Lake Ōnoke Freshwater Improvement Fund Project- Restoration Plan

Prepared for the Department of Conservation

March 2018

focus
resource management group

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Report submitted:

2 March 2018

Acknowledgements:

We are grateful for the support and comment from a variety of people and organisations including Anna Burrows (DOC), Ranjan Cyril (GWRC), Ian Gunn, David Hancock, Joe Houghton, Russell Kawana, Helen Kettles (DOC), Dougal and Denise MacKenzie, Charlie and Karla Matthews, Rob McCreary, Amber McEwan, Horipo Rimene, Tony Silbery (DOC), and Ra Smith.

Citation:

Graeme, M. & Dahm, J., 2018: Lake Ōnoke Freshwater Improvement Fund Project - Restoration Plan. Focus Report No. 18/128. Prepared for Wairarapa District Office, Department of Conservation by the Focus Resource Management Group.

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1 INTRODUCTION

The 18 hectare project area is located on the western side of Lake Ōnoke in the southern Wairarapa (and Figure 2). The area comprises the upper reaches of a former arm of Lake Ōnoke and prior to human modification consisted of estuarine wetland and freshwater wetlands surrounded by patches of remnant lowland or coastal forest vegetation communities (see Leach & Anderson, 1974; Beadel et al. 2000 etc).

Over time, the area has been extensively modified by human activity. In particular, sometime in the period between 1944 and 1961, extensive stopbanking, drainage and stream diversion occurred. Aerial photographs indicate that the area has been grazed and cropped since these works.

The land titles of the project area are part of a Treaty of Waitangi settlement and ownership will be returned to treaty partners Ngati Kahangunu and Rangitane as part of this process. The area is known as Pou Aruhe after the main stream that drains into it. The treaty partners wish to investigate the potential to restore the natural values and functioning of the area and to enhance native fisheries.

In 2017 the Ministry for the Environment Freshwater Improvement Fund (FIF) granted three years of funding to restore the natural functioning of this area under the Ōnoke Saltmarsh Freshwater Improvement Fund Project. This project is being managed by the Department of Conservation.

1.1 Restoration project objectives

The objectives of the restoration project are to:

- Hydrologically reconnect the restoration area with Lake Ōnoke and its' catchments.
- Revegetate the project area towards the plant communities that were likely to have been historically present.
- Improve recreation opportunities by shifting the Remutaka Cycleway off the road and directing it through the project site.
- Install appropriate signage/interpretation.

This report outlines the recommended actions required to achieve the hydrological and ecological aspects of the project; the monitoring regime to track progress; and provides comment on signage and interpretation for the cycleway.

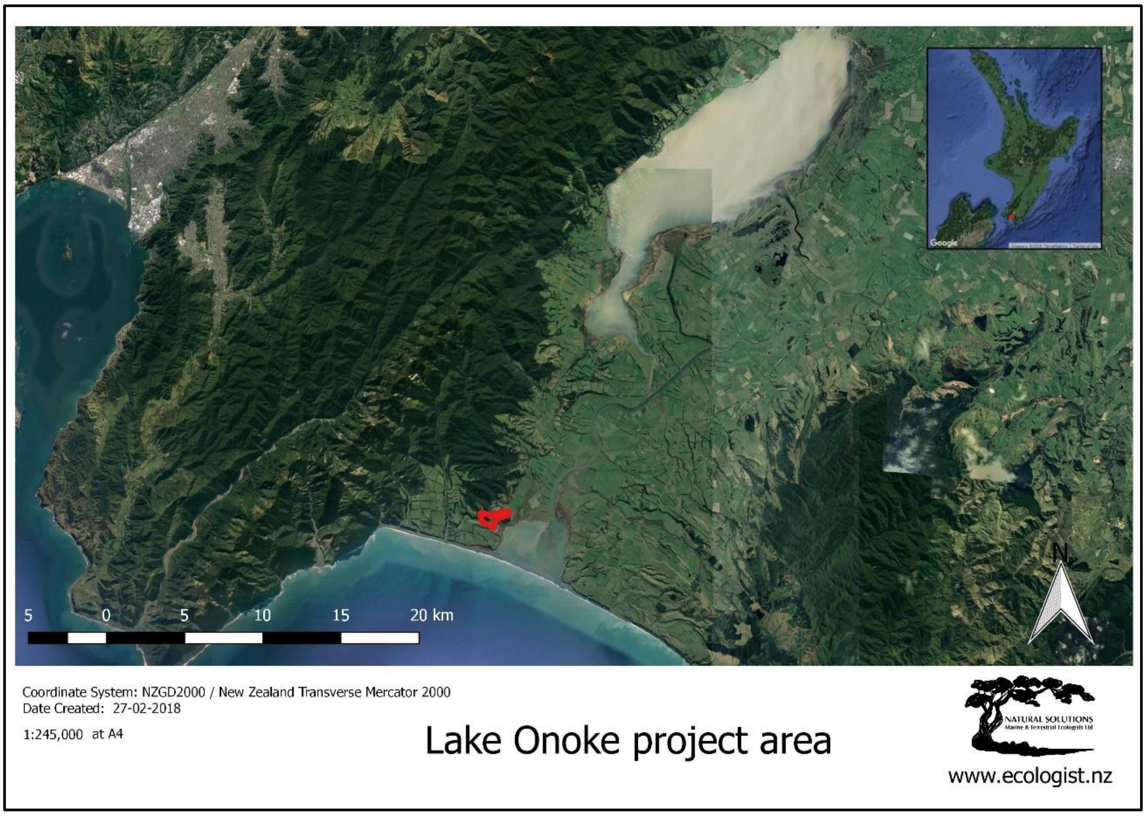


Figure 1: Lake Ōnoke and the project area (red), South Wairarapa

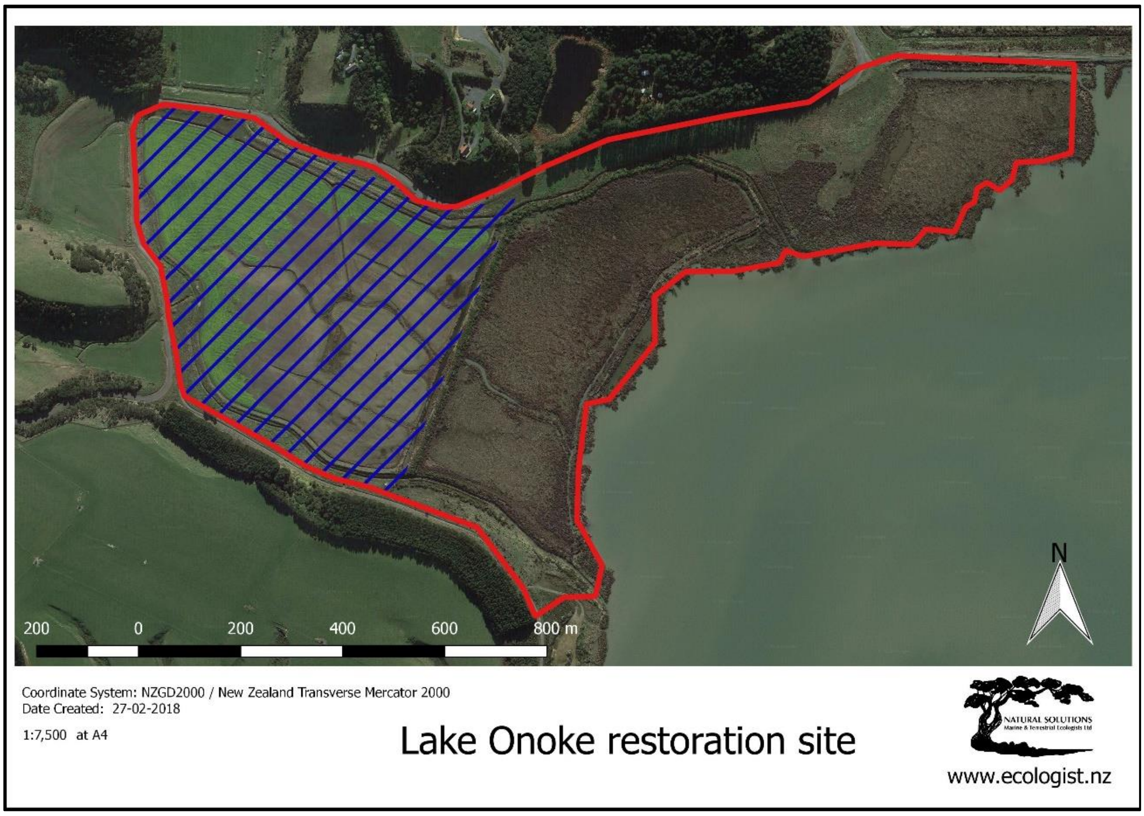


Figure 2: The project area (red) and wetland restoration site (blue hash)

2 SETTING AND SITE DESCRIPTION

Wairarapa Moana includes the beds of Lake Wairarapa and Lake Ōnoke and their associated edge wetlands. It covers more than 9,000 hectares. This is over half the area of wetlands left in the wider Wellington Region (GWRC, 2015). The Wairarapa Moana Wetland complex contains mudflats, lagoons, sand flats, marshlands, salt marshes and back waters which are regularly flooded or exposed, depending on the season.

Wairarapa Moana is considered of national importance for flora and fauna, especially wading birds and rare turf plants. Wairarapa Moana is traditionally very important to Ngāti Kahungunu and Rangitāne o Wairarapa for mahinga kai (food gathering), traditional materials and medicines. It is also a popular duck shooting area. Wairarapa Moana also supports or historically supported regionally important fisheries for whitebait, flounder, trout, perch, tuna (eels), yelloweyed mullet, kahawai and red cod (Hicks, 1993). Commercial eeling within the public conservation land parts of Wairarapa Moana requires a Concession from the Department of Conservation. No Concessions have been granted for this activity.

The National Water Conservation (Lake Wairarapa) Order was made in 1989. It recognizes that "the wildlife habitat created in part as a consequence of the natural fluctuations of water levels, particularly over the eastern shoreline, is an outstanding feature of Lake Wairarapa." An application to Ramsar to recognise the international importance of Wairarapa Moana is pending.

Wairarapa Moana is also recognised for its role in the landscape, water, carbon and nutrient cycles, and the provision of wildlife habitat (particularly threatened species). The Wairarapa Moana Wetlands Project (see www.waiwetlands.org.nz) was set up in 2008 to actively manage and restore this area. The Project partners are Ngāti Kahungunu, Rangitane, Greater Wellington Regional Council (GWRC), Department of Conservation (DOC), South Wairarapa District Council (SWDC), Papawai and Kohunui marae. Adjacent landowners, community groups, Fish and Game and Victoria University are also working on projects in this area. The mission of the Wairarapa Moana Wetlands Project is to enhance the spiritual identity and ecology of the wetlands and improve recreational and economic opportunities for the benefit of everyone. A Treaty settlement is currently underway. Once this has been finalised (within the next two years) a new Statutory Board (chaired by iwi) will replace the Wairarapa Moana Wetland Project governance structure.

The Wairarapa Moana Wetlands lie within the Wairarapa Plains Ecological District and Lake Ōnoke is within the Coastal Bioclimatic Zone.

Historically, extensive non-forested wetland vegetation would have surrounded Lake Wairarapa and Lake Ōnoke including – toetoe (*Cortaderia toetoe)* and raupo (*Typha orientalis*), with scattered or local harakeke (*Phormium tenax*), sow thistle (*Sonchus oleraceus*), karetu (*Hierochloe redolens*), *Glyceria stricta*, *Epilobium* sp., *Myriophyllum triphyllum*, *Myriophyllum robustum*, *Myriophyllum propinquum*, *Cardamine* sp., *Rorippa palustris*, *Ranunculus macropus*, bachelor's button (*Cotula coronopifolia*), and other species (Hill 1962, 1963 in Beadel et al. 2000). Scattered groves of swamp forest would have occurred amongst the non-forest vegetation, and patches of scrub (mānuka (*Leptospermum scoparium* var. *scoparium*), kānuka (*Kunzea robusta*), tauhinu (*Ozothamnus leptophyllus*) and matagouri (*Discaria toumatou*) probably dominant) and groves of trees on higher ground (Beadel et al. 2000).

Within the Wairarapa Plains Ecological District, Beadel et al. (2000) estimated that by 1998 there was 7% estuarine and 13% freshwater wetland vegetation left compared to that present in 1853.

2.1 Lake Ōnoke

Lake Ōnoke (630ha) is a shallow brackish lake (5-6m deep at its deepest point but primarily <1m) (Bunny et al., 2014) located at the mouth of the Ruamahunga River. The lake is bordered by wetlands and separated from Palliser Bay by a 3km gravel and sand spit with a narrow opening to the sea at its eastern end. The lake entrance is periodically closed by wave action and littoral drift (Robertson and Stevens, 2007; Hayward et al., 2011). It is either naturally breached by rising lake levels or, more commonly in recent years, cut artificially to reduce the danger of flooding on nearby farmland. The Ruamahunga River is the main inflow to the lake and drains the entire Wairarapa Valley, a large agricultural catchment with about 64% in pasture cover (Bunny et al., 2014).

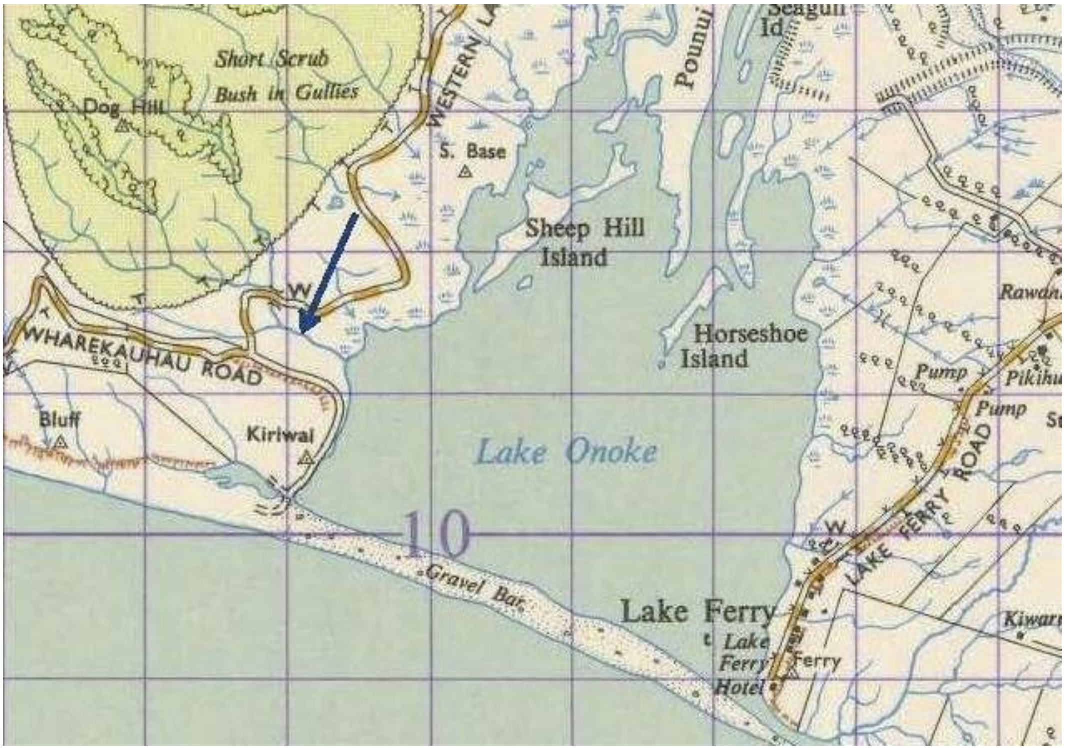


Figure 3: View of original larger Lake Ōnoke from 1953 Lands and Survey map. The restoration site on the western side of the lake is arrowed (blue).

During periods when the entrance is open the lake is subject to tidal influence with up to a 1.2m spring tidal range and salinities (salt concentration) varying from 35 PSU (or g/kg) near the entrance to <5 PSU near the river entrance. Tidal and river currents together with periodic wind-generated waves help mix the saline and freshwaters (Hayward et al., 2011). When the lake entrance is closed, the lake infills with water from the Ruamahunga River and water levels can reach elevations up to 1.5m above extreme high-water springs (EHWS). GWRC advise that it can reach elevations of 12.00m relative to their datum; which is equivalent to about 2.6m above mean sea level (MSL), the datum used in this report. The lake levels are managed by GWRC and the lake mouth is typically opened within days to weeks of closure to minimise flood risk (Bunny et al., 2014). Water levels in the lake are therefore usually within the tidal range but can rise to 1-1.5m above EHWS 5-10 times per year for periods of 1-7 days (Hayward et al., 2011). The freshwater inputs reduce salinity, particularly in the surface layers until the barrier is breached.

The lower Ruamahunga River, Lake Ōnoke, Lake Wairarapa and associated wetlands have been significantly modified through flood protection and drainage activities carried out under the Wairarapa Catchment Board led Lower Wairarapa Valley Development Scheme (LWVDS) (Bunny et al., 2014). The most significant changes occurred in the 1960s and the 1970s and included:

- the diversion of the Ruamahunga River from its direct course into Lake Wairarapa to its current course directly into Lake Ōnoke;
- the drainage of over 1200 ha of wetlands (Bunny et al., 1994), and
- construction of a causeway (Paul's Bank) across the northern side of Lake Ōnoke to the Ruamahunga River entrance, reducing the lake size (including separation of Pounui Lagoon from Lake Ōnoke) and changing the character of upstream wetlands.

While the works are considered to have had major socio-economic benefits in terms of flood protection and agricultural use, they have had significant negative effects on the wetland, lake, river and stream ecosystems, cultural food sources and fisheries (Hicks, 1993; Bunny et al., 2014).

Lake Ōnoke has degraded water quality, with elevated levels of nutrients, poor water clarity and, at times, high algal biomass; classed as being in a 'eutrophic' to 'supertrophic' state (Bunny et al., 2014). Tidal exchange appears to increase the water quality in the lake (Bunny et al., 2014).

Under the Proposed Natural Resources Plan for the Wellington Region Lake Ōnoke is listed as a historic heritage freshwater site and a site of significance to Ngāti Kahungunu ki Wairarapa and Rangitāne o Wairarapa. It is also an identified significant natural wetland and site with significant indigenous biodiversity values in the Coastal Marine Area (CMA). The Lake Ōnoke wetlands are part of an extensive system of wetlands and lagoons associated with Lake Ōnoke and provide a buffer to the lake.

These wetlands and the lake support a large variety of wildlife (see Todd et al. 2016, Goodman et al, 2014; Beadel et al, 2000) including twenty-one species of nationally Threatened and At Risk bird species plus three species of threatened plants[1] (native musk and sea holly) including pygmy clubrush recorded in nearby Kiriwai Lagoon (see Appendix A). An additional three Threatened and At Risk plants were found during the survey for this report (see Section 4.5.1) Twenty seven species of freshwater, and estuarine, fish have also been recorded in Lake Ōnoke. Of these the lamprey and shortjaw kōkopu are Nationally Vulnerable and īnanga, bluegill bully, longfin eel, redfin bully, giant kokopu, kōaro, torrentfish and brown mudfish are At Risk - Declining.

Beadel et al (2000) described the following vegetation types within Recommended Area for Protection (RAP) 17 that includes the project area and other nearby significant vegetation and is relevant to the restoration project:

> 'Saltmarsh ribbonwood-tall fescue-(*Cyperus ustulatus*)-(sea rush) shrubland',
>
> 'Mercer grass *Isolepis prolifer* grassland' around lake margins;
>
> 'Saltmarsh ribbonwood-oioi-sea rush-tall fescue-(gorse) shrub- saltmarsh rushland' with occasional bachelor's button and *Isolepis prolifera*;
>
> 'Remuremu, *Apium prostratum* and *Samolus repens* turf' locally at the water's edge and beneath rushes.

Other freshwater or brackish plants noted include occasional local *Schoenoplectus pungens, Schoenoplectus tabernaemontani, Carex geminata, Isolepis nodosa*, sea rush, soft rush, sand sedge and *Isolepis cernua*.

Coastal scrub noted in RAP 17 includes vegetation in the gully leading to Kiriwai Lake. This coastal scrub is noteworthy as this vegetation type was previously widespread but is now very uncommon in the Wairarapa Plains Ecological District (Beadel et al, 2000). It includes a mosaic of:

- kānuka treeland;
- *Carex geminata* rushland;
- harakeke/pukio-*Carex geminata*-(giant umbrella sedge) flaxland (with occasional ferns, treefern, kānuka);
- ti kouka/mahoe-kānuka-gorse-(wheki)-(harakeke)-(mamaku) shrubland;
- oioi-raupo-*Cyperus ustulatus* sedgeland;
- *Schoenoplectus validus*/*Carex geminata*-tall fescue grass-sedgeland;
- *Isolepis prolifera* -jointed rush sedgeland;
- *Carex geminata*-tall fescue-water pepper-pukio-(jointed rush)-(gorse) grass-sedgeland;

[1] Note additional threatened plants found during the survey for this report (Section 4.5.1)

- *Carex geminata* sedgeland with local giant umbrella grass;
- *Isolepis prolifera*-jointed rush-water pepper sedgeland;
- Raupo reedland.

Habitat for wetland plants, birds and fish has been severely degraded through the physical loss of habitat (vegetation clearance, drainage, infilling and grazing) and structures that have altered natural tidal and flood flows and migratory fish passage (e.g. flood gates, weirs, poorly sited culverts).

2.2 Restoration Site

The proposed restoration area has a highly modified hydrological regime and is used for agriculture. The intention of the proposed restoration works will be to restore approximately 30 hectares of wetland and floodplain back towards a more natural state by rehabilitating natural water flows and estuarine and freshwater wetland plant communities on the floodplain and coastal scrub on the higher ground.

2.2.1 SITE HYDROLOGY AND HISTORIC MODIFICATION

The restoration site was originally part of a large embayment on the western side of Lake Ōnoke (Figure 3).

The embayment has a catchment area of approximately 630ha. The streams draining this catchment originally amalgamated and drained through the center of the embayment (Figure 4).

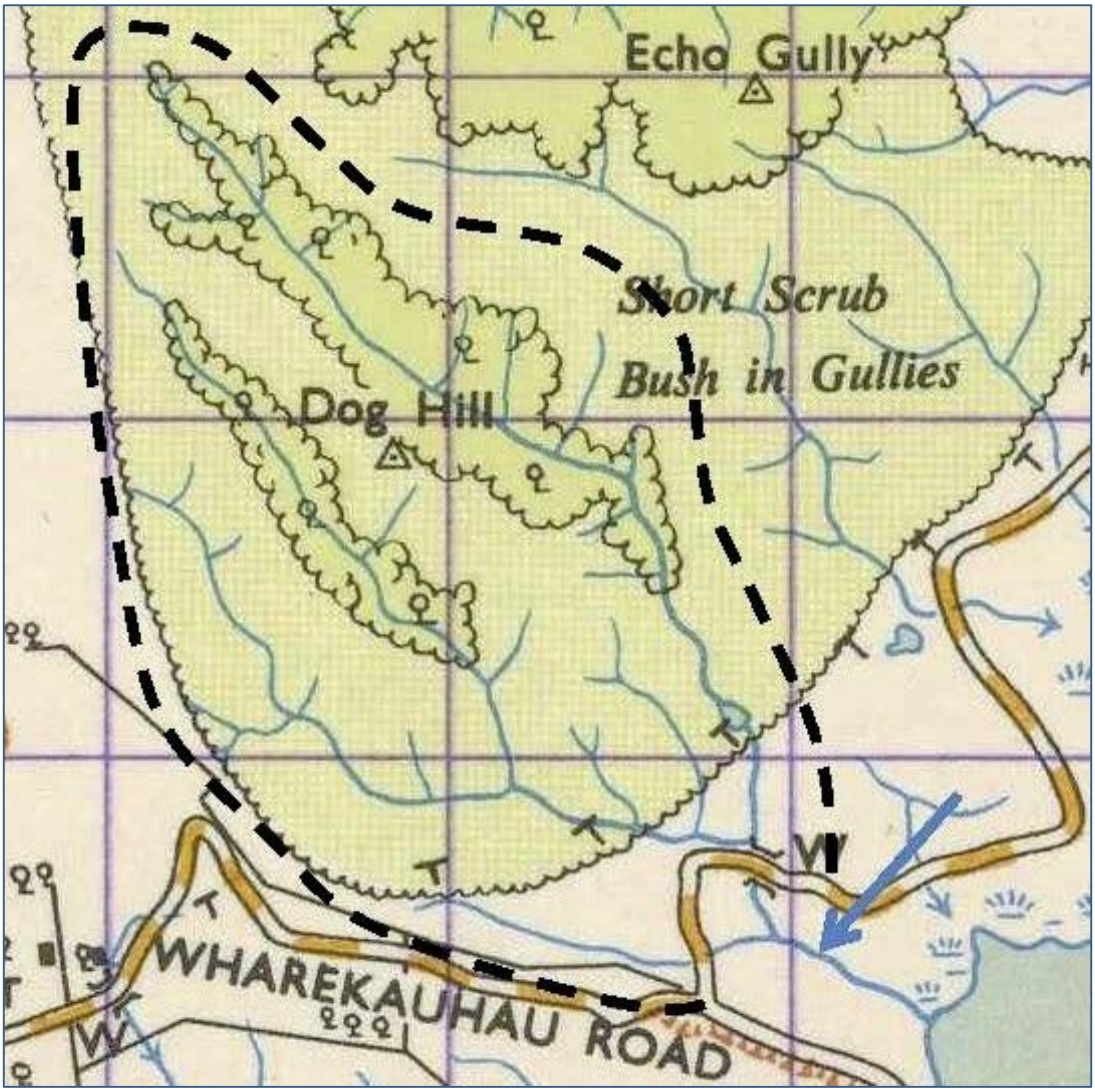


Figure 4: View of restoration area (blue arrow) and catchment (dashed line) from Lands and Survey map of 1953, showing the original stream channels. Note that the catchment streams originally drained through the center of the embayment.

Early aerial photographs taken prior to extensive human modification indicate that the more seaward areas of the embayment were vegetated with dense saltmarsh grading to saltmarsh ribbonwood and then to some bare areas and lighter vegetation (possibly freshwater wetlands) further upstream (Figure 5). Close examination of early aerial photos indicates a complex network of minor channels extended to central and central-upper areas of the embayment; typical of tidally influenced areas (Figure 5). Many of these former minor channels are also still evident in the field. Long-standing locals indicate that there were large areas of flax/harakeke (*Phormium tenax*) in upstream areas and patches of kānuka remnants on higher areas (Joe Houghton pers. comm. 2017).

Figure 5: Aerial view of original embayment from 17 February 1941 prior to the installation of stopbanks. (Photo reference 172/22 - sourced from Retrolens).

However, by 1961 aerial photographs indicate extensive modification of the embayment hydrology, including:

- Construction of stopbanks and drains to divert the inflowing streams around the margin of the embayment; and
- Construction of a stopbank across the seaward edge of the embayment (Figure 6).

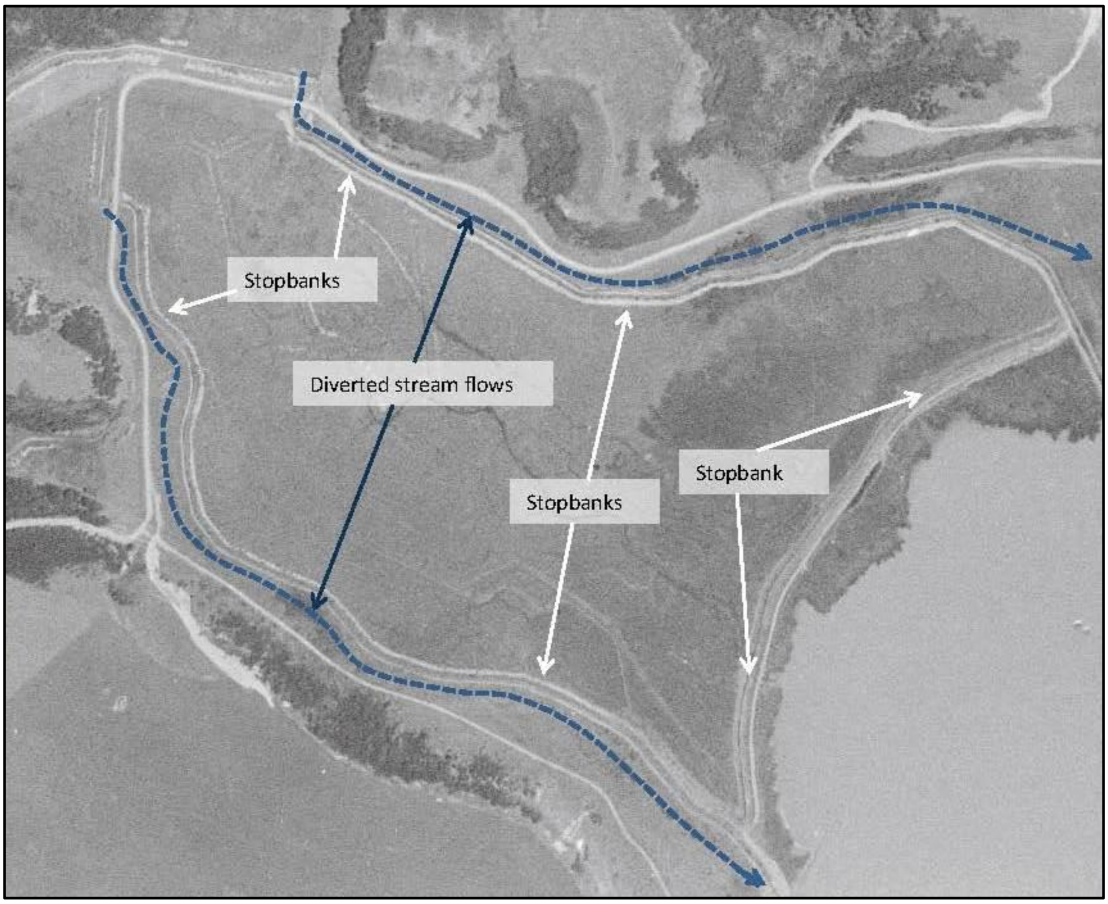


Figure 6: View of embayment in 1961 showing stopbanking and stream diversion works (Photo 3304/6 sourced from Retrolens).

The diverted stream pathways were also shown in the 1965 Lands and Survey map (Figure 7), in contrast to the main stream channel through the centre of the embayment evident in earlier maps (e.g. Figure 4).

The second inner stopbank between the saltmarsh and the present restoration area was constructed at a later date; available aerial photographs indicating this occurred sometime after 1965 and before 1980. Contact with GWRC indicates they hold no information on the works. They advised that the works were probably undertaken by local landowners with grants from the former Wairarapa catchment Board (Mr Ranjan Cyril, Flood Engineer, GWRC, email of 23 Feb 2018). GWRC have no concerns with the proposed restoration but advised that if stopbanks are to be removed or breached that a check be conducted on upstream flooding.

Figure 8 shows a recent aerial view of the restoration site showing the older seaward stopbank and newer inland stopbank.

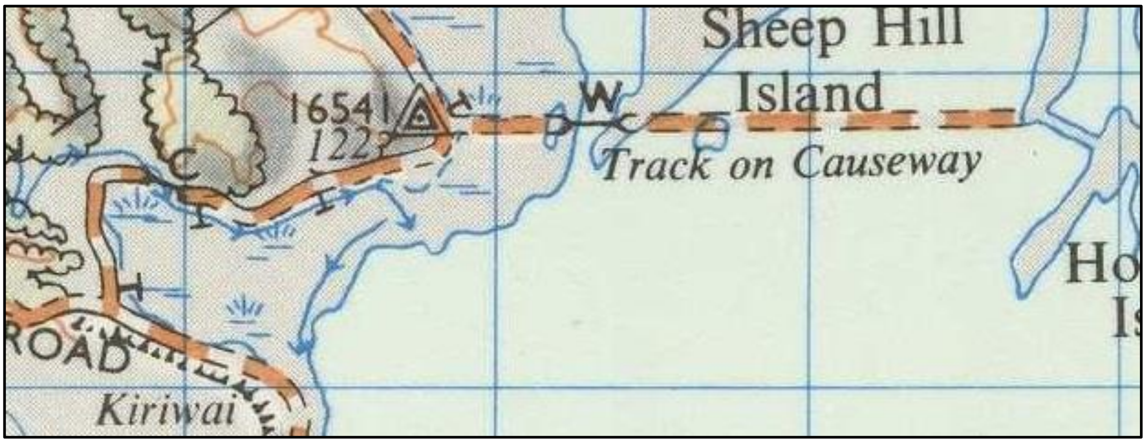


Figure 7: View of embayment from 1965 Lands and Survey map showing stream diversion paths. Note however that the symbols on the map suggest that the embayment was still largely wetland at this time despite the extensive stopbanking and stream diversion works.

Figure 8: Recent oblique aerial view of the project area looking west showing the seaward and inner stopbanks 2/11/2017 (Photo: Tony Silbery, DOC).

The outer stopbank across the seaward edge of the embayment allows inflows from the lake which maintains the saltmarsh (see Figure 8). The inner stopbank has flap-gated culverts and primarily allows only discharges. Nonetheless, observations and photographs provided by locals (J. Houghton, D & D MacKenzie pers. comm. 9&13/11/2017) indicate that the restoration area is subject to flooding (Figure 9). Field inspections indicate that the area commonly flooded is dominated by the native bachelor's button (*Cotula coronopifolia*) (Figure 10) which is a salt tolerant wetland species; suggesting the flooding is probably brackish water from the lake rather than runoff from local areas impounded during high lake levels. Accordingly, the various works do not entirely protect the area from flooding. These flooding events occur when the lake mouth has closed (ranging from 5 to 15 times a year) for an extended period and there is a build-up of water from the upper catchment (Vorster, 2018; D. MacKenzie pers. comm.).

Figure 9: Views of the project area showing a flood event in April 2016. (Photos: Dougal MacKenzie)

Figure 10: Aerial view of project area showing the original central water course and constructed drains. The area of yellow bachelor's button corresponds to the area most regularly affected by flooding and indicates the flood waters are brackish. (Photo: Tony Silbery 2/11/2017)

Overall, the hydrology of the project site has been significantly modified through historic drainage, stopbanking and diversion of natural water flows in an effort to reclaim the area for pastoral use. However, it is clear that these works are not adequate to prevent frequent and serious flooding. The existing land drainage is shown in Figure 11. Despite the extensive modification by drains and stopbanks the original main drainage course is still in place.

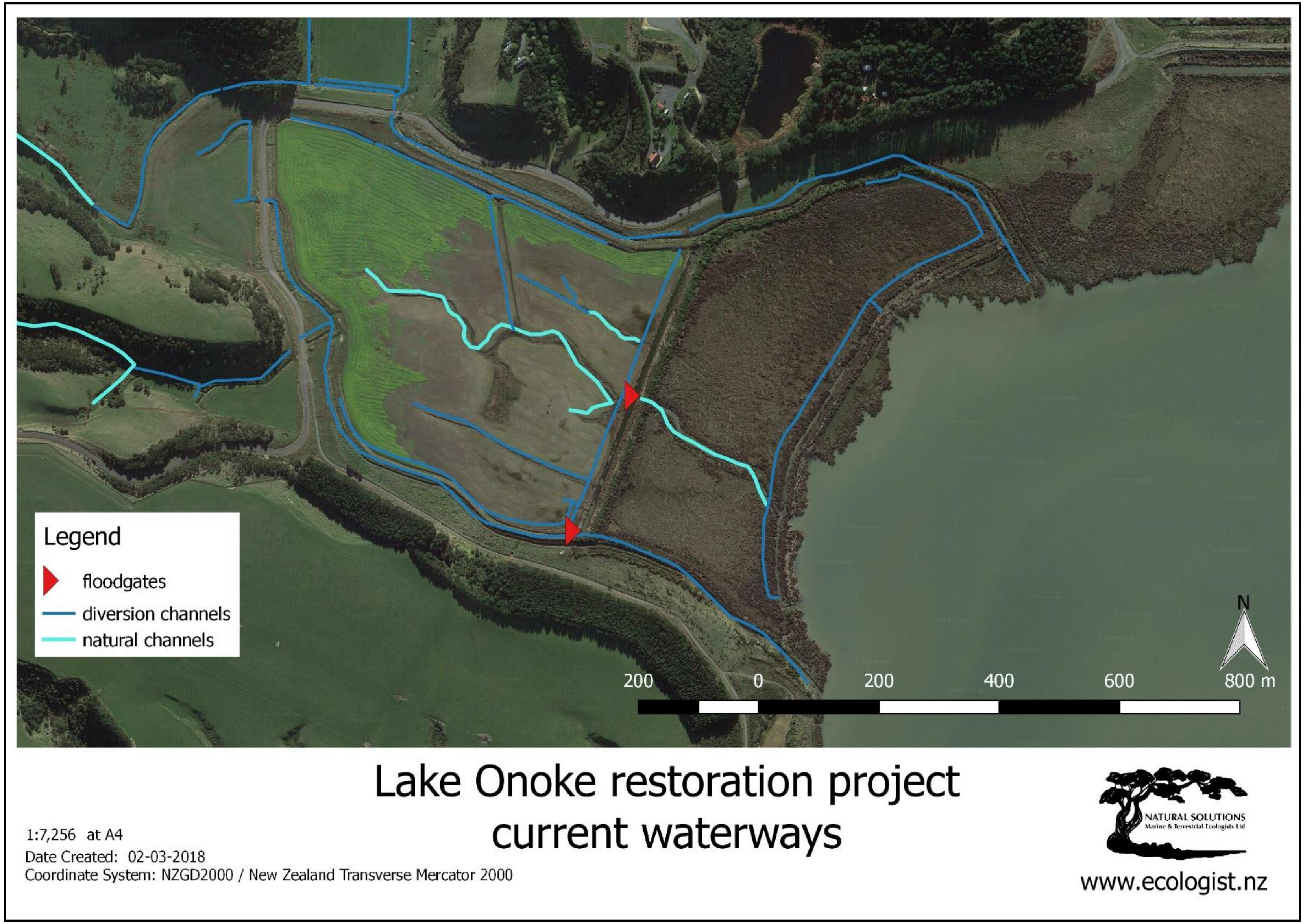


Figure 11: Current waterways associated with the project area.

3 METHODOLOGY

The compilation of this restoration plan has included:

- Collation and review of existing information
- Field investigations
- Meeting and consultation with local stakeholder groups and relevant GWRC staff

The information from this work has then been analysed and integrated to develop a draft restoration plan for further consultation with stakeholders. The potential impact of future sea level rise has also been considered, focusing particularly on the next 100 years.

3.1 Collation and Review of Existing Information

Available information on the study site has been collated and reviewed, including historic photography and previous reports on the general area.

Historic aerial photography dating from 1941 to the present was able to be collated from various sources including the Retrolens Historical Image Resource site, the online GIS data available via the GWRC and South Wairarapa District Council web sites, and Google Earth. A detailed search was also undertaken of imagery held on the national library website but no images of the study area were found. The vertical aerial photography able to be accessed and examined is listed in Table 1.

Table 1: Aerial photography accessed and examined during the project

Date of photography	Description/Source		
17 Feb 1941	Photo 172/22 - sourced from http://retrolens.nz		
9 Aug 1944	Photo 1008/33 - "	"	"
4 Nov 1961	Photo 3304/6 - "	"	"
11 May 1964	Photo SAg 36/800 -	"	"
1980	SN 5497 J/34 - "	"	"
14 Oct 2005	SN 50451c CSN 1810	"	"
Various 2010-2017	Google Earth, GWRC and SWDC		

Historic maps from various sources (primarily the national library) were also examined, dating from 1845 to the present. However, in general, the early maps able to be accessed contained little useful information on the project site except for the period since 1953 when more detailed Lands and Survey maps were available.

While no specific reports were able to be found on the project site a wide range of previous papers and reports on Lake Ōnoke and the wider local area were able to be accessed via the internet and other sources. These included reports on evolution of the area over the Holocene (Leach and Anderson, 1974; Deng et al, 2006; Hayward et al, 2011), sediments (Woolfe, 1996) and ecological, cultural and environmental issues (McEwan, 2017, Todd et al., 2016; GWRC, 2015, Reeves et al., 2013; Grant, 2012; Robertson and Stevens, 2007; Beadel et al, 2000; Hicks, 1993; Leach, 1981). Contact was made with the GWRC to obtain any available reports relating to drainage and flood protection works in the study area but we were advised that they hold no information on these works. It was noted that the works were probably undertaken by landowners with grants from the former Wairarapa Catchment Board.

LiDAR provided for the area was only available as 1m Digital Elevation Models which did not provide enough detail on topography for this project and so additional levelling was conducted as described in Section 2.2.

Locals also provided useful photos and information on recent and historic changes to the site.

3.2 Field Investigations

Field investigations were conducted in the period 7-9 November 2017 including a general assessment of the project area and neighbouring wetland areas and both bed level measurements and examination of existing vegetation communities over the project site.

3.2.1 BED LEVEL MEASUREMENTS

Estuarine vegetation communities exhibit a sequence or zonation along environmental gradients (e.g. Chapman, 1960; Partridge and Wilson, 1998; King et al. 1990, Bishop, 1992; Morton and Cameron, 1993; Deng et al. 2004). This zonation or sequence reflects variations in hydro-period, salinity and other physical constraints as well as interactions between vegetation communities and other factors.

Accordingly, bed levels were surveyed over the proposed restoration area and among existing wetland vegetation communities to provide an indication of the likely estuarine vegetation communities to develop once hydrological connections to the lake are restored. These measurements were conducted in both an exposed area along the northern margin of the lake and within the sheltered estuarine vegetation immediately seaward of the restoration area. The latter measurements provide the best indication for the restoration area if the existing stopbanks are retained. The measurements in the exposed area provide an indication of how the estuarine vegetation communities may shift if the present stopbank seaward of that area is ever removed.

The bed level heights were approximately adjusted to mean sea level using a high tide water level measurement taken on the morning 8 November 2017 which was related to the high tide elevation recorded at the Lake Ferry water level recorder. Water levels at the Lake Ferry recorder are expressed relative to a datum 10m below Mean High Water Spring (MHWS) in which Mean Sea Level (MSL) is RL 9.4m (Appendix B). As the high tide water level may have varied slightly between the measurement site and the Lake Ferry water level recorder on the opposite side of the lake, the elevations are only accurate to MSL within ±0.05m. However, this accuracy is adequate for the purposes of this project.

A local Wairarapa Catchment Board (WCB) benchmark (Figure 12) was also surveyed to allow more accurate correction of bed levels to MSL at a later date if required. Discussion with Greater Wellington Regional Council (GWRC) flood engineer Mr Ranjan Cyril indicates that the elevation of the former WCB benchmark is not presently known by GWRC. However, there are other former WCB benchmarks nearby with known elevations which can be readily used to level the benchmark at a future date if required.

3.2.2 ECOLOGICAL CHARACTERISTICS

Plant species present in the project area and equivalent areas nearby were noted in relation to the bed levels and environmental conditions (e.g. wave exposure) they were exposed to.

Any birds or fish seen during the site visit were noted and the area assessed for suitable habitat for birds and fish.

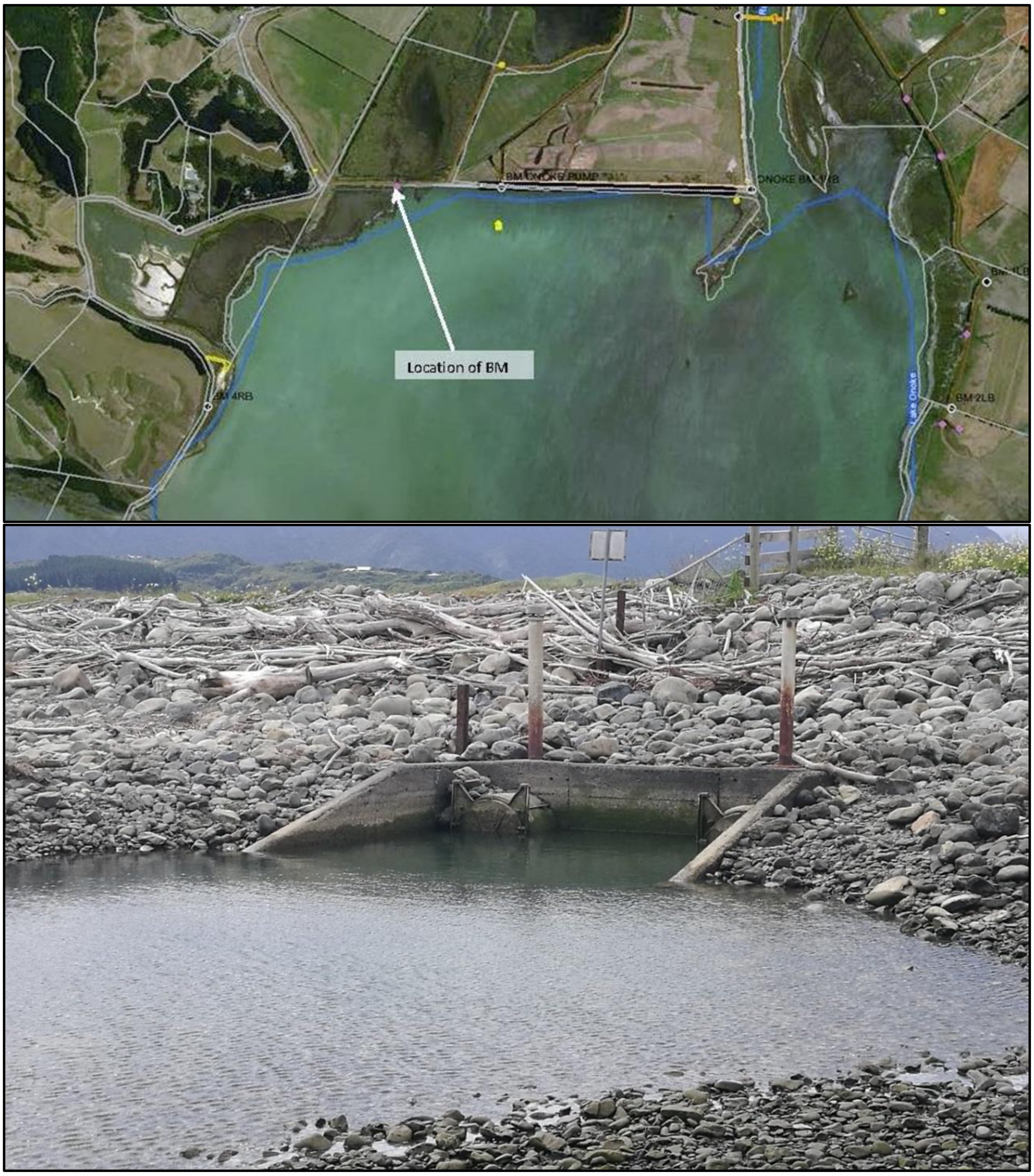


Figure 12: Location of former Wairarapa Catchment Board benchmark (BM) levelled during the field investigations. The elevation of this former WCB benchmark is not presently known but it can be readily levelled using other nearby benchmarks of known elevation. This would enable more accurate correction of the surveyed bed levels to MSL if required.

3.3 Stakeholder Consultation

An initial meeting was held with affected and interested stakeholders (including local landowners, iwi and other parties) in the Featherston Community Hall on the 9th November 2017. The main purposes of this meeting were to:

- Identify and discuss any concerns, issues or general questions relevant to the project and future restoration; and
- Obtain information on the study site (including historic changes, values and flooding) from the locals.

The draft report was also circulated among the stakeholders for comments in December 2017.

3.4 Sea Level Rise

In the longer term, any restoration could be affected by projected future sea-level rise. Accordingly, we have given brief consideration to this potential influence.

There is considerable uncertainty as to the nature and rate of future sea level rise. In New Zealand, national guidelines for future sea level rise follow figures from the most recent review conducted by the Intergovernmental Panel on Climate Change (IPCC), with adjustments as recommended by relevant NZ experts. The most recent review by the IPCC was conducted in 2013 (Church et al., 2013) and considered 4 emissions scenarios. The sea level rise projections for the differing scenarios are shown in Figure 13.

For the purposes of this study we have considered the IPCC (2013) RCP8.5 scenario, the most conservative/precautionary of the 4 emissions scenarios modelled by the IPCC. It is important to note that these are sea level rise “projections” for the relevant emissions scenario and planning periods and should not be confused with “predictions”.

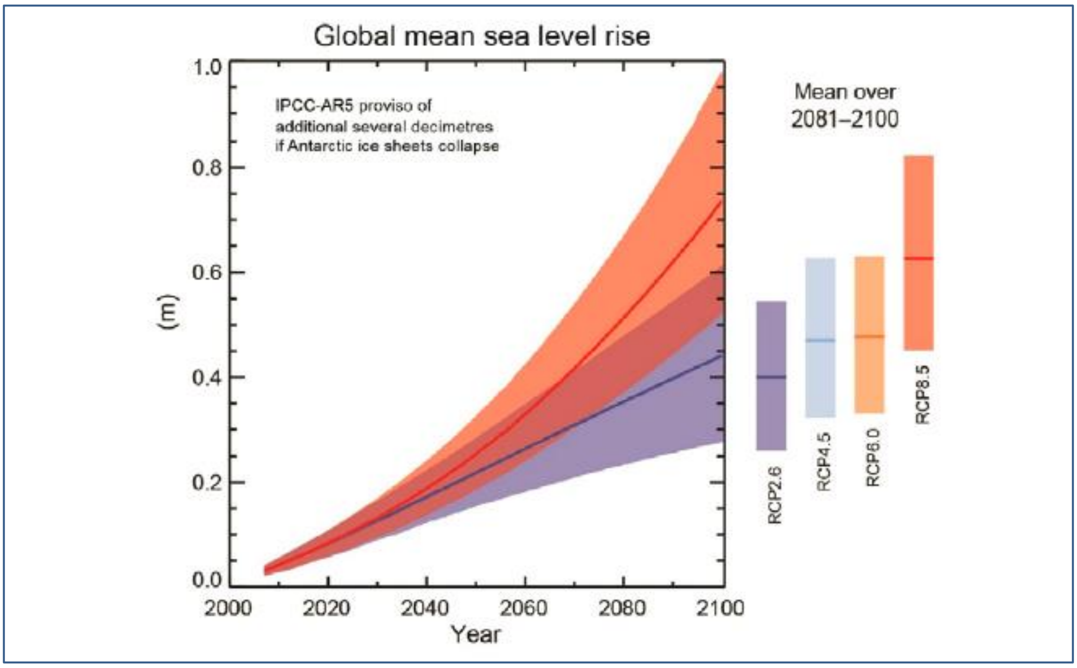


Figure 13: IPCC projections of global average mean sea level (MSL) rise in metres for the various emsssions scenarios (RCP2.6 to RCP8.5) they modelled.

The "most likely" sea level rise projections for the RCP8.5 scenario are listed in Table 1 for the 2060, 2100 and 2120 planning horizons. While higher levels of sea level rise cannot of course be ruled out, these are reasonable upper limits for the relevant planning periods as RCP 8.5 was the most conservative scenario in the most recent (Church et al. 2013) IPCC review (Figure 13).

Table 2: Projected sea level rise values for the RCP8.5 scenario. (Taken from Table 2.3 of Tonkin and Taylor, 2017 – referencing NIWA, 2015 and IPCC, 2013). Note that sea level rise figures have been rounded up to nearest 0.05m to provide round figures).

Planning Period	Most likely Sea Level Rise (RCP 8.5)
2060	**0.35**
2100	**0.75**
2120	**1.05**

In addition to sea level rise, it is important to note that the restoration site lies in an area that is tectonically active; with the Wairarapa Fault bounding the eastern side of the Tararua Ranges and numerous other active faults in the Wairarapa valley and eastern hills (WELA, undated). Movements on some of these faults can cause vertical displacement, sometimes significant. Cromarty & Scott (1995) note the wetlands have been significantly modified over the last 150 years through uplift of the former lake-bed in the 1855 earthquake. Obviously, any such vertical displacement would result in (almost instantaneous) relative sea level change. Accordingly, tectonic change could be as significant as or even considerably more significant than sea level rise in this area.

4 RESULTS FROM FIELD INVESTIGATIONS

This section briefly summarises the results from the field investigations and the implications of these results for the proposed restoration.

4.1 Bed levels over the restoration area

The survey work indicates that bed levels over the restoration area range from about RL 0.6-4m above mean sea level (MSL); with elevations generally increasing inland as would be expected (Figure 14).

The lowest elevations occur in the inverts of stream and drain channels. Elevations in other areas are generally >RL 1-1.2m (Figure 14).

The lowest areas of farmland further upstream (i.e. landward of the road) have much higher elevations; measurements ranging from RL 2.9-4.9m and typically being >RL3.9m. The lowest road elevations are >R3.8m (Figure 14).

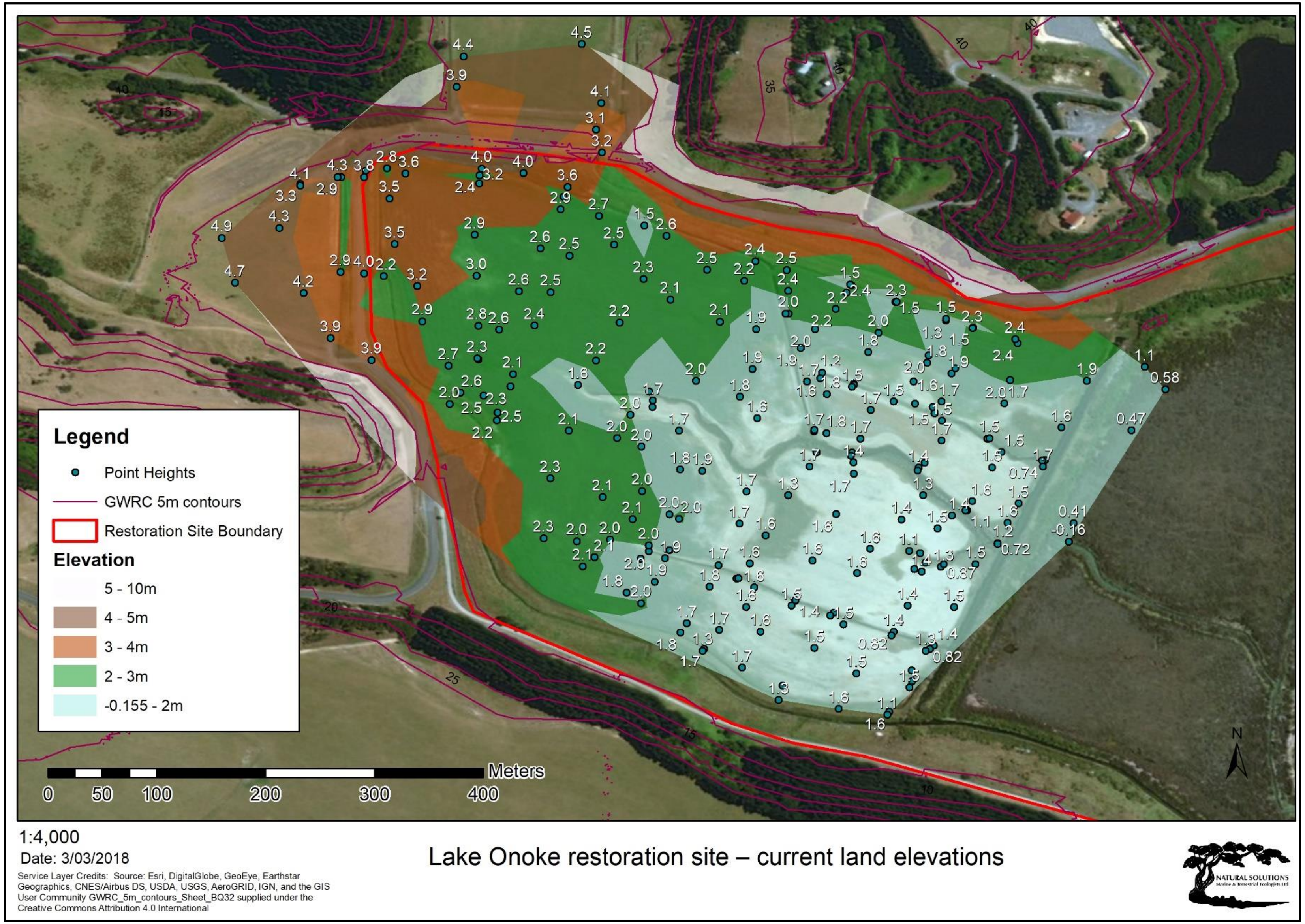


Figure 14: Bed levels measured over the site and farmland further upstream. Elevations are in metres relative to mean sea level. Note that the contours are broadly indicative only and there is significant local variation in bed levels right across the site.

4.2 Bed level elevations of estuarine vegetation

Estuarine vegetation typically occurs within defined elevations at any particular site. Accordingly, field measurements of the bed levels at which different species occur can help predict which areas of the site may be colonised by which species. The relationship to bed levels also varies with exposure for any particular species. Therefore, measurements of the occurrence of different species in areas of varying exposure can help understand the implications of increasing exposure (e.g. removing stopbanks). The following sections briefly describe the results from field measurements at the site and implications for the restoration work.

As discussed in section 3.2.1, bed levels were measured among estuarine wetland vegetation in an exposed site (adjacent to the causeway road to the Ruamahunga River entrance - Paul's Bank) and in the sheltered estuarine vegetation immediately seaward of the restoration site (i.e. between the two stopbanks). The distribution of saltmarsh ribbonwood was also measured in an area of intermediate exposure; being an area on the margin of the main lake but sheltered by wide saltmarsh to seaward which is likely to reduce wave action.

The measurements for saltmarsh focused particularly on the highest elevations in which the various estuarine vegetation species were found. The more seaward (and lower) elevations are much lower than the restoration site and therefore not relevant. However, both the highest and lowest elevations were measured for saltmarsh ribbonwood. Figure 19 shows an example of the interface between saltmarsh (sea rush and oioi) and saltmarsh ribbonwood communities.

The bed elevation results for the saltmarsh species (oioi and sea rush) are shown in Figure 15 and for saltmarsh ribbonwood in Figure 16. Note that the numbers along the horizontal (X) axis are not important; we simply applied arbitrary numbers to the various measurement sites so that when plotted all sites from similar areas were grouped together. Otherwise the plots would be quite complex. Figure 17 shows the expected extent of coastal vegetation following restoration of natural hydrological flows and removal of grazing.

There is considerable difference in bed levels between the exposed and sheltered areas for both the saltmarsh and saltmarsh ribbonwood; with these species occurring at much higher elevations (approximately 1m higher) in the exposed location. The data for the sheltered location provides the best indication for the bed levels in which these species are likely to occur at the project site.

The data suggests that with the stopbanks in place (but opened to provide hydraulic connections) saltmarsh is only likely to occur in areas with bed level elevations less than RL 0.6m. Accordingly, following restoration works saltmarsh is only likely to occur in low areas along the margins of streams and drains. However, if the outer stopbank was removed and the site became more exposed, much of the saltmarsh between the stopbanks might be lost. This is of concern as the inner stopbank cannot be removed as it is required for the cycleway.

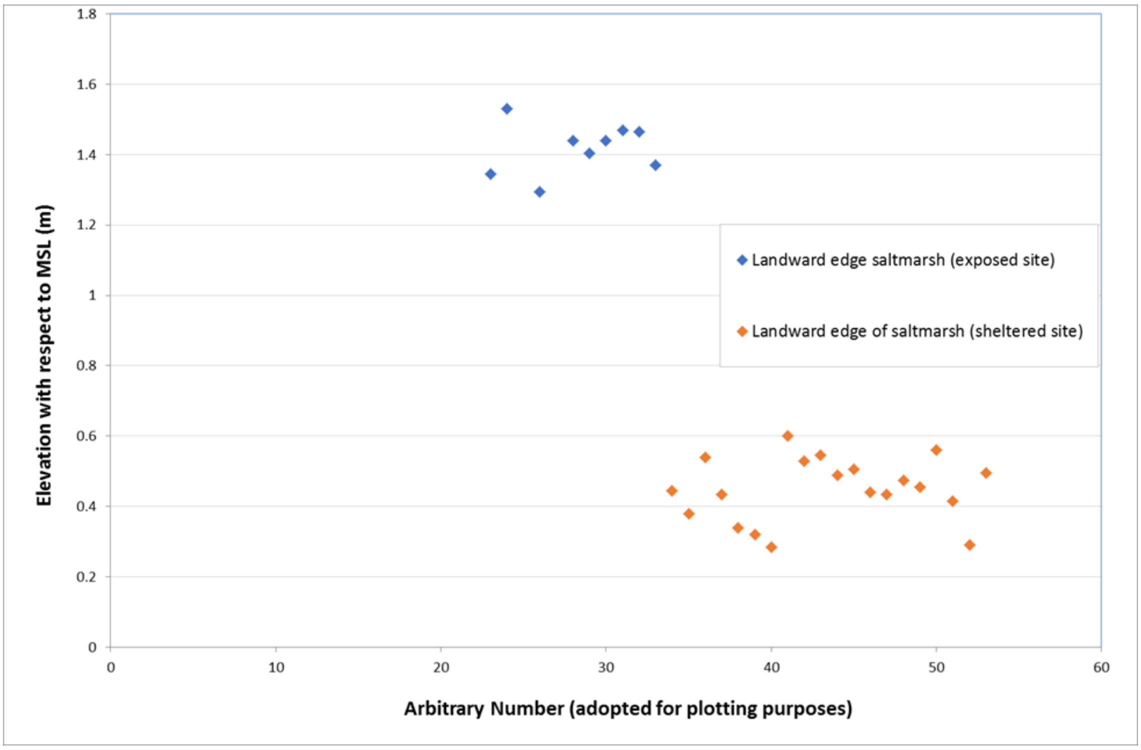


Figure 15: This graph shows that the landward limit of saltmarsh communities occurs at lower ground elevations in sheltered areas behind stopbanks (typically only extending to about 0.6m above MSL) but at higher bed level elevations in more exposed areas subject to wave action (e.g. along the edge of the causeway/Paul's Bank).

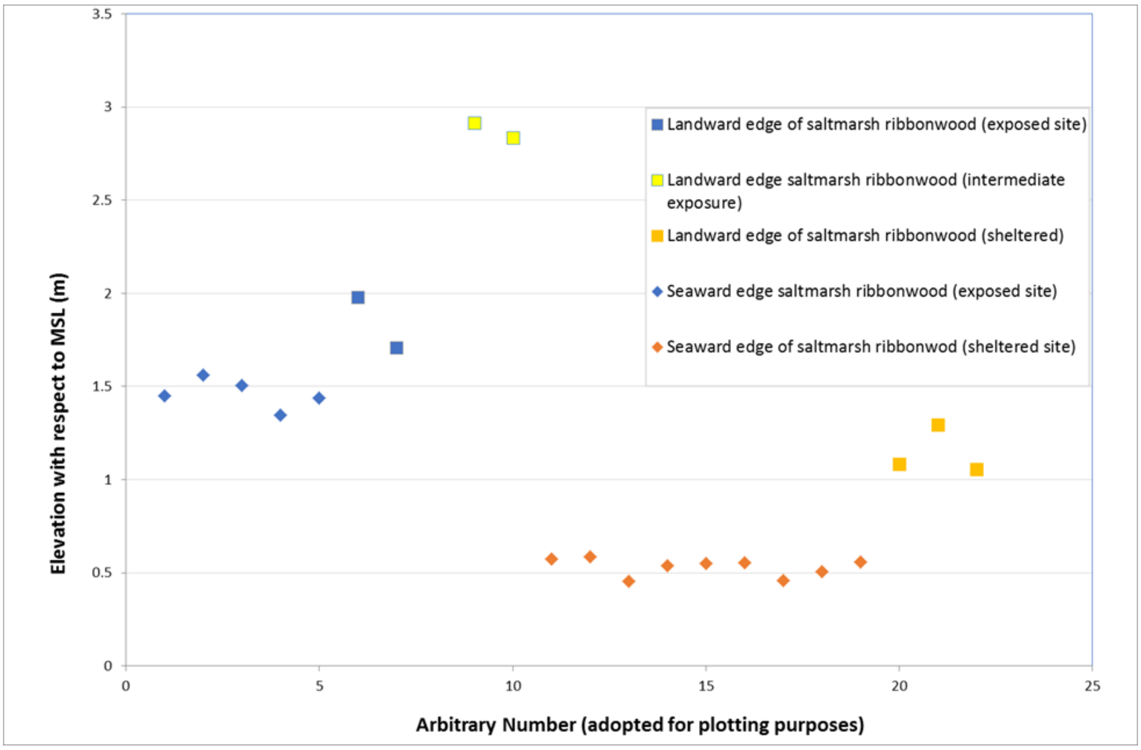


Figure 16: This graph shows that saltmarsh ribbonwood extends over lower elevations in sheltered areas like the restoration site but over higher elevations in exposed areas.

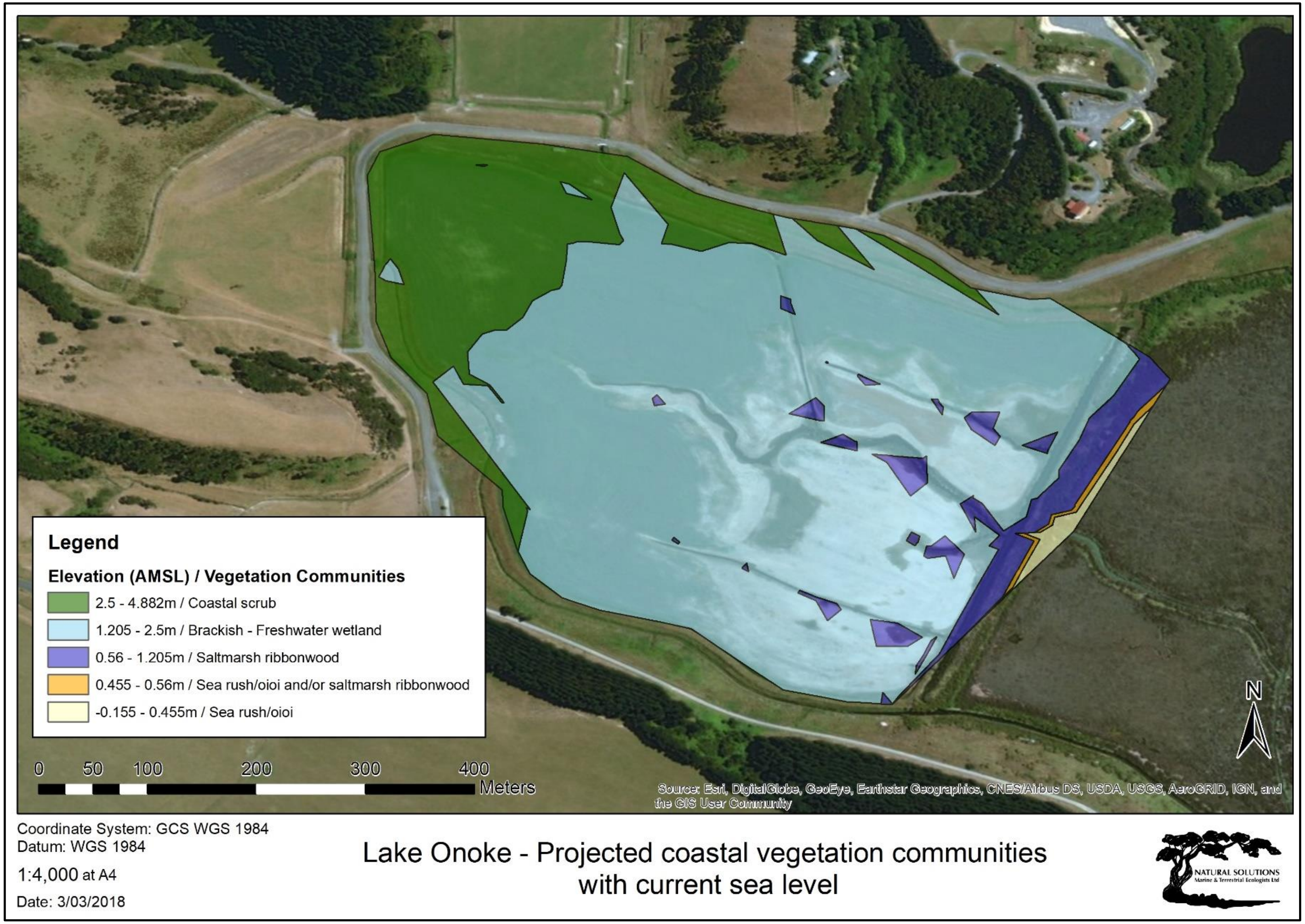


Figure 17: The estimated extent of coastal vegetation communities with the current sea level and full restoration of hydrological connections with the lake and upper catchment. Note that the contours are broadly indicative only and there is significant local variation in bed levels right across the site.

Accordingly, any saltmarsh lost to seaward is not likely to replaced further landward. Therefore, as the saltmarsh between the stopbanks is in very good condition and valuable, we believe it is wisest to retain the outer stopbank for the interim.

Similarly, the field measurements noted that in sheltered areas the saltmarsh ribbonwood occurred over elevations ranging from just less than RL 0.5m up to at least RL 1.4m. In contrast, this species occurred between higher elevations (extending up to of RL 2.8-2.9m) in the more exposed areas outside the stopbanks (Figure 16). In the restoration area landward of the inner stopbank, we suspect that saltmarsh ribbonwood might extend to elevations slightly higher than RL 1.4m due to periodic inundation of the restoration area by brackish lake waters; once estuarine hydrology is restored (see discussion of latter in Chapter 5). However, it would be wise to restrict large plantings to elevations less than RL 1.4m unless experiments conducted indicate that it is appropriate at higher elevations. Small trial plantings of saltmarsh ribbonwood at various elevations should be conducted after hydrological restoration to assess the highest elevations at which this species will thrive prior to any extensive plantings of the species.

Overall, it appears that the shelter provided by the outer stopbank significantly reduces the elevation at which salt marsh and saltmarsh ribbonwood occur. While this could be changed by removing the stopbank, we suggest that a cautious approach be adopted in this regard. For instance, the seaward edge of the existing saltmarsh may retreat/erode if the outer stopbank were simply removed (i.e. the saltmarsh zone may translate landward). It would also be quite difficult and expensive to remove the stopbanks.

In areas above RL 2.0m (much of the restoration area) the results suggest that vegetation communities are more likely to be freshwater wetland communities and (in highest areas) various shrubs and trees. These results are consistent with the advice from long-time local Mr Joe Houghton that extensive areas of flax and (in higher levels) patches of kānuka occurred prior to extensive modification. These are now absent from the area except for one remaining kānuka.

4.3 Floods and upstream elevations

One of the concerns raised in regard to restoration of the area is the potential for more frequent flooding of upstream farmlands or the road around the landward margin. To assess implications for such flooding, bed levels were measured in the lowest areas of upstream farmland (including the paddock upstream of the road bridge and the paddock upstream of the small road culvert) and the road (Figure 14).

In addition, extreme wood debris levels (from elevated lake levels) were measured in:

- Exposed lake margin areas along the causeway to the river entrance (Paul's Bank) - being locations with no or only narrow saltmarsh wetlands to seaward (see Figure 18).

- More sheltered areas (intermediate exposure) along the lake margin causeway - being locations with >150m width of saltmarsh to seaward.

In both cases, the measurements were taken along the top landward edge of the flood debris to err on the side of caution. These highest levels are very likely to include a wave component that will not be present in the much more sheltered restoration area.

No similar wood debris levels were noted in the sheltered saltmarsh immediately seaward of the restoration area. However, a fine debris level from a flood event was noted and levelled. (see Figure 19). The results are summarised in Figure 20.

Figure 18: Wooden debris deposited on the exposed margin of the causeway road (Paul's Bank).

Figure 19: Fine debris deposited in the sheltered saltmarsh immediately seaward of the restoration area. Note the clear boundary between the saltmarsh and taller saltmarsh ribbonwood communities (9/11/2017)

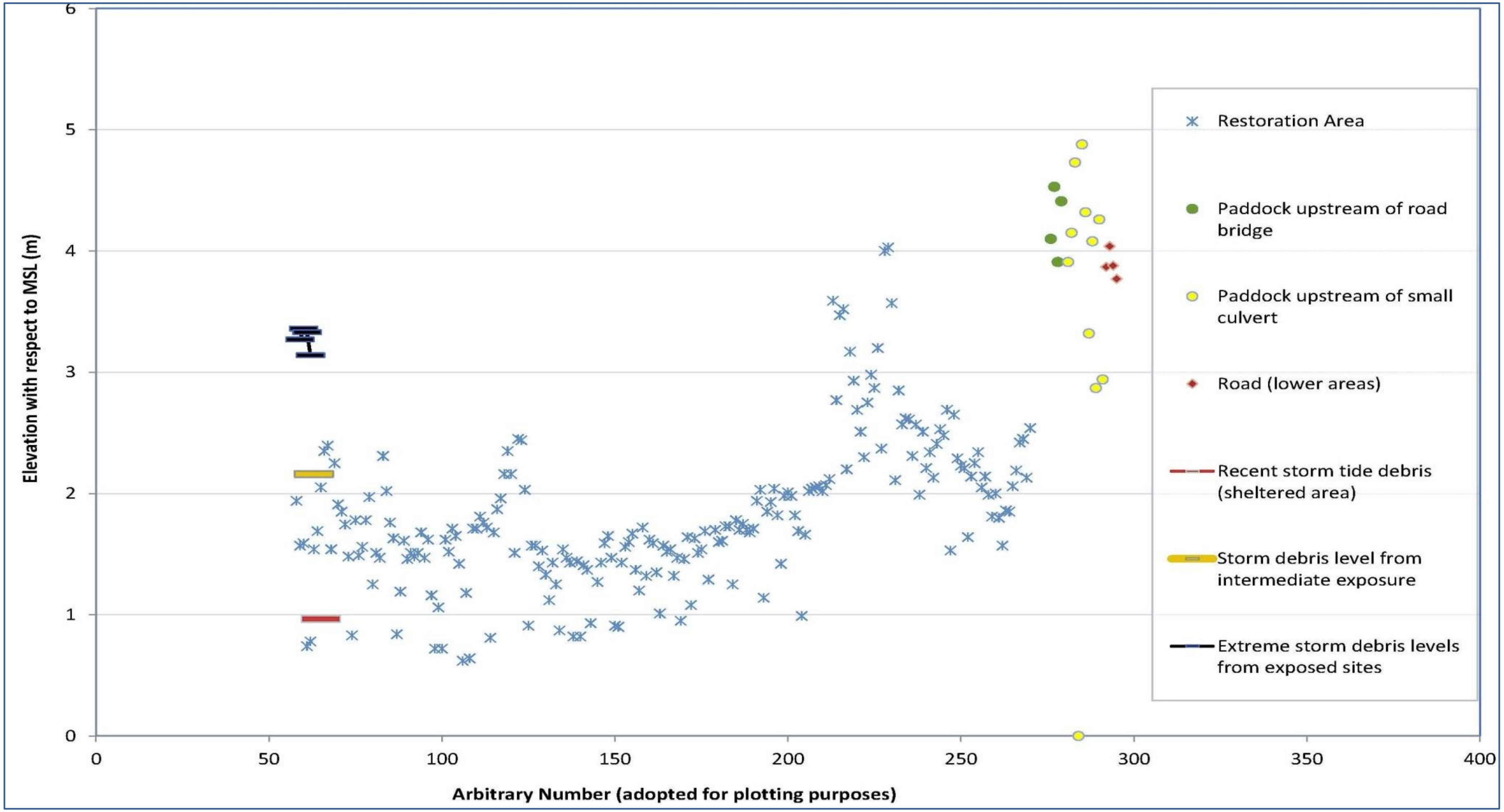


Figure 20: Elevation of restoration area, neighbouring paddocks and road relative to flood event debris. To simplify plotting on this diagram, the various sites were given arbitrary numbers so they could be grouped according to different locations (see legend). The elevation or height of each site above mean sea level (MSL) is shown on the Y axis.

It can be seen in Figure 20 that the ground elevations on the road and over upstream paddocks are above even the extreme flood debris levels measured in exposed areas near the causeway (Paul's Bank). This indicates the paddocks and road will not be affected by flooding from the lake if the stopbanks are breached or removed.

GWRC advised that the lake can reach elevations of 12.00 relative to their datum when the lake is blocked (Mr Ranjan Cyril, Flood Engineer, GWRC, Email of 23 Feb 2018); a level equivalent to 2.6m above MSL. This suggests that the flood levels in the lake are actually quite a bit lower than the highest debris levels (surveyed in exposed areas) shown in Figure 20. It can be seen that the lowest ground elevations on the road and the upstream paddocks are all higher than 2.6m above MSL and typically higher than 3m above MSL. In fact, the only elevations in the upstream paddocks that are less than 3m above MSL (Figure 20) were measured at the bottom of a drain just upstream of the road and not in the paddocks. And even these drain elevations are higher than 2.6m above MSL.

Accordingly, the indications from both Figure 20 and from the GWRC advice on lake flood levels are that the road and upstream paddocks will not be subject to flooding from the lake if the stopbanks are breached or removed.

This is also consistent with existing experience. The feedback from locals suggests that no flooding of the upstream paddocks or road occurs from the lake through the existing diversion drains adjacent to the stopbanks. The only flooding of the paddocks they noted occurred with flood events from the local catchments (i.e. Aruhe Stream); not from elevated lake levels. The diversion channels provide a similar level of hydraulic connectivity to the lake as that likely to be provided by the reinstated stream channel proposed (see Section 5.2). Accordingly, if flooding of the road and upstream paddocks is not experienced through these diversion channels during extreme lake levels, then it is also not likely to be experienced with the reinstated stream channel proposed for the restoration.

4.4 Potential effect of projected sea level rise

The primary effect of sea level rise will be for estuarine vegetation communities to transition upwards and landwards; with the change in the elevation of these species being similar to the rise in sea level.

The effect of the future sea level rise projections listed in Table 2 on estuarine wetlands is summarised in Table 3.

It can be seen that sea level rise of 1.05m over the period to 2120 would likely move the landward edge of saltmarsh communities from RL 0.6m inland to RL 1.65m and the landward edge of the saltmarsh ribbonwood communities from RL 1.5m to RL 2.55m. These elevations are comfortably within the proposed restoration area; the more landward elevations of which are typically in the order of at least RL 3.5m (Figure 14). Accordingly, with the proposed restoration, these estuarine wetland communities will be free to translate landward in their entirety, even with sea level rise of up to 1.05m. Figure 21 and Figure 22 give an indication of likely vegetation community extents modelled on a 0.5m and a 1m sea level rise.

The landward distance that the estuarine wetland communities would translate with 1.05m sea level rise is approximately 150-180m at this site. Both the landward and seaward edges of these wetland communities would likely move landward by a similar distance.

In the absence of the proposed restoration these wetland communities are not free to migrate landward. The saltmarsh ribbonwood community would likely to be lost in its entirety or reduced to a narrow band higher on the stopbank. The saltmarsh community seaward of the stopbank would be reduced in width by 150-180m, markedly reducing the existing width of saltmarsh.

Accordingly, the proposed restoration will increase the resilience of the estuarine wetland to future sea level rise.

Table 3: Potential effect of future sea level rise on the landward edge of estuarine wetland communities. The various sea level rise projections are for the planning periods detailed in Table 2 and are based on RCP 8.5, the more precautionary of the emissions scenarios modelled in the most recent IPCC review. As such, they are reasonable upper limit projections (not predictions) for the relevant planning periods.

	Landward edge of wetland vegetation (RL in m above MSL)			
	Existing sea level	0.35m sea level rise	0.75m sea level rise	1.05m sea level rise
Saltmarsh	0.60	0.95	1.35	1.65
Saltmarsh ribbonwood	1.50	1.85	2.25	2.55

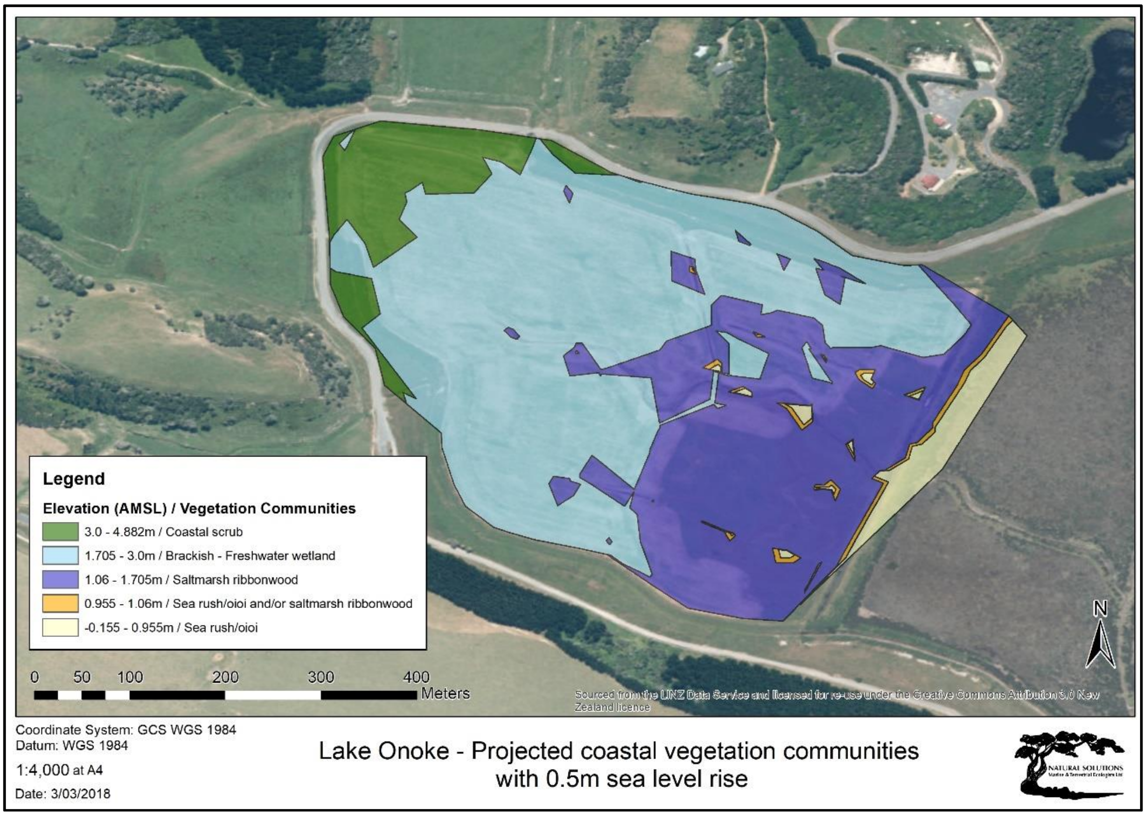


Figure 21: The estimated extent of coastal vegetation communities in response to a 0.5m sea level rise and full restoration of hydrological connections with the lake and upper catchment. Note that the contours are broadly indicative only and there is significant local variation in bed levels right across the site.

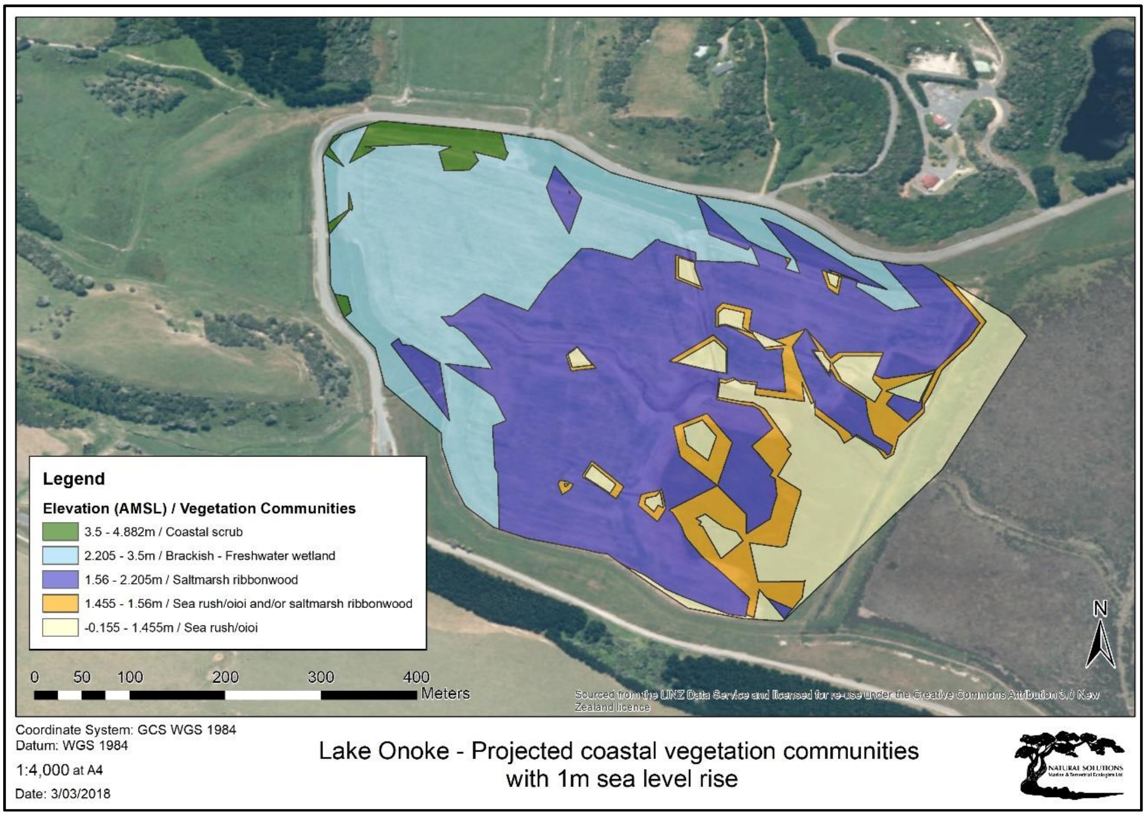


Figure 22: The estimated extent of coastal vegetation communities in response to a 1m sea level rise and full restoration of hydrological connections with the lake and upper catchment. Note that the contours are broadly indicative only and there is significant local variation in bed levels right across the site.

4.5 Ecological characteristics of existing area

4.5.1 VEGETATION

Remnant native plant species within the project area are limited to the low-lying land that experiences flooding and are often confined to watercourse edges where stock browsing was limited. Native wetland species noted during the November 2017 site visit include oioi (*Apadisma similis*), sea rush (*Juncus kraussii* subsp. *australiensis*), saltmarsh ribbonwood (*Plagianthus divaricatus*), purua grass (*Bolboschoenus medianus*), bachelor's button, *Isolepis cernua*, *Isolepis prolifera* and giant umbrella sedge (*Cyperus ustulatus*). Wiw/Edgars rush (*Juncus edgariae*) and *Juncus australis(?)* also occurs on higher ground with pasture. Small patches of a number of At Risk and Threatened plant species were also found in tidal waterways and associated with the bachelor's button meadow. These included *Ruppia megacarpa* (At Risk species – Naturally Uncommon), native musk (*Thyridia repens*) (At Risk species – Naturally Uncommon), *Lepilaena bilocularis* (Threatened species – Nationally Vulnerable), and Kirk's crassula (*Crassula kirkii*) (At Risk species – Naturally Uncommon). These species have also been noted as present in the surrounding wetlands by Wildlands (2013).

The lower stopbanks support dense populations of mahoe (*Melicytus ramiflorus* subsp. *ramiflorus*), kānuka, native spinach (*Tetragonia implexicoma*), pohuehue (*Muehlenbeckia complexa* var. *complexa* and *M. australis*), taupata (*Coprosma repens*), ngaio (*Myoporum laetum*), *Carex geminata*.

Figure 24 shows the approximate location of vegetation communities present under the current hydrological and grazing regime.

The following weed species were seen within the wetland project area: mercer grass (*Paspalum distichum*) and toad rush (*Juncus bufonius*) both present within the bachelor's button meadow and some water pepper (Polygonum hydropiper) with mercer grass in drains. Tall fescue (*Lolium arundinaceum* subsp. *arundinaceum*) and gorse (*Ulex europaeus*) were noted associated with stopbanks. Weeds in the wider Lake Ōnoke environment also include spartina (*Spartina* sp.), yellow flag iris (*Iris pseudacorus*), pampas (*Cortaderia selloana*) and Chilean rhubarb (*Gunnera tinctorial*).

4.5.2 OTHER VALUES

Like other pastural paddocks, the site in its current state provides a high tide roost for various coastal wading bird species and is used as a feeding site when the flood gate/s allow high tides to enter the area. This will change as the area is restored back to native vegetation communities. The change in the vegetation types from pasture species to native rushes, sedges and shrubs will change the wildlife habitat. While open grassland is currently used by wading birds, ducks and swans, the vegetation will change to favour more cryptic wetland species such as Australasian bittern and grey duck This will mean a change from a common exotic habitat type to less common native habitat types.

Īnanga (a fish species with a whitebait life stage) were observed in the western drain below the road culvert indicating that these water courses are still used by migratory fish to access upstream habitat. A recent survey by McEwan (2017) found tuna (shortfin eel), īnanga and common bully and did not find any mudfish within the survey area. However further surveys are recommended as the full extent of the restoration works was not anticipated by the fish survey. It is envisaged that the restored site will provide habitat for lowland native fish species that favour coastal floodplains with slow moving water and well vegetated waterway margins as well as other migratory species.   Rushes, sedges, grasses, herbs and flax within riparian areas that flood above the upper tidal wedge will provide potential whitebait spawning sites.

Figure 23: A fringe of sea rush and oioi lining the original natural channel in the restoration site with *Ruppia megacarpa* growing in the lower channel bed. Note the degraded channel edge where stock have easy access. (8/11/2017)

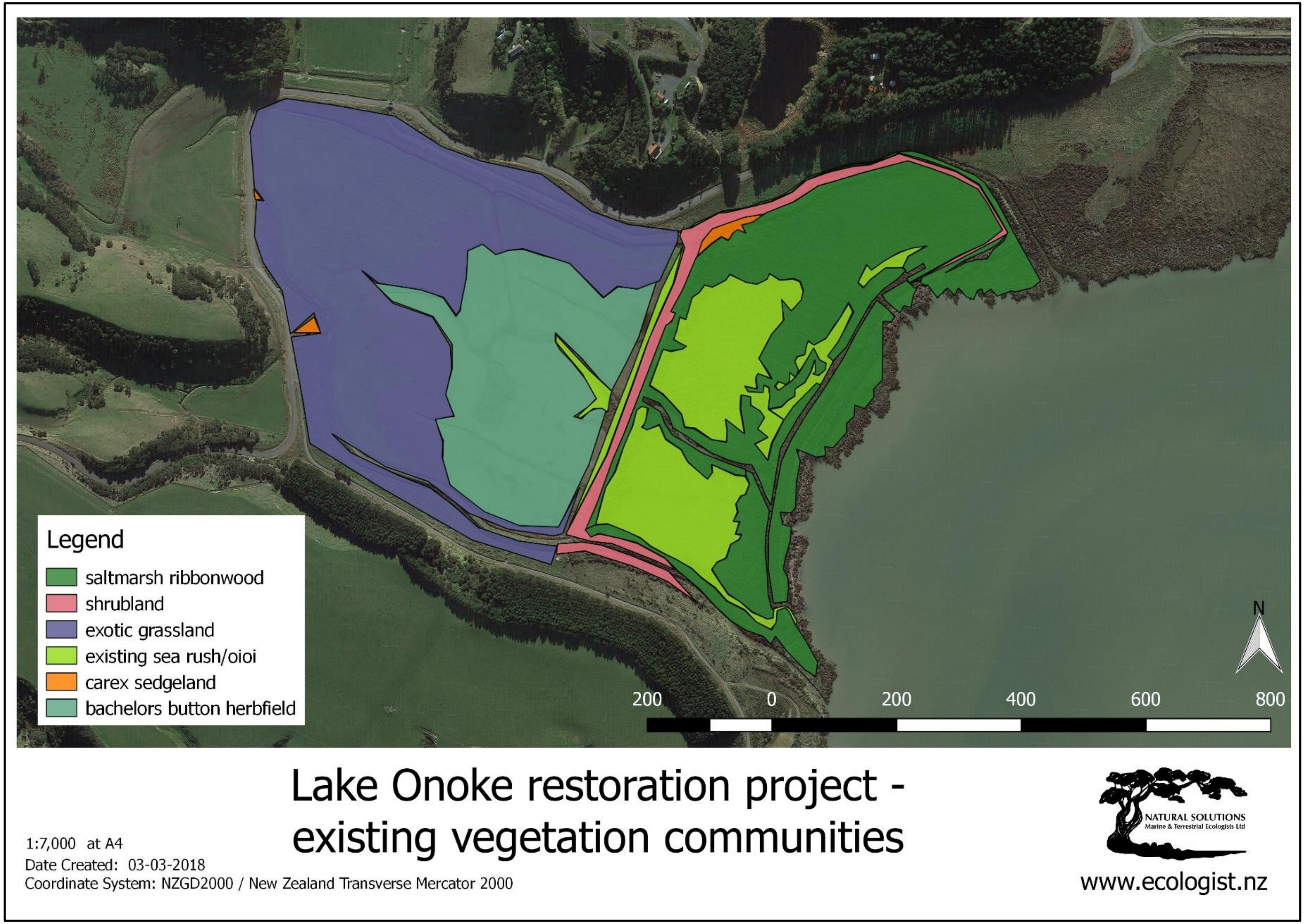


Figure 24: The approximate location of existing plant communities under the current hydrological and land use conditions.

4.6 Community input

Areas of interest raised by the community included:

- enhancing water quality;
- enhancing wildlife habitat;
- enhancing mahinga kai and recreational fishery habitat (e.g. whitebait spawning habitat);
- enhancing the natural wetland sequences;
- identifying a suitable safe cycleway route; and
- ensuring there are no negative effects on roading or private land.
- ensuring fish passage is maintained
- finding a name for the restoration site
- returning the area to iwi in a more natural (rather than heavily degraded!) state

These issues are discussed below in Section 5.

5 RESTORATION IMPLEMENTATION & MONITORING

The site has been significantly modified through historic drainage, stream diversion and stopbanking which have altered the natural water flows and hydrology of the site. Vegetation clearance and pastoral use have further modified the natural characteristics.

Restoration of estuarine and freshwater wetlands will require restoration of stream flows and hydraulic connections with the lake. Various other work will also be required as part of the restoration of wetlands and other native vegetation communities and associated fauna, including site preparation, planting and maintenance. Appropriate ongoing monitoring is also required through the restoration process until the relevant vegetation communities and associated fauna are restored. The incorporation of a cycleway and interpretation can provide complimentary uses of the area.

The Ministry for the Environment Freshwater Improvement Fund and Wairarapa Moana Wetlands Project have jointly allocated three years of funding (December 2017 – November 2020) specifically for the restoration of this site. The following sections describe the implementation recommendations for this time period (and at times, beyond 2020).

5.1 Restoration of hydrological regime

A key element in the restoration of wetlands and other native ecosystems in this area is the restoration of estuarine hydrology. This requires restoration of natural stream flows (including floods), natural tidal exchange and periodic inundation by brackish waters during high lake levels.

It is recommended that the stream flows be re-diverted through the restoration area along a route similar to the original natural stream path (Figure 25). The existing diversion channels and other side channels will need to be partially infilled where they intercept this restored channel; as shown by the blue dots in Figure 25. This is required to prevent the restored stream flows from being diverted. The following sections describe these works in more detail.

When undertaking any earthworks care must be taken around the buried telephone cable (see Figure 25). Also, it is recommended that any waterways that were not surveyed by McEwan (2017) but are to be affected by the proposed hydrological changes are surveyed for threatened fish species prior to earthworks commencing. Fish affected by hydrological modifications that will disturb or dewater their habitat can be moved prior to any diversion or earthworks works following typical fish salvage techniques.

In Area 1 (Figure 26) earthworks are required to relocate the diversion embankment (stopbank) to close off the diversion channel downstream of the road bridge and redivert the stream flow back into the floodplain. The new section of stopbank needs to be high enough so that even flood flows cannot divert back into the northern diversion channel. In all other areas (i.e. Areas 2-4 in Figure 26), the diversion channels or drains need only be infilled to the same elevation as the adjacent paddocks so that low flows enter the floodplain but high flows can flow into both the floodplain and all associated channels.

The original route of the natural stream channel from the road bridge (Figure 27) to the centre of the embayment is unclear on the available early (i.e. pre-diversion) aerial photography. On the basis of our brief field inspection we believe it will be possible simply to use existing drains as the low flow channel as shown in Figure 25. The adequacy of these channels (i.e. do they need to be widened?) will need to be examined further during detailed design. Flood flows are likely to disperse over the floodplains and this is desirable.

Draining the center of the restoration site is the original natural channel. However, it may have narrowed slightly over the decades since the original diversion due to the significantly reduced stream flows and the absence of tidal influence. For instance, the channel immediately downstream of the inner stopbank is typically 2-3m wider than the channel immediately upstream.

Accordingly, there may be some minor channel excavation required to restore natural stream channel dimensions in places and this will require further assessment during detailed design. Obviously, any such works should be undertaken before the stream is diverted back to its natural course and before openings are formed in the stopbank.

Where the restored steam channel intercepts the central stopbank (Area 4 in Figure 26), it is recommended that:

- A channel is cut through the stopbank (replacing the existing flood-gated culvert) to allow passage of stream (including flood) flows and restoration of tidal flows.
- A small portion of the drain on the landward side of the stopbank is infilled either side of the stopbank cut to adjacent (landward) ground levels so as to prevent diversion of low stream flows.

The channel downstream of the stopbank is offset from the channel upstream and so the connecting channel cut through the stopbank will form a bend in the stream. It is possible there may be some erosion on the outside of this bend although this seems unlikely as there have not been issues with erosion on tight bends in the existing diversion channel. Nonetheless, the works should ensure a good channel waterway area to avoid locally accelerated velocities. The design of this channel through the stopbank will require further work during detailed design but we recommend a minimum invert (channel bed) width of 6m for the low flow channel; with the stopbanks either side battered no steeper than 1V:1H and ideally more gently (e.g. 1V:2H) where practicable. This suggests the cycleway bridge will probably need to be at least 15-20m wide. The existing upstream road bridge (actually a box culvert, see Figure 27) has a lesser waterway and according to advice from local landowners acts as something of a choke during floods; which will limit the flood flows passing through the new waterway. However, ensuring a wide waterway will help minimise the risk of erosion and help future proof the restoration (e.g. if the upstream bridge is ever replaced with a wider structure).

It is also important to ensure that the outer stopbank has an adequate waterway opening. Dimensions of this opening (Area 5 in Figure 26) should be at least the same dimensions as the waterway area on the inner stopbank; ideally slightly larger as lesser channel gradients are likely in the outer area.

We also recommend replacing the culvert at the southern end of the cycleway (Area 6 in Figure 26) with a bridge to encourage tidal flows (see discussion of diversion channels in section 5.2 below). However, this channel need only be 1.5-2m wide at bed level and can have relatively steep batters (probably 1V:1H or steeper), similar to a drain. The bridge here however has to cross the existing perimeter drain and so will still likely need to be approximately 10m long.

5.2 Management of existing stopbanks and diversion channels

In general, we recommend that the existing stopbanks are not removed but simply opened up where required to provide for restoration of estuarine hydrology – as discussed in Section 5.1. Similarly, we recommend retention rather than infilling of the various existing drains and diversion channels, except for the localised infilling noted above in Areas 1-4 (Figure 26).

It is likely that the outer stopbank is having an influence on the elevations over which various species occur; as discussed in Chapter 4. However, removal of this stopbank would be expensive and would involve considerable disruption. It would also have unpredictable environmental effects. For instance, it could result in some erosion and/or landward retreat of the dense valuable saltmarsh habitat between the two stopbanks due to increased wave exposure. It is likely that this existing wetland community has adjusted to the increased shelter provided by the stopbank. It may be possible at some future date to lower or reshape the stopbank to resemble natural chenier ridges, including creation of additional openings. If appropriate, such work would certainly enhance the natural character. However, such work is best undertaken slowly and with careful localised experimentation to ensure that useful rather than damaging outcomes are achieved.

The inner stopbank is required for the cycleway and so cannot be removed. The feature could potentially be lowered to reduce visual impacts. However, it is important to bear in mind that elevated lake levels commonly reach RL 2.6m above MSL and there is also potential for 1-2m sea level rise (possibly even more, depending on future emissions) over the next 100-200 years. Accordingly, if lowering is desired, then detailed design should ensure this lowering does not compromise longer term sustainability of the cycleway.

Removal of the stopbanks around the landward edge could be undertaken, using the removed materials to infill the adjacent diversion channels. However, this would be expensive and, in our view, would achieve little. There is likely more ecological merit in retaining the stopbanks as elevated wildlife habitat (e.g. bird nesting) above flood levels than removing them. We recommend that the stopbanks be retained but planted in appropriate riparian vegetation and native trees and shrubs to form a visual screen around the landward edge of the wetland.

Infilling of the various diversion channels would be possible by excavating the stopbanks into these channels. However, we believe better ecological outcomes would likely be achieved by retaining these channels. For instance, we recommend that the drain immediately landward of the inner stopbank be excavated at both ends so that it links with the diversion channels either side. This will provide for improved tidal conveyance to the main restoration area and enhance the opportunities for expansion of estuarine wetlands.

Obviously, there is potential for weed invasion of the diversion channels above tidal elevations. Accordingly, appropriate riparian and shrubland plantings should be undertaken above tidal elevations to ensure canopy closure and prevent the channels becoming weedy.

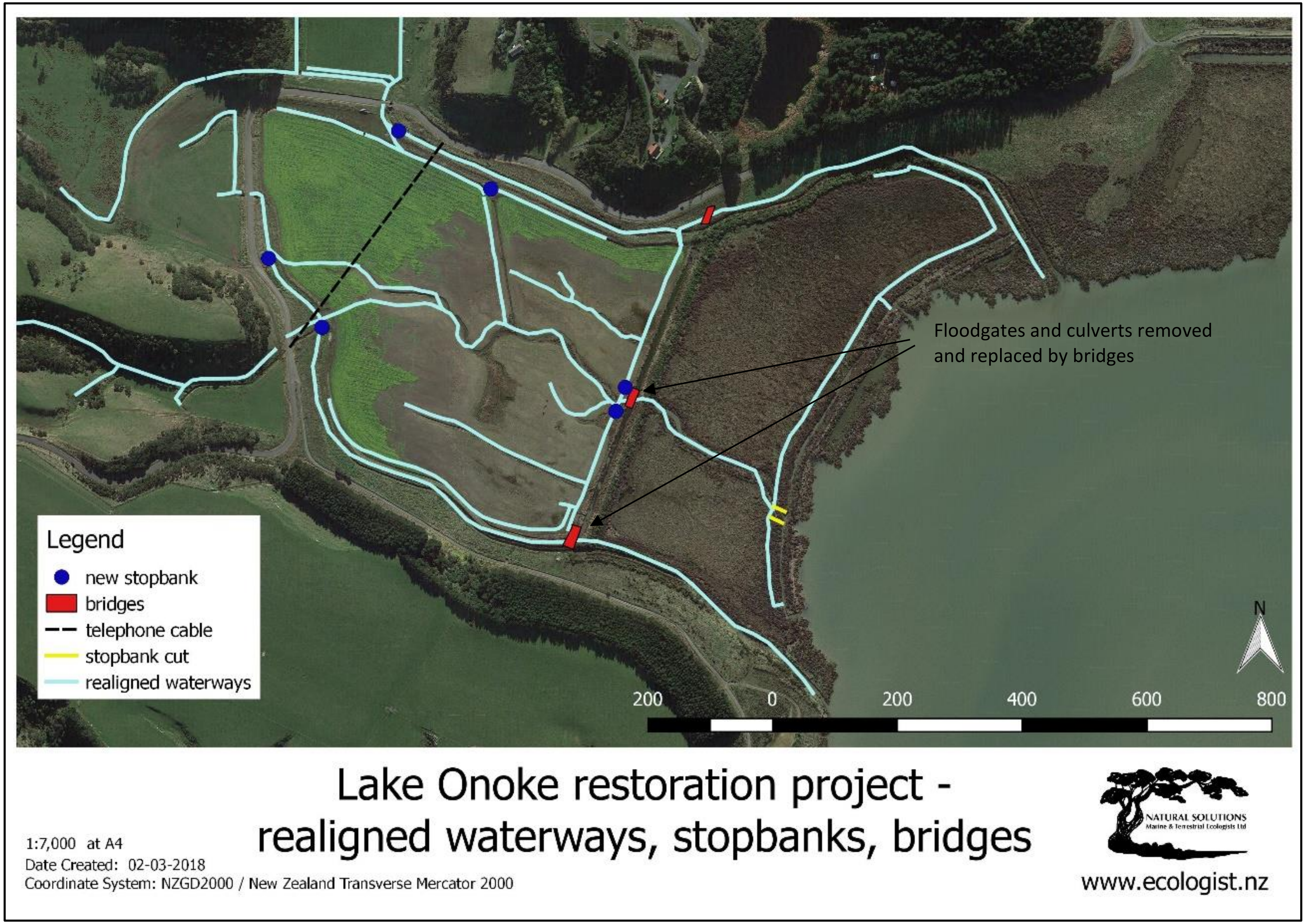


Figure 25: Proposed realigned waterways and associated new stopbanks to direct flows into the project site and directly through the outer stopbank, and bridges for the cycleway.

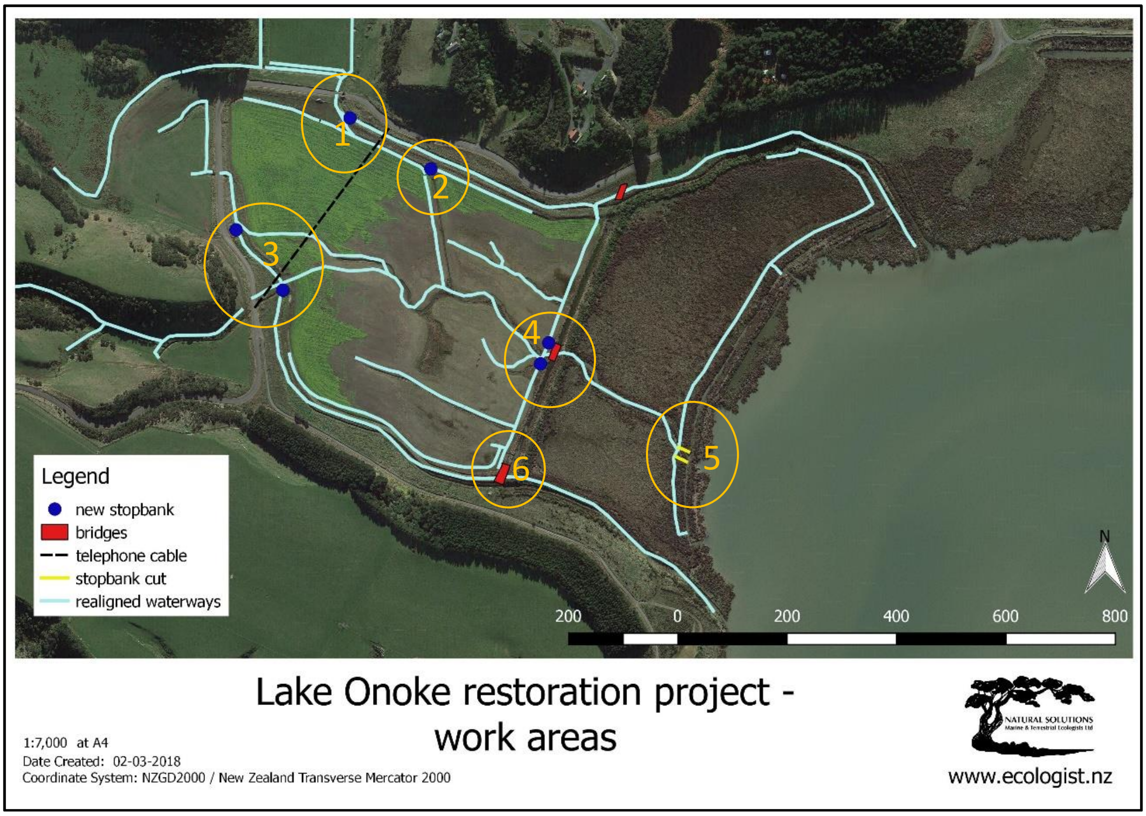


Figure 26: Work areas associated with the proposed hydrological restoration plan. Note the telephone cable and requirement to contact Keith Nielson, Downer (keith.nielsen@downer.co.nz) to accurately locate its position.

Figure 27: The box culvert under Western Lake Road. Note this culvert does not provide ideal fish passage but īnanga were seen upstream. 8/11/2017

5.3 Revegetation

5.3.1 GENERAL

The contouring of the site (Figure 14), the bed levels associated with the various estuarine wetland species (Figure 15 and Figure 16) and the various flooding levels (Figure 20) provide a broad indication of the vegetation species likely to be most appropriate in different areas. Broadly speaking, it is likely that:

- Estuarine saltmarsh will largely be restricted to areas with bed elevations less than RL 0.6m, largely low areas near streams;
- Saltmarsh ribbonwood is likely to very common in elevations from RL 0.5-1.5m and possibly even to higher elevations;
- Various freshwater wetland communities are likely to develop in areas upstream and landward of saltmarsh and those areas frequently affected by flooding;
- Coastal and lowland shrubland and tree species are likely to occur in the higher areas (e.g. elevations above RL2.5-3m) but some of the hardier species (e.g. mānuka, cabbage tree and flax) will probably occur down to the landward edge of the saltmarsh ribbonwood and even possibly to elevations just above extreme high spring tides.

However, the influence of brackish waters during periods of elevated lake levels introduces a significant complication to accurately predicting vegetation communities as this influence may allow wetland communities to extend into higher elevations.

It is also important to note that the contours in Figure 14 are broadly indicative only and there is significant local variation in bed levels right across the site. This should assist the development of a diverse mosaic of vegetation communities across the site.

Accordingly, an adaptive management approach with appropriate monitoring is recommended for revegetation of the lower areas where estuarine and freshwater wetland species are likely. Allowing natural revegetation to occur is the most ecologically sound and efficient method of restoring the vegetation communities. This allows the appropriate species to establish in the appropriate areas. However, while this natural process occurs it will be important to undertake regular weed control to ensure exotic species do not outcompete or hinder the establishment of native plant species. This may involve the use of selective herbicides e.g. haloxyfop to control grasses such as mercer grass or pampas. The majority of the restoration area is currently in pasture grasses and so will likely provide little weed threat except for initially outgrowing new plantings. Gorse is common in the wider area and is likely to invade drier open areas (e.g. stopbanks) and will require spot spraying. Tall fescue is also common in the wider area and can be difficult to control once well established (Todd et al. 2016). Constant weed monitoring is essential for the success of the native revegetation.

A slight variation could involve planting "nodes" of plants across the site; being isolated patches of various native species most likely to be appropriate. This provides a local seed source to assist natural revegetation. The mosaic of patches will also gradually coalesce over time with nature selecting the most appropriate species. This may prove to be the best balance.

We would strongly advise against any more significant plantings in lower lying areas until allowing at least 3-5 years of natural regeneration unless significant issues are being experienced with exotic weeds and it is very clear from monitoring which native communities are likely to be most appropriate. With appropriate monitoring, the extent of intervention required in lower areas will become evident within this timeframe. Trial planting 'nodes' within the brackish-freshwater wetland zone will allow plantings to be monitored for survival within this complex area that experiences infrequent flooding with varying salinity and water levels. Monitoring of naturally regenerating native plants will also be important. Natural regeneration is the best option for many reasons – including eco-sourcing, plant and planting costs, reduced carbon footprint (cf. planting materials, labour) and plant survival.

However, in the higher areas (~ >RL2.5-3m, see Figure 28) active planting is likely to be required to facilitate native vegetation cover and to avoid early successional recovery being dominated by vigorous exotic species. We recommend planting these areas with appropriate native species at relatively high density to ensure canopy closure within 3-4 years; with active weed maintenance until canopy closure is achieved.

It has been assumed that the small number of Threatened or At Risk plant species found within the site will adapt and spread as conditions become more favourable and/or recolonise from nearby seed sources. If monitoring shows that plant diversity is not increasing over the long term (8-10 years) as species naturally recolonise the restoration area, it is recommended that additional planting is undertaken to introduce the species identified as missing from the community. Another option is to collect any Threatened or At Risk plants found and transplant these following site preparation and hydrological changes after the removal of the flood gates. Successfully replanting of species will however depend on the ability to match suitable site characteristics to those where the plants were originally found.

5.3.2 SITE PREPARATION

Areas dominated by dense exotic vegetation (e.g. thick pastoral grasses) which are likely to be affected by tidal and brackish waters after the restoration of a more natural hydrologic regime should be sprayed before the relevant earthworks for the hydrologic changes (removal of floodgates and re-diversion of catchment flows) are undertaken. Dense rotting vegetation has been a problem in other restoration sites around the country and can affect natural plant regeneration. Prior grazing of the area will help reduce the organic matter density and amount of spraying required. Any native vegetation or areas thinly vegetated (e.g. bachelor's button sea meadow) can be left alone.

This will minimize the volume of decaying vegetation that will occur following the anticipated hydrological changes (as noted occurring after a recent flood event (Vorster, 2018)). It will also help prevent weed invasion of the recovering native plant communities.

Flooding levels vary depending on the amount of rain in the catchment and how long the lake mouth has been blocked. However, photographs of recent flooding events and the present vegetation assemblages provide a fairly reliable indication of where flood levels often reach. An arbitrary 2.5m bed height has been used to determine the coastal scrub zone which roughly corresponds with the recent (January 2018) large flood event.

These short-term openings will define the areas requiring spraying very well and will also assist in killing off the exotic vegetation. The opening during a period of higher lake level will also be important in helping reassure upstream landowners that their land will not be significantly affected by the proposed restoration.

Once the area requiring spraying is defined and lake levels have lowered, the spraying can be conducted – ideally waiting at least 1-2 weeks after the inundation (including 2-3 rainfall events) to maximise the benefit of the spraying.

In higher areas where planting of native trees and shrubs will be undertaken, spot-spraying should also be undertaken prior to planting; followed by ongoing maintenance spraying until canopy closure is achieved. This is critical as otherwise competition from exotic pasture species will significantly affect survival and growth rates.

5.3.3 PLANTING

As noted above, active planting is mainly recommended for higher areas more susceptible to weed invasion and where natural revegetation of native plants could be slower. The areas recommended for active planting are indicated in Figure 28 and are predominantly in the upper survey site associated with the road edge and stopbanks. The plantings will focus on early successional vegetation communities; allowing nature to then shape the future forest. Additional supplementary planting to introduce rare local species to enhance the vegetation biodiversity can also be undertaken once a native ground cover has established.

Suitable local species to plant to establish early successional vegetation communities and fast ground cover to help suppress weed establishment are listed in Table 4. Nursery plants should be sourced from within the Wairarapa Plains Ecological District.

Many plant species with seed that is spread by water or wind (e.g. rush, sedge and fern species) are likely to establish naturally from local seed sources. To establish fast-growing low vegetation cover along brackish waterway edges, *Cyperus ustulatus* is a hardy species to use.

Figure 28 provides indicative planting zones while acknowledging that relatively small local bed height variations within the floodplain can have significant effects on what species are most suited to the hydrological conditions. Fine scale plant layout is best done in the field by planters who recognise changes in topography and can match specific plant species to specific conditions.

It is recommended to plant at a density of one plant per 1 - 1.5 square metre (depending on plant species) using PB3 or similar sized plants to attain fast ground cover. This planting density can vary depending on the size of the plant used (e.g. flax compared with sedges) and the resources available for weed control. Therefore, it is estimated that the approximately 3.5 hectares of coastal scrub is to be planted which at 1.5m spacings will require approximately 18,000 plants.

Within the lower lying land that will be occasionally flooded (brackish-freshwater wetland area ~13.2ha), it is recommended that planting “nodes” are initially established across the upper site above the bachelor’s button zone to provide scattered patches of native species most likely to be appropriate for this zone. This will provide a local seed source to assist natural revegetation and provide trials to see which species are best suited to the fluctuating water levels and salinity in this area. If 1 ha is planted at 1.5m spacings this will require approximately 5,000 plants.

Table 4: Recommended species for restoration planting

SMR zone	Brackish species	Freshwater species	Terrestrial coastal edge species
saltmarsh ribbonwood *(Plagianthus divaricatus)*	bachelor's button * *(Cotula coronopifolia)*	giant umbrella sedge *(Cyperus ustulatus)*	kānuka *(Kunzea robusta)*
oioi *(Apodasmia similis)*	giant umbrella sedge *(Cyperus ustulatus)*	*Isolepis prolifera* *	harakeke, flax *(Phormium tenax)*
sea primrose * *Samolus repens* var. *repens*	*Carex geminata*	three-square * *(Schoenoplectus pungens)*	ti kouka, cabbage tree *(Cordyline australis)*
Remuremu * *(Selliera radicans)*	*Isolepis cernua* *	kapungawha, lake clubrush * *Schoenoplectus tabernaemontani*	mahoe (*Melicytus ramiflorus*)
NZ celery * *(Apium prostratum* subsp. *prostratum* var. *filiforme)*	*Isolepis prolifera* *	*Carex geminata*	mamaku * *(Cyathea medullaris)*
		harakeke, flax *(Phormium tenax)*	toetoe *(Cortaderia toetoe)*
		ti kouka, cabbage tree *(Cordyline australis)*	
		raupo * *(Typha orientalis)*	

* Note these species are likely to quickly self-seed into the area and will only require planting if this does not occur to help increase the local plant biodiversity.

Figure 28: Recommended areas for planting. Note the influence of brackish waters during periods of elevated lake levels introduces a significant complication to accurately predicting vegetation communities' extent.

5.3.4 WEED MAINTENANCE

Planting weed maintenance is essential to control competing vegetation to ensure plantings and natural regeneration can establish successfully and dominate the site. Initially it is recommended that weed control around plantings is undertaken in spring following the autumn/winter planting, during summer and in early autumn if required. Follow-up weed control should then be undertaken in spring and late summer for the next two years or more until the plantings are well established.

Table 5 outlines current weed control recommendations however this should be updated following ongoing monitoring. The site is currently relatively weed free as it is grazed however this will change once the grazing pressure is removed. Animal pest control (e.g. hares, rabbits) and/or protection of the plantings may also be required.

Table 5: Recommended weed control.

Weed species	Commonly found	Action
gorse	Any open free draining areas e.g. stopbanks	Monitor site and spot spray when small
tall fescue	From the saltmarsh ribbonwood zone upwards	Monitor site and spray when found. Use the selective herbicide haloxyfop if amongst other native non-grass species.
Mercer grass	Damp edges	Monitor site and spray if dominating open areas. Use the selective herbicide haloxyfop if amongst other native non-grass species.
Other weed species		Monitor site and attempt local eradication before a weed species can get established.

5.4 Cycleway/Recreation

The Remutaka Cycleway currently runs along the road. The project working group have identified a proposed new cycleway route. This proposed route runs along the lower stopbank and provides a safe track, good views of the wetland and opportunities for site interpretation.

As the stopbank is already in place, any adverse effects from the cycleway will be minor, particularly if established in conjunction with pest animal control.

It is also recommended that the stopbank batters are revegetated with local native plant species similar to those listed in Section 5.3.3 above.

Figure 29 shows the proposed new cycleway route and associated bridging that will be necessary.

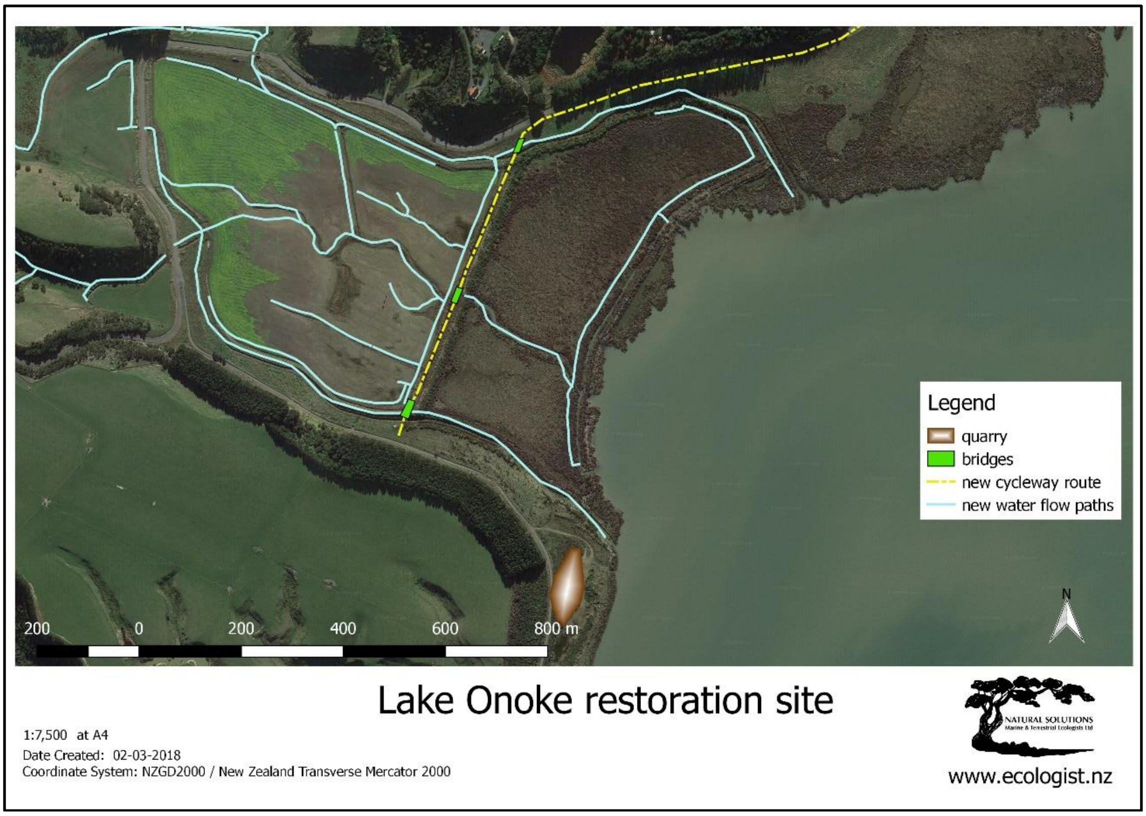


Figure 29: Proposed cycleway route across the wetland restoration site and gravel quarry.

5.5 Signage

It is planned to set up a working group to develop interpretative signs for the site. We recommend that potential interpretive themes could include:

- The objectives of the restoration project (rebuild the values lost, history of the site).
- Species and sites of cultural significance/value
- Coastal vegetation communities (tidal zonation, ecosystem sequences inland from estuarine wetland – freshwater wetland – coastal forest)
- Coastal fish and birds (including threatened species and fish migration (whitebait species, tuna)
- Sea level rise (and link to the tidal zonation and need for vegetation to be able to migrate landward)
- Ecosystem services of coastal wetlands e.g. massive carbon sinks for climate change mitigation, fish nurseries, water purification.

It is suggested that signs could be placed as the trail leaves the high ground beside Western Lake Rd (good vantage point over the project area), at either end of the central stopbank and maybe at the bridge in the middle of the stopbank. It would be a good idea to place signs where there are views and seating.

Figure 30: Examples of signs (from www.whatsthestory.co.nz)

5.6 Monitoring

Monitoring is essential to track the progress of activities and to evaluate the success of achieving project objectives. Following are monitoring suggestions. It is recommended these are reviewed to incorporate Maori monitoring indicators.

1. Hydrological changes – hydrograph to show site becoming wetter.
2. Carbon sequestration – soil and vegetation samples pre and post restoration.
3. Establish ground photo points to regularly document the restoration works and ecosystem health over the long term.
4. Undertake aerial imaging (orthomosaic and photo points) of the site before and after restoration work to document changes.
5. Regularly monitor weed growth and adjust weed control programme accordingly.
6. Record weed species present over time, time/cost to control weeds.
7. Undertake plant surveys (annually) to document changes in the vegetation communities (including diversion channels that have been modified or cut off).
8. Monitor planting success and natural native revegetation to allow for adaptive management of planting plans (e.g. once small trial plantings of saltmarsh ribbonwood at various elevations have shown the highest elevations at which this species will thrive).
9. Monitor animal species' usage of the area –
    a. fish – including mudfish, longfin eel, giant kokopu and other migratory species. Survey for īnanga spawning sites. Survey upper catchment fish populations before and after enhancement works. Check for fish passage issues further up the catchment.
    b. birds – establish 5 minute listen monitoring sites. Note preferred nesting areas and vegetation. Record general observations provided by agencies and the public.
10. Record wood debris extent after flood events using GPS and photos.

6 REFERENCES

Beadel S., Perfect A., Rebergen A., and Sawyer J. 2000: Wairarapa Plains Ecological District: Survey report for the Protected Natural Areas Programme. Department of Conservation, Wellington. 203 pp.

Chapman, V.J. & Ronaldson, J.W. 1958: The mangrove and saltmarsh flats of the Auckland Isthmus. Bulletin 125, DSIR, NZ.

Chapman, V.J. 1960: Salt marshes and salt deserts of the world. Interscience Publishers Inc, New York, New York, USA.

Church, J.A., Clark, P.U., Cazenave, A., Gregory, G.M., Jevrejeva, S., A. Levermann, A., M.A. Merrifield, M., Milne, G.A., Nerem, R.S, Nunn, P.D., Payne, A.J., Pfeffer, W.T., Stammer, D. & Unnikrishnan, A.S., 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Cromarty, P. & Scott, D.A. (eds). 1995. A Directory of Wetlands in New Zealand. Department of Conservation, Wellington, New Zealand

Denyer, K. & Peter, M. 2014: WETMAK: A wetland monitoring and assessment kit for community groups. NZ Landcare Trust, Hamilton. http://www.landcare.org.nz/wetmak

Deng Y.B., Horrocks M, Ogden J. & Anderson S. 2006. Modern pollen–vegetation relationships along transects on the Whangapoua Estuary, Great Barrier Island, northern New Zealand. Journal of Biogeography33: 592–608.

Goodman, J.M., Dunn, N.R. Ravenscroft, P.J., Allibone, R.M., Boubee, J.A.T., David, B.O., Griffiths, M., Ling, N., Hitchmough, R.A. & Rolfe, J.R. 2014: Conservation status of New Zealand freshwater fish 2013. New Zealand Threat Classification Series 7. 12 p.

Grant, I.F. (ed). 2012: Wairarapa Moana – The Lake and Its People. Wairarapa Archive, Masterton and Fraser Books, Masterton.

Greater Wellington Regional Council website - http://www.gw.govt.nz/background-2/ accessed 13/12/2017.

GWRC, 2015: Section 32 report: Wetlands for the Proposed Natural Resources Plan for the Wellington Region. Issues and Evaluation Report. Greater Wellington Regional Council, Wellington.

Hayward, B.W., Grenfell, H.R.,Sabaa, A.T., Kay, J and Clark, K. 2011: Ecological distribution of the foraminfera in a tidal lagoon-brackish lake, New Zealand, and its Holocene origins. Journal of Foraminferal Research v41(2): 124-37.

Hicks, B.J. 1993: Investigation of the fish and fisheries of the Lake Wairarapa wetlands. Report to the Wellington Conservancy Department of Conservation. NZ Freshwater Fisheries Miscellaneous Report No. 126.

King, W. M., Wilson, J.B. & Sykes, M. T. 1990: A vegetation zonation from salt marsh to riverbank in New Zealand. Journal of Vegetation Science 1:411-418.

Leach, B.F. 1981: The prehistory of the Southern Wairarapa. Journal of the Royal Society of New Zealand 11(1) 11-33.

Leach, B.F. and Anderson, A.J. 1974: The transformation from an estuarine to lacustrine environment in the Lower Wairarapa. Journal of the Royal Society of New Zealand 4: 267-75.

McEwan, A. 2017: Ōnoke Saltmarsh – mudfish survey. Riverscapes Freshwater Ecology Limited Report No. 17-24. Prepared for the Department of Conservation.

Morton, J. (ed) 1993: A natural history of Auckland (see particularly Chapter 6 "Shore Vegetation). Published by David Bateman Ltd in association with Auckland Regional Council. 131p.

Partridge, T. R. & Wilson, J.B. 1988: Vegetation patterns in salt marshes of Otago, New Zealand. New Zealand Journal of Botany 26: 497-510.

Reeves, P., Todd, M/. Myers, S., Bawden, R. 2013: Extent and significance of Wairarapa Moana wetlands and Lake Pounui. DRAFT, March 2013. Wildlands Contract Report No. 3105 prepared for Greater Wellington Regional Council.

Robertson, B. and Stevens, L. 2007: Lake Ōnoke 2007 – Vulnerability assessment and monitoring recommendations. Report prpared for GWRC by Wriggle Ltd.

Todd, M., Kettles, H., Graeme, C., Sawyer, J., McEwan, A. & Adams, L. 2016: Estuarine systems in the lower North Island/Te Ika-a-Māui: ranking of significance, current status and future management options. Department of Conservation, Wellington, New Zealand. 400 p.

Vorster, E. 2018: Lake Ōnoke control 'must get better'. Article in the Wairarapa Times-Age. Friday Jan 19, 2018. https://times-age.co.nz/lake-Ōnoke-control-must-get-better/

WELA (undated). Chapter 2 – Natural Hazards in the Wairarapa. https://www.civildefence.govt.nz/assets/Uploads/publications/wela-risk-to-lifelines-from-natural-hazards-chapter-2.pdf

Woolfe, K.J. 1993: Lakes Ōnoke and Wairarapa as modern analogues for the Hautotara and Te Muna formations (mid-Pleistocene), southern Wairarapa, New Zealand. Sedimentary Geology 84: 123-37.

7 APPENDIX A: LAKE ŌNOKE THREATENED AND AT RISK SPECIES LIST

Species listed adapted from Todd et al. (2016) indicating Threatened and At Risk species. Additional observations made during this survey are indicated with an asterisk*.

Common Name	Scientific Name	Conservation Status (2018)
Threatened Plants:		
horse mane weed*	*Ruppia megacarpa*	At Risk– Naturally Uncommon
Kirk's crassula*	*Crassula kirkii*	At Risk– Naturally Uncommon
native musk	*Thyridia repens (=Mimulus repens)*	At Risk - Naturally Uncommon
pygmy clubrush	*Isolepis basilaris*	Threatened – Nationally Vulnerable
sea holly	*Eryngium vesiculosum*	At Risk - Declining
	*Lepilaena bilocularis**	Threatened– Nationally Vulnerable
Fish:		
Banded kōkopu (whitebait species)	*Galaxias fasciatus*	
Black flounder	*Rhombosolea retiaria*	
Bluegill bully	*Gobiomorphus hubbsi*	At Risk: Declining
Brown mudfish[2]	*Neochanna apoda*	At Risk: Declining
Cockabully		
Common bully	*Gobiomorphus cotidianus*	
Common smelt	*Retropinna retropinna*	
Estuarine stargazer	*Leptoscopus macropygus*	
Estuarine triplefin	*Forsterygion nigripenne*	
Giant kōkopu (whitebait species)	*Galaxias argenteus*	At Risk: Declining
Grey mullet	*Mugil cephalus*	
Gurnard	*Chelidonichthys kumu*	
Hoki	*Macruronus novaezelandiae*	
Inanga (predominant whitebait species)	*Galaxias maculatus*	At Risk: Declining
Kahawai	*Arripis trutta*	
Kōaro (whitebait species)	*Galaxias brevipinnis*	At Risk: Declining
Lamprey	*Geotria australis*	Threatened: Nationally Vulnerable
Longfin eel	*Anguilla dieffenbachii*	At Risk: Declining
Red cod	*Pseudophycis bacchus*	
Redfin bully	*Gobiomorphus huttoni*	At Risk: Declining
Sand flounder	*Rhombosolea plebeia*	

[2] McEwan (2017)

Shortfin eel	*Anguilla australis*	
Shortjaw kōkopu (whitebait species)	*Galaxias postvectis*	Threatened Nationally Vulnerable
Torrentfish	*Cheimarrichthys fosteri*	At Risk: Declining
Trevally	*Caranx georgianus*	
Variable triplefin	*Forsterygion varium*	
Yellow-eyed mullet	*Aldrichetta forsteri*	
Birds:		
Australasian bittern	*Botaurus poiciloptilus*	Threatened: Nationally Critical
Australasian shoveler	*Anas rhynchotis*	
Banded dotterel	*Charadrius bicinctus*	Threatened: Nationally Vulnerable
Bar-tailed godwit	*Limosa lapponica*	At Risk: Declining
Black-billed gull	*Larus bulleri*	Threatened: Nationally Critical
Black-fronted dotterel	*Elseyornis melanops*	
Black-fronted tern	*Childonias albostriatus*	Threatened: Nationally Endangered
Black shag	*Phalacrocorax carbo*	At Risk: Naturally Uncommon
Black swan	*Cygnus atratus*	
Caspian tern	*Hydroprogne caspia*	Threatened: Nationally Vulnerable
Dabchick	*Poliocephalus rufopectus*	At Risk: Recovering
Grey duck	*Anas superciliosa*	Threatened: Nationally Critical
Grey teal	*Anas gracilis*	
Kingfisher	*Todiramphus sanctus vagans*	
Little black shag	*Phalacrocorax sulcirostris*	At Risk: Naturally Uncommon
Little shag	*Phalacrocorax melanoleucos*	
Paradise shelduck	*Tadorna variegata*	
Pied shag	*Phalacrocorax varius*	At Risk: Recovering
Pied stilt	*Himantopus himantopus*	At Risk: Declining
Pūkeko	*Porphyrio melanotus*	
NZ Pipit	*Anthus novaeseelandiae novaeseelandiae*	At Risk: Declining
Red-billed gull	*Larus novaehollandiae*	At Risk: Declining
Royal spoonbill	*Platalea regia*	At Risk: Naturally Uncommon
Scaup	*Aythya novaeseelandiae*	
South Island pied oystercatcher	*Haematopus finschi*	At Risk: Declining
Southern black-backed gull	*Larus dominicanus*	
Spotless crake	*Porzana tabuensis*	At Risk: Declining
Spotted shag	*Stictocarbo punctatus*	
Spur-winged plover	*Vanellus miles*	
Swamp harrier	*Circus approximans*	
Terek sandpiper	*Tringa cinerea*	
Tūī*	*Prosthemadera novaeseelandiae*	

Turnstone	*Arenaria intepres*	
Variable oystercatcher	*Haematopus unicolor*	At Risk: Recovering
Welcome swallow	*Hirundo neoxena*	
White heron	*Ardea modesta*	Threatened: Nationally Critical
White-faced heron	*Egretta novaehollandiae*	
White-fronted tern	*Sterna striata*	At Risk: Declining
White-winged black tern	*Chlidonias leucopterus*	
Wrybill	*Anarhynchus frontalis*	Threatened: Nationally Vulnerable
Reptiles:		
Copper skink	*Oligosoma aeneum*	
Marlborough mini gecko	*Woodworthia* "Marlborough mini"	
Northern grass skink	*Oligosoma polychroma*	
Raukawa gecko	*Woodworthia maculatus*	
Spotted skink	*Oligosoma lineoocellatum*	At Risk: Relict
Wellington green gecko	*Naultinus punctatus*	At Risk: Declining
Terrestrial invertebrates:		
Katipō spider	*Latrodectus katipō*	At Risk: Declining
Moth	*Ericodesma aerodana*	At Risk: Declining
Moth	*Notoreas perornata* "Wairarapa Wellington"	Threatened: Nationally Vulnerable
Native dragonfly	*Uropetala carovei*	

8 APPENDIX B: NOTES ON DATUM FROM GWRC

NOTES ON DATUM & REDUCED LEVEL

'Datum' is a horizontal plan surface such as sea-level or some other assumed plane surface above or below sea-level, adopted for a reference plane, to which all elevations called 'reduced levels' are referred.

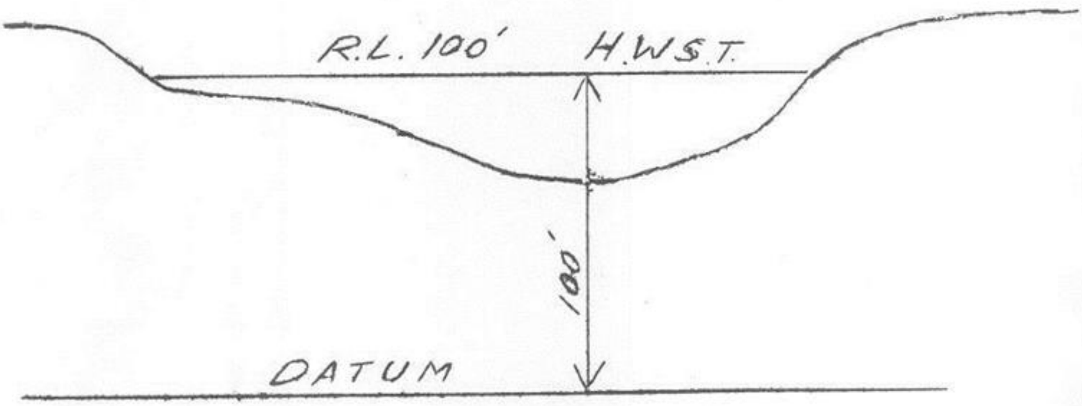
'Reduced level' is the elevation of a particular point above the 'datum' or plane of reference.

By comparing the reduced levels of any two points it is possible to find the difference in elevation between them.

In the Lower Wairarapa Valley Scheme the datum for all elevations is a plane surface 100 feet below High Water Spring Tides.

The High Water Spring tides have a reduced level of RL100'.
The Mean Sea level which is 2 ft below HWST is RL 98'.

In making conversion to the Metric System a new datum or plane of reference was adopted which is 10 metres, below HWST making the reduce level of HWST equal to RL10.0m. Mean sea level which is 2 ft or 0.6m below HWST equals RL9.4m.



NOTES ON SURVEY LEVEL DATUM CONVENTIONS

The Lower Wairarapa Valley Datum is related to High Water Ordinary Spring Tide in Palliser Bay. Originally this level was designated as 100.00 feet. Since the adoption of metrication the level has been designated as 10.000 metres.

To convert from imperial to metric one method is (level in feet) minus 67.19 multiplied by 0.3048 equals (level in metres).

Another method is (level in feet) minus 100.00 multiplied by 0.3048, then add 10.000 to the result to give (level in metres).

Examples of the methods are:

1) 125.86 - 67.19 = 58.67 x .3048 = 17.880
2) 125.86 - 100.00 = 25.86 x .3048 = 7.88 + 10.000 = 17.880

It should be noted carefully that these methods give results which are absolute only when referring to levels based on the Lower Wairarapa Valley Datum. If used for other areas where the original datum was adopted as 100.00 just for convenience then confusing conclusions may be drawn. In these cases it is probably better just to change the imperial value to the metric equivalent; (level in feet) multiplied by 0.3048 = (level in metres). This implies that the base datum is zero in both cases.

For areas where the difference in the original "datums" is known then levels can be transformed but extreme care should be exercised in this process.

The Lands and Survey datum is based on a different tide level, and this level is given the value of zero. To express Lower Wairarapa Valley levels in Lands and Survey terms 9.22 metres should be subtracted.

In the Waiohine area older projects may be to the "Waiohine datum".

BM 9 near the SH Bridge has a level of 269.09 ft (Waiohine datum). KA 13A is a L & S benchmark with a level of 54.908 metres (L & S). To convert this to LWV datum add 9.22 to get 64.130 metres (LWV). The difference in level between KA 13 and BM 9 is -3.225 metres therefore the level of BM 9 is 64.130 - 3.225 = 60.905 metres (LWV).

This means that 269.09 ft (Waiohine) is the same level as 60.905 metres (LWV) and zero LWV is the same level as [269.09 - (60.905 x 3.2808)] = 69.27 ft. Therefore to convert from Waiohine to (LWV metric) subtract 69.270 and multiply the result by 0.3048 eg 100.00 (Waiohine) = 100 - 69.27 = 30.73 x 0.3048 = 9.367 metres (LWV).

OLD TAUHERENIKAU DATUM OF 0ft = 96.6ft (SWRB)

∴ OLD TAUHERENIKAU DATUM + 8.96m = WCB (LVD)

15-10-84

TO CONVERT
OLD RUAMAHANGA DATUM TO LWV DATUM (WCB).

OLD RUAMAHANGA DATUM X 0.3048 − 20.0m = WCB DATUM LWV