fig. 14 reproduced from Tanner et al. (2021)). Recreated features would be planted with appropriate native riparian cover to support stream functioning. Reintroducing and constructing wetlands can also contribute significantly to water quality improvements, and flood mitigation.

<u>Target composition and structure</u>

The riparian planting composition would be as per Table 4 with the addition of the swamp specialists maire tawake and pukatea in the enrichment phase.

Restored wetlands should be repopulated based on the vegetation class appropriate to the specific wetland type on a case-by-case basis. Constructed wetlands should be vegetated according to the zonation as described in Table 10.

Table 10. Species for planting into constructed wetlands – with depth zonation

Constructed wetland planting		Depth range
Name	NVS Code	
Giant umbrella sedge	CYPUST	0-0.2
Harakeke	PHOTEN	Margin
Jointed baumea	MACATC	0-0.4
Kuta	ELESPH	0.2-0.6
Lake clubrush	SCHTAB	0-0.4
Purei	CARSEC	0-0.2
Purua grass	BULFUL	0-0.3
Raupo	TYPORI	0-0.4
Rautahi	CARGEM	0-0.2

4.9.4 Implementation

Risks	• Naturalising the drainage network will require some amendments in land use configuration. Such as allowing room in paddocks to build channel sinuosity or space for wetland creation/recreation. • Ideally naturalising features would be planned at the subcatchment scale and it is possible that not all landowners in the same subcatchment would work collaboratively meaning some work happens in isolation.
Benefits	• While functioning as a flow mitigation and water treatment 'device' constructed wetlands can add considerable aesthetic appeal. • Constructed wetlands increase plant and animal diversity (e.g., birds) on the property. • Compared to other water treatment devices/options, constructed wetlands have higher up-front costs but are lower maintenance in the long-term, with more co-benefits (Tanner et al. 2022).
Key advice points	• Check requirements for resource consents for works in or modifications of streams and wetlands. • Identify natural locations and alignments and consider using those features as a basis for naturalisation. • Seek input from people experienced in waterway or wetland related design and construction.
Resources needed	• Advice on resource consenting requirements. • Advice on design and construction of naturalised features. • Fencing and planting materials and labour.
Avenues of support	• Northland Regional Council (wetland team).

	• Department of Conservation (Nga awa programme, native wetland species plant supply). • Technical documents on constructed wetlands (see Tanner et al., 2021; Tanner et al., 2022). • New Zealand Wetland Trust. • Experienced earthworks contractors. • Native plant nurseries.

4.10 Option 9 – Management of existing native forests

Objective

1. To manage existing forests so they are self-sustaining and resilient to climate change.

4.10.1 Site photograph(s)

Figure 15: (Top) Seral and (Bottom) mature forest stands in the Ōtangaroa Forest, accessed via Tipatipa Road and near the highpoint Maungahotoa. Location in the upper Kenana and Wainui Rivers, respectively.

4.10.2 Context

Pre-human cover	Kauri/taraire-kohekohe-tawa forest
Pests	Possums, goats, deer. Mammalian predators. Various plant pests. Stock when not excluded by fencing.
Seed sources and dispersers	In mature forest seed sources are normally immediately available in the canopy and these sites serve as a propagule dispersal to adjacent areas. Aspects of species diversity might be missing from seral forests.
Site factors	Higher-elevation, more remote lands less suitable to pastural farming.
Existing vegetation cover	The main seral canopy appears to be kānuka. Mature forests were kauri with kauri associates. Gullies are sites suited to higher levels of podocarp dominance.
Land stability	Modelling suggests significant areas of native cover occur on soils vulnerable to erosion.
Disturbance from stream/river flows	Overall not relevant to hill country forests.
Climate change issues	20 to 30 more hot days (>25^{o}C) by 2040, increased drought and thus wildfire risk, and also increased rainfall intensity and thus increased slip and erosion risk during rare extreme events (Pearce, 2017).

4.10.3 Option description

<u>Overview</u>

The example location is the Ōtangaroa Forest which is part of a significant semi-continuous area of native forest spanning to the southwest along the Maungataniwha Range into the Maungataniwha Forest and further still the Raetea and Herekino Forests.

Climate change temperature rises will increase forest threats with increased weed growth rates plus increased pest breeding rates taking a toll on native forest canopy and fauna. The focus of the option is management to address threats and to ensure forest integrity is achieved/maintained, and forest regeneration and succession occurs.

In terms of achieving key project objectives, management of existing forest is a highly favourable option as the biodiversity and carbon is already in place, as is the stabilising effect of root systems on erodible soils.

Specific interventions

1. Browser control. Potential species needing to be addressed are possums, goats, pigs and feral cattle, potentially also deer where they are illegally released. Coordinated landscape scale control of these animals is preferable to spatially isolated control.
2. Plant pest management. Priority species will be specific to any given stand of native forest. Intact native forests are likely to be at threat of shade-tolerant rather than light-demanding weeds. Seral forests may contain legacies of past land use phases such as conditions created by exotic conifer plantation clear-fell or retirement of pastoral land. Weed issues in disturbed sites can be a major issue for management.
3. Predator control. Where feasible, coordinated control of predators can benefit populations of native fauna and aspects of fauna such as fruiting and viable seed biomass. Possums first arrived in these northern native forests in late 1970's and they breed at high rates in the warm climate. Canopy collapse of mature species such as Northern rata, taraire and puriri has been noted where control Is lacking.
4. Stock exclusion. Native forest in farming systems should be retired from grazing to secure forest permanence. Continuous grazing of native forest presents a serious threat to maintaining project objectives over time. Biodiversity and carbon stocks would decline with time. Grazed forests are likely to become carbon sources rather than carbon sinks. Soil erosion is likely to increase and become adverse as forest cover diminishes.
5. Legal protection. Securing legal covenants over areas of native forest to ensure their management is for conservation purposes and is intergenerational and maintained across landownership changes. Examples of conservation covenants are Ngā Whenua Rāhui (although this programme is closed due to being oversubscribed) and QEII National Trust/Ngā Kairauhī Papa.
6. Enrichment planting. Planting of representative locally extinct species or those that are likely to be very slow to re-join the forest composition can help direct successional pathways.
7. Enrichment planting may need to be coupled with small-scale stand level interventions (gap creation through pruning or felling) to achieve suitable site conditions for enrichment planted seedlings.

Target composition and structure

In terms of meeting the project objectives, and the forest types naturally occurring within the project area, the target composition for management of existing forests should be old growth/mature phase kauri or podocarp-broadleaved forest species. Composition will vary by site however existing remnants and pre-human compositions provide targets for restoration. These species tend to be high volume (tall and single stemmed) and support high levels of biodiversity and ecological functionality. Old growth forests also provide the greatest level of land stabilising.

Management and maintenance

While management of existing forests will benefit from a landscape-scale planning approach, a smaller-scale approach to assigning responsibility for ongoing management and maintenance might be more effective. In other words, catchment management groups may wish to focus on a particular sub-catchment that is a size and location that is practical for them to take responsibility for.

4.10.4 Implementation

Risks	• Inadequate levels of support for landowners to effect management such as retirement from grazing or stock proof fencing. • Browsing mammals uncontrolled. • Plant pest invasions and increases in biomass. • Pathogens such as kauri dieback. • Conversions from native to agriculture or plantation forestry. • Disturbing effects of extreme weather events. • Wildfire.
Key advice points	• It is more efficent to maintain existing forests than establish new native forests from scratch. • Existing forests already contain biodiversity and carbon stocks and therefore their maintenance and management must be prioritised. • Maintaining existing forests boosts forest resilience at the landscape scale in terms of disperser habitats, seed sources, and ecological functionality. • Maintaining intact forest canopy helps maintain a forest microclimate and increases resilience to the effects of drought.
Resources needed	• Management requires adequate levels of technical and financial support. • Skills and resources to implement management interventions such as pest control or enrichment planting. • Collaboration among individuals at catchment scales to help achieve outcomes at scale.
Avenues of support	• Likeminded community members. • Nurseries. • Biodiversity/landscaping contractors. • Regional Council.

	• Department of Conservation. • Queen Elizabeth II National Trust.

4.11 Option 10 – Working with available incentives to increase native forest cover

Objective

1. To use existing markets and Council incentives to help support native forest establishment and management.

4.11.1 Site photograph(s)

Figure 16: Native forest registered in the ETS and returning an income from carbon sequestration.

4.11.2 Context

Pre-human cover	Kauri forest.
Pests	Possums. Browsing stock are a threat where not excluded by fencing.
Seed sources and dispersers	Adjacent native seed sources. Likely to be a limited frugivore disperser availability. Depleted soil seed bank.
Site factors	Hill country.
Existing vegetation cover	Kānuka forest.
Land stability	No immediate instability issues.
Disturbance from stream/river flows	Not relevant to this elevated site.

Climate change issues	20 to 30 more hot days (>25ºC) by 2040, increased drought and thus wildfire risk, and also increased rainfall intensity and thus increased slip and erosion risk during rare extreme events (Pearce, 2017). The ETS incentivises carbon storage and thus mitigation of climate change. Increased afforestation will increase the resilience of the catchment to climate change.

4.11.3 Option description

Overview

A Peria landowner (with the help of a professional carbon consultant) registered 32 ha of regenerating native forest in 2018 into the New Zealand Emissions Trading Scheme to earn financial payments for the carbon sequestered.

This revegetation option relies on regeneration of native forests which can be achieved in some landscapes if local seed trees are nearby, and grazing animals are fenced out and pests are managed. There are ecological, catchment and some financial benefits to retiring hill country for native revegetation. The land is QEII reserved, which provides funding opportunities for fencing, pest control, and maintenance. As the land is reserved, the Far North District Council (FNDC) offers rates relief.

All land that was bare in 1990 and is now 'in trees' is eligible for registration to receive carbon credits. Native forest is a sound long-term solution.

As the registered forest is <100 ha, the carbon yield upon which payments are made is based on the MPI native lookup table. This table gives estimates of biomass over time for native forest growth rates in New Zealand.

The forest is aged 18-24 years and was registered from 2013. Over the first 5 years following registration the native regenerating forest returned 1761 units which equated to an average of 10.73 units/ha/year. Carbon prices varied from $24 - $75 per unit from 2017 - 2022 = a return of $257 - $804 ha/year. The carbon price has fluctuated in recent years and is currently $45.50 per unit as of 29 May 2024.

Management of the forest since 1990 has involved on-going possum pest control for a continuing healthy native forest canopy cover. The registered land is also part of the 2,000 ha Honeymoon Valley Landcare Charitable Trust project area, established in 2015 which now also neighbours and supports the larger 7000 ha Mangamuka Honeymoon Valley Maungataniwha Otangaroa Kiwi Corridor project[14].

4.11.4 Implementation

Risks	• This option requires the permanent retirement of land from stock grazing which means a change of the farming regime. • This option requires a permanent commitment to native forest cover as liabilities exist where the land is modified to no longer meet MPI's Forest Land[15] definition.
Key advice points	• Registration of regenerating native forest is an option to yield income where the native forest is intended to be permanent. • Start by looking for land areas that did not meet the MPI Forest Land definititon at 1990 but do post 1990. Retrolens[16] is a good source of historical aerial photographs to help with identifying the forest status of land around the time of 1990. • Seek specialist advice from a professional carbon consultant.
Resources needed	• Evidence of forest status at 1990 (e.g., historical aerial images, photographs). • Carbon consultant's input to confirm eligibility and to carry out registration. • Advice on forest management needs (e.g., specific pest control methods).
Avenues of support	• Carbon consultant. • Forest restoration and management specialists. • Likeminded community members. • Biodiversity/landscaping contractors. • Regional Council. • Department of Conservation. • QEII National Trust. • FNDC rates relief.

[14] See https://honeymoonvalleylandcare.org.nz
[15] See https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/about-forestry-in-the-emissions-trading-scheme-ets/how-forest-land-is-defined-in-the-ets/
[16] See https://retrolens.co.nz

4.12 Option 11 – Management of retired land

Objective

1. To shift the compositional trajectory towards diverse native forest cover – particularly in riparian or small to moderate blocks assessed as less profitable/suitable for plantation forestry.

4.12.1 Site photograph(s)

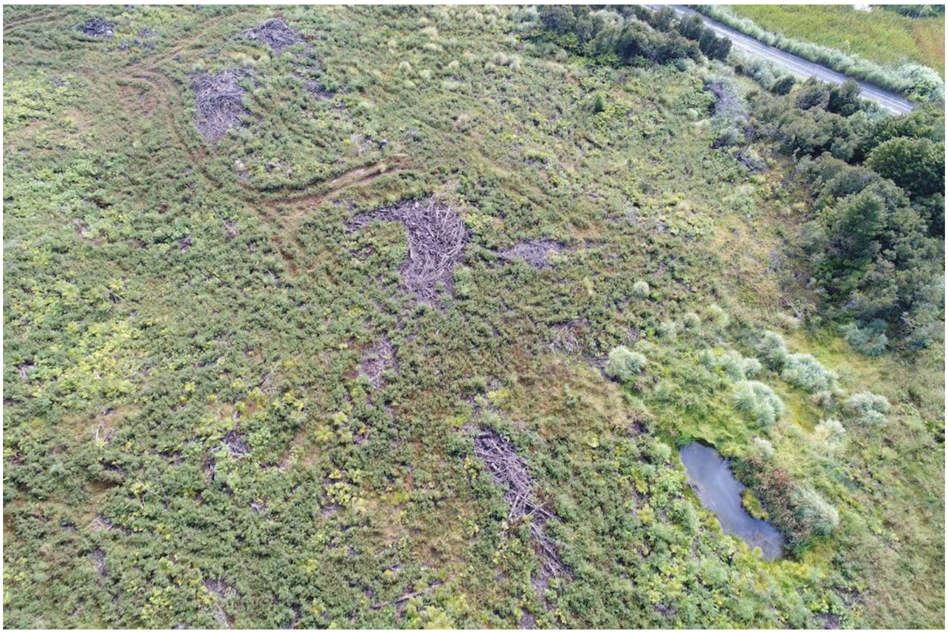

Figure 17: (Top) Paranui valley with remnant alluvial forests (kahikatea dominated) riparian to the Paranui stream and interspersed with ex-plantation clear-fells not intended to be restored and not replanted in pines. (Middle) Gorse stand with mixed native and exotic regeneration (Bottom) wider view of the clear-fell.

4.12.2 Context

Pre-human cover	Podocarp forest.
Pests	Possums. Various plant pests of differing levels of threat.
Seed sources and dispersers	Low to excellent proximity to seed sources. Presumed to be adequate disperser availability. Depleted soil seed bank.
Site factors	Flat-rolling alluvial surface. History of plantation clear-fell. Variable slopes and aspects.
Existing vegetation cover	Highly variable and mostly exotic dominated. Dominant species include gorse, tobacco weed, pampas, privet. Native ferns (ground and tree), cabbage tree also present. Sites are often adjacent to riparian buffers required in plantation forestry. The buffers provide a seed source and add value to the regeneration by forming corridors of mature native vegetation cover.
Land stability	No apparent instability issues.

Disturbance from stream/river flows	Most of the site is above the flood zone.
Climate change issues	20 to 30 more hot days (>25°C) by 2040, increased drought and thus wildfire risk, and also increased rainfall intensity and thus increased slip and erosion risk during rare extreme events (Pearce, 2017).

4.12.3 Option description

Overview

The example location is the Paranui stream accessed from Paranui road.

The option involves minimum-interference management[17] of the clear-felled lands. The main management inputs are removal of shade-tolerant and structurally dominant weeds and limited enrichment planting to establish local seed sources. The basic philosophy is to remove weeds that will take over and allow other weeds to outcompete each other and provide a nursery for longer-term regeneration by native species. The reasons for this approach are the high regeneration potential of the site and the high cost of planting and managing planted natives in this remote and weedy environment. Most of the site is in gorse and with the site's rainfall and seed source proximity, regeneration by natives under maturing gorse is quite certain over the next 10-15 years.

Specific interventions

1. Assess weed species present and prepare a plan for which weeds to control and which to leave in place. Examples of weeds needing control would be wilding pines, privet, and tobacco weed. Examples of weeds that can be left in place and beaten through competition are pampas and gorse.
2. Control those weeds with low disturbance techniques such as manual pulling of pine seedlings or cut-and-paste option of woody weeds. The point of avoiding disturbance is to minimise opportunities for establishment of weeds on disturbed sites.
3. Plant seed islands of native trees on suitable sites which are accessible for maintenance. Seed islands could also make use of gorse cover by planting into existing gorse, into managed clearings of cut strips through the gorse cover. The purpose of the enrichment

[17] Minimum-interference management means the removal of the most deleterious factors militating against natural regeneration and restoration such as exotic herbivorous animals, fire, aerially sprayed herbicides and a few seriously invasive weeds – and watching nature run her fascinating course (Hugh Wilson, https://bts.nzpcn.org.nz/site/assets/files/22595/cant_2003_37__25-41.pdf).

planting is to reintroduce local seed sources for future regeneration processes to propagate out across the wider restoration site (Table 11).

Target composition and structure

The composition would be initially formed from whichever species have managed to regenerate following clear-fell. Problematic weeds would be removed, and gradually native species will enter the succession via seed rain from adjacent forest or on a smaller scale via enrichment planting.

Table 11. Seed island enrichment planting species list

Enrichment planting species	
Name	NVS Code
Hīnau	ELADEN
Horoeka	PSECRA
Houhere	HOHPOP
Kahikatea	DACDAC
Māhoe	MELRAM
Maire tawake	SYZMAI
Mataī	PRUTAX
Miro	PECFER
Pāte	SCHDIG
Porokaiwhiri	HEDARB
Pukatea	LAUNOV
Pūriri	VITLUC
Rewarewa	KNIEXC
Rimu	DACCUP
Tānekaha	PHYTRI
Taraire	BEITAR
Tawa	BEITAW
Titoki	ALEEXC
Tōtara	PODTOT
Towai	PTESYL

Management and maintenance

Post-planting management would include ongoing control of the specified problem weed species, planting and maintenance of the enrichment planted seedlings (e.g., release weeding, protection from browsers, and potentially manipulation of the surrounding canopy to optimise seedling growth rates).

4.12.4 Implementation

Risks	• Weed control results in high levels of site disturbance which provides site conditions which favour regeneration of more undesirable weed species. • Problem weeds are not controlled to adequate levels and are retained in the succession going forward, impacting the restoration outcome.

	• We note that gorse stands present a wildfire risk but at this site it is most efficient to work with the gorse (as a nursery crop that protects the native seedlings) rather than attempting removal.
Key advice points	• Carefully prioritise which weed species absolutely must be removed from the composition, versus those that can be overcome with time and competition. • Strive to eradicate aggressive weeds from the site before planting using low disturbance control methods. • Enrichment plant in seed islands and locate the islands in ecologically suitable but readily accessible sites for maintenance. Locate species according to any particular microsite preferences and undertake physical modification of the pioneer stand by pruning or felling where needed.
Resources needed	• Pest control expertise, labour and funding. • Seedlings for enrichment planting.
Avenues of support	• Nurseries. • Biodiversity/landscaping contractors.

4.13 Option 12 – Culturally/socially centred riparian restoration in key areas

Objective

1. To create an indigenous riparian composition resilient to flooding disturbance and highly desirable from cultural and amenity perspectives to support a key area used for grazing and recreation by locals and the nearby Marae.

4.13.1 Site photograph(s)

Figure 18: (Top) Riparian conditions downstream and (Bottom) upstream of the Kenana Road crossing of the Kenana River, in the Oruaiti catchment.

4.13.2 Context

Pre-human cover	Podocarp forest.
Pests	Wild ginger, crack willow, tobacco weed, possums.
Seed sources and dispersers	Native seed sources are on surrounding hills but not immediate to the riparian zone.
Site factors	Flat alluvial surface (floodplain) containing the Kenana river. Grazed including with horses.

Existing vegetation cover	Pasture grasses with patches of tobacco weed, and wild ginger. The stream banks feature crack willow.
Land stability	Possible bank instability.
Disturbance from stream/river flows	Frequent flooding. Floodwaters leave channel spreading across adjacent floodplain.

4.13.3 Option description

Overview

The example location is the Kenana river accessed from Kenana Road. The site is the area around the road crossing of the Kenana river a short distance downstream of the marae location.

The option involves removing weeds and reinstating the area in pasture with amenity grade seedlings in tall stock-protector sleeves. The option aims to achieve a native treeland which can withstand flooding and continued grazing, help stabilise soils, offer shade, host native birds to this high use recreation area. The site is used for swimming so maintaining good access to the awa and providing shade and shelter is also important. If the site is also used for mahinga kai collection (e.g., wātakirihi/watercress, kēwai/freshwater crayfish) excluding stock from some riverbank areas would promote water quality and increase food desirability and safety.

Specific interventions

1. Remove weed stands and crack willow from the floodplain.
2. Plant amenity grade (i.e., greater than 2 m tall) native trees in clusters and wide spacing across the riparian zone.

Target composition and structure

The composition would be species that meet at least most of the following criteria:

- Are adapted to riparian zones;
- Do not need the shelter of surrounding vegetation, and;
- Are of lower palatability and relatively fast-growing to grow out of the browse tier rapidly.

Table 12. Species for riparian cultural/amenity planting of the Kenana river riparian zone near Kenana Marae.

Cultural/amenity planting	
Name	NVS Code
Harakeke	PHOTEN
Kahikatea	DACDAC
Kānuka	KUNERI
Kōwhai	SOPMIC
Mataī	PRUTAX
Pōhutukawa	METEXC
Pūriri	VITLUC
Tī kōuka	CORAUS
Tōtara	PODTOT

Management and maintenance

Post-planting management would include releasing and maintaining the plant guards. Some fencing or animal control measures to limit stock and horses accessing the seedlings is likely to help growth and survival. Follow up maintenance of problem weed species will be necessary on an ongoing basis.

4.13.4 Implementation

Risks	• Stock and horse damage of planted seedlings. • Floodwaters may damage planted seedlings, especially when they are in their early stages of growth.
Key advice points	• Control problem weeds before planting natives. • Weeds will be ongoing and need ongoing maintenance. • Select amenity grade seedlings/saplings and use tall plant protectors to shield the seedlings from stock. • Some temporary exclusion of stock to the seedlings is likely to aid establishment and early growth.
Resources needed	• Resources for weed control, site preparation, planting and maintenance. • Materials and labour for temporary fencing.
Avenues of support	• Local community/marae members. • Nurseries. • Biodiversity/landscaping contractors.

	• Tangata Whenua and Catchment[18].

[18] Offered through Tangata Whenua and Catchment Engagement Team (contact: Warren Morunga)
Tangata whenua groups and catchment/community groups who do not fit the traditional 'landowner' criteria.

5. ILLUSTRATIVE CASE STUDIES

5.1 Lower Oruru receiving catchment

The receiving catchment area, draining the lower *c.* 8-km of the Oruru river from about the fork of the Oruru and Dangen Roads at the upper end to where the Oruru River begins to widen into the Taipa estuary at the lower end, provides an example typical of lowland areas of this region.

5.1.1 Characteristics and current conditions

This catchment area (Figs. 19 & 20) is characterised by:

- A mix of indigenous and exotic woody vegetation cover in extensive parts of the upland areas of this catchment and a predominance of intensive livestock farming (dairy and beef) on the alluvial terraces (Fig. 19A).
- Relatively high receiving catchment vulnerability concerns (bottom left pane in Fig. 19B), driven by relatively low existing stream water quality (MCI levels), extensive and frequent flooding, and relatively low levels of riparian vegetation coverage and ecosystem protection.
- Relatively moderate headwater vulnerability concerns, mostly located in the lower half of this receiving catchment and related largely to higher slope gradients and proneness to erosion, combined with possible implications of exotic forestry operations in certain locations (Fig. 19C).
- A wide, flat riparian zone along the length of the whole catchment characterised by dynamic river behaviour (high levels of streambank erosion) and a wide flood zone area that is largely aligned with recommended stock-exclusion/management zones (MfE 2022); coastal inundation is also predicted to extend inland along the first 200-m of the Oruru due to climate change impacts on sea level rise, tides, etc. (Fig. 20A).
- The predicted occurrence of a significant wetland complex in the lower parts of this catchment prior to human arrival and modification (Fig. 20A).

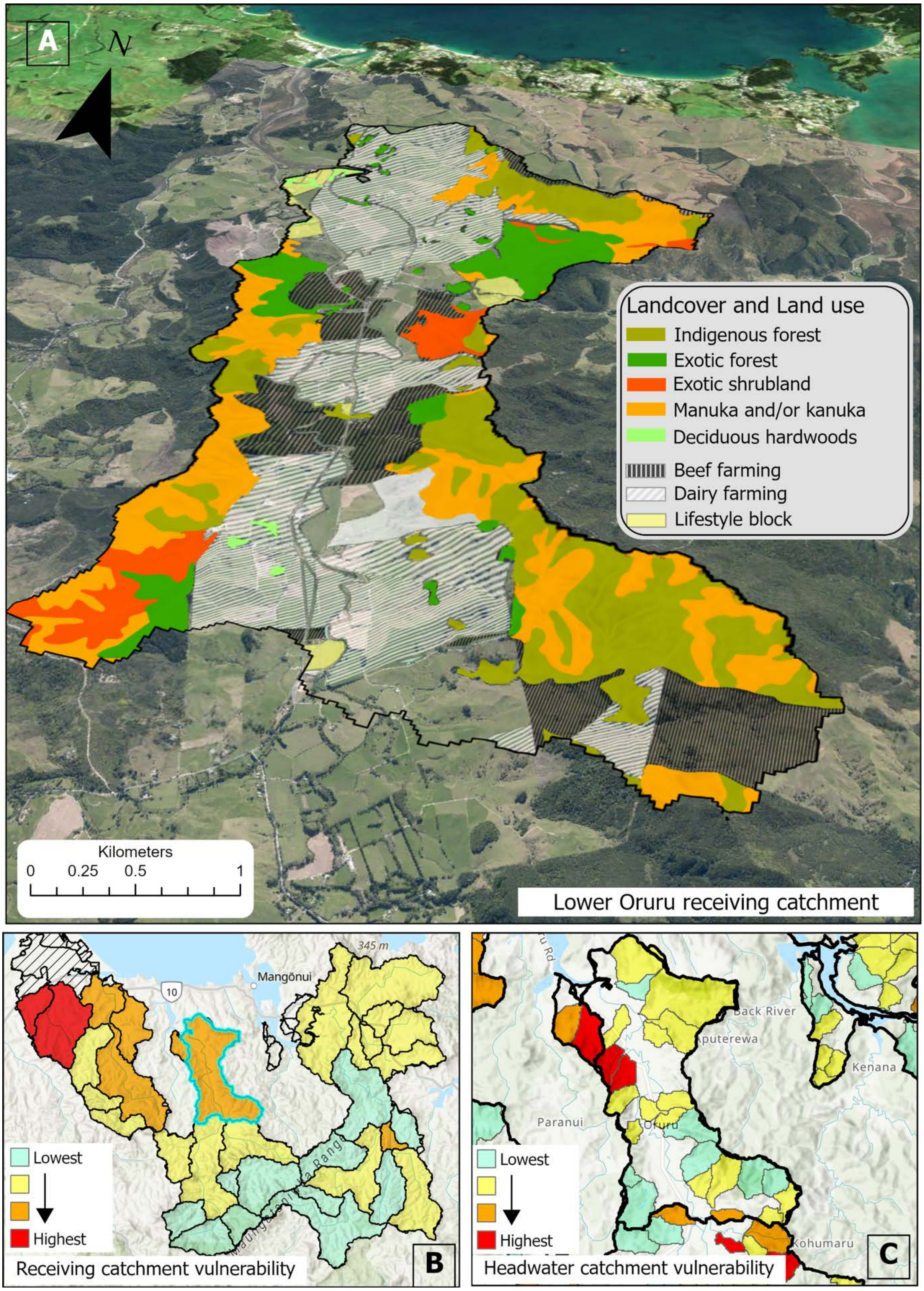

Figure 19: Distribution of woody vegetation types and dominant land uses in the Oruru receiving catchment. Receiving (B) and headwater (C) vulnerability rankings from the GIS-based analysis.

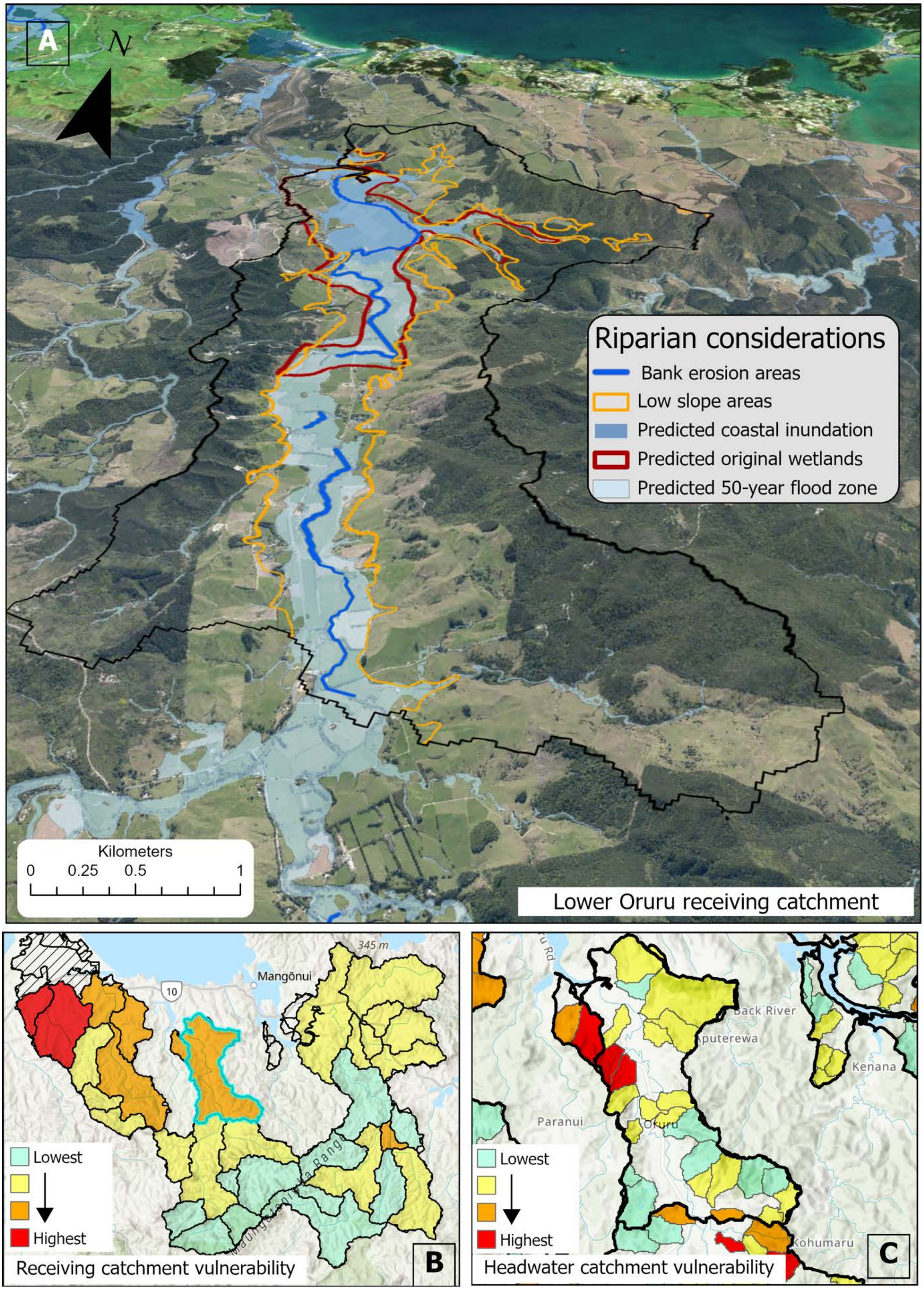

Figure 20: (A) Riparian-related factors and considerations in the Oruru receiving catchment. Receiving (B) and headwater (C) vulnerability rankings from the GIS-based analysis.

5.1.2 Assessment

This is a long, narrow catchment (only about 2.1-km in width at its narrowest point) with relatively short and steep slopes along the east/west valley sides. Thus, while much of the upland area of the catchment is covered in woody vegetation, the narrowness of the catchment, potential for fast hillslope runoff into the Oruru, combined with large, relatively unvegetated alluvial terrace areas in the river valley, likely contributes to the significant flooding potential along the whole length of the catchment. Coupled with relatively intensive land use on the alluvial terrace and lack of riparian vegetation and management, the risk of bank erosion and sedimentation is high, and the stream biodiversity condition and water quality are consequently being compromised.

Lowland ecosystems in New Zealand, from a biodiversity perspective, lack protection and representation and have been modified extensively from their original state in most parts of Aotearoa (Walker et al. 2005). For example, this catchment would have originally comprised a mixture of wetland ecosystems and a mixture of kauri and riverine kahikatea forest ecosystems (as per Singers & Rogers 2014). The knock-on effect of removing representation of original ecosystems in any lowland catchment is a decrease in overall resilience - the ability to absorb and recover from the impacts of events like heavy rainfall - and a serious compromising of river health, biodiversity, and indigenous species habitat (e.g., for īnanga spawning).

5.1.2 Ideas for building ecosystem resilience under climate change

Multi-use lowland landscapes, as exemplified by the lower Oruru catchment area, present a range of climate adaptation challenges with respect to potential ecological, socio-cultural, and economic factors and trade-offs. Ultimately, how and where interventions can and should be made to build resilience needs to be based on sound scientific evidence, but realistically can only happen via community/landowner collaboration and motivations and with adequate resourcing. Combining the GIS-based evidence and treatment options presented in this report, opportunities to build climate resilience, enhance biodiversity, and improve stream condition in this landscape area could be considered (e.g., Table 13) using landscape and local scale thinking, planning, and testing of interventions. Each opportunity would need to be considered from a range of perspectives and ranked in terms of priority and the likelihood for it to be practically achieved. Further, it is useful to consider such opportunities in a stepwise or staged manner, where intervention locations could be prioritised and scheduled over a longer timeframe to increase the likelihood of success.

Table 13. Examples of resilience interventions for climate adaptation and resilience enhancement in the Oruru receiving catchment: potential benefits, priorities, and challenge levels. These types of interventions should be considered and planned in a stepwise manner, from the highest to lowest priority locations, and contingent on resources and level of buy-in from the community and landowners.

Resilience intervention	Resilience benefits	Priority	Challenge
Institute a 5 to 20-m riparian no-farm zone (native vegetated buffer) along riverbank edge for Oruru and main feeder streams. (Treatment options 1, 3, 5, 8, 12)	- Enable natural river behaviour - Flood and erosion mitigation - Enhancement of water quality and stream conditions - Enhance native biodiversity (terrestrial and stream) and habitat	High	High
Reestablish wetland in lower Oruru river zone (Treatment options 1,5,7)	- Coastal flooding protection - Enhance native biodiversity - Decrease sedimentation issues in Taipa estuary - Enhance water quality and habitat	Moderate to high	High
Native re-vegetation of all headwater catchment areas, particularly those prone to erosion on the western side of the valley (Treatment options 2, 3, 4 & 8)	- Enhance native biodiversity - Decrease runoff - Increase carbon sequestration	High	Low to moderate
Accelerate successional development of indigenous and exotic shrubland in headwater catchments and other hillside areas via enrichment planting with late-successional native species (Treatment options 4, 9)	- Enhance native biodiversity - Decrease runoff - Increase carbon sequestration	Moderate	Moderate
Conversion of exotic forests to indigenous forests (Treatment options 10, 11)	- Biodiversity enhancement - Decrease harvesting effect	Low	Moderate to high

5.2 Landscape flammability potential in the Doubtless Bay catchment

Wildfire risk in mixed-use landscapes typified by the Doubtless Bay catchment is related to the distribution of flammable woody material across the landscape (Pagadala et al. 2024). Indeed, we have seen examples of these types of wildfire events playing out in parts of Aotearoa over recent years. It is therefore of interest to consider landscape flammability in the context of climate resilience and adaptation in the Doubtless Bay catchment.

5.2.1 Characteristics and current conditions

A considerable portion of the Doubtless Bay catchment is covered by various types of woody vegetation with different associated levels of flammability (Fig. 21). The distribution of flammable material provides a baseline for assessing wildfire risk.

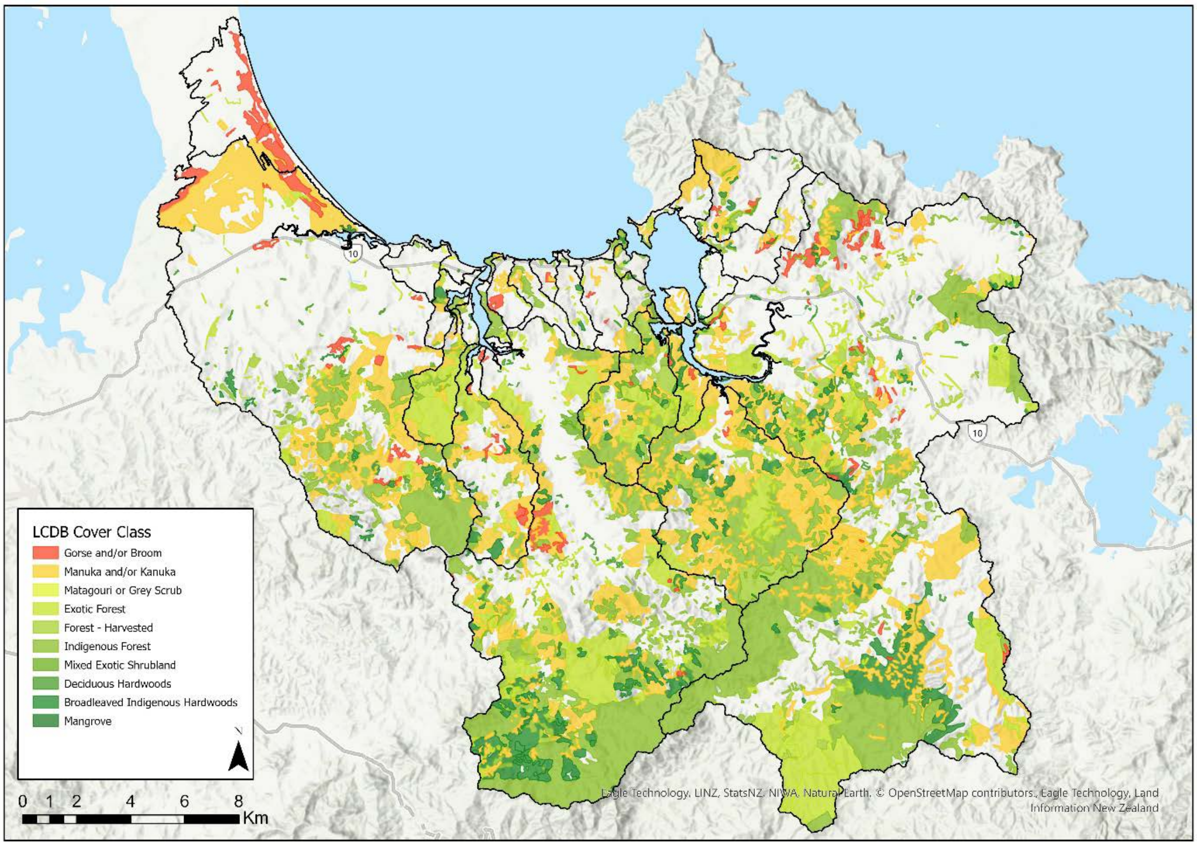

Figure 21: The vegetation types of the Doubtless Bay catchment coloured based on relative flammability risk. Flammability risk increases from dark green (low risk) to lime green (moderate risk) to red (high risk). Indigenous forest types have lower flammability while exotic forest, mānuka/kānuka, and gorse/broom vegetation types have the highest flammability. Flammability levels for different vegetation were assessed based on flammability scores available in the published literature and coarse species composition estimates.

5.2.2 Assessment

There are hotspots of flammability in the Doubtless Bay catchment (Fig 22) that reflect the spatial configuration of the most flammable vegetation across the landscape. These hotspots correspond mainly to areas of exotic and native shrubland, much of which appears to comprise regenerating vegetation, possibly after retirement from farming.

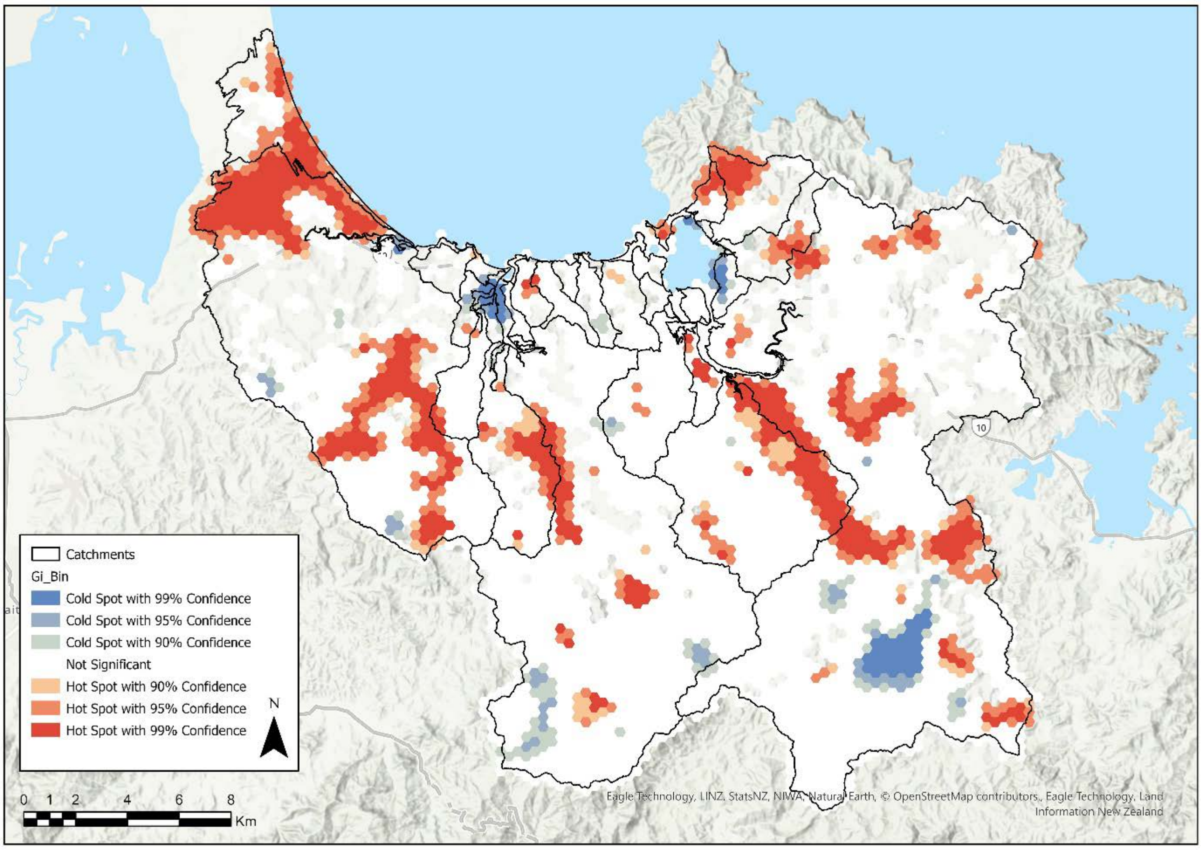

Figure 22: A GIS-based 'hotspot' analysis of flammability conditions across the Doubtless Bay catchment. This analysis assesses both the relative flammability of different vegetation types present in the landscape as well as the relative contiguity of flammable vegetation patches. The result is the statistical probability that particular zones in the landscape are more likely to be flammable or not relative to expectation.

5.2.3 Ideas for building ecosystem resilience under climate change

As temperatures and drought frequencies increase as the climate changes, we can expect an increase in the length of the wildfire season across Aotearoa (and in Northland) and the potential for very extreme wildfire weather (Melia et al. 2022). Therefore, it is worthwhile considering how climate adaptation interventions, such as those proposed in this report, could be carried out to also reduce flammability and to increase the resistance to wildfire ignition and spread. For example, the acceleration of succession in woody shrubland to taller indigenous forest would lead to a less flammable landscape. Further, additions of low-flammability native vegetation in areas where new trees are being established (e.g., in riparian zones or headwater catchments) would provide opportunities for strategic placement of ‘green firebreaks’.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Risks and mitigations in vulnerable areas

There is considerable complexity involved in assessing landscape vulnerabilities, risks, and mitigations and in the implementation of potential interventions. Although somewhat subjective in nature, the GIS-based multi-criterion analysis of vulnerability presented here provides a baseline framework for the consideration of future risks and mitigations in the context of climate change while also addressing social, cultural, and economic objectives and needs/desires in the catchment (Table 14). The ongoing, and potentially accelerating, impacts of climate change are of concern as increased temperatures and extreme weather events (i.e., droughts and extreme rainfall) are expected in Northland (MFE, 2020). To mitigate these impacts, a number of interventions that build landscape resilience should be considered (e.g., Table 13) and implemented as a part of future planning at the landscape-scale.

In the Doubtless Bay catchment, considering vulnerabilities and risks in mapped priority areas can provide a directed way to improve resilience as part of an emerging Nature-Based Solutions strategy for this catchment. Such prioritisation maps can also inform ongoing compliance with policy and regulatory frameworks associated with farm planning, soil improvement and loss mitigation, and freshwater quality. Ultimately, these maps can be a part of community-level discussions and planning efforts underway in the Doubtless Bay catchment.

Table 14. Future risks that can exacerbate conditions in vulnerable source and receiving areas and possible mitigations.

Scale	Future risks	Mitigations (see Section 4 for option explanations)
Source catchments	Increased extreme rainfall events	Erosion mitigation plantings (**Option 2**)
	Conversion to exotic plantation forestry	Consideration of permanent cover native forestry (**Options 10 & 11**)
	Unmanaged upland gully riparian zones	Gully revegetation and fencing to improve quality, habitat connectivity, and to protect source streams (**Options 4, 8, 10 & 11**)

Receiving areas	Increased extreme rainfall events + ongoing lack of riparian management and lack of recognition of river geomorphology Ongoing intensive farming (stock pressure) in floodplains Increased drought events + increased flammability conditions	Source area management (revegetation) + focussed wetland reestablishment + science-based riparian rejuvenation (**Options 1, 2, 7, 8, 10, 12**) Farm management that reduces stock numbers and impacts. Regenerative agricultural soil management practices. Agroforestry options. Replacement of flammable vegetation hotspots with less flammable species + Strategically-placed green firebreaks (**Option 3**)

6.2 Representative revegetation options

We identify 12 representative revegetation options which are relevant to the catchments and communities of Doubtless Bay and which meet multiple freshwater, climate, restoration and human preference factors. The options go beyond the scope of classical forest restoration planting to span the following aspects of restoration and forestry (in no particular order):

- Protection and management of existing values,
- Addressing ecological threats,
- Matching species to local conditions,
- Altering inappropriate land use,
- Naturalising freshwater form and hydrology,
- Interventions to overcome limitations in natural systems,
- Working with available markets and incentives,
- Considering cultural and social preferences.

6.3 Recommendations

In light of this analysis, our recommendations are:

- An assessment of vulnerability analysis outputs against ground-based data and against community collective objectives, economic considerations and feasibilities, and landowner, mana whenua and iwi aspirations. The work presented here could be extended to develop a more detailed landscape intervention plan based on these considerations.

- Collection and overlay of more detailed information on vegetation (e.g. weeds, wetlands) and biodiversity values in the catchments to provide nuance to mapped vulnerabilities.
- The recommended revegetation options provide content for extension to landowners within the Doubtless Bay catchment and further afield where the revegetation options remain relevant.
- Consider the establishment of field trials to help demonstrate the use of enrichment plantings, which is an aspect of restoration common to many of the recommended options. Field trials could effectively be used to demonstrate all recommended options presented in this report.
- Explore options for the provision of technical and financial support for individuals to achieve their revegetation objectives, since many revegetation options require management at smaller, sub-catchment scales.
- Consider wildfire risks at a landscape scale to collectively contribute to reducing the risk. 'Green firebreaks' could be planted to minimise the impacts of future fires – while still maintaining vegetation corridors for wildlife migrating with a changing climate.
- This work should be integrated with other work carried out in the catchment (Boffa Miskell, Morphum Environmental).

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Appendix A

GIS datasets used in the spatial multi-criteria analysis (MCA) analysis

Dataset	Source	Variable used
Headwater catchment analysis		
Erosion rates	LRIS GIS portal; Dymond et al. 2008	Erosion rate (tonnes of sediment lost per km^2 per year)
Slope gradient	LRIS GIS portal	Slope gradient in degrees
Soil drainage	LRIS GIS portal – Fundamental Soil Layers; Newsome et al. 2008	Soil drainage class
Exotic plantation forest	LRIS GIS portal - NZ Landcover Database (LCDB) v. 5.0	Areal percentage of exotic forest class occurring
Unvegetated gully riparian zones	GIS-derived – LCDB and EcoSat woody vegetation (from LRIS GIS portal) within headwater stream buffer zones	
Receiving catchment analysis		
Results from 1st order catchment analysis for stream sections	GIS-derived (as above)	Area weighted mean ranks of headwater catchments within receiving area catchments
Modelled 50-year regional flooding extents	NRC open access GIS data	Proportion receiving catchment area flooded
Macroinvertebrate community index (MCI)	MfE; Stark & Maxted 2007; Whitehead et al. 2021.	Modelled MCI values per stream section
Percentage of riparian zones with woody vegetation	GIS-derived – woody vegetation within receiving catchment river buffer zones	Non-vegetated percentage of 15-m riparian zones within receiving catchments
Threatened environments	LRIS GIS portal – Cieraad et al. 2015	Threatened ecosystem class

Data source references

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Appendix B

Species relevant to native restoration in the project area. A depth range is provided only for those species that would thrive if planted in water.

Depth range (m)	Flammability rating	Name	NVS Code	NVS Structural Class	Notes
–	M/H	Akeake	DODVIS	Trees & shrubs	
–		*Alseuosmia banksii var. Linariifolia*	ALSBVL	Trees & shrubs	
–		Black maire	NESCUN	Trees & shrubs	
–		Gumland grass tree	DRASIN	Trees & shrubs	Gumland scrub, kauri forests, seral vegetation, along ridgelines
–		*Halocarpus kirkii*	HALKIR	Trees & shrubs	With kauri along ridgelines, swampy hollows or gully heads
–	L	Hangehange	GENLIG	Trees & shrubs	
–		Hīnau	ELADEN	Trees & shrubs	
–	L	Horoeka	PSECRA	Trees & shrubs	
–	L/M	Houhere	HOHPOP	Trees & shrubs	
–	M	Kahikatea	DACDAC	Trees & shrubs	
–	L	Kanono	COPGRA	Trees & shrubs	
–	H	Kānuka	KUNERI	Trees & shrubs	
–	L	Kāpuka	GRILIT	Trees & shrubs	
–	L	Karamū	COPROB	Trees & shrubs	
–		Kawaka	LIBPLU	Trees & shrubs	Often on ridgelines or spurs. Favours disturbance. Likes fertile soils
–	L	Kawakawa	PIPEXC	Trees & shrubs	
–		Kohekohe	DIDSPE	Trees & shrubs	
–	M	Kōhūhū	PITTEN	Trees & shrubs	

Depth range (m)	Flammability rating	Name	NVS Code	NVS Structural Class	Notes
–	L/M	Koromiko	VERSTR	Trees & shrubs	
–	L	Kōtukutuku	FUCEXC	Trees & shrubs	
–		Kōwhai	SOPMIC	Trees & shrubs	
–		Kumarahou	POMKUM	Trees & shrubs	
–		Māhoe	MELRAM	Trees & shrubs	
–		Maire	MIDSAL	Trees & shrubs	
–		Maire tawake	SYZMAI	Trees & shrubs	
–		Makamaka	ACKROS	Trees & shrubs	Damp soils
–	L/M	Makomako	ARISER	Trees & shrubs	
–		Mangeao	LITCAL	Trees & shrubs	Tolerates ultramafic rocks at North Cape
–	H	Mānuka	LETSCO	Trees & shrubs	
–		Mataī	PRUTAX	Trees & shrubs	
–		Miro	PECFER	Trees & shrubs	
–		Narrow leaved maire	NESMON	Trees & shrubs	
–		Neinei	DRALAT	Trees & shrubs	Slopes and stream banks often with kauri
–	L/M	Ngaio	MYOLAE	Trees & shrubs	
–		Nīkau	RHOSAP	Trees & shrubs	
–		Northern rātā	METROB	Trees & shrubs	
–		Pāte	SCHDIG	Trees & shrubs	
–		*Pittosporium ellipticum*	PITELL	Trees & shrubs	Often with kauri, ridgelines, disturbance, flood prone streams and rivers. Open sites
–		*Pittosporium virgatum*	PITVIR	Trees & shrubs	Often with kauri, also tanekaha, towai, kamahi. Likes open conditions. Often on ridgelines, slips, seral forest
–		Poataniwha	MELSIM	Trees & shrubs	

Depth range (m)	Flammability rating	Name	NVS Code	NVS Structural Class	Notes
–		Pōhutukawa	METEXC	Trees & shrubs	
–		Porokaiwhiri	HEDARB	Trees & shrubs	
–	L	Poroporo	SOLAVI	Trees & shrubs	
–	L	Puka	GRILUC	Trees & shrubs	
–		Pukatea	LAUNOV	Trees & shrubs	
–		Pūriri	VITLUC	Trees & shrubs	
–	L	Putaputawētā	CARSER	Trees & shrubs	
–		Ramarama	LOPBUL	Trees & shrubs	
–		Red mapou	MYRAUS	Trees & shrubs	
–	L/M	Rewarewa	KNIEXC	Trees & shrubs	
–	M	Rimu	DACCUP	Trees & shrubs	
–		Tamingi	EPAPAU	Trees & shrubs	Bushy shrub
–		Tānekaha	PHYTRI	Trees & shrubs	
–		Taraire	BEITAR	Trees & shrubs	
–		Tauhinu	OZOLEP	Trees & shrubs	
–		Taurepo	RHASCA	Trees & shrubs	
–	M	Tawa	BEITAW	Trees & shrubs	
–		Tāwhiri karo	PITCOR	Trees & shrubs	
–	M	Tī kōuka	CORAUS	Trees & shrubs	
–		Titoki	ALEEXC	Trees & shrubs	
–		Toro	MYRSAL	Trees & shrubs	Can dominate in riparian zones
–		Toropapa	ALSMAC	Trees & shrubs	Semi shade with damp soils
–		Toru	TORTOR	Trees & shrubs	Infertile soils, favours disturbance, with kauri, small tree
–	M/H	Tōtara	PODTOT	Trees & shrubs	
–		Towai	PTESYL	Trees & shrubs	

Depth range (m)	Flammability rating		Name	NVS Code	NVS Structural Class	Notes
–			Tūrepo	STRHET	Trees & shrubs	
–			Wharangi	MELTER	Trees & shrubs	
–			<u>Whau</u>	ENTARB	Trees & shrubs	
–	L		Whauwhaupaku	PSEARB	Trees & shrubs	
–			White maire	NESLAN	Trees & shrubs	Hill slopes and ridgelines, riparian but not on sites that flood
Margin			Harakeke	PHOTEN	Herbs - monocots	
0-0.2			Giant umbrella sedge	CYPUST	Sedges	
0-0.4			Jointed baumea	MACATC	Sedges	
0.2-0.6			Kuta	ELESPH	Sedges	
0-0.4			Lake clubrush	SCHTAB	Sedges	
0-0.2			Purei	CARSEC	Sedges	
0-0.3			Purua grass	BULFUL	Sedges	
0-0.4			Raupo	TYPORI	Sedges	
0-0.2			Rautahi	CARGEM	Sedges	

Notes: [1] NVS is the National Vegetation Survey and the six letter codes are used in that system. The codes abbreviate the scientific name and are searchable in the New Zealand Plant Conservation and NVS systems. Flammability ratings are: L = Low, L/M = Low/Moderate, M = Moderate, M/H = Moderate to high, H = High. Light and dark green cells in column 3 represent either pioneer or enrichment phase species, respectively, under most conditions. Those species with names underlined have natural distributions over northern New Zealand (over differing extents).

Appendix C

Relevant website resources

General

Bacterial quality of watercress – https://www.landcareresearch.co.nz/assets/Publications/Te-reo-o-te-repo/4_1_Flora_Watakirihi.pdf

Species-specific information on weed biology and control techniques – https://www.weedbusters.org.nz/what-are-weeds/weed-list/c/

Whitebait Connection – https://www.whitebaitconnection.co.nz

Wetland Handbook Series – https://www.landcareresearch.co.nz/publications/wetland-handbook-series/

Far North District Council Rates Relief – https://beta.fndc.govt.nz/files/assets/public/v/2/objectivedocuments/corporate-management-cor/financial-management/administration/p21-01-land-subject-to-protection-for-outstanding-natural-landscape-cultural-historic.pdf

Information on Native Restoration Options – https://www.tanestrees.org.nz/projects/

Kaipara Moana Remediation Planting Guide – https://kmr.org.nz/wp-content/uploads/2024/05/KMR-Planting-Guide-Nov-2023.pdf

Northland Regional Council Resources

Grants for Fencing and/or Planting Natives on Erosion Prone Land – https://www.nrc.govt.nz/your-council/work-with-us/funding-and-awards/for-landowners/grants-for-fencing-andor-planting-natives-on-erosion-prone-land/

Guide to Northland's Plant Pests – https://www.nrc.govt.nz/environment/weed-and-pest-control/strategies-and-resources/a-guide-to-northlands-pest-plants/

Pest Plants and Animals – https://www.nrc.govt.nz/resource-library-archive/environmental-monitoring-archive2/state-of-the-environment-report-archive/2011/state-of-the-environment-monitoring/our-land-our-air/pest-plants-and-animals/#What%20are%20the%20main%20pest%20species%20in%20Northland?

Plant Pests Information for Schools – https://www.nrc.govt.nz/for-schools/school-information-packs/pest-plants/

Regional Pest Strategy – https://www.nrc.govt.nz/media/uhudlio4/northlandregionalpestandmarinepathwaymanagementplan20172027.pdf

Review of Riparian Setbacks Science – https://www.nrc.govt.nz/media/yoxonnvq/riparian-setbacks-summary-of-the-science.pdf