Appendix A: Waituna Wetland Statutory Acknowledgement

Schedule 73
Statutory acknowledgement for Waituna Wetland

ss 205, 206

Statutory area

The statutory area to which this statutory acknowledgement applies is the wetland known as Waituna, the location of which is shown on Allocation Plan MD 58 (SO 12260).

Preamble

Under section 206, the Crown acknowledges Te Rūnanga o Ngāi Tahu's statement of Ngāi Tahu's cultural, spiritual, historic, and traditional association to Waituna, as set out below.

Ngāi Tahu association with Waituna

Intermittently open to the sea, Waituna wetland (with the western end, where the lagoon breaks out to sea known as Kā-puna-wai) was a major food basket utilised by nohoanga and permanent settlements located in the immediate vicinity of the wetlands, and further away, for its wide variety of reliable mahinga kai. The great diversity of wildlife associated with the complex includes several breeds of ducks, white heron, gulls, spoonbill, kōtuku, oyster-catcher, dotterels, terns and fernbirds. The wetlands are important kōhanga (spawning) grounds for a number of indigenous fish species. Kaimoana available includes giant and banded kōkopu, varieties of flatfish, tuna (eels), kanakana (lamprey), inaka (whitebait), waikākahi (freshwater mussel) and waikōura (freshwater crayfish). Harakeke, raupō, mānuka, tōtara and tōtara bark, and pingao were also regularly harvested cultural materials. Paru or black mud was available, particularly sought after as a product for making dyes.

The tūpuna had considerable knowledge of whakapapa, traditional trails and tauranga waka, places for gathering kai and other taonga, ways in which to use the resources of Waituna, the relationship of people with the lake and their dependence on it, and tikanga for the proper and sustainable utilisation of resources. All of these values remain important to Ngāi Tahu today.

As a result of this history of use and occupation of the area, there are wāhi tapu and wāhi taonga all along its shores. It is also possible that particular sections of the wetland were used for waiwhakaheketūpāpāku (water burial).

Urupā and wāhi tapu are the resting places of Ngāi Tahu tūpuna and, as such, are the focus for whānau traditions. These are places holding the memories, traditions, victories and defeats of Ngāi Tahu tūpuna, and are frequently protected by secret locations.

The mauri of Waituna represents the essence that binds the physical and spiritual elements of all things together, generating and upholding all life. All elements of the natural environment possess a life force, and all forms of life are related. Mauri is a critical element of the spiritual relationship of Ngāi Tahu Whānui with the area.

Purposes of statutory acknowledgement

Pursuant to section 215, and without limiting the rest of this schedule, the only purposes of this statutory acknowledgement are—

(a) to require that consent authorities forward summaries of resource consent applications to Te Rūnanga o Ngāi Tahu as required by regulations made pursuant to section 207 (clause 12.2.3 of the deed of settlement); and

(b) to require that consent authorities, Heritage New Zealand Pouhere Taonga, or the Environment Court, as the case may be, have regard to this statutory acknowledgement in relation to Waituna, as provided in sections 208 to 210 (clause 12.2.4 of the deed of settlement); and

(c) to empower the Minister responsible for management of Waituna or the Commissioner of Crown Lands, as the case may be, to enter into a Deed of Recognition as provided in section 212 (clause 12.2.6 of the deed of settlement); and

(d) to enable Te Rūnanga o Ngāi Tahu and any member of Ngāi Tahu Whānui to cite this statutory acknowledgement as evidence of the association of Ngāi Tahu to Waituna as provided in section 211 (clause 12.2.5 of the deed of settlement).

Limitations on effect of statutory acknowledgement

Except as expressly provided in sections 208 to 211, 213, and 215,—

(a) this statutory acknowledgement does not affect, and is not to be taken into account in, the exercise of any power, duty, or function by any person or entity under any statute, regulation, or bylaw; and

(b) without limiting paragraph (a), no person or entity, in considering any matter or making any decision or recommendation under any statute, regulation, or bylaw, may give any greater or lesser weight to Ngāi Tahu's association to Waituna (as described in this statutory acknowledgement) than that person or entity would give under the relevant statute, regulation, or bylaw, if this statutory acknowledgement did not exist in respect of Waituna.

Except as expressly provided in this Act, this statutory acknowledgement does not affect the lawful rights or interests of any person who is not a party to the deed of settlement.

Except as expressly provided in this Act, this statutory acknowledgement does not, of itself, have the effect of granting, creating, or providing evidence of any estate or interest in, or any rights of any kind whatsoever relating to, Waituna.

Schedule 73: amended, on 20 May 2014, by section 107 of the Heritage New Zealand Pouhere Taonga Act 2014 (2014 No 26).

Appendix B: Science Advisory Report

June 2024

Technical review of conditions for opening Waituna Lagoon

H. Robertson, N. Atkinson, M. de Winton, M. Schallenberg, R. Holmes, A. Rabel, K. Wilson, C. Jenkins, D. Whaanga

Prepared for the Department of Conservation, Te Rūnanga o Awarua and Environment Southland

Acknowledgements:

Technical input and data was provided from G. Ryder, N. Ward, J. Kitson, S. Blair, D. Murray, J. Williams, S. Stewart, C O'Donnell, A. Mora-Teddy, K. Collins, D. Hamilton,

Citation:

H. Robertson, N. Atkinson, M. de Winton, M. Schallenberg, R. Holmes, A. Rabel, K. Wilson, C. Jenkins, D. Whaanga. (2024) Technical review of conditions for opening Waituna Lagoon. Prepared for the Department of Conservation, Te Rūnanga o Awarua and Environment Southland.

Table of Contents

Executive Summary

Waituna Lagoon is one of the few remaining coastal lagoons in New Zealand that exhibits relatively natural flora and fauna and retains outstanding cultural values. The significance of the lagoon and its margins were recognised internationally in 1976 when it was designated a Ramsar Site and nationally by gaining Scientific Reserve status in 1983. The cultural significance to the local Ngāi Tahu people was recognised under a Statutory Acknowledgement in the Ngāi Tahu Claims Settlement Act 1998.

The lagoon's ecology and water quality have been strongly influenced by a history of increased frequency of mechanical opening and closing of the lagoon to the sea, reduction in extent of associated wetlands, and increasing nutrient and sediment inputs from its catchment. The two main risks to the ecological health of the lagoon are continued nutrient and fine sediment inputs and a hydrological regime that has been artificially altered to facilitate farming and land drainage in proximity to the lagoon.

This report provides technical information to support the development of resource consent conditions for opening Waituna Lagoon to the sea. It presents the rationale for specific thresholds for managing lagoon water levels to align more closely with restoring the ecological and cultural health of the lagoon ecosystem.

Prior to 2017, the water level threshold at which the lagoon was able to be opened to the sea was ~2.0m ASL. A short-term (5 year) consent for lagoon opening came into effect in February 2017 that retained a primary focus on land drainage but included provisions to open the lagoon to manage for poor water quality and established a higher opening threshold (2.2m ASL) during spring-summer months in an effort to avoid too frequent opening events. The short-term consent was a positive step forward although the changes to the water level thresholds for lagoon opening were not sufficient to affect the frequency of opening events. Poor water quality and the potential for algal blooms remain critical issues for Waituna Lagoon as was highlighted by a recent severe cyanobacterial bloom in the lagoon in January of 2024.

The technical review identified five key issues to address when developing conditions for the long-term ecological and cultural management of Waituna Lagoon. These five issues are:

- Incorporating conditions to reduce the frequency of spring/summer opening events. The previous 2.0m and 2.2m water level thresholds were not sufficient to prevent such openings
- Reviewing mechanisms to address poor water quality and lagoon ecosystem health
- Providing lagoon openings to facilitate fish migration
- Ensuring the proposed lagoon opening regime considers the benefits/risks to ecological and cultural values, including recreational values and the risks to surrounding wetlands
- Ensuring the lagoon opening regime considers the potential impacts on land drainage.

Given the long-term objective for opening Waituna Lagoon to the sea is to maintain and restore the ecological health and cultural values of the lagoon ecosystem, the technical review proposed the following amendments to consent conditions:

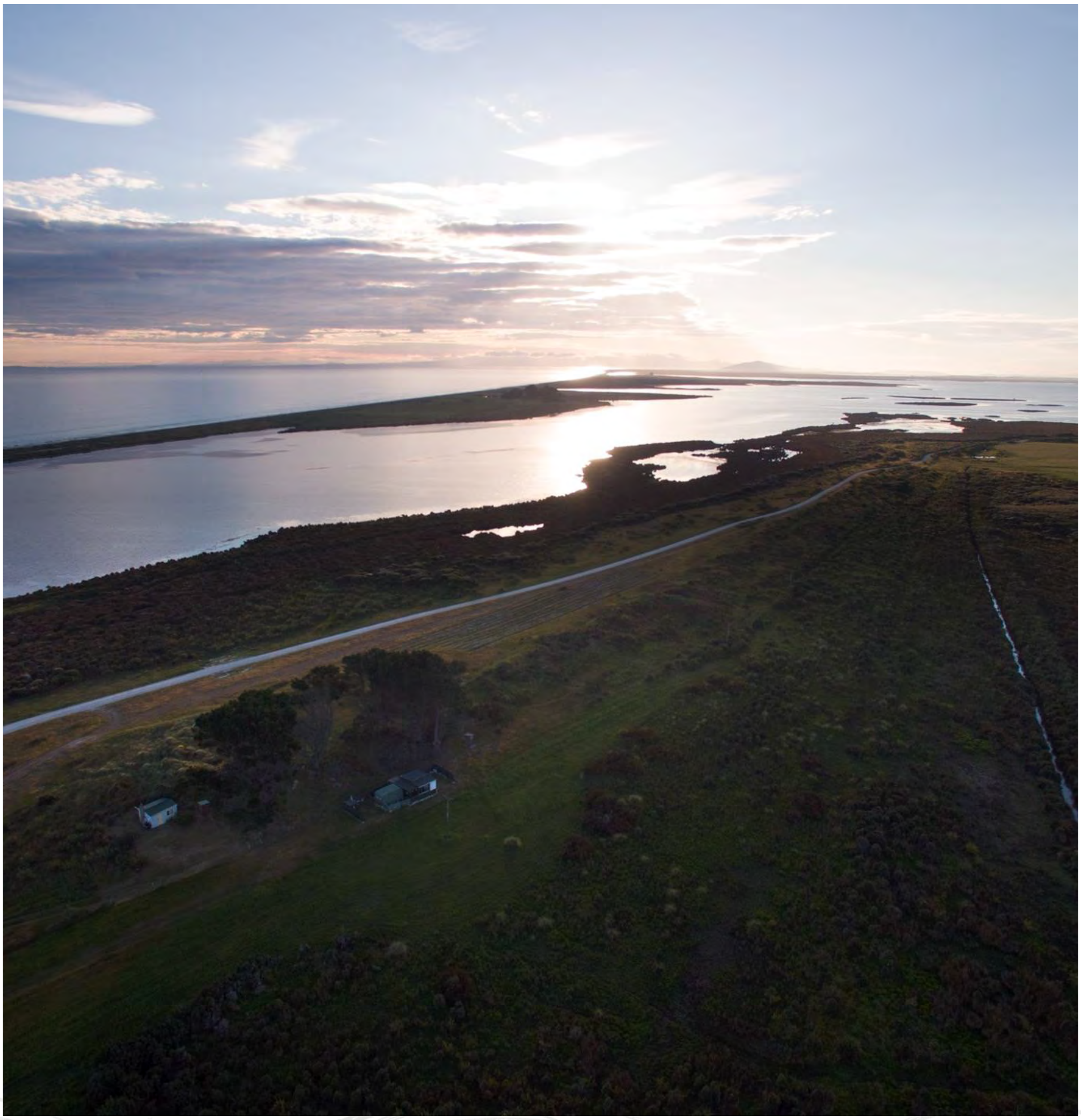
- An increase in the maximum lagoon opening threshold level to 2.5m (above msl) to restore ecological health and support cultural values
- Inclusion of new conditions to facilitate fish passage at least every 2 years
- Refinement of the conditions for emergency lagoon opening to mitigate risks of algal blooms on ecosystem health.

1. Purpose

This report provides technical information to support the development of resource consent conditions for opening Waituna Lagoon to the sea. It presents the rationale for specific lagoon opening thresholds aimed at maintaining and restoring the ecological and cultural health of the lagoon ecosystem.

The authors acknowledge that the management of lagoon water levels has impacts beyond the immediate lagoon ecosystem and have gone someway to assess the impact of an ecologically-based opening regime on land drainage and recreational uses.

A technical report was initially completed in 2021. This revised report provides further information on lagoon health and response to water levels for the period 2021-2023, including monitoring of aquatic vegetation, fish populations and water quality, as well as a geospatial assessment of land affected by proposed conditions.



2. Introduction

2.1 Waituna Lagoon

Waituna Lagoon is one of the few remaining coastal lagoons in New Zealand that exhibits a relatively natural flora and fauna. The significance of the lagoon and its margins were recognised internationally in 1976 when it was designated a Ramsar Site and nationally by gaining Scientific Reserve status in 1983. The cultural significance to the local Ngāi Tahu people was recognised under a Statutory Acknowledgement in the Ngāi Tahu Claims Settlement Act 1998.

The lagoon and associated wetlands are identified by the Department of Conservation (DOC) as a priority ecosystem for the conservation of New Zealand's natural heritage, it is a focus catchment in the DOC/Fonterra Living Water programme and one of three wetland systems in DOC's Arawai Kākāriki wetland restoration programme. It is also highly valued for its aesthetic appeal, rich native biodiversity, waterfowl hunting, fishing, boating, bird watching, walking and opportunities for scientific study.

The lagoon covers an area of approximately 1350 hectares and is Southland's largest coastal lake. It is shallow, (water depth is usually <2m) and is usually isolated from the sea by a gravel bar. Prior to human management of the lagoon opening, the bar was breached and an opening to the sea was temporarily established when high lagoon water levels overtopped the barrier bar. This overtopping would cut a gap in the barrier bar, effectively draining much of the lagoon. In a natural state the coastal lake would have had prolonged freshwater periods due to closed conditions with water levels >2.0m above sea level much more frequently than under current management which was designed to maintain lowered water levels (LTG 2013). When the lagoon was open to the sea it became estuarine and tidal for a time until certain conditions, likely related to neap tides, low freshwater inflows and calm wind and sea conditions would close the mouth.

With the advent of farming and land development, the lagoon has been mechanically opened to the sea, typically with excavators, to facilitate land drainage. For the last 100 or so years the lagoon has been opened on average about once a year, usually when the lagoon water level exceeded 2.0m above sea level.

The lagoon's ecology and water quality have been strongly influenced by both the history of opening and closing of the lagoon to the sea, and the high nutrient and sediment inputs from the contributing catchment. The fluctuations in water level and salinity have created a highly variable environment with associated high variability in species dominance and ecological community structure. Species alter their distribution and abundance in response to changes in water level, salinity, other environmental factors, and species interactions, creating an ecologically diverse and productive ecosystem, but one that is also at risk of being degraded by anthropogenic stressors, as has occurred in other South Island lagoons (e.g., LakeEllesmere/Te Waihora, Lake Forsyth/Wairewa, Wainono Lagoon).

In 2010, concerns surrounding the state of Waituna Lagoon led to the publication of ecological guidelines to improve the management of the lagoon. These guidelines, which were developed by a Lagoon Technical Group (LTG 2013) identified key attributes of the lagoon's ecosystem health such as macrophytes, slime/benthic algae, phytoplankton, sediment anoxia, water clarity, hydrology and nutrients.

The ecosystem health of Waituna Lagoon is supported by submerged native aquatic plants known as *Ruppia* (two species: *R. megacarpa* and *R. polycarpa*), which are considered foundation or keystone species due to their function as ecosystem engineers and for regulating water quality. However, the *Ruppia*-dominated plant community is vulnerable to a range of stressors including nutrient enrichment, decreased water clarity, prolonged high salinity and frequent lagoon opening events.

Figure 1. Aerial photograph of Waituna Lagoon showing adjacent farmland developed and maintained by the drainage of wetland soils.

According to LTG (2013), the two main risks to the ecological health of the lagoon are:

- poor water quality, largely due to high nutrient and sediment inputs from the catchment
- a hydrological regime with ill-timed or too frequent openings that threaten to diminish the macrophyte cover and biomass and, thereby, the ecological health of the lagoon.

2.2 Lagoon opening activity and previous short-term resource consent

For the past ~100 years Waituna Lagoon has been primarily opened to the sea for purpose of land drainage. The lagoon was mechanically opened so that water levels in the lagoon were restricted, allowing for the drainage of low-lying agricultural land surrounding the lagoon.

Prior to 2017, the water level threshold at which the lagoon was consented to be opened to the sea was ~2.0m ASL, although the specific water level when openings occurred varied, as the opening activity is also dependent on suitable wind and sea conditions.

With the increasing risk to ecological health recognised, a short-term (5 year) consent for opening Waituna Lagoon[1] came into effect in February 2017 (Appendix A). This short-term consent retained a primary focus on land drainage but included some provisions to open the lagoon to alleviate poor water quality (e.g., opening to disrupt algal blooms) and established a higher opening water level threshold (2.2m ASL) during spring-summer months in an effort to avoid frequent opening events during the early part of the macrophyte growing season. The short-term consent expired on 14 February 2022.

The Department of Conservation, Awarua Rūnanga, Environment Southland and other agencies recognised that the short-term consent was an interim measure and jointly held aspirations to

[1] Environment Southland Coastal Permit AUTH- 20146407-01.

resolve the conflict between farming operations and higher water levels, thereby improving the long-term management of the lagoon opening.

In 2017, the Waituna Science Advisory Group established that higher water levels would be beneficial to ecology of the lagoon, and that 2.5m ASL is the maximum water level that the lagoon should be allowed to reach if it were being managed for ecological values (WSAG, 2017).

In 2019-20 the Whakamana Te Waituna Trust[2] successfully facilitated the purchase of most of the farmland that would be affected by inundation at higher lagoon levels (Figure 2), thus, enabling an increase of the maximum allowed water level in the lagoon with the aim of maintaining and enhancing a broad range ecological and cultural values.

Between 2022-23 consultation between the Department of Conservation, Awarua Rūnanga, Environment Southland and a group of interested landowners (Lake Waituna Control Association) considered options for long-term management of lagoon opening events, drawing on information in the 2021 technical report. The discussions resulted in a proposed transition regime for lagoon opening events.

The method and rationale for determining the indicators to guide lagoon opening are described in the following sections of this report.

Figure 2. Areas of farmland purchased as part of the Whakamana Te Waituna project and areas of land affected by inundation at high lagoon levels that have not been purchased.

[2] Whakamana Te Waituna Trust is made up of representatives from DOC and Fonterra (representing the Living Water Partnership), Environment Southland, Southland District Council, Awarua Runanga and two independent trustees.

3. Approach

The Whakamana Te Waituna Trust initiated a workstream during 2020-21 to develop an ecologically based opening regime for Waituna Lagoon. This involved assessment of the short-term consent conditions for opening Waituna Lagoon to the sea and the water level requirements of a range of ecological and cultural values associated with the lagoon.

An expert workshop was held in March 2021, involving representatives from NIWA, Cawthron Institute, Kitson Consulting (on behalf of Awarua Rūnanga), Environment Southland, University of Otago, DOC and Ryder Consulting. This group confirmed that the lagoon's water level, open/closed status and water quality remain key factors affecting many of its values. Many attributes of the lagoon and surrounding wetland ecosystem benefit from a closed lagoon (i.e., a freshwater state) while some attributes benefit from an open lagoon.

The technical review of the conditions for opening Waituna Lagoon (described in this report) involved four key steps. These were:

1. **Identify ecological and cultural values (section 4):**

   Reconfirm the suite of key ecological and cultural values that are affected by lagoon opening and, therefore, need to be considered in relation to any change in opening regime.

2. **Review the previous consent conditions (section 5):**

   Review the impact of the previous consent conditions and monitoring information on key ecological and cultural values of the lagoon.

3. **Propose new consent conditions (section 6):**

   Conduct an integrated assessment of ecological and cultural values and identify conditions that will maintain or enhance the values identified.

4. **Assess the impact of proposed consent conditions on other values (section 7):**

   Assess the impact of the proposed consent conditions on other key values for the Waituna Community including on land drainage, trout fishing, bird populations and duck hunting.

In December 2023, the expert group reconvened to review and update technical information. This revised report includes recent monitoring of aquatic vegetation, fish populations and water quality, an analysis of the impacts of opening the lagoon at different locations, a geospatial assessment of the area of land affected by proposed conditions and feedback on the proposed transition regime for lagoon opening.

4. Ecological and cultural values

A clear understanding of the ecological and cultural values of Waituna Lagoon is fundamental to reviewing the conditions for lagoon opening to the sea. Previously, the ecological guidelines for Waituna Lagoon (LTG 2013), cultural mapping project (Kitson, pers. comm) and other forums and literature have described the lagoon's values.

To develop new consent conditions, a summary of ecological and cultural values for Waituna Lagoon was established through an iterative process based on both existing reports and discussions with experts knowledgeable of the lagoon's biodiversity and its relationship with local Ngāi Tahu people including whanau members from Awarua Rūnanga. These values were also assessed in relation to Environment Southland's draft Murihiku Southland Freshwater Objectives (2020).

The ecological and cultural values defined in Table 1 relate to water quality, submerged macrophytes, fish and aquatic invertebrate populations, bird populations, indigenous flora and fauna community, fringing wetlands, taonga species and cultural significance.

Once the values were defined, it was possible to identify how the different values are likely to be affected by anthropogenic pressures, particularly the lagoon opening regime, and what a more ecologically favourable opening regime would aim to achieve with respect to specific values (Table 1).

The expert group confirmed that the *Ruppia*-dominated plant community is an important ecosystem engineer that promotes ecosystem health. *Ruppia megacarpa* and *R. polycarpa* are sensitive to water level, salinity, and algal blooms. The status of *Ruppia* provides an indication of the lagoon condition, which relates to the health of many taonga species. Similarly, other ecological and cultural values such as the lagoon and catchment's fish community were identified as being sensitive to lagoon open/closed status. The open status allows for the migration of diadromous species (which require access to both the sea and freshwater to complete their life cycle) such as īnanga and kanakana/lamprey. In contrast, the closed status allows for more successful rearing of giant kōkopu in the lagoon (David et al. 2004, Hicks pers. comm.) and the provision of productive rearing habitat for tuna/eel. Sections 5-7 of this report provide further assessment of the benefits and risks of lagoon opening on the key values of the lagoon.

Aerial photograph of Waituna Lagoon at Walkers Bay opening site. The lagoon was closed at the time.

Table 1. Ecological and cultural values of Waituna Lagoon and surrounding wetland.

	Value	Impacted by	Aims of an opening regime
Taonga species	Iwi recognise a range of taonga species present in the Waituna wetland system, including (but not limited to); tuna (longfin and shortfin eel), kanakana (lamprey), īnanga (whitebait), koura (freshwater crayfish), pātiki (flounder), smelt, kōkopu (whitebait), kākahi (freshwater mussel). Around and within the fringes of the lagoon, taonga include swan, water fowl, pukeko, cabbage trees, flax, mānuka and other plant species. Māori use local black mud (paru) for dyeing textiles.	• a closed lagoon prevents fish species migrations to and from the sea, including several taonga species • opening the lagoon for long periods may increase the presence of exotic weed species in fringing wetlands to the detriment of native species, and reduce food and habitat for taonga freshwater species • high salinity favours estuarine species over freshwater species	• enhance taonga species • maintain the lagoon as close to natural (unmanipulated) state as possible without compromising overall lagoon health
Cultural significance	Cultural values of the lagoon include (but are not limited to): aesthetic appeal, mahinga kai, safety of access, identity, landscape and connection to landscape and human health.	• prolonged opening may alter the identity, aesthetic appeal and connection to the lagoon ecosystem • also refer to impacts on taonga species above	• move towards a natural opening regime (if it can be done without compromising lagoon health)
Water quality	Water quality of the lagoon supports a desirable aquatic ecosystem without algal blooms and anoxic "dead zones". Toxicants and detrimental contaminants don't detract from a state of Hauora	• high nutrients (concentrations in the water column and in lagoon bed sediments) • elevated water temperature • high inflows (increasing nutrient & sediment delivery) • fine sediments (in the water column and in lagoon bed sediments) • *Faecal contamination* (*E. coli and Enterococci,* affecting human contact, food gathering & cultural values) • Lagoon flushing (openings and closings) • water levels • contaminant loads from farming activities in the catchment • extent and status of fringing wetlands • changes in biomass of macrophyte communities or other photosynthetic organisms may contribute to nutrient release or reduce dissolved oxygen	• provide a mechanism for excessive nutrients , sediment and algae to be flushed to the ocean • provide a mechanism to disrupt prolonged algal blooms • manage algae proliferations including cyanobacteria blooms and macroalgae • reduce levels of faecal contamination • improve or maintain the health of fringing wetlands, which buffer against contaminants in overland flow • maintain *Ruppia* within optimal >30-60% cover abundance • mechanism to address contaminant or toxin issues • re-oxygenation of lagoon waters • protect against events that cause large-scale macrophyte decline and lagoon to shift to algal-dominated state
Submerged macrophytes	Sustain and enhance the population of submerged macrophytes including the keystone taxa, *Ruppia* spp. The macrophyte community also supports at-risk *Ruppia megacarpa*.	• poor water clarity which may be exacerbated under high water levels >2.5m (light limitation of macrophyte growth) or low water levels (enhanced sediment resuspension)	• prevent frequent spring/summer opening to enable macrophyte regeneration (benefit from low salinity during germination) • at least two consecutive years of closed lagoon over the main vegetation growth

	Value	Impacted by	Aims of an opening regime
		• low water levels resulting in loss of habitat • elevated salinity when the lagoon is opened • wave action and sediment resuspension when the lagoon is shallow • macroalgae and phytoplankton proliferation caused by high nutrient concentrations	period to enable *Ruppia* development/flowering • ensure maximum water levels do not exceed 2.5m (may cause negative effects on aquatic/wetland plants due to light limitation) • provide a mechanism for excessive nutrients to be flushed to the ocean • reduce the risk of high salinity during key *Ruppia* growing period
Fish and aquatic invertebrate populations	A diverse population of freshwater fish is present in the lagoon system, including a number of migratory species (refer above to taonga species) as well as marine wanderers such as kahawai. Aquatic invertebrates in the lagoon include benthic and pelagic species which likely play important roles in the lagoon's food web. Large invertebrates such as koura (freshwater crayfish) and kākahi (freshwater mussel) are also present in low numbers near the tributary inflows.	• a closed lagoon limits fish migration • low water levels may reduce or degrade spawning habitat • an open lagoon reduces food and habitat for freshwater species, while providing habitat for brackish/estuarine species • poor water quality (including high nutrients, high turbidity, low dissolved oxygen and elevated water temperatures) negatively impact fish and invertebrates	• allow for the timing of opening events to benefit fish spawning and migration where possible • ensure that closures are sufficient in duration to provide food and habitat for multiple species, including for spawning • managing openings for water quality and macrophytes (incl. *Ruppia*) to support migration/movement of fish and invertebrate populations
Indigenous species dominance of coastal lake	The flora and fauna of Waituna Lagoon is dominated by native species that are characteristic of coastal lake ecosystems.	• extended freshwater phase may permit invasion by non-native freshwater pests (weeds, fish, invertebrates). • extended estuarine phase may permit invasion by non-native saltwater pests (weeds, fish, invertebrates)	• Allow for openings to disrupt freshwater pest invasions that are a significant biosecurity risk to the ecological health of Waituna Lagoon
Bird populations	The lagoon and associated wetlands provides habitat for a broad range of bird species including many native and threatened species, migratory waterbirds, and waterfowl.	• an open lagoon reduces habitat for wetland bird species and waterfowl in that it affects optimal feeding depths, but increases habitat for waders • a closed lagoon reduces habitat for migratory wading birds, while recognising estuarine habitat for waders is nearby	• provide for water levels that support wetland birds, although it is recognised that differing water levels will favour different bird species over others (e.g., waders vs swimmers, i.e., different functional groups) • provision of habitat for migratory wading birds
Fringing wetlands	A diverse native plant community is present within the fringing wetlands surrounding the lagoon. These wetlands provide habitat to support indigenous fauna, including threatened species.	• persistent low water levels and very high-water levels can alter native plant communities, with some species/community-types benefiting at the expense of others • high water levels may protect wetland vegetation from exotic plant invasion	• manage a fluctuating water regime to support fringing wetlands, e.g., oioi, turf plants • avoid prolonged periods of low water levels that de-water the fringing wetlands

5. Review of short-term resource consent

In February 2017, a 5-year consent for opening Waituna Lagoon to the sea came into effect (Appendix A). The consent retained a primary focus on land drainage but included provisions to open the lagoon to manage for poor water quality (e.g., algal blooms). The consent also established a higher water level opening threshold during spring-summer months in an effort to avoid frequent opening events that impact on aquatic macrophytes.

5.1 Water level variation

The short term (5-year) consent had specific conditions providing for:

- A higher opening threshold in spring-summer (2.2m) in effort to reduce the frequency of opening events and decrease negative effects on aquatic plants
- The ability to open lagoon in spring-summer at 2.0m (not 2.2m) if there had been strong macrophyte growth in previous 3 years
- A lagoon opening threshold of 2.0m in winter (May-September)
- A lagoon opening threshold of 1.8m in winter, if it had not been open for 12 months
- Emergency opening at >1.5m in the event of prolonged algal blooms or poor water quality.

Water levels in Waituna Lagoon are continuously monitored by Environment Southland at the Waghorns Road/Bridge site. This is where the water height for lagoon opening threshold is measured.

Review of the water level variation between September 2015 and February 2022 (Figure 3) indicates there were six opening events of the lagoon during this period, including five opening events since the commencement of the 5-year consent (in February 2017).

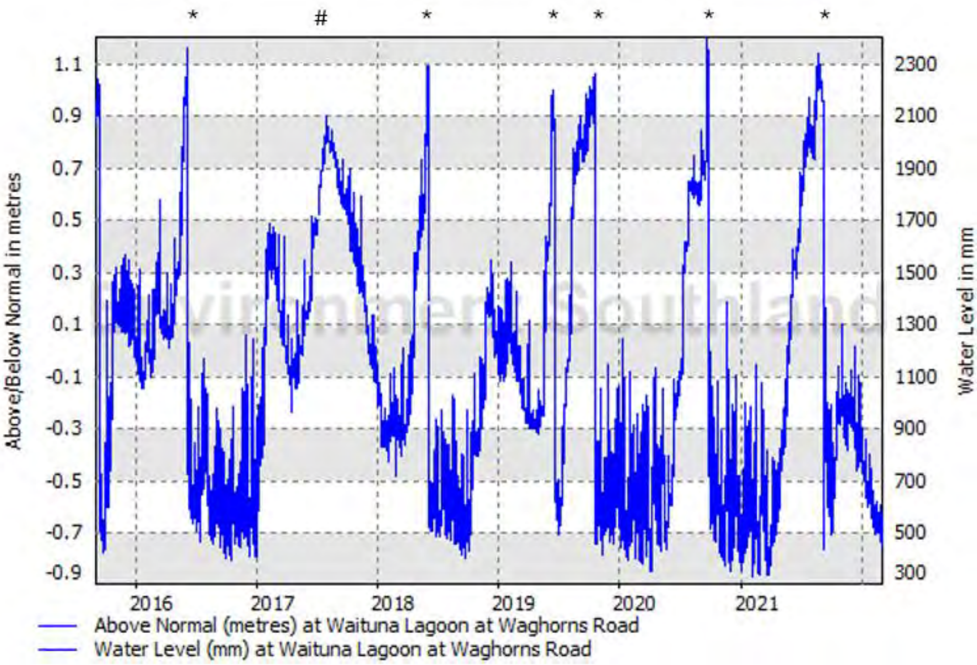


Figure 3. Water levels in Waituna Lagoon for the period September 2015 to February 2022. Asterisks (*) indicate lagoon openings. Hash (#) indicates where the 2.0m winter opening threshold was reached, however water levels naturally receded, and the lagoon was not opened.

Between February 2017 and February 2022, where the spring/summer threshold of 2.2m was in place, only one opening event above 2.0m was avoided and water levels naturally receded (Figure

3). In this instance, the water levels were above 2.0m for several days during the months of July and August 2017 (Figure 4) so the consent holder was able to open the lagoon in respect of the consent conditions for winter opening but chose not to.

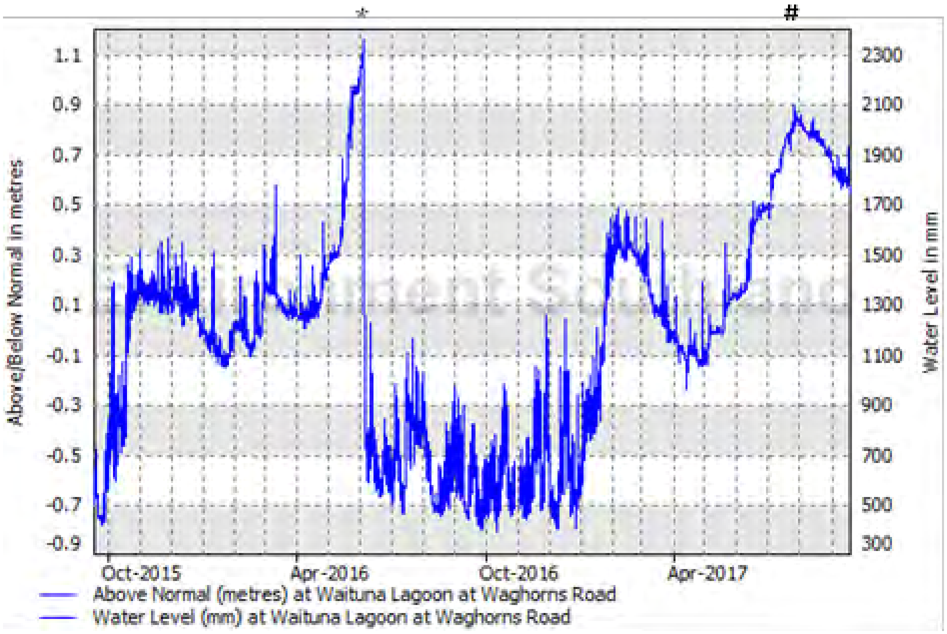


Figure 4. Water levels in Waituna Lagoon for the period September 2015 to September 2017. Asterisks (*) indicate lagoon openings. Hash (#) indicates where the 2.0m winter opening threshold was reached, however water levels naturally receded, and the lagoon was not opened.

Between February 2017 and February 2022, 60% of the opening events (3 of 5) resulted in the lagoon being opened during the spring/summer period (October 2019, September 2020 and briefly for four weeks August-September 2021) (Figures 3 and 5). That is, the 2017 changes to the water level thresholds for lagoon opening were not sufficient to prevent the consent conditions being triggered and opening events from occurring.

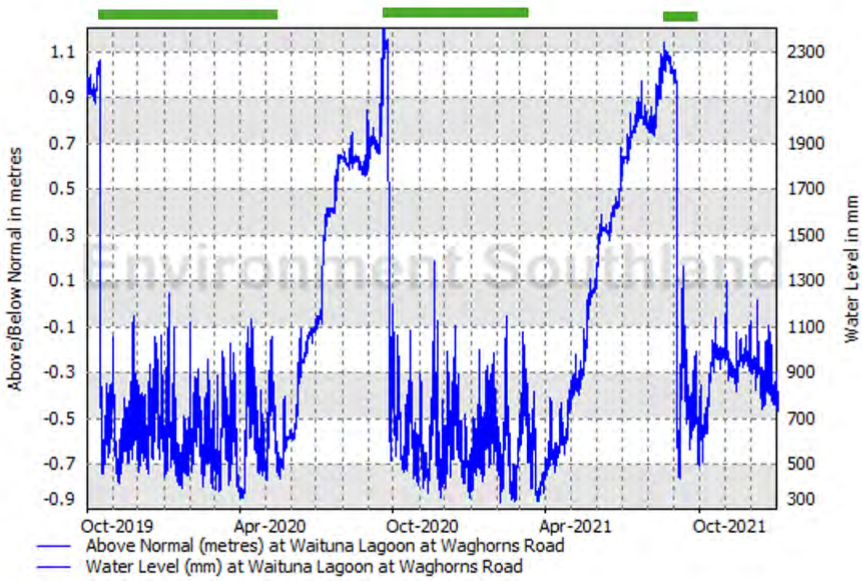


Figure 5. Water levels in Waituna Lagoon for the period September 2019 to January 2022. Green bars (▬) indicate when the lagoon was open during spring/summer months.

Since the short-term consent expired in February 2022, the lagoon remained in a closed freshwater phase, exhibiting only seasonal variation in water levels (Figure 6).

Based on the (expired) short-term consent conditions, the lagoon met the 2.0m winter threshold for opening in September 2022, July 2023 and September 2023. However, as the consent had expired, there was no authorisation to open the lagoon and it remained closed for two consecutive seasons. This prolonged period of closed conditions and ongoing accumulation of nutrients contributed a sustained phytoplankton growth in 2023 that resulted in a significant algal bloom during December 2023-January 2024. This algal bloom triggered an emergency opening on 31 January 2024 to disrupt the bloom (Figure 6).

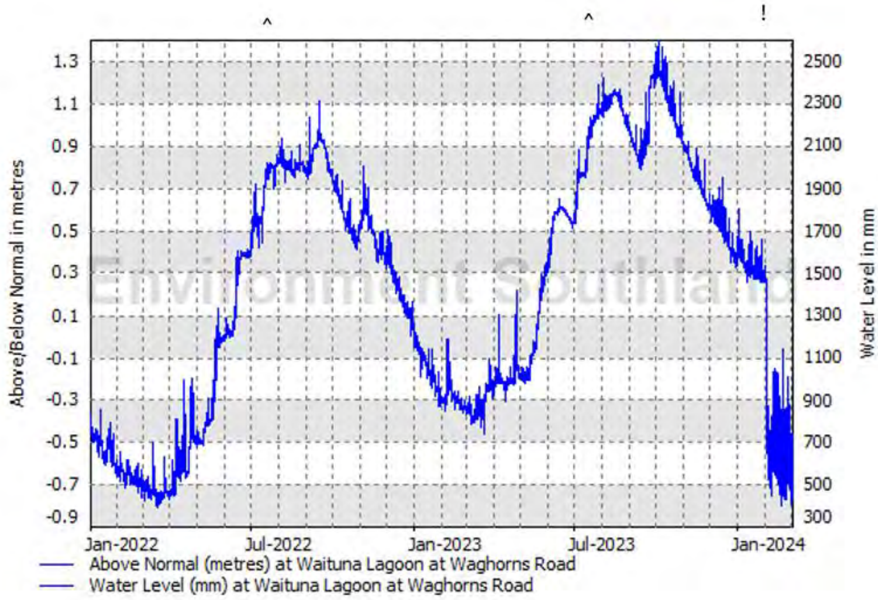


Figure 6. Water levels in Waituna Lagoon for the period February 2022 to February 2024, when the short-term consent for opening had expired. Circumflex (^) indicates when the winter threshold for lagoon opening from the expired consent was met. Exclamation mark (!) indicates emergency lagoon opening.

5.2 Response of lagoon ecosystem

Monitoring of lagoon water quality, the submerged macrophyte population, macroalgae and fish populations in tributary streams has been undertaken since the early 2000's. The monitoring data have been used to evaluate the response of the lagoon ecosystem to open/closed conditions.

Water quality

Waituna Lagoon is affected by high catchment nutrient and fine sediment loads that may lead to an increase in phytoplankton (measured as chlorophyll-a), increased light attenuation through the water column and increased deposited fine sediments or benthic mud. High nutrient loads may also stimulate macroalgae blooms. The 2013 ecological guidelines included lagoon health targets for total nitrogen (TN), total phosphorus (TP) and chlorophyll-a (chl-a) concentrations within the water column. These targets were reviewed as part of this technical report.

The Trophic Level Index (TLI) provides an overall measure of water quality based on a combined assessment of TN, TP, water clarity and chl-a concentrations in Waituna Lagoon. Higher values of TLI represent a more eutrophic (nutrient enriched) ecosystem. Between 2001 and 2023 the lagoon-wide trophic status (TLI) has remained fairly stable during both open and closed conditions on an annual basis (Figure 7), however short-term fluctuations in TLI are known to occur.

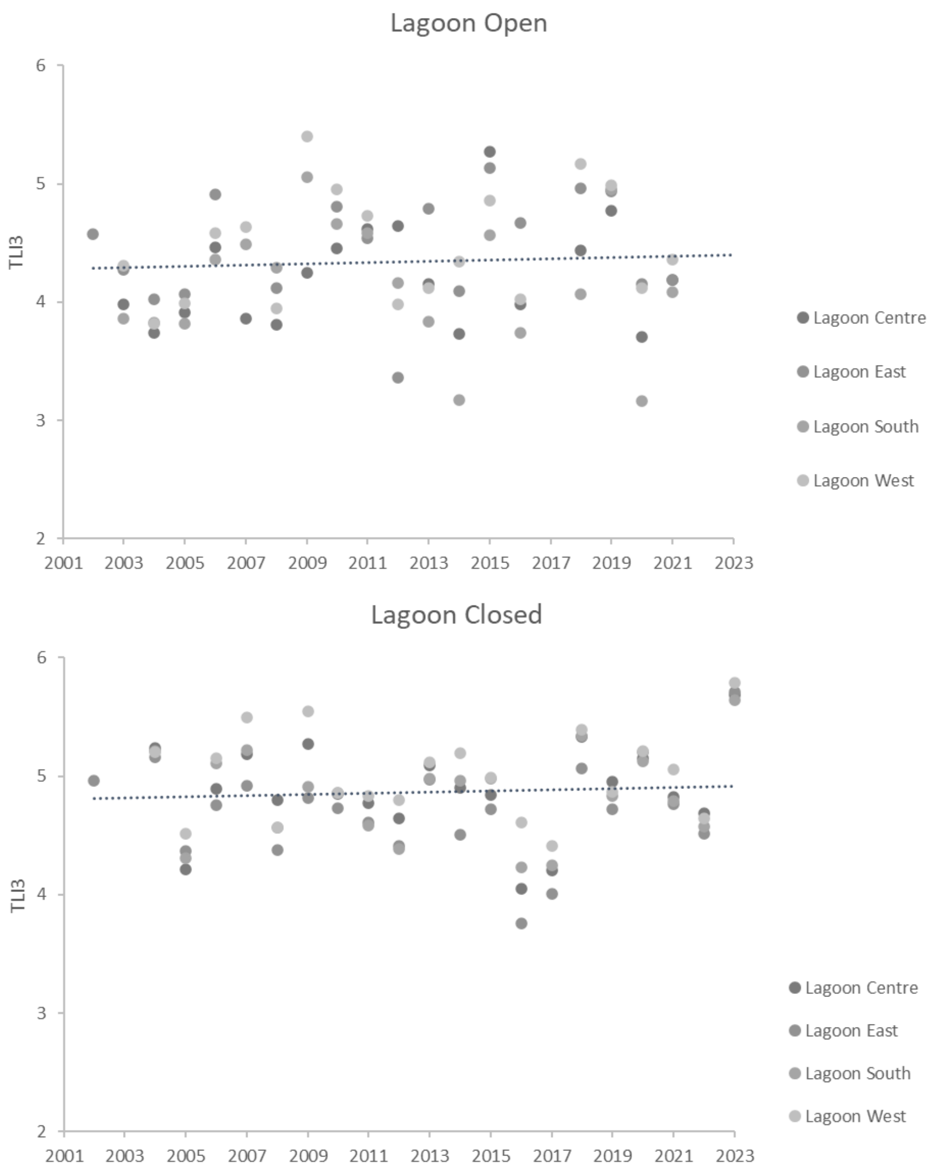


Figure 7. Lagoon-wide trophic status (TLI3) from 2001 to 2023 (annual median) for when the lagoon is open (top) and closed (bottom). TLI3 is an index that provides an overall measure of water quality based on a combined assessment of chlorophyll-*a*, water clarity, total nitrogen and total phosphorus concentrations.

The shorter-term (monthly) response of TN, TP and chl-a to lagoon opening between 2001 and 2020 is shown in Figure 8a. TN concentrations are typically lower when the lagoon is opened to the sea. The amount of time TP concentrations exceed critical TP levels is similar for open and closed conditions. Previous assessment of long-term water quality trends indicate dissolved reactive phosphorus (DRP), chl-a and turbidity are decreasing over time (when the lagoon is closed), suggesting an improvement of lagoon water quality (Appendix B, Environment Southland monitoring 2001-2020). However, this does not necessarily equate to an improvement in ecosystem health as other nutrient pools (e.g., sediment, macroalgae, epiphytes) are not measured.

A more recent assessment of lagoon water quality (Figure 8b, 8c) was reported by de Winton et al. (2023). The 12-month period January 2022 - January 2023 coincided with a period of prolonged closed conditions, during this time:

- Chl-a concentrations were low (<0.01 mg/l) without some of the higher peaks (>0.2 mg/l) observed in 2009, 2012, 2015 and 2018 to 2021.
- TN levels showed similar patterns to previous years with winter peaks.

- TP concentrations were in a lower range <0.05 g/m^3.

The lower range of TP may be in response to reduced catchment inflows during 2022 and 2023. Well-developed aquatic vegetation in 2023 may have also reduced TP (de Winton et a. 2023). An upward trend of TP was observed over time during closed conditions (Figure 8b) that may be due to accumulation of riverine inputs, groundwater inputs or internal recycling from lagoon sediments.

During the summer period December 2023 - January 2024, an algal bloom occurred in the lagoon that resulted in very high concentrations of phytoplankton (chl-a 0.06 to 0.3 mg/L) dominated by a potentially toxin producing cyanobacteria (>100 mm^3/cm). The algal bloom appeared to be in response to the high nutrient levels in Waituna Lagoon that had increased steadily during 2023 and warm summer conditions. Water quality monitoring on 10 January 2024 indicated TN was >2 mg/L and TP was >0.150 mg/L. Due to the risk to the ecological health of Waituna Lagoon, an emergency opening to disrupt the algal bloom was recommended, consistent with the water quality conditions of the previous short-term consent. Monitoring also showed the increase in nutrients during the 2021 closure (Appendix C), highlighting the caution needed during prolonged closed periods.

The closed freshwater phase for 2 consecutive years supported a lagoon-wide recovery of macrophytes (see macrophyte section below) and phytoplankton levels initially remained relatively low. However, Figure 8d shows that as the lagoon remained closed for more than two years phytoplankton levels (chl-a) increased in mid-late 2023 leading to the algal bloom observed in December 2023. These data indicate prolonged closure (e.g. >2 years) increases the risk of eutrophication, given the ongoing catchment inputs and nutrient recycling.

The critical water quality thresholds previously defined (LTG 2013) for the lagoon were TP ($\geq$ 0.045 mg/L), TN ($\geq$ 1.0 mg/L) and chl-a ($\geq$ 0.012 mg/L). These thresholds are generally consistent with the national bottom lines for polymictic lakes and lagoons specified in the National Policy Statement for Freshwater Management 2020 (MfE 2023) and apply to the closed lagoon state.

Based on recent monitoring and guidance, updated 'warning' and 'critical' levels for Waituna Lagoon are suggested (refer Section 6). The levels do not represent the long-term water quality objectives for the Waituna Freshwater Management Unit, these are addressed as part of the draft Murihiku Southland Freshwater objectives and upcoming Plan Change Tuatahi. Their purpose is to provide important guidelines to inform management of opening and closing events.

Overall, the TN, TP and chl-a monitoring indicates Waituna Lagoon remains under threat from eutrophication and catchment mitigation remains essential to reduce nutrient loads to the lagoon and to improve its condition.

It is recommended that a future consent would enable the lagoon to be opened should water quality and ecosystem indicators reach levels of concern, while supporting closed conditions that promote a restoration gradually towards a more natural hydrological regime for Waituna Lagoon, within the constraint of contemporary catchment inputs.

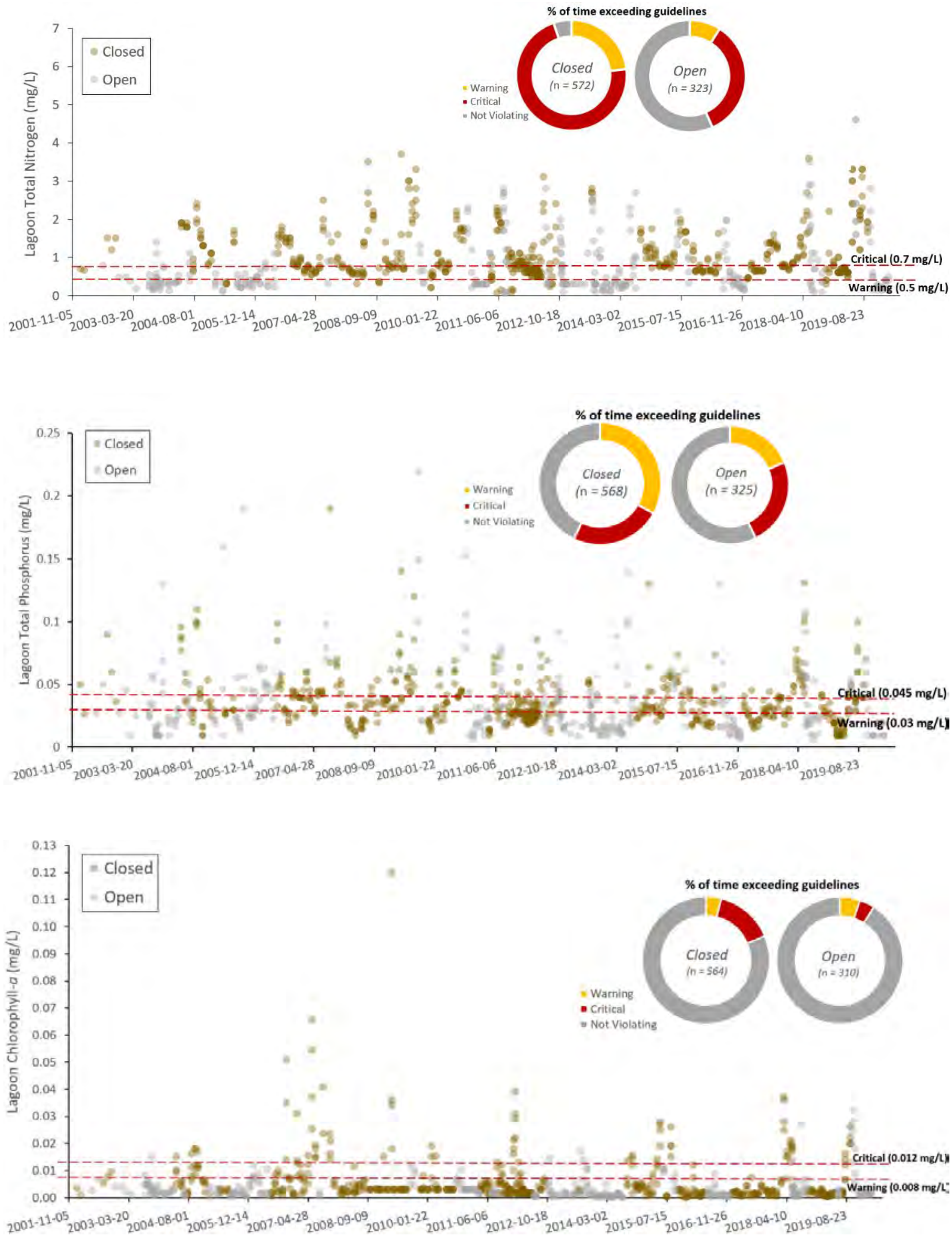


Figure 8a. Total nitrogen (TN), total phosphorus (TP) and chlorophyll-a concentrations in Waituna Lagoon for the period 2001 to 2020.

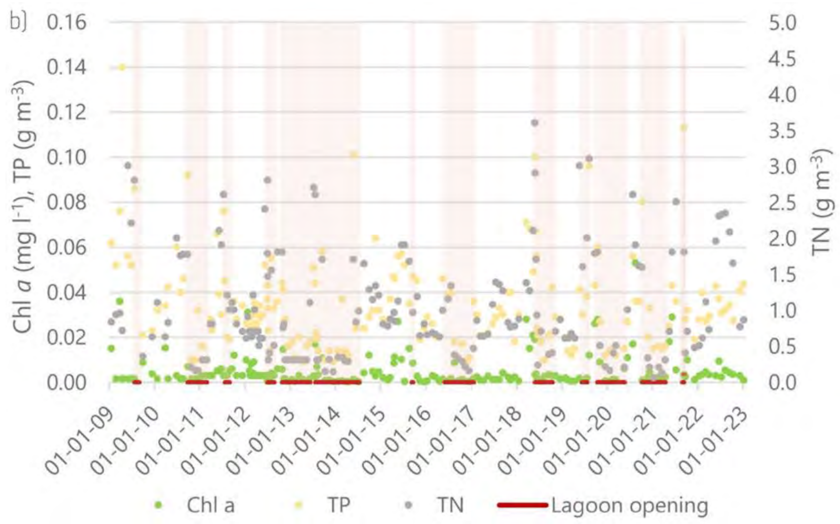


Figure 8b. Total nitrogen (TN), total phosphorus (TP) and chlorophyll-a (chl a) concentrations in Waituna Lagoon between 2009 and 2023. NB data is from the central monitoring site only. Source: de Winton et al. (2023).

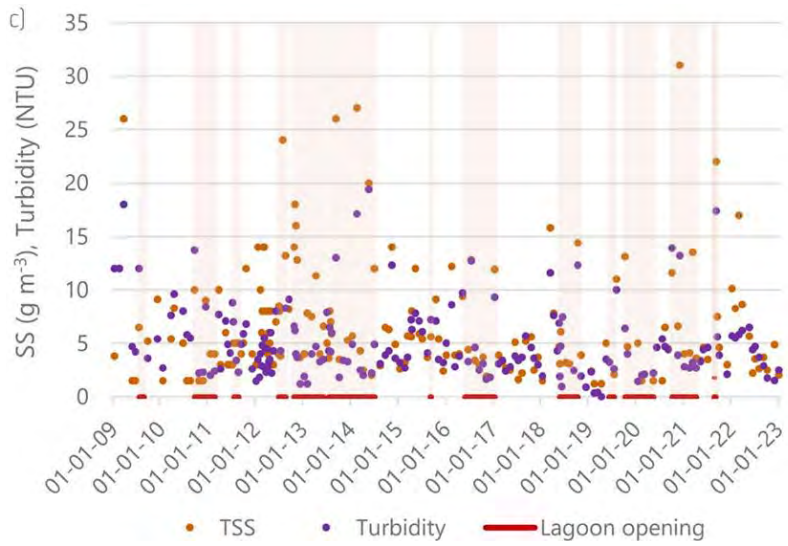


Figure 8c. Total suspended solids (TSS) and turbidity in Waituna Lagoon between 2009 and 2023. NB data is from the central monitoring site only. Source: de Winton et al. (2023).

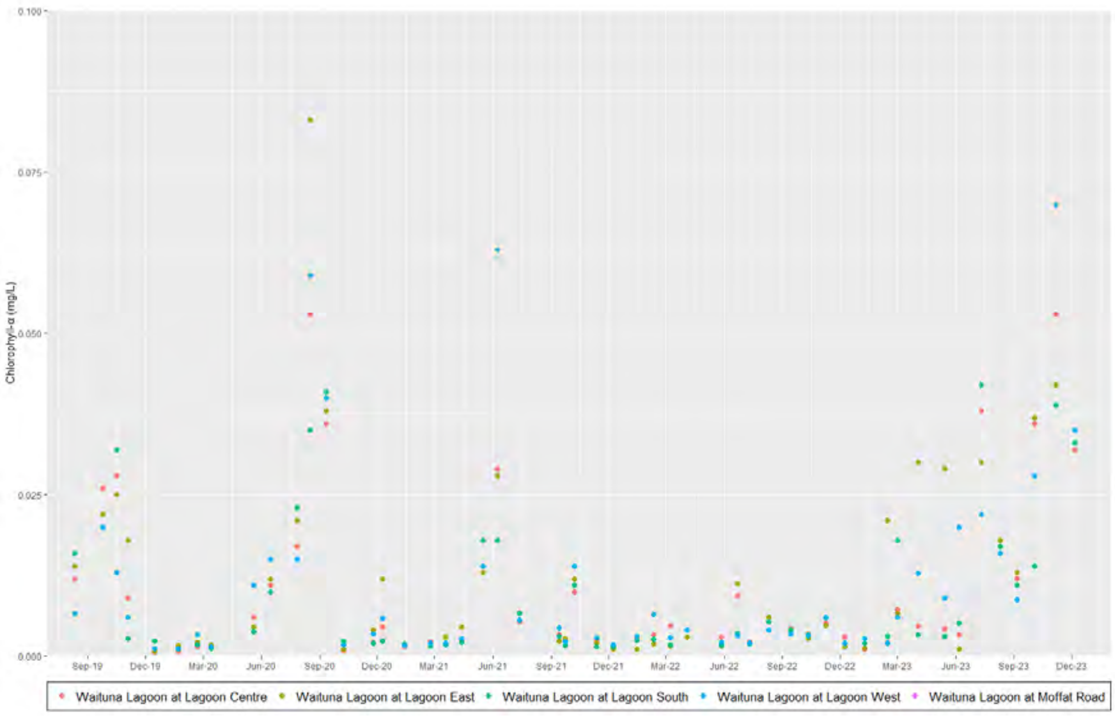


Figure 8d. Chlorophyll-a (phytoplankton) concentration in Waituna Lagoon for period September 2019 to January 2024. Source: Environment Southland.

Submerged macrophytes and macroalgae

Annual monitoring of the status of submerged macrophytes and macroalgae in Waituna Lagoon is undertaken by NIWA, on behalf of the Department of Conservation (de Winton & Elcock 2021, de Winton et al. 2023a, 2023b). The monitoring examines whether the lagoon ecosystem is meeting its objectives in terms of lagoon closure, macrophyte abundance and macroalgae abundance. Overall, six ecological targets are evaluated for the report (Table 2), including achieving a lagoon-wide cover of 30-60% for aquatic macrophytes, primarily *Ruppia* species.

As summarised by NIWA (de Winton & Elcock 2021), the lagoon ecosystem was in a poor state in 2021 following two consecutive years of opening, specifically:

- In 2021, none of the six ecological targets for macrophytes and macroalgae were achieved for Waituna Lagoon:
    - The lagoon was open to the sea over the critical spring-summer period for *Ruppia* growth (for >3 months before monitoring) for the second consecutive year and this is likely responsible for the poor performance of submerged plants in 2021.
    - There was a further large reduction in the distribution and abundance (biomass) of submerged plants (mainly *Ruppia* species) since reductions were recorded in the 2020 survey.
    - *Ruppia* (and other submerged plants) were not observed in the south-western sector (approximately half the lagoon area).
    - In 2021, results measuring lagoon-wide *Ruppia* cover, biomass index and *Ruppia* reproductive success were only 1/10th of the ecological target.
    - *Ruppia megacarpa* was limited to only three sites, which was one third of the ecological target.
    - Macroalgae development exceeded the maximum acceptable threshold of <10% cover.

- Based on all six ecological targets:
    - 2021 was the third monitoring year the lagoon failed to achieve any targets, with 2013 and 2017 also not meeting any ecological targets.
    - Years that achieved only one or no targets were when the target for lagoon closure (closed >3months before survey) was not met.
    - The evidence indicated that having a closed lagoon for at least two consecutive growing seasons was important for maintaining macrophyte communities.

The implementation of the 5-year consent in 2017 to limit spring-summer openings was only partly successful. Five of the six ecological targets were achieved in 2018 and 2019 following a period of closure, however the status of the macrophytes declined again in 2020 and 2021 (de Winton & Elcock 2021) in response to prolonged opening events. The abundance of macroalgae remained relatively high in 2020 and 2021 (target was not met), suggesting drivers other than mouth status (e.g., temperature, sediment and nutrients) are also important.

The increase of the lagoon opening threshold in 2017 to 2.2m during spring/summer, did not prevent lagoon openings from occurring during the early growing season. Furthermore, the spring/summer openings in consecutive years (2020 and 2021) negatively impacted *Ruppia* populations.

Table 2. Summary of results for macrophyte/macroalgae targets since 2009 (de Winton et al. 2023). A tick indicates the target has been met, a cross indicates the target has not been met.

Year	Lagoon closure	*Ruppia* cover	*Ruppia* biomass index	Macroalgae cover	*Ruppia* reproductive success	Status of *Ruppia megacarpa*	Target met
2009	✓	✗	✗	✓	✗	✗	2
2010	✓	✗	✗	✓	✗	✓	3
2011		✗	✗	✓	✗	✗	1
2012	✓	✗	✗	✓	✓	✗	3
2013	✗	✗	✗	✗	✗	✗	0
2014	✗	✗	✗	✓	✗	✗	1
2015	✓	✗	✓	✗	✓	✗	3
2016	✓	✓	✓	✗	✓	✗	4
2017	✗	✗	✗	✗	✗	✗	0
2018	✓	✗	✓	✓	✓	✓	5
2019	✓	✓	✓	✗	✓	✓	5
2020	✗	✗	✗	✗	✗	✓	1
2021	✗	✗	✗	✗	✗	✗	0
2022	✓	✗	✗	✗	✗	✓	2
2023	✓	✓	✓	✓	✓	✓	6

In contrast, a significant recovery of submerged aquatic plants (*Ruppia* spp.) occurred in 2022 and 2023, as the lagoon remained in a closed, freshwater state for two consecutive growing seasons (de Winton et al. 2023).

All ecological targets were met in 2023, the first time this has been achieved since monitoring began 15 years ago (Table 3). The 2023 monitoring report concluded that:

- Ecological targets for Waituna Lagoon are not met when lagoon openings occur or extend over late spring to summer.
- Two or more consecutive years of openings during the main vegetation growth period should be avoided to ensure *Ruppia* can regenerate successfully.
- At least two consecutive years of a favourable closed lagoon over the main vegetation growth period enable higher *Ruppia* development.
- There may be trade-offs between a stable closed lagoon for good *Ruppia* development and risk of nutrient build-up fuelling macroalgae and phytoplankton blooms.
- Ecological targets for lagoon-wide *Ruppia* cover and biomass index are likely to be met when *Ruppia megacarpa* is more prevalent, due to its ability to form tall, dense beds.

Table 3. Summary of 2023 results for all ecological targets. Source: de Winton et al. 2023.

Ecological target	Targets met?	Comment
Lagoon closure	✓	Lagoon had been closed for two consecutive *Ruppia* growing seasons prior to monitoring.
Ruppia cover	✓	Lagoon-wide *Ruppia* cover exceeded the target (>30% cover) and was the highest cover yet monitored.
Ruppia biomass index	✓	*Ruppia* a biomass index exceeded the target (>1000) and was the highest value yet monitored.
Macroalgae cover	✓	Macroalgae development was within the acceptable threshold of 10% cover.
Ruppia reproductive success	✓	The target for reproductive success (≥40% of samples flowered) was exceeded with reproductive *Ruppia* at almost all sites.
Status of *Ruppia megacarpa*	✓	*Ruppia megacarpa* contributed significantly to lagoon vegetation.

The response of aquatic plants following two consecutive years of closed conditions illustrates the ability of the lagoon ecosystem to recover, as plants re-establish from the seed bank and vegetative propagules. The ecological guidelines for Waituna Lagoon (LTG 2013) recommended a minimum target of 30-60% cover-abundance for *Ruppia* and other macrophytes. Although the benefits from an abundant macrophyte community are sought, we recognise a potential risk to lagoon health if adverse conditions (e.g., turbidity event/phytoplankton bloom, sustained high water level) trigger a rapid, wide-spread macrophyte decline. Impacts on water quality may occur due to plant decay decreasing dissolved oxygen levels and/or resulting in nutrient release. A decline in the aquatic plant community was observed in late 2023, prior to the development of the significant cyanobacterial bloom of early 2024, although the reason for this decline is unknown. This information highlights the need for a balance between closed lagoon status to promote periods of freshwater and higher water levels and the need to regularly flush algae and nutrients out of the system via lagoon openings. The cyanobacterial bloom that occurred in early 2024 suggests that prolonged closures of greater than c. 2.5 years may be detrimental, given the current nutrient loads to the system.

Fish populations

Waituna Lagoon and its catchment has relatively abundant populations of indigenous and taonga fish species, including giant kōkopu, īnaka, kanakana, common bullies, shortfin eel, longfin eel, and flounder. Twelve freshwater fish species (excluding marine wanderers) have been recorded in the Waituna Lagoon catchment tributaries and within Waituna Lagoon itself. The catchment has no known introduced pest fish, with brown trout being the only introduced fish present that supports a local trout fishery.

Prior to human arrival, Waituna Lagoon experienced periods of prolonged closure that naturally influenced the composition of the fish community. However, efforts to maintain the ecological values ought to consider the response of fish populations to the opening regime.

Many of the species found within the Waituna Lagoon catchment are migratory (e.g., kanakana/lamprey, īnanga), meaning that at least one aspect of their life stage requires movement to and from the sea or brackish water. As such, the timing of lagoon opening to the sea has substantial impacts on fish populations and the fish community, particularly for at-risk species (Meijer et al. 2024). On the one hand, fish such as giant kōkopu are thought to benefit from some of the conditions associated with prolonged lagoon closures (especially during summer). On the other hand, migratory species such as kanakana/lamprey could potentially (temporarily) disappear from the catchment if the lagoon stayed closed for more than four years. This is because three to four years is thought to be the period that juvenile kanakana/lamprey typically spend in freshwater before they must migrate to the sea for spawning.

Stable isotope analysis provides insight into the food resources relied on by īnanga, giant kōkopu, and tuna (shortfin and longfin eel) at Waituna Lagoon. A very high biomass of large predatory fishes (e.g., longfin eel) are maintained in Waituna Creek through its connectivity to Waituna Lagoon. Īnanga migrating upstream from the lagoon supported 60-80% of longfin eel and 40-90% of brown trout biomass over the two years sampled (Stewart et al. 2022). These migratory fish species often rely on the lagoon for >50% of their food resource and larger fish are particularly reliant on the lagoon for their diet (Stewart & Holmes 2023). Holmes (2019) examined the influence of recent (2014-2023) lagoon open and closed periods on the abundance of fish species in Waituna Creek, observing that:

- both īnanga and kanakana/lamprey abundance in Waituna Creek tends to increase with the number of days that the lagoon is open to the sea – either during the preceding spring for īnanga or the winter-spring period (three years previous) for lamprey/kanakana.
- Giant bullies also showed a positive (but weaker) correlation with increasing open days during summer (two years previous).
- No patterns were observed between eel density or biomass and lagoon opening duration.

Recent data from fish monitoring (2020-2023) were consistent with earlier surveys and indicated that the lagoon opening regime influences the recruitment of īnanga and kanakana/lamprey (Figure 9). The intermittent barrier will influence fish passage, although īnanga populations naturally vary between years in normal river systems and coastal lagoons based on coastal and river conditions.

Since February 2017, there were regular periods when the lagoon was open during the winter-spring period, a critical migration period for most ocean migratory species in the Waituna catchment (Table 4). Although the lagoon was not opened for the specific purpose of facilitating fish migration, opening events for other reasons will support ocean migratory fish populations, depending on timing.

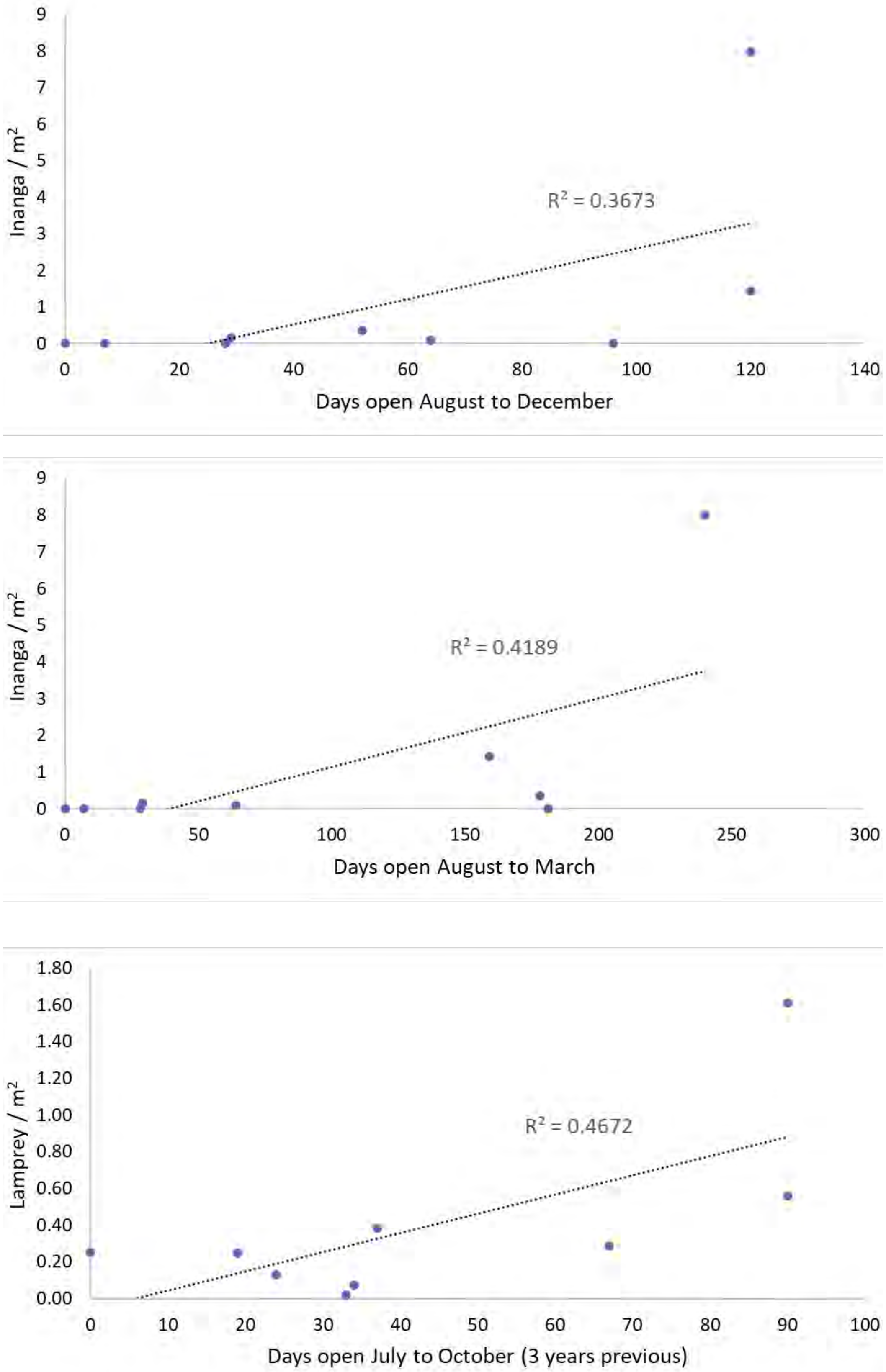


Figure 9. Average īnanga and lamprey/kankana density (fish/m²) from all sites during the annual March fish population sampling in Waituna creek (2014-2023) correlated against the number of days Waituna Lagoon was open to the sea. From Holmes (2019) and ongoing fish population monitoring 2020-2023.

Table 4. Months open per annum (2017-2023) supporting fish migration.

Year (July-June)	Lagoon open	# Months open	Season/s	Supported fish migration
2017-2018	Yes	1	Winter 2018	Yes
2018-2019	Yes	3	Winter-Spring 2018	Yes
2019-2020	Yes	8	Spring-Winter 2019-20	Yes
2020-2021	Yes	6	Spring-Autumn 2020-21	Yes
2021-2022	Yes	2	Winter-Spring 2021	Yes
2022-2023	No	0	Closed phase	No

It is important to consider the frequency of lagoon openings required to support a healthy and persistent population of īnanga in the catchment. When īnanga migrate into the lagoon and catchment, they provide an abundant food supply for other species such as giant kōkopu, trout and tuna (Stewart & Holmes 2023), enabling the latter populations to flourish. The life cycle of īnanga is annual (with a very small proportion of fish spawning twice). However, considering other ecological and cultural values, we recommend that the lagoon is opened during August to October at least every two years. This would allow a two-yearly pulse of īnanga to migrate into the lagoon and catchment and supply predators, such as longfin eel, with high numbers of forage fish. The August to October period also coincides with the upstream migration of adult kanakana/lamprey. Juvenile kanakana/lamprey rear in fresh water for up to four years, and so a limit of a two-year closed period during the August to October ought to maintain continuous populations of lamprey within the catchment.

5.3 Issues for consideration

Considering the information presented above, and the technical review of the existing consent, there are five key ecological issues that are considered most important to address in developing conditions for the long-term management of Waituna Lagoon.

These five issues are:

- Incorporating conditions that aim to reduce the frequency of spring/summer opening events. Previous 2.0m and 2.2m water level thresholds were not sufficient to prevent such openings.
- Reviewing the mechanisms for lagoon openings to address poor water quality and ecosystem health concerns.
- Providing lagoon openings to facilitate fish passage, during key migration periods, particularly if there are prolonged periods when the lagoon is closed.
- Ensuring the proposed lagoon opening regime considers the benefits/risks to all ecological and cultural values, including recreational values and risk to surrounding wetlands.
- Consideration of the potential impacts of the opening regime on land drainage.

6. Proposed new conditions

6.1 Long-term objective

As guided by the Whakamana Te Waituna project, the long-term objective for opening the Waituna Lagoon to the sea is to **maintain and restore the ecological health and cultural values of the lagoon ecosystem.**

6.2 Proposed amendments

To achieve the long-term objective for safeguarding of the lagoon, several amendments to conditions for lagoon opening are proposed. These amendments address the specific issues outlined in section 5.3.

The proposed amendments include:

- An increase in the lagoon opening threshold level to 2.5m (above msl) to enhance ecological health and cultural values
- Inclusion of new conditions to facilitate fish passage
- Refinement of the conditions providing for emergency lagoon opening in order to mitigate risks to water quality and ecosystem health.

A rationale for these proposed amendments is provided in sections 6.3 to 6.7.

6.3 Lagoon opening to enhance ecological health and cultural values

Review of the existing 5-year consent identified that the 2.0m/2.2m lagoon opening threshold water levels did not prevent spring-summer opening events - events associated with negative impacts on macrophyte recruitment.

In 2017, the Waituna Science Advisory Group investigated lagoon opening levels that support ecosystem health (Table 5), with a specific objective of recommending a maximum level for opening as well as retaining the option to open at lower levels to mitigate poor water quality (algal blooms)[3].

The 2017 review concluded that the health of the lagoon would benefit from higher water levels, and that 2.5m is a recommended maximum water level to improve ecological values. The Whakamana Te Waituna Trust subsequently used a lagoon water level of 2.5m to identify where to purchase surrounding land to allow the lagoon to be managed for ecological benefit[4].

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[3] Schallenberg, M. & Robertson, H. (2017). Report on the findings of the Waituna Science Advisory Group (SAG) into water levels in Waituna Lagoon for the management of the lagoon's ecological health.

[4] To date, three properties adjacent to the lagoon have been purchased though the Whakamana Te Waituna programme to ease the impact of high lagoon levels on farming operations and to support the ecological and cultural restoration of the lagoon.

Table 5. Summary of threshold level considerations

Value/Driver	Maximum level (mASL)	Details
Preventing spring/summer openings during 'years of concern' to enable macrophyte regeneration.	2.5	Summer openings stress macrophytes and favour macroalgae. *Ruppia* benefits from closure and low salinity during key growth stage (spring/summer).
Allowing the timing of opening events to benefit fish spawning and migration where possible.	na	Issues for fish include timing of events and the maximum water level.
Managing a fluctuating water regime to support fringing wetlands – e.g., Oioi, turf plants.	2.5	LiDAR elevation models indicate that most wetland vegetation will be inundated when lagoon levels are ~2.3m. Irregular inundation at higher levels is positive for these systems.
Providing a mechanism for excessive nutrients to be flushed to the ocean.	>1.8*	Flushing of nutrients can occur when there is sufficient hydraulic gradient. The higher the water level, the better the flushing when opened.
Providing a mechanism to disrupt a prolonged algal bloom.	>1.5	Ecological guidelines suggested that if needed an opening could occur at 1.5m to disrupt a prolonged algal bloom. A minimum height is needed for a mechanically effective opening, not a maximum.
Ensuring maximum water levels do not cause negative effects on aquatic/wetland plants (e.g., light limitation).	2.0**	Light limitation is likely to have an impact on submerged vegetation in deeper parts of the lagoon. Prolonged inundation (>20 days per annum) at higher water levels (e.g., >2.3m) may limit productivity.
Recommendation	**2.5 mASL**	

Notes: * Flushing of nutrients may be feasible at lower levels if there is sufficient hydraulic gradient. **Because the gravel barrier is leaky, prolonged events (e.g. ~ 2.3m) may be unlikely. Unknown potential positive effect of raised water level on sediment resuspension/turbidity and light penetration.

The proposed 2.5m opening threshold is based on the following assumptions:

- that increasing the opening threshold level to 2.5m will reduce the frequency of opening events,
- the duration of high-water levels will be limited (e.g., less than 20 days above 2.3m), and therefore periods of light limitation on submerged plants and inundation of ex-farmed soils will be minimal
- that opening events will still occur to support fish passage and ecological and cultural values that benefit from open lagoon conditions

To test these assumptions, the hydrological model of Waituna Lagoon developed by Chris Jenkins (Team Leader Hydrological Response, Environment Southland) was applied. This model uses a ~50 year hydrological record to predict the number and duration of water level events exceeding specified levels.

A series of opening scenarios were examined by the model, including a base scenario (short-term consent conditions), lagoon opening at 2.5m and other permutations to provide for fish passage. The specific scenarios assessed were:

- **Previous consent:** open when level is at 2.0 m for the period May – 19 September, and open when level is at 2.2 m for the period 20 September – 30 April
- **Scenario 1:** open when level is at 2.2 m or above for 7 consecutive days
- **Scenario A:** open when level is at 2.5 m or above for 7 consecutive days
- **Scenario B:** open when level is 2.5 m or above for 7 consecutive days or, if no opening occurred in the previous year, open if the level exceeds 1.5 m (for fish passage)

- **Scenario C:** open when level is 2.5 m or above for 7 consecutive days or, if no opening occurred in the previous 2 years, open if the level exceeds 1.5 m (for fish passage)
- **Scenario D:** open when level is 2.5m for 1 day for the period 1 September to 30 April, and open when level is 2.3m for 7 consecutive days for the period of 1 May to 30 August or, if no opening occurred in the previous 2 years, open if the level exceeds 2 m (for fish passage)

A summary of the model results is presented in Table 6. In broad terms, the analysis indicates that under the short-term (5-year) consent conditions (2.0m/2.2m) lagoon openings are likely to occur about once every year (1.07 openings/year). If the opening threshold were raised to 2.2m (Scenario 1) for the entire year, opening events would occur with a slightly lower frequency (0.85 openings/year). Whereas, if a threshold level of 2.5m were applied (Scenario A), this would result in lagoon openings decreasing substantially in frequency (0.42 openings/year).

The less frequent openings under Scenario A will support the *Ruppia*-dominated plant community and the ecological function of the coastal lake ecosystem, as it has been previously shown that macrophyte species are adversely affected when the lagoon is open over spring/summer. Scenario A provides for closed lagoon conditions for two consecutive years which is important for *Ruppia* growth, reproduction and development. Under Scenario A, spring/summer openings are likely to occur almost half as frequently as they did under the short-term consent (0.14 vs 0.24 openings/year).

Scenario A would result in approximately 45 more days per year when water level is above 2.0 m relative to the current situation. Scenario A would result in 5.8 days above 2.4m per year, compared to 0.4 days for the current consent, indicating that the duration of high-water levels will remain limited. This indicates that periods of prolonged light limitation on submerged aquatic plants and macroalgae would not be expected to occur if the opening threshold level were raised to 2.5m.

Table 6. Opening scenarios and probabilities of the lagoon opening and for how long based on historic data (modified table supplied by Chris Jenkins, Environment Southland, December 2023).

Summary statistics	Short term Consent	Scenario				
		1	A	B	C	D
Average Openings per Year	1.07	0.85	0.42	0.79	0.55	0.67
Average Num. Openings 1 Sep to 30 April	0.24	0.33	0.14	0.25	0.17	0.15
Annual average days above 2.0m	10.21	23.2	55.48	36.42	49.16	36.23
Annual average total events of 2.0m	1.31	1.79	2.11	1.59	1.93	1.93
Average duration of events above 2.0m (days)	8.9	21.41	53.37	34.84	47.23	18.75
Annual average days above 2.2m	2.01	4.61	24.18	15.11	21.24	11.72
Annual average total events of 2.2m	0.62	0.95	1.59	1.04	1.37	1.23
Average duration of events above 2.2m (days)	1.39	3.66	22.6	14.06	19.88	9.54
Annual average days above 2.4m	0.38	0.69	5.78	4.03	4.98	1.66
Annual average total events of 2.4m	0.1	0.18	0.78	0.54	0.67	0.44
Average duration of events above 2.4m (days)	0.28	0.51	5	3.49	4.3	3.75

Based on this, it is recommended that the general conditions for lagoon opening be amended to: Lagoon Opening – general opening for ecological health and cultural values.

4. (a) *Regardless of the time of the year, the lagoon may be opened to the sea when the water level in the lagoon reaches 2.5 metres, as measured on the Waghorn's Road bridge gauge board, and remains at or above that level for 7 days continuously.*

Note: the proposed transitional regime for lagoon opening is described in section 6.7.

6.4 Lagoon opening to promote fish passage

Setting a single threshold level of 2.5m may not appropriately provide for all key ecological and cultural values of Waituna Lagoon. In particular, while Scenario A (2.5m) supports the long-term management of the macrophyte community and the natural functioning of the coastal lake ecosystem, it may not adequately support the migration of indigenous and taonga fish species. Consequently, further details around the opening conditions (triggers) are recommended.

Based on knowledge of lifecycles of indigenous and taonga fish species in Waituna Lagoon, the key months for upstream and downstream migration were identified to show when lagoon openings would benefit multiple fish species and life-stages (Table 7). There are key times of the year, such as August-October, when an open lagoon would support the migration and recruitment of several fish species. Enabling opening events to promote upstream migration of threatened and at-risk fish species, particularly kanakana/lamprey (which is Nationally Vulnerable) and īnanga (as a primary food resource) is particularly important.

Table 7. Downstream and upstream migration periods for native fish in the Waituna Catchment (from Smith 2014).

Common name	Upstream migration period	Peak upstream migration period	Downstream migration period
Shortfin eel (glass eel)	July-December	August-November	March-September
Longfin eel (glass eel)	August-January	September-December	February-July
Giant kōkopu	October-January	November	?
Banded kōkopu	August-January	September-November	March-July
Īnanga	May-December	August	March-September
Kanakana/lamprey	May-December	August-October	March-September
Common bully	December-April	December-April	September-January
Giant bully	December-April	December-April	September-December
Redfin bully	November-April	November-April	September-December
Common smelt	August-December	September-November	November-May
Black flounder	September-December	December-December	November-May

To examine whether it would be possible to reduce the frequency of spring/summer openings and provide for fish passage, two scenarios were examined through hydrological modelling. These scenarios considered an opening threshold of 2.5 m together with an option to open for fish passage if no opening had occurred in the previous 12 (Scenario B) or 24 months (Scenario C):

- Scenario B: open when level is 2.5 m or above for 7 consecutive days or, if no opening occurred in the previous year, open if the level exceeds 1.5 m (for fish passage).

- **Scenario C:** Open when level is 2.5 m or above for 7 consecutive days or, if no opening occurred in the previous 2 years, open if the level exceeds 1.5 m (for fish passage).

As would be anticipated, Scenario B (open for fish passage after 12 months) results in a greater average number of spring/summer openings per year (0.25 openings/year) relative to Scenario A (0.14 spring/summer openings per year). Therefore, Scenario B would favour fish migration but would likely have detrimental effects on the macrophyte community and natural lake ecosystem function due to the higher frequency of spring/summer lagoon opening.

Under Scenario C (open for fish passage after 24 months) there would be 0.17 spring/summer opening events per year - about the same frequency as Scenario A (0.14). Note that the average number of days when water levels are above 2.0m and average duration of events are broadly similar for Scenario A (2.5m only) and Scenario C (2.5m and fish passage).

The preferred opening regime to benefit the migration of fish species and the overall health of the coastal lake ecosystem is Scenario C (2.5m; open for fish passage after 24 months).

It is recommended to include specific conditions for fish passage as follows:

Lagoon Opening for the purpose of providing fish passage

Z. *(a)* *The lagoon may be opened to the sea to provide for passage for diadromous fish species when the water level in the lagoon is able to facilitate an opening, during the period 1 April to 30 November, provided that:*

The lagoon has not been opened in the previous 24 months, or

If the lagoon was opened during the past 24 months, where the timing of the open period did not support upstream migration of threatened or at-risk fish species, and

The Technical Advisory Group has considered the lagoon water quality and ecosystem health indicators listed in Appendix 1A and Appendix 2A, and any other relevant scientific information, and has advised the consent holder and Consent Authority (in writing) that opening the lagoon to the sea is recommended to enable fish passage.

While lagoon opening every three years would have the least potential for spring/summer openings that adversely affect the *Ruppia*-dominated macrophyte community, the 2-yearly cycle is proposed to ensure life-cycles of important migratory fish and taonga species are protected, including īnanga and kanakana/lamprey, while minimising openings in spring/summer. In addition, a provision has been included if lagoon opening events for other reasons (e.g. water quality) do not adequately support upstream migration for threatened and at-risk fish species. The 2-yearly opening frequency is also anticipated to mitigate poor water quality (see Section 5.2).

Ongoing monitoring of the status of fish populations, macrophytes, cyanobacteria, and macroalgae will be critical. If monitoring indicates fish populations decline substantially, or if fish populations are doing better than expected under prolonged lagoon closures, then the conditions regarding opening for fish passage can be reviewed accordingly.

6.5 Lagoon opening to manage water quality or biosecurity risk

Environment Southland water quality monitoring and NIWA macrophyte monitoring (de Winton 2019, de Winton and Elcock 2021, de Winton et.al. 2023) show the lagoon can be subject to periodic algal blooms.

Revised warning and critical water quality levels for Waituna Lagoon are presented in Appendix 1 and Appendix 2 below. Water quality monitoring indicates that chlorophyll-*a* concentrations exceeded the warning trigger level (0.012 mg/L) and critical trigger level (0.06 mg/L) when the lagoon was closed as well as during open conditions, although less frequently. For persistent algal blooms, opening the lagoon to the sea provides a valuable mechanism to disrupt the bloom and reduce chlorophyll-*a* concentrations.

Retaining conditions for emergency opening of the lagoon to disrupt phytoplankton and cyanobacteria blooms remains important, as highlighted by the January 2024 cyanobacterial bloom, and considering the complex nature of water quality and algal interactions. The previous consent did not specifically include ‘cyanobacteria’ as a primary trigger for water quality and it is recommended this is amended in Appendix 1A because of the threat to human and ecological health as well as to wildlife, directly.

In addition to water quality, opening events may be a useful mechanism to address significant biosecurity risks, such as the incursion of a new unwanted organism that is requiring a regionally or nationally coordinated biosecurity response (e.g. Gold Clam). Opening events may alter salinity or available habitat and, as such, provide a tool to protect the lagoon ecosystem. It is therefore proposed to include an option for lagoon opening to mitigate a significant biosecurity risk.

It is recommended to amend the conditions for water quality or biosecurity risk as follows:

Lagoon Opening in the case of poor water quality or biosecurity events

6. (a) The lagoon may be opened to the sea at any time of the year when water level in the lagoon is able to facilitate an opening, provided that:

(i) One or both primary water quality and ecosystem health indicators set out in Appendix 1A has reached its Critical Indicator Level, and

(ii) A Technical Advisory Group has considered the Primary Indicators in Appendix 1A, and any other relevant scientific information, including additional indicators of Ecosystem Health set out in Appendix 2A, and has recommended in writing that opening the lagoon to the sea is necessary to disrupt an actual or probable algal bloom, or biosecurity risk, in order to avoid a significant adverse ecological effect on the lagoon.

Appendix 1A: Primary and Secondary Indicators Levels for Waituna Lagoon

	Water quality, biosecurity or ecosystem health indicator	Warning indicator level	Critical indicator level
PRIMARY indicators	Chlorophyll-*a* (a sustained visible algal bloom* over a period of 14 days or longer)	0.012 - 0.06 mg/L	⩾ 0.06 mg/L
	Cyanobacteria	Biovolume great than 5mm³/L (and more than 50% of phytoplankton biovolume present as toxic or potentially toxic cyanobacteria	Biovolume greater than 10mm³/L (and more than 80% of phytoplankton biovolume present as toxic or potentially toxic cyanobacteria)
	Bottom water dissolved oxygen concentration	< 2 and ⩾ 0.5 mg/L	< 0.5 mg/L
	Incursion of a new non-native species that is a significant biosecurity risk	Incursion of worrisome species but low risk of proliferation	High risk species incursion (eDNA or positive sighting or capture of new non-native species)
Interpretation	* A "visible algal bloom" shall be identified by: (i) A chlorophyll-a concentration and/or (ii) An observations by an appropriately qualified and experienced person. These observations shall include the location and approximate extent and intensity of the visible algal bloom on each day of observation.		

Appendix 2A:

	Water quality or ecosystem health indicator		Critical indicator level
SECONDARY indicators	Total phosphorus concentration	⩾ 0.05 and < 0.1 mg/L	⩾ 0.1 mg/L
	Total nitrogen concentration	⩾ 0.75 and < 1.5 mg/L	⩾ 1.5 mg/L
	Water clarity (Secchi disc depth)	⩾ 0.5 m and < 1 m	< 0.5 m
	Nuisance epiphytes or benthic algae**	>10% cover	>30% cover
	Macrophytes**	<30% lagoon wide cover abundance	<20% lagoon wide cover abundance
	*Ruppia megacarpa***	Present at <20% of lagoon monitoring sites	Present at <10% of lagoon monitoring sites
	Diadromous fish (īnanga, lamprey/kanakana, eel/tuna) density (Waituna Creek)	Declines in diadromous fish populations (density and/or biomass)	Substantial declines in diadromous fish populations (density and/or biomass)
	Toxins/pathogens	Cyanotoxin producing genes in cyanobacteria present, but no cyanotoxins detected. Prolonged level of *E. coli* >260 cfu/100ml and not human source	Cyanotoxins detected across lagoon *E. coli* prolonged level above 1200 cfu/100ml

** Based on the results from annual surveys undertaken in late summer.

6.6 Integrated assessment of ecological and cultural values

The development of proposed conditions for lagoon opening was based on a subset of the ecological and cultural values of Waituna Lagoon, specifically: submerged macrophytes, fish/taonga species populations and water quality.

There may be concerns that the proposed regime will have negative consequences on other values at Waituna Lagoon, such as the fringing wetlands and bird populations. An integrated assessment of the predicted impact of the proposed changes to lagoon opening on all key values is summarised in Table 8. Overall, the proposed conditions (Scenario C) will have a beneficial impact, although for some values the proposed conditions will likely be neutral (bird populations, water quality). It is not predicted that significant negative effects on the coastal ecosystem will occur due to dilution. For further information on bird populations refer to section 7.3.

Table 8. Multi-value assessment of the predicted impact of recommended conditions

Value	Impact of previous consent conditions	Predicted impact of recommended conditions (Scenario C)	Predicted change in value due to proposed conditions
Taonga species	Does not specifically provide for fish passage for taonga species. Opening events may or may not align with key migratory periods	Specific provisions for fish migration. Increased focus on monitoring	Improvement/Neutral
Cultural significance	Frequent opening events (>1x/year) not aligned with restoring ecosystem to more natural regime	Conditions specifically target a transition to a more natural state (longer freshwater phase)	Improvement
Water quality	Included provision for emergency opening to disrupt phytoplankton bloom	Conditions for emergency opening retained in case of poor water quality. Lagoon flushing will still occur (given conditions for fish passage)	Neutral
Submerged macrophytes	Spring/summer openings led to regular decline in abundance of submerged macrophytes	Conditions specifically target improved management of macrophytes due to higher (2.5m) opening threshold	Improvement
Fish and invertebrate populations	Does not specifically provide for fish passage. Opening events may or may not align with key migratory periods. Kōura and kākahi habitat maybe limited with lower lagoon levels and more frequent saline conditions.	Specific provisions for fish migration. Increased focus on monitoring Kōura and kākahi may benefit from increased habitat from higher lagoon levels and less frequent openings and lower salinity	Improvement
Bird populations	Conditions provide for both open and closed lagoon conditions that support broad range of bird species.	Conditions provide for both open and closed lagoon conditions that support broad range of bird species. Longer freshwater phase will benefit threatened species (bittern) and waterfowl (incl. ducks). A reduction in the estuarine phase is not considered to have a significant impact on the bird species that favour an open lagoon due to the availability of other estuarine habitats in the area (e.g.,	Neutral

Value	Impact of previous consent conditions	Predicted impact of recommended conditions (Scenario C)	Predicted change in value due to proposed conditions
		New River estuary, Awarua Bay, Fortrose estuary)	
Fringing Wetlands	Lack of high (>2.2m) water levels promoted more exotic weed species. Frequent draining of fringing wetlands.	Conditions provide for greater water level fluctuation to support fringing native plant communities, e.g. oioi, turf plants. Avoids prolonged periods of lower water levels that dewaters fringing wetlands. .	Improvement

In terms of the cultural significance of Waituna Lagoon (which incorporates the aesthetic appeal, mahinga kai, safety of access, identity, naturalness, and connection to landscape and human health), the overall purpose of proposed new conditions (Scenario C) is to return the lagoon to as natural a state as possible within the constraints of elevated catchment nutrient and sediment loads. The predicted impact on the lagoon's cultural values is, therefore, also expected to be positive, while taking a holistic approach that considers the opportunities to enhance fish passage/mahinga kai and to improve water quality.

6.7 Proposed transition regime: technical feedback

Consultation with stakeholders occurred during 2022 and 2023. The focal point of discussions was the proposed maximum water level (2.5 m ASL), the duration of time above the water level threshold prior to lagoon opening and allowing for a transition period to the proposed opening regime. The consultation resulted in a transitional regime for lagoon opening that was agreed in principle. Specifically,

Lagoon Opening – transitional regime

(a) *for the first five years from the grant of consent (years 1-5), being to [day month year]:*

(i) summer openings (1 September to 30 April) may occur if water levels are at or above 2.5m for 24 consecutive hours; and

(ii) winter openings (1 May to 30 August) may occur if water levels are at or above 2.3m for seven consecutive days;

(b) *for the next ten years of the consent (years 6-15), being from [day month year] to [day month year], openings may occur if water levels are at or above 2.5m for three consecutive days; and*

(c) *for the final five years of the consent (years 16-20), being from [day month year] to [day month year] openings may occur if water levels are at or above 2.5m for seven days.*

The long-term objective for Waituna Lagoon is for opening events to maintain and enhance multiple ecological and cultural outcomes, by enabling more natural functioning of the lagoon. The transitional regime, initially provides a lower winter opening threshold (2.3m) and a shorter time period prior to opening (between 1-3 days) that we understand will allow residual areas of agricultural land to transition, while recognising the vulnerability of the lagoon ecosystem.

Managing the lagoon at higher levels over time (2.5m) will support ecosystem recovery by promoting two consecutive growing seasons for submerged aquatic plants, enabling inundation of fringing wetlands and providing a diversity of habitats for water birds and fish.

The implications of applying the transition regime were examined in Scenario D of the hydrological model for Waituna Lagoon (Table 6). The transition regime is anticipated to result in more frequent openings per year (0.66) compared to the proposed regime (0.55; Schedule C). Technical expert review resulted in general agreement that the transition provides a positive step to enhancing the ecosystem health of Waituna Lagoon. It was noted that ecological and cultural values remain at risk and would benefit from immediate application of the long-term regime (Scenario C). Maintaining water quality and fish passage provisions remain important during the transition period.

6.8 Proposed location for opening events

The location of opening events is an important consideration, taking into account the potential positive or adverse effects on ecological and cultural values, water quality management and fish passage. Logistical, cost and hydrological feasibility of an opening may also be considered; however, this technical assessment is focused on implications for lagoon health.

The previous short-term consent for lagoon opening provided the following conditions:

1. This consent authorises the opening of the Waituna Lagoon to the sea through the gravel barrier at either:

(a) Walker's Bay between NZTM 1,262,340E 4,831,360 N and 1,261,460E 4,831,000N; or

(b) Hansen's Bay, between NZTM 1,265,305E 4,832,570N and 1,265,405E 4,832,605N

2. Except as specified in Condition 6, the openings authorised by this resource consent shall be at the Walker's Bay site specified in Condition 1(a).

(i) Openings under Condition 6 may be at either the Walker's Bay or the Hansen's Bay sites, dependent upon the recommendation of the technical advisory group as described in Condition 6(b).

The commonly used site for lagoon opening for at least the past 20 years has been Walker's Bay, except for one opening that occurred at Hansen's Bay and the opening in the summer of 2024 at 'the Fence' near the eastern end of the Lagoon.

The environmental factors that should be considered when determining opening location are:

- the positive or negative effects of the opening site on ecological and cultural values
- the suitability of the site for managing poor water quality
- the suitability of the site for providing fish passage for migratory fish species
- the potential for managed closure at the opening site (during prolonged open periods)

For many ecological values (bird communities, fringing wetland vegetation) the site used for opening may not have implications for important habitats, which are more directly impacted by water levels. However, there is a potential risk to submerged aquatic vegetation in Waituna Lagoon, as the abundance and diversity of aquatic plants is not uniform across the lagoon.

The annual monitoring of submerged plants (including *Ruppia megacarpa, Ruppia polycarpa, Lamprothamnium macropogon, Myriophyllum triphyllum*) occurs on 10 transects that are dispersed from the east (transect 1) to the west (transect 10) of Waituna Lagoon (Figure 10).

Figure 10. Location of submerged plant monitoring transects in Waituna Lagoon.

The abundance of aquatic plants often varies significantly between the eastern and western regions of Waituna Lagoon. In February 2022, following a period of over 5 months of closed conditions suitable for plant recruitment and growth, a high abundance of aquatic plants was present in the eastern regions of Waituna Lagoon (Figure 11a), while the abundance and diversity of aquatic plants in western regions was notably lower (Figure 11b). For example, the abundance of *Ruppia megacarpa* in 2022 was significantly higher in the eastern regions of the lagoon.

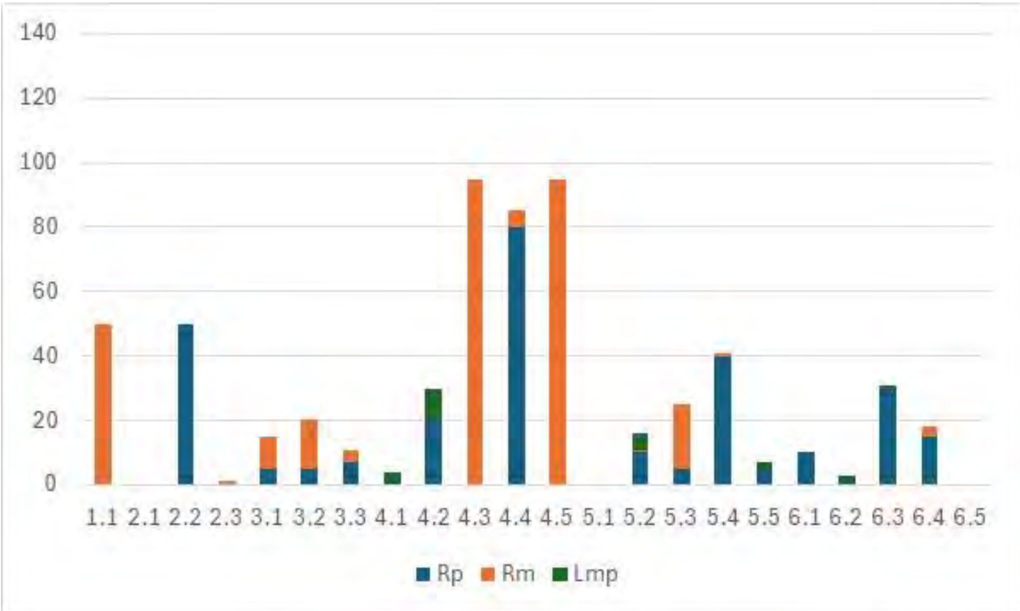

Figure 11a. Abundance and diversity of aquatic plants in the eastern areas (transects 1-6) of Waituna Lagoon in 2022 following a period of ~ 6 months closed conditions. Rp = *Ruppia polycarpa,* Rm = *Ruppia megacarpa,* Lmp = *Lamprothamnium macropogon.*

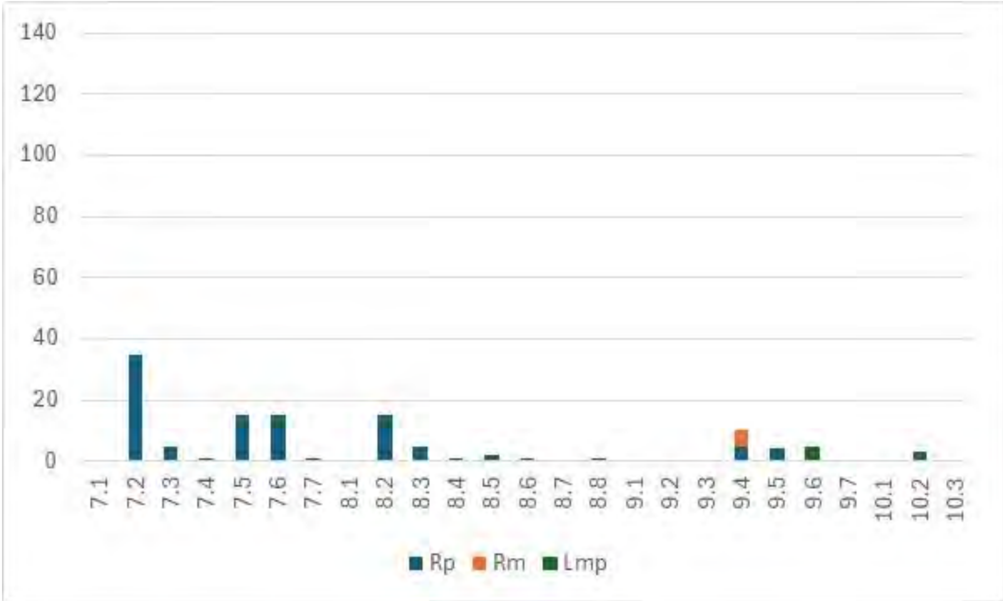

Figure 11b. Abundance and diversity of aquatic plants in the western areas (transects 7-10) of Waituna Lagoon in 2022 following a period of ~ 6 months closed conditions. Rp = *Ruppia polycarpa,* Rm = *Ruppia megacarpa,* Lmp = *Lamprothamnium macropogon.*

In 2023, after the lagoon had been closed for 12 months, the abundance of aquatic plants was high throughout the lagoon, with more diversity of native species on the eastern regions of the lagoon (Appendix D1-D2).

In April 2024, after the lagoon had been closed for two weeks following an opening at the Fence on the eastern side of the lagoon, the abundance of aquatic plants was higher on the western side of the lagoon (Appendix D3-D4). This suggests that the location of opening reduces the abundance and diversity of aquatic plants in its vicinity and that changing opening locations may have long term consequences for the resilience of the lagoon ecosystem. Limiting habitat disturbance and the potential for marine gravels and sand to accumulate in eastern regions is recommended, to ensure the aquatic plant beds and their seedbank are not subject to high disturbance without a more comprehensive risk assessment being completed.

There may also be implications for the structure and abundance of fish communities in the streams that flow into Waituna Lagoon. No īnanga were found in the 2024 fish survey in Waituna Creek following the opening event at The Fence. However, the timing of the 2024 opening did not coincide with peak upstream migration periods for īnanga. Given the uniform nature of the beach and coastal environment bordering Waituna Lagoon, there is no reason to expect that the opening location will influence the catchments fish community. However, ongoing monitoring will enable any potential effect of opening location on fish communities to be investigated.

The benefits and risks associated with alternative lagoon opening sites are briefly described in Table 9 below. Based on this assessment the recommendation is to continue to use the Walker's Bay location for opening events, given the proximity to Waituna Creek (the primary source of contaminants to the lagoon) and as the site is further away from regions of the lagoon with established macrophyte beds. Alternative locations may also be considered if the location does not have an impact on established macrophytes beds or other lagoon values. It is advised to complete a comprehensive risk assessment on potential adverse effects on ecological and cultural values, including water quality management for alternative locations.

Table 9. Alternative opening locations and environmental implications.

Value	Walkers Bay	Hansens Bay	The fence
Ecological and cultural values	Historical opening site that is further away from areas of lagoon that regularly supports healthy beds of submerged plants No direct effects on birds Maintains fish populations in Waituna Creek	Site is close in proximity to eastern end of lagoon that often supports healthy beds of submerged plants No direct effects on birds. Potential indirect effects on stream fish populations and plant community.	Site is close in proximity to eastern end of lagoon that often supports healthy beds of submerged plants No direct effects on birds. Potential indirect effects on stream fish populations and plant community.
Suitability for managing poor water quality	Site is closer in location to Waituna Creek, the sub-catchment that provides highest contaminant loads Previous opening events have improved water quality	Site is considerably further away from Waituna Creek, the sub-catchment that provides highest contaminant loads Previous opening events have improved water quality	Site is considerably further away from Waituna Creek, the sub-catchment that provides highest contaminant loads Previous opening events have improved water quality
Suitability for providing fish passage	No expected difference between sites in terms of fish passage into the lagoon		
Potential for managed closure at the opening site	No expected difference between sites in terms of potential for managed closure, although further assessment may be necessary		
Overall	Preferred opening location based on current information	Not advised to use location until further risk assessment undertaken	Not advised to use location until further risk assessment undertaken

7. Impacts of proposed consent conditions on other values

7.1 Land drainage and road/track infrastructure

This review of the conditions for lagoon opening was focused on determining the optimal management approach to enhance the ecological and cultural values of Waituna Lagoon. As outlined in section 6 it is proposed to increase the threshold level for lagoon opening to 2.5mASL. That is, the lagoon opening (under Scenario C) will occur when water levels are at or above 2.5m.

The recommendation of 2.5m as the opening threshold level considered the implications on land drainage. A detailed investigation of the effects of lagoon water levels on land drainage was previously undertaken by NIWA (Walsh et al. 2016). This investigation used complex hydrological models, LiDAR elevation data, flow and level monitoring data, in combination with a channel roughness coefficient (to simulate a cleared or vegetated channel) to map the extent of land that is affected directly by inundation (Table 10, Figure 13), and impeded land drainage (Table 10, Figure 12), at different lagoon water levels.

The area of land affected by direct inundation and impeded drainage is a function of lagoon level, flow rate and plant growth in the creeks. The relative importance of these factors varies spatially with the most downstream parts of the creeks strongly affected by lagoon level but further upstream the influence of flow rate and vegetation dominate. This is important to consider when interpreting Figure 12 where the land drainage impacts furthest from the lagoon are caused by vegetation rather than lagoon level (Walsh et al. 2016).

The NIWA investigation supported the purchase of low-lying land by Whakamana Te Waituna. Land purchase specifically targeted agricultural land adjacent to Waituna, Moffat and Carran Creek with inundation or restricted drainage when the lagoon water level is at 2.5m. Consequently, it is no longer necessary to maintain drainage to most of the agricultural lands that were vulnerable to inundation and impeded land drainage. However, under the recommended opening regime, some properties have residual areas with short-term restricted access or drainage limitations (Table 10). Notably, many of these areas are affected also by water levels at 2.0m as restrictions in the stream channel capacity and instream vegetation contribute to land drainage.

By raising the maximum level to 2.5m from 2.0m, it is estimated that the additional area of productive land inundated with a cleared channel and median flow, is 3.5ha and increases to 3.7ha with a vegetated channel and high flow (Table 10). This represents approximately 0.02% of agricultural land in the catchment. Similarly, the additional area of productive land that is drainage impeded with a clear channel and median flow is 27ha and increases to 28ha with a vegetated channel and high flow (Table 9). This represents approximately 0.15% of agricultural land in the catchment.

A few small sections of roads and tracks on Waghorn Road are similarly affected by inundation at lagoon levels above 2.0m ASL (Figure 14). When the lagoon water level is at approximately 2.0m ASL, Southland District Council estimates that about 300m of road/track is inundated. When the water level is at 2.5m ASL this increases slightly to approximately 400m of road/track being inundated. However, this only limits access to the Department of Conservation viewing platform and one of the properties purchased through the Whakamana Te Waituna project.

One property on the southern side of Waituna Lagoon between the lagoon and the sea is most easily accessed by a track through Conservation Land. Approximately 500m of this track is affected by inundation when lagoon levels get to about 2.2m. An unformed track exists on the seaward side of the Conservation Land (on the beach) that provides alternative and legal access.

A concern for road infrastructure, access to private land and agricultural land drainage, may be that lagoon water levels will be high (>2.4m) for prolonged periods of time. However, the results from hydrological modelling (Table 6) indicate that under proposed lagoon opening (Scenario C) water levels will be >2.4 for approximately 5 days per year, and >2.2m for approximately 21 days per year.

Any land drainage impediment for low-lying properties not purchased by Whakamana Te Waituna is considered minor in both extent and frequency. Similarly, the duration of inundation on road infrastructure is relatively short-lived.

Table 10. Agricultural land* affected (hectares) by inundation and land drainage when water levels in the lagoon are 2.0m, and 2.5m ASL. Q50 is mean (50th percentile) stream flow conditions, Q90 is 90th percentile stream flow. 'V' stream with vegetation, 'N' stream with no vegetation

Flow scenario		Area (ha) at Waituna Creek		Area (ha) at Moffats Creek		Area (ha) at Carran Creek		Total catchment Area (ha) affected by raising lagoon threshold level from 2.0m to 2.5m
		2.0m	2.5m	2.0m	2.5m	2.0m	2.5m	
Inundated land	Q90_V	4.2	7.0	1.6	2.0	0.5	1.0	3.7
	Q50_V	2.3	4.7	0.8	1.2	0.5	1.0	3.3
	Q90_N	2.4	4.8	0.7	1.1	0.5	1.0	3.3
	Q50_N	1.9	4.4	0.5	0.9	0.2	0.8	3.5
Drainage affected	Q90_V	119.4	125.9	6.9**	25.5	29.1	32.2	28.2
	Q50_V	20.3	30.9	6.9	9.9	7.1	14.1	20.6
	Q90_N	23.8	33.3	5.3	8.7	11.5	17.6	19
	Q50_N	13.7	27.7	3.3	7.6	3.3	12.0	27

*Agricultural land is calculated by the area of productive land, minus Public Conservation Land, wetland (as mapped by Land Cover Data Base) and land purchased for the purpose of managing the lagoon's ecological and cultural health.
** likely to be underestimated

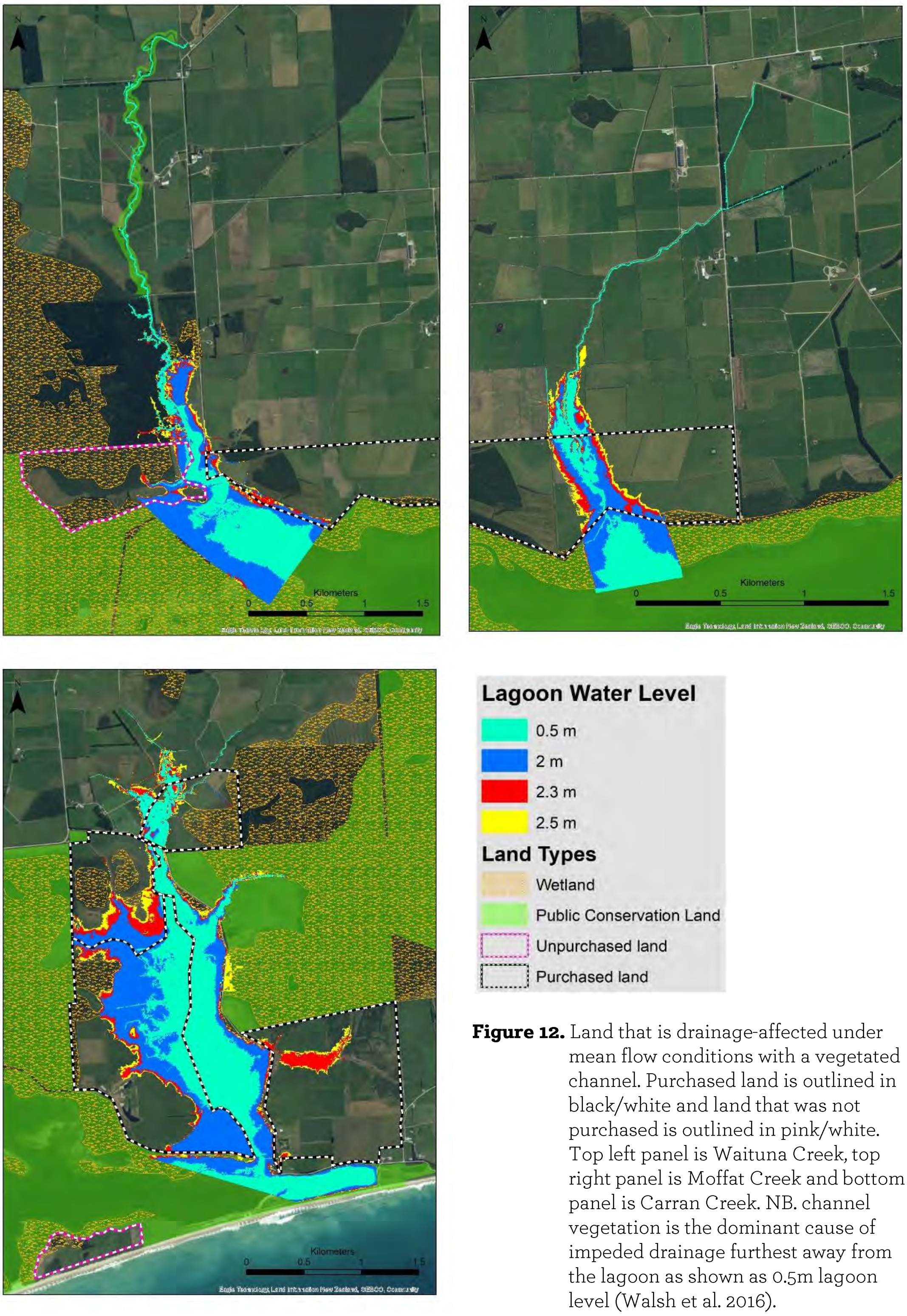

Figure 12. Land that is drainage-affected under mean flow conditions with a vegetated channel. Purchased land is outlined in black/white and land that was not purchased is outlined in pink/white. Top left panel is Waituna Creek, top right panel is Moffat Creek and bottom panel is Carran Creek. NB. channel vegetation is the dominant cause of impeded drainage furthest away from the lagoon as shown as 0.5m lagoon level (Walsh et al. 2016).

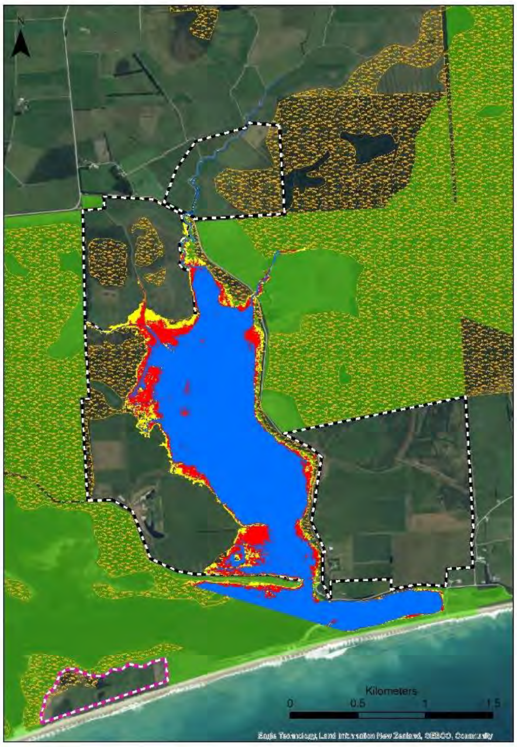

Figure 13. Extent of inundated land from Waituna creek (top left), Moffat Creek (top right) and Carran Creek (bottom) at different lagoon levels, modelled under a scenario of mean flow and channel vegetated. Purchased properties outlined in black/white, land not purchased outlined in pink/white. Walsh et al 2016.

Figure 14. Extent of inundation of Waghorn Road and Waghorn Road Bridge at different lagoon levels.

7.2 Trout fishery

Waituna lagoon is highly valued regionally for its brown trout fishery and particularly for the opportunity to catch 'sea-run' trout when the lagoon is open. Anglers specifically target trout at the lagoon outlet when the lagoon opening coincides with upstream īnanga migration (whitebait run) which provides a feeding opportunity for trout.

Holmes (2019) observed no detectable pattern between brown trout density (or biomass) and lagoon open-closure status, stating that the effects of lagoon opening and closed status on trout populations may be indirect or subtle, likely though food web effects.

Inward migration of īnanga provides a significant pulse of food for trout into the Waituna catchment, contributing in the order of 20% of total fish biomass in Waituna Creek during strong recruitment years. This addition of food into the wider ecosystem ultimately increases productivity of the whole system, including the brown trout population.

Compared to the status quo, the proposed consent conditions have specific provisions to ensure native fish, particularly īnanga, can regularly migrate into the lagoon and catchment, thereby ensuring the opportunity for catching sea run trout continues, at least every two years. While opportunities to target sea-run fish will be reduced during years when the lagoon is closed, the resident trout population will likely benefit from closed lagoon conditions. The lagoon is highly productive when closed over the summer periods and the available foraging area for trout will be increased. This will likely provide good fishing conditions for anglers targeting trout around the lagoon edge and near tributary inflows.

In addition, optimising the lagoon for ecological health will protect the trout population by helping to maintain water quality and clarity. Overall, the impact of an ecologically-focused opening regime should protect and enhance the brown trout population and its fishery values.

7.3 Duck hunting and bird populations

Waituna Lagoon and surrounding wetlands are highly valued for the opportunity for duck hunting.

The proposed lagoon opening conditions (Scenario C) outlined in this report will result in a reduced frequency of lagoon opening events, including a reduced likelihood of lagoon opening during the opening of the duck hunting season. Increased duration of freshwater conditions, with extensive open water areas that support a healthy lagoon ecosystem dominated by submerged macrophytes, will provide habitat and food resources for waterfowl (ducks, swans).

In respect of migratory waterbirds and other native wetland bird species, Waituna Lagoon forms part of the wider Awarua-Waituna wetland complex on the Southland coast. Awarua is a large wetland/estuarine complex that comprises Awarua Bay, the New River estuary, extensive peatlands and the lagoon. Other coastal wetlands also occur nearby, including Fortrose estuary.

Collectively these areas form an important feeding area for more than 80 bird species including threatened species and trans-equatorial migrants, such as the far eastern curlew (*Numenius madagascariensis*), whimbrel (*N. phaeopus*), and Caspian terns (*Hydroprogne caspia*). The Awarua wetland also supports notable populations of Australasian Bittern, Fernbird, New Zealand Dotterel, Black Swan, Grey Duck, Black Shag and Royal Spoonbill.

The positive or negative impact of the changes to the hydrological regime for Waituna Lagoon needs to consider the available habitat and resources for bird populations in Waituna Lagoon and across their geographical range. Research on the water level requirements for wetland bird species at Te Waihora (O'Donnell pers. comm.) indicates that different bird functional groups have different habitat preferences. For example, Arctic migrant and overwintering wading birds inhabit the shoreline (0.6 to 0.8m depth); Swamp birds inhabit flooded reeds/rushes (>0.7m); and Waterfowl and shags inhabit open water (0.4-1.4m).

Given these contrasting habitat preferences, the open and closed status of the lagoon will have a varied effect on bird functional groups. The proposed conditions for lagoon opening (Scenario C) include both closed (freshwater) and open (tidal) phases. In this scenario water levels are estimated to be above 2.2m for on average approximately 21 days per year (Table 6) and will still provide for lower water levels during other times of the year for those bird species that prefer more shallow water. The bathymetric map for Waituna Lagoon (Figure 15) further indicates that extensive areas are inundated to depths >1m when water levels are 1.5m or 2.0m which limits the use of these areas by wading species, however, this will provide habitat for waterfowl and specialist swamp-dwelling species. Waders also frequently use habitats at Awarua Bay and New River estuary.

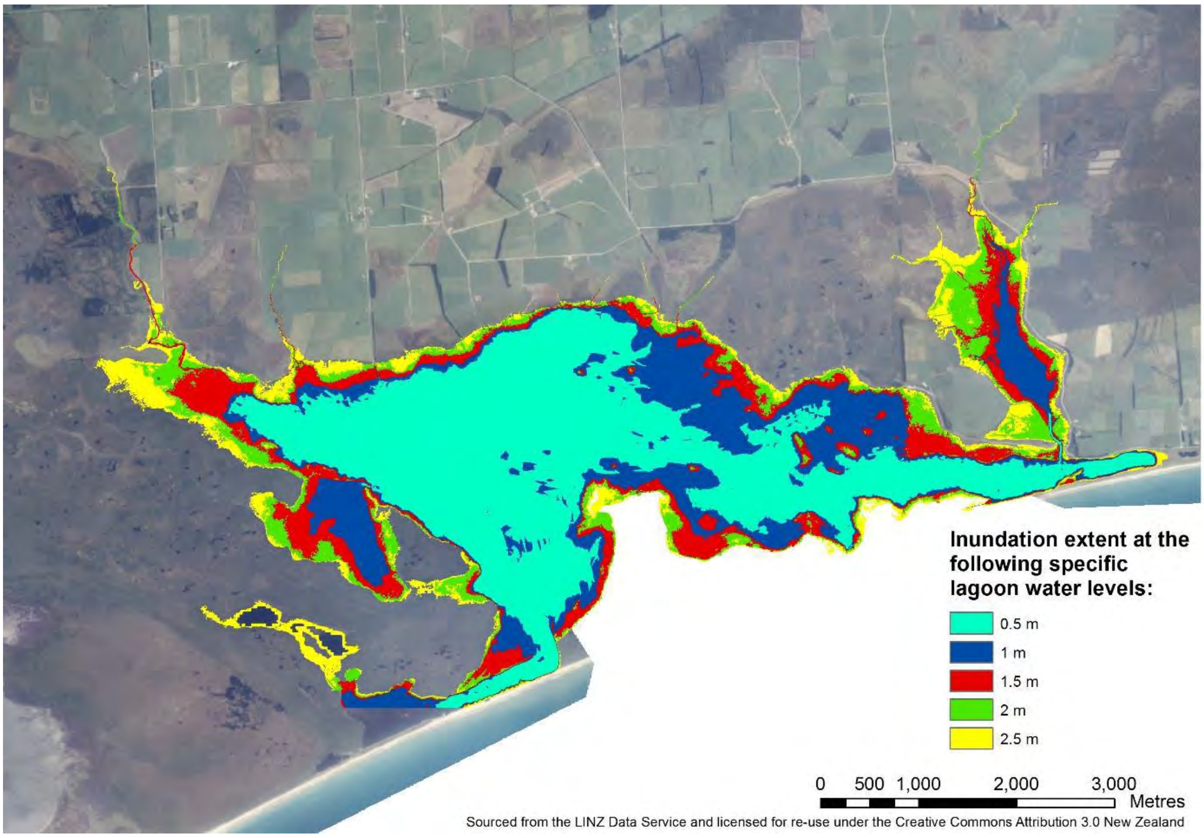

Figure 15. Waituna Lagoon inundation extent at different water depths. Source: Walsh et al. (2016).

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9. Appendix A – Short term consent (February 2017 – February 2022) to open Waituna Lagoon

Coastal Permit

Pursuant to Section 104B of the Resource Management Act 1991, a resource consent is hereby granted by the Southland Regional Council to **Lake Waituna Control Association,** care of **E R Pirie, 389 Kapuka North Road, RD 3, Wyndham 9893** from **14 February 2017.**

Please read this Consent carefully, and ensure that any staff or contractors carrying out activities under this Consent on your behalf are aware of all the conditions of the Consent.

Details of Permit

Purpose for which permit is granted:		To periodically open Lake Waituna to the sea
Location	– site locality	Walker's Bay and Hansen's Bay, Lake Waituna
	– map reference	Between NZTM 1262340E 4831137oN and 1261460E 4831000N (Walker's Bay), and about NZTM 1265350E 4832550N (Hansen's Bay)
Legal description at the site:		Section 29 Block XIII Oteramika Hundred and Crown Land (seabed)
Expiry date:		14 February 2022

Schedule of Conditions

1. This consent authorises the opening of the Waituna Lagoon to the sea through the gravel barrier at either:
   (a) Walker's Bay between NZTM 1,262,340E 4,831,360 N and 1,261,460E 4,831,000N; or
   (b) Hansen's Bay, between NZTM 1,265,305E 4,832,570N and 1,265,405E 4,832,605N
2. Except as specified in Condition 6, the openings authorised by this resource consent shall be at the Walker's Bay site specified in Condition 1(a).
   (i) Openings under Condition 6 may be at either the Walker's Bay or the Hansen's Bay sites, dependent upon the recommendation of the technical advisory group as described in Condition 6(b).
3. (a) Immediately prior to lagoon opening, the consent holder must notify the Consent Authority (email: escompliance@es.govt.nz), the Kaupapa Taiao Manager at Te Ao Marama Inc and Operations Manager (Murihiku) of the Department of Conservation about the proposed opening location. The notification shall be in writing and shall include:
   (i) the current water level at the Waghorn's Road bridge gauge board[5]; and
   (ii) note of the prevailing wind conditions (direction and strength)[6], and comment whether or not there is any reason to suspect that the water level is only temporarily raised at the gauge board by strong wind conditions; and

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[5] Continuous water level readings are available at: http://www.es.govt.nz/rivers-and-rainfall/graph/?site=Waituna-Lagoon-at-Waghorns-Road&measurement=river level&start=12-May-2016&end=19-May-2016&owner=0

[6] Wind conditions at Invercargill airport can be viewed at: http://www.metservice.com/towns-cities/invercargill?gclid=CIuft6z1gM8CFQGavAod19kAsA#!/your-weather

(iii) information to show compliance with the opening criteria specified in Conditions 4, 5 or 6.

Note: 'in writing' may be by email.

Lagoon Opening May to 19 September inclusive

4. (a) During the months from 1 May to, and including, 31 August the lagoon may be opened to the sea when water level in the lagoon reaches 2.0 metres, as measured on the Waghorn's Road bridge gauge board.

(b) During the period 1 September to 19 September the lagoon may be opened to the sea when water level in the lagoon reaches 2.0 metres, as measured on the Waghorn's Road bridge gauge board once the lagoon has been above that level for 7 days out of a continuous period of ten days.

(c) During the month of July the lagoon may be opened when water level in the lagoon reaches 1.8 metres as measured on the Waghorn's Road bridge gauge board, if the lagoon has not been opened in the previous 12 month period.

Lagoon Opening 20 September to April inclusive

5. (a) During the months from 20 September to, and including, 30 April the lagoon may be opened to the sea when the water level in the lagoon reaches 2.2 metres, as measured on the Waghorn's Road bridge gauge board;

(b) During the months from 20 September to, and including, 30 April the lagoon may be opened to the sea when the water level exceeds 2.0 metres, as measured on the Waghorn's Road bridge gauge board, provided that:

(i) the lagoon has been above that level for 14 days out of a continuous period of twenty days; and

(ii) the mean aquatic plant (macrophyte) cover in the lagoon has exceeded 30 percent for the previous three years, as determined by annual summer surveys or monitoring by a suitably qualified person

Lagoon Opening in the case of poor water quality events

6. (a) Notwithstanding conditions 4-6 of this consent, the lagoon may be opened to the sea when water level in the lagoon is above 1.5 metres, as measured on the Waghorn's Road bridge gauge board, provided that:

a primary ecological trigger (outlined in Appendix 1) has been reached, and

a technical advisory group, convened jointly by Environment Southland, Te Ao Marama Inc and the Department of Conservation, with scientific knowledge of coastal lagoon ecosystems, has considered the secondary and tertiary indicators (Appendix 1), and any other relevant scientific information, and has advised the consent holder and Consent Authority in writing that opening the lagoon to the sea is advisable to disrupt an actual or probable algal bloom in order to avoid a significant adverse ecological effect on the lagoon,

(b) If the technical advisory group required by Condition 6(a)(ii) specifies a preference (in writing) for the opening to occur at one or the other of the locations specified in Condition 1, the opening in accordance with this condition shall only occur at that location.

(c) In the event that the lagoon is opened to the sea in accordance with condition 6(a), the consent holder shall notify the following parties that a primary ecological trigger has been reached and that opening the lagoon to the sea has been recommended. The notification shall include evidence that the ecological trigger has been reached and a copy of the written advice from the technical advisory group specified in condition 6(a):

Kaupapa Taiao Manager, Te Ao Marama Inc, PO Box 7078, South Invercargill 9844

Operations Manager, Murihiku District Office, Department of Conservation, PO Box 743, Invercargill 9840

The Manager, Fish & Game New Zealand, PO Box 159, Invercargill 9840

The Consent Authority

7. (a) With regard to the Primary indicator in Appendix 1, a "visible algal bloom" shall be identified by:

   (i) ≥0.012 mg/l Chlorophyll *a* (or other figure identified in writing by the technical advisory group referred to in condition 6); and/or

   (ii) The observations of an appropriately qualified person. These observations shall include the location and approximate scale and intensity of the visible algal bloom on each day of observation.

   (b) These observations or readings are to be recorded and shall be made available to the Lagoon technical advisory group and the Consent Authority.

Responses to disturbance of artefacts or fuel spills

8. In the event of:

   (a) the discovery, or suspected discovery, of a site of cultural importance (Waahi Taonga/Tapu), the consent holder shall immediately cease operations in that location and inform the local Iwi authority (Te Ao Marama Inc) and the Consent Authority Operations may recommence at a time as agreed upon in writing with the Consent Authority. The discovery of Koiwi (human skeletal remains) or Taonga or artefact material (e.g., pounamu/greenstone) would indicate a site of cultural importance. Appendix 2 to this consent outlines the process that is to be followed in the event of such a discovery.

   (b) contamination of the lagoon or foreshore, such as with fuel or oil spilt from the digger during the lagoon opening, the consent holder shall remove the contaminants immediately from the site and notify, without undue delay, the Consent Authority (email: compliance@es.govt.nz or phone 03 211 5115) and the Area Manager (Murihiku) of the Department of Conservation.

Information Gathering Requirements

9. The consent holder shall record the following information:

   (a) when and where the lagoon is opened to the sea;

   (b) the water level in the lagoon at the time it was opened;

   (c) information to show compliance with the opening criteria specified in Conditions 4, 5 or 6.

   (d) when and at what gauge board level access across Carran Creek bridge was lost for stock and farm vehicles and when was this access re-established.

   (e) how long the lagoon is open to the sea and when it closes (to the nearest week);

10. The consent holder shall provide the information specified in condition 9, to the Consent Authority and to the Operations Manager (Murihiku) of the Department of Conservation within one month of the opening of the lagoon to the sea, and without undue delay following closure of the channel to the sea.

Consent Review and Council Charges

11. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the

conditions of this consent during the period 1 February to 30 September each year, or within two months of any enforcement action being taken by the Consent Authority in relation to the exercise of this consent, or on receiving monitoring results, for the purposes of:

determining whether the conditions of this permit are adequate to deal with any adverse effect on the environment, including cumulative effects, which may arise from the exercise of the permit, and which it is appropriate to deal with at a later stage, or which become evident after the date of commencement of the permit;

ensuring the conditions of this consent are consistent with any National Environmental Standards Regulations, relevant plans and/or Policy Statement;

amending the monitoring programme to be undertaken; or

adding or adjusting compliance limits.

Note: Under s127 of the Resource Management Act the Consent Holder can apply for a change or cancellation of a resource consent condition (other than the consent duration) at any time during the consent period.

12. The consent holder shall pay an annual administration and monitoring charge to the Consent Authority, collected in accordance with Section 36 of the Resource Management Act, 1991.

Meetings

13. The consent holder shall hold liaison meetings, at least once each year, to report and discuss available monitoring information regarding the following in Lake Waituna:
    - water level
    - water quality, particularly nutrients
    - algae, particularly chlorophyll a
    - macrophytes
    - fish

    The consent holder shall invite the following to the liaison meetings:
    - representatives of each of the organisations in Section 3.1 of Appendix 3; and
    - each of the individuals (or their representatives) in Section 3.2 of Appendix 3

Any other person or group at the discretion of the applicant.

The consent holder shall record a summary of the attendees and discussion at each meeting, and report the summary to the consent authority within 20 working days of the meeting.

In the event that contact details for any of the individuals or organisations in Appendix 3 becomes outdated, and the consent holder has not been notified of updated contact details, the consent holder may omit invitation of that individual or organisation to the meeting.

for the **Southland Regional Council**

Vin Smith

Director of Policy, Planning & Regulatory Services

Appendix 1

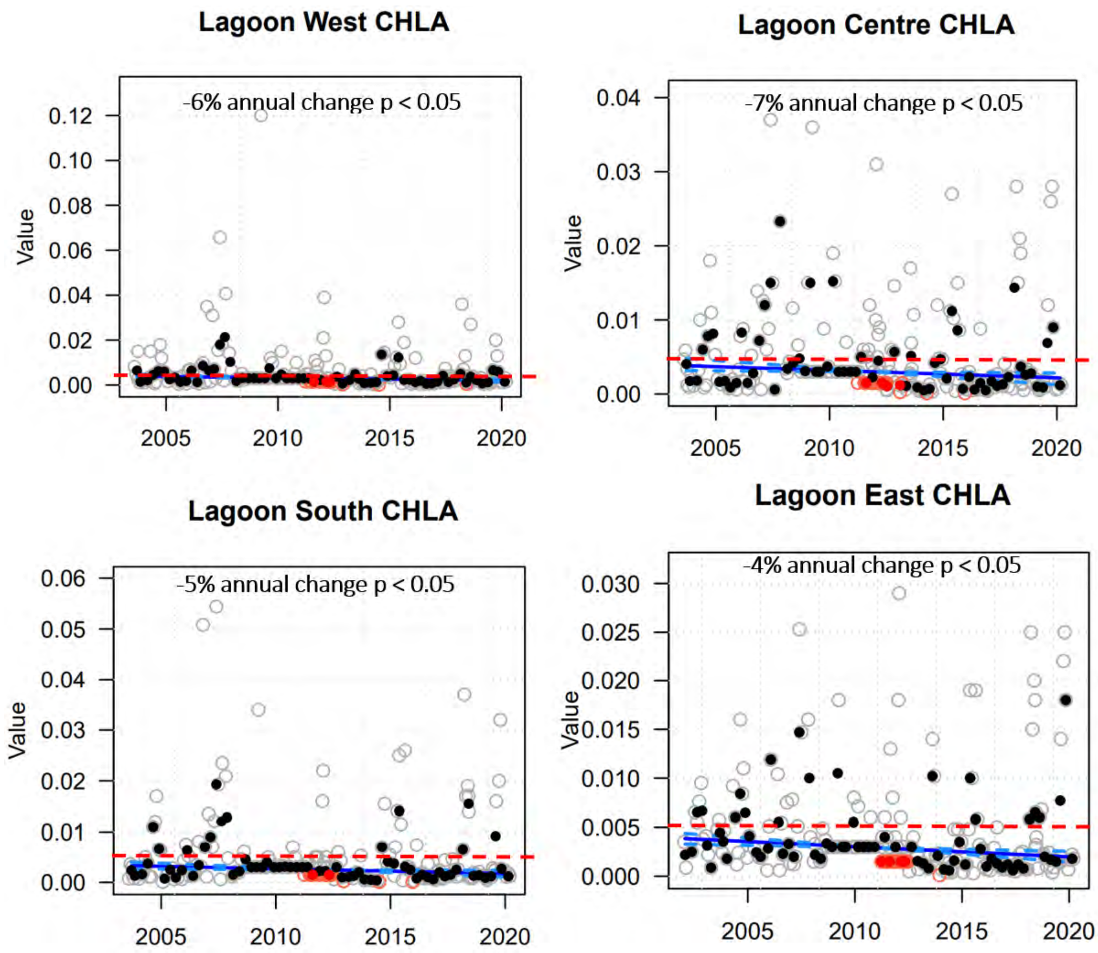
Indicators

Appendix 1:

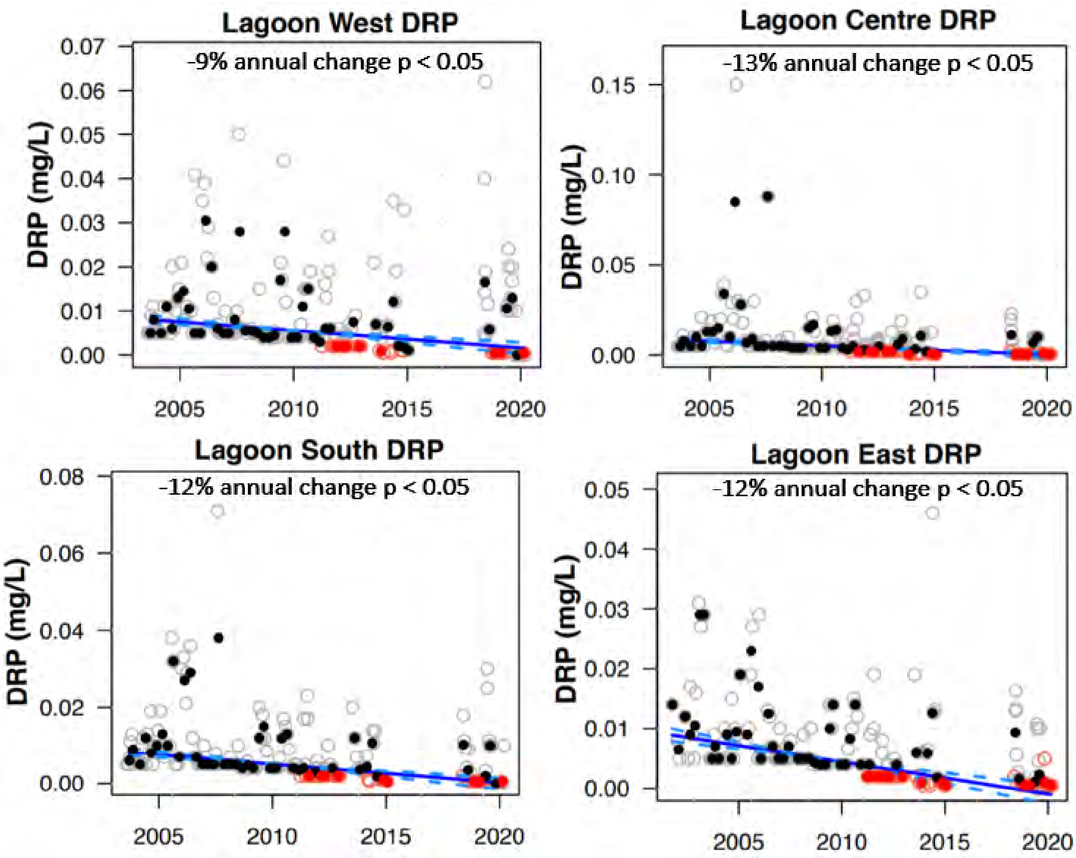
	Water quality, biosecurity or ecosystem health indicator	Critical trigger
PRIMARY indicators	Chlorophyll-*a*	a sustained visible algal bloom* over a period of 14 days or longer
	Cyano-bacteria	≥ 500 cells/mL or ≥ 0.5 mm3/L biovolume [of potentially toxin producing species]
	Incursion of a new non-native species that is a significant biosecurity risk	eDNA or positive sighting or capture of new non-native species
		Critical indicator level
SECONDARY indicators	Total Phosphorus concentration	≥ 0.045 mg/l
	Total Nitrogen concentration	≥ 0.700 mg/l
TERTIARY indicators	Nuisance epiphytes or benthic algae	
	Ruppia and other macrophytes	
	RPD (Redox Potential Discontinuity) – bottom sediments	
	Turbidity	
	Bottom water dissolved oxygen concentration	
	Aquatic and surrounding wetland life	
	Algal blooms	

Note: Appendix 2 and 3 not included.

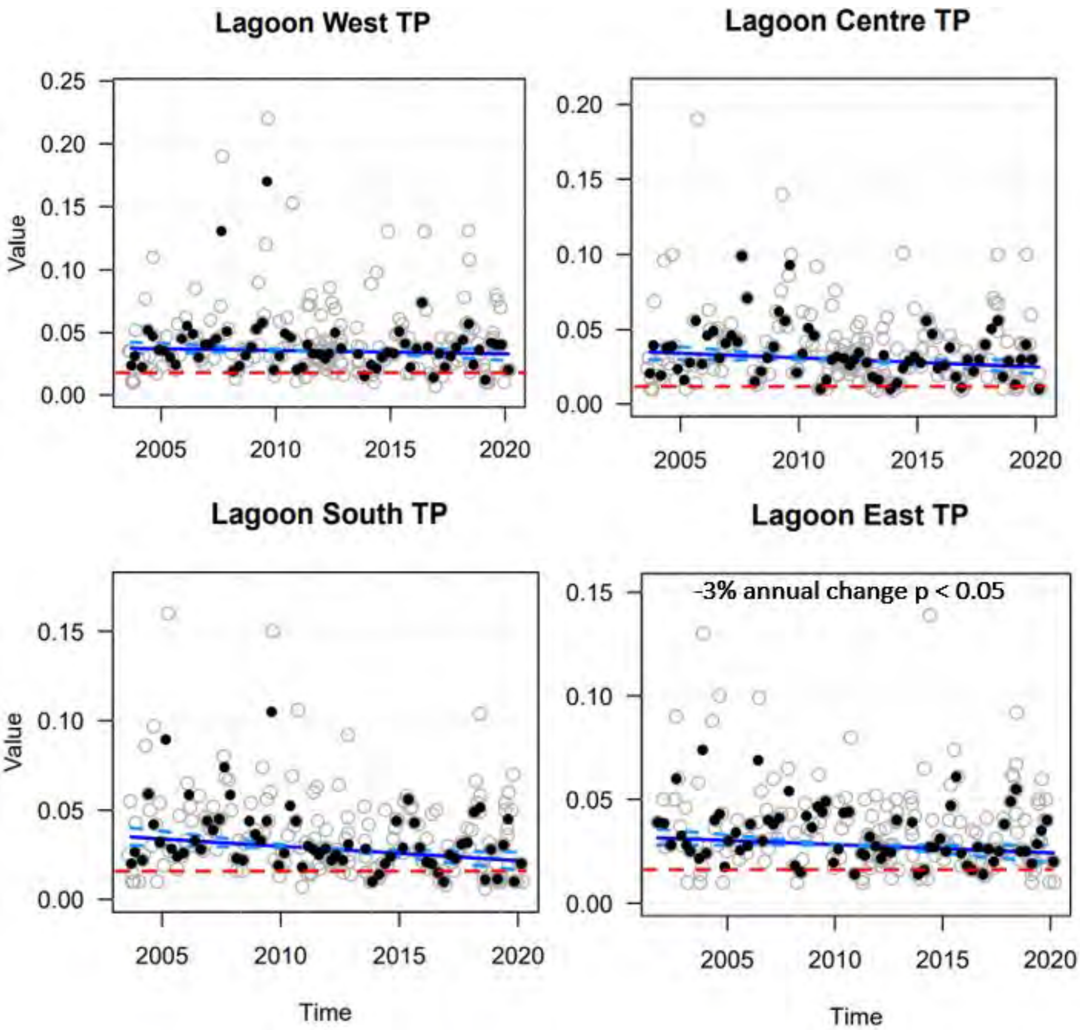
10. Appendix B – Water quality trends



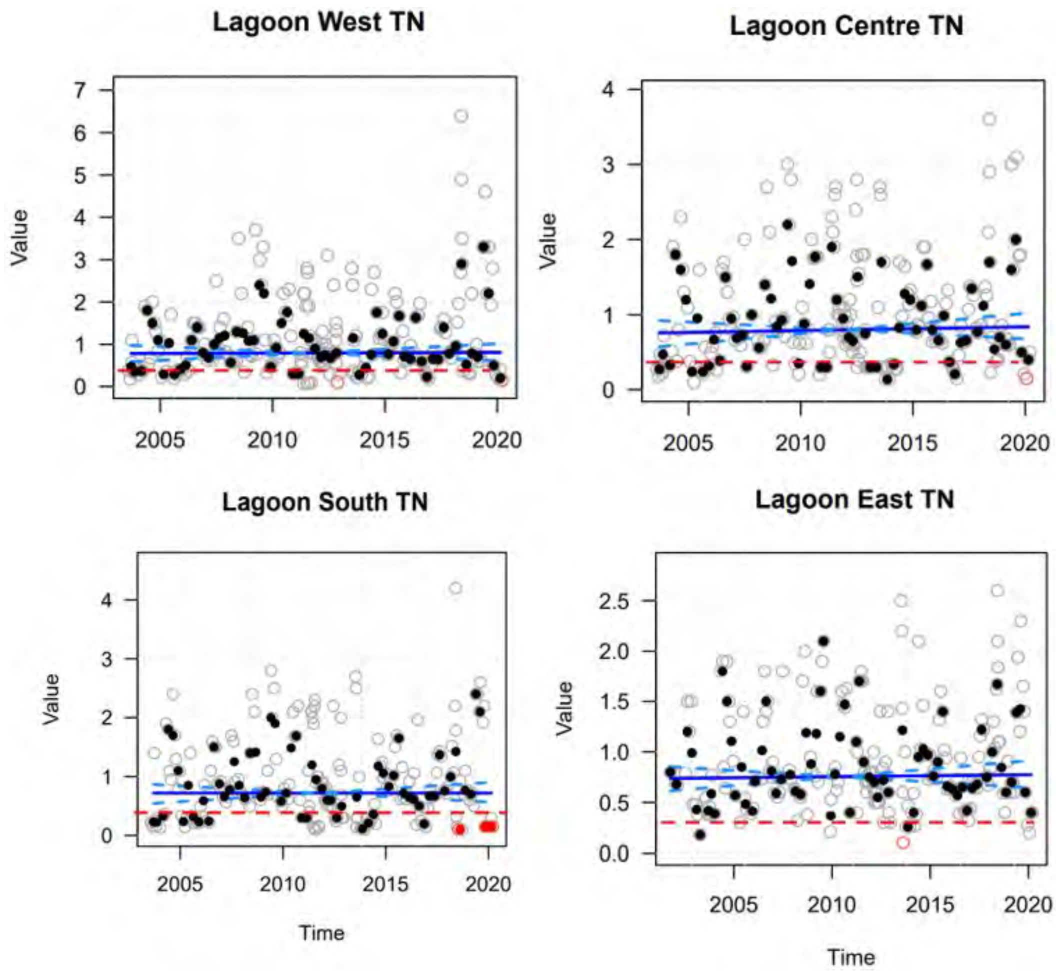
Long-term trends of chlorophyll-a (chl a, mg/L) concentrations in Waituna Lagoon. All sites displayed a significant decreasing trend in chlorophyll-a concentrations. The LTG 2013 minimum threshold of 0.005 mg/L is noted with the red dashed line. Open circles denote raw data, closed circles denote quarterly medians used in the model, the blue line is the regression line with 95% confidence intervals.



DRP (mg/L) trend analysis results from Waituna Lagoon sites from 2001 to 2020. **All sites displayed a significant decreasing trend** (blue line). Closed circles represent the quarterly median value used in the trend analysis, open points represent the raw data, and red points represent censored values.



Total Phosphorous (mg/L) trend analysis results from Waituna Lagoon sites from 2001 to 2020. The Lagoon East site displayed a significant decreasing trend (blue line). Closed circles represent the quarterly median value used in the trend analysis, open points represent the raw data, and red points represent censored values. Note that the LTG 2013 guideline for TP is 0.02 mg/L (dashed red line).



Total Nitrogen (mg/L) trend analysis results from Waituna Lagoon sites from 2001 to 2020. No sites displayed a significant decreasing trend (blue line). Closed circles represent the quarterly median value used in the trend analysis, open points represent the raw data, and red points represent censored values. Note that the LTG 2013 guideline for TN is 0.337 mg/L (dashed red line).

11. Appendix C – Water quality 2019-2023

Figure C1: Total nitrogen and Total phosphorus concentration in Waituna lagoon from 2019 to the end of 2023 and the start of the 2023/24 cyanobacterial bloom event.

12. Appendix D – Submerged macrophyte status

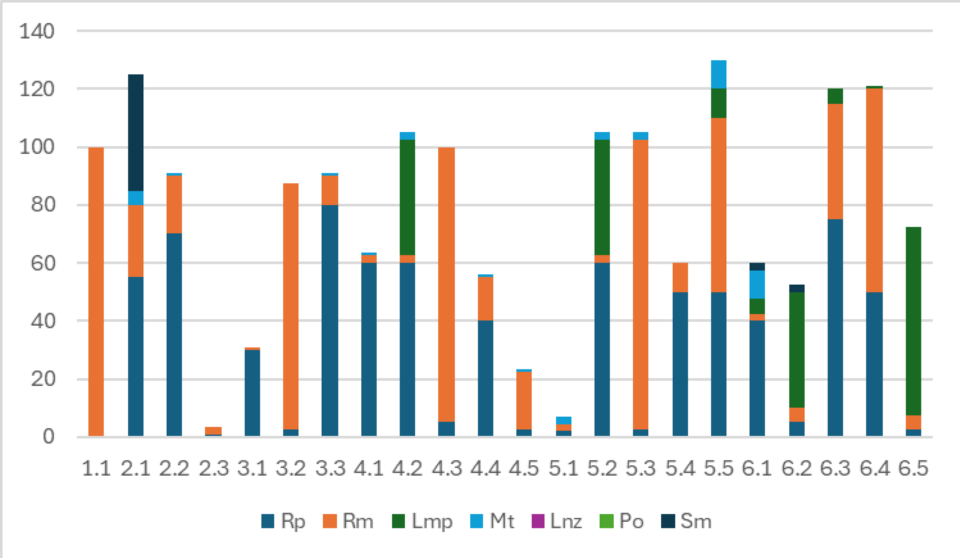


Figure D1. Abundance and diversity of aquatic plants in the eastern areas (transects 1-6) of Waituna Lagoon in February 2023 after c. 2 years of closure. Rp = *Ruppia polycarpa,* Rm = *Ruppia megacarpa,* Lmp = *Lamprothamnium macropogon.*

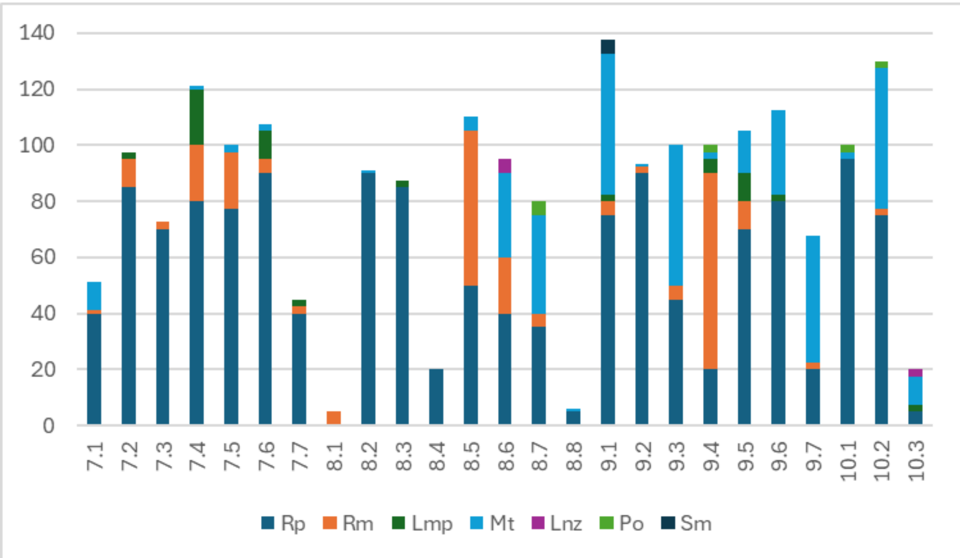


Figure D2. Abundance and diversity of aquatic plants in the western areas (transects 7-10) of Waituna Lagoon in February 2023 after c. 2 years of closure. Rp = *Ruppia polycarpa,* Rm = *Ruppia megacarpa,* Lmp = *Lamprothamnium macropogon.*

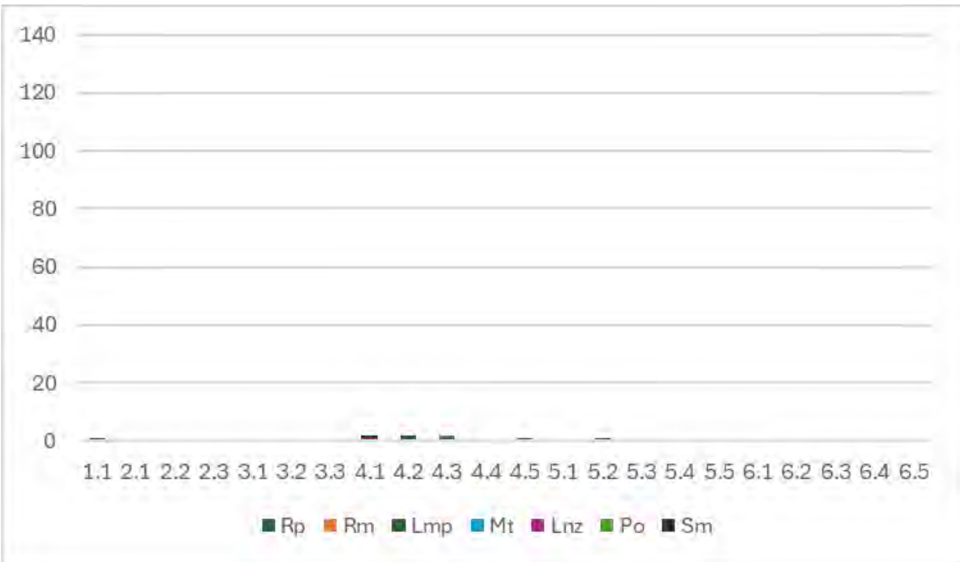


Figure D3. Abundance and diversity of aquatic plants in the eastern areas (transects 1-6) of Waituna Lagoon in April 2024 after emergency opening at the fence, in the eastern region of the lagoon (see Fig. 10).

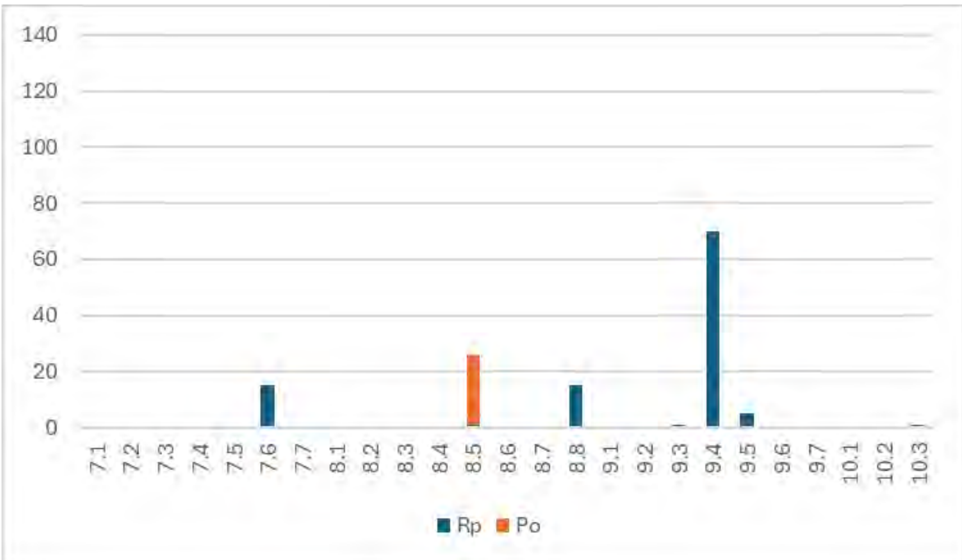


Figure D4. Abundance and diversity of aquatic plants in the western areas (transects 7-10) of Waituna Lagoon in April 2024 after emergency opening at the fence, in the eastern region of the lagoon (See Fig. 10).

Appendix C: Proposed Conditions of Consent

Draft Proposed Conditions of Consent

1. This consent authorises the opening of the Waituna Lagoon (Lagoon) to the sea through the gravel barrier in accordance with Conditions 5 to 7 at Walker's Bay between NZTM 1,262,340E 4,831,360 N and 1,261,460E 4,831,000 N or unless otherwise certified by the Consent Authority in accordance with Condition 19.

2. The level of the Lagoon will be measured at the Waghorn's Bridge gauge or if that gauge for any reason is not available an alternative gauge approved by the Consent Authority.

3. In this consent a Lagoon opening means:

    a) use of excavators operating on the gravel bar, starting from the landward side of the Lagoon; and

    b) formation of a channel between the Lagoon and sea, with excavated material retained alongside the channel and levelled off.

Lagoon Opening Conditions

4. Lagoon Opening – transitional regime:

    c) for the first five years from the grant of consent (years 1-5), being to [day month year]:

        i. summer openings (1 September to 30 April) may occur if water levels are at or above 2.5m for 24 consecutive hours; and

        ii. winter openings (1 May to 30 August) may occur if water levels are at or above 2.3m for seven consecutive days;

    d) for the next ten years of the consent (years 6-15), being from [day month year] to [day month year], openings may occur if water levels are at or above 2.5m for three consecutive days; and

    e) for the final five years of the consent (years 16-20), being from [day month year] to [day month year] openings may occur if water levels are at or above 2.5m for seven consecutive days.

5. Lagoon Opening – to protect water quality and ecosystem health:

    a) The Lagoon may be opened to the sea at any time of the year when the water level in the lagoon is able to facilitate an opening, provided that:

        i. One or more of the primary lagoon water quality and ecosystem health indicators in Appendix 1 have reached a Critical Indicator Level; and

ii. The Science Advisory Group has considered the Primary Indicators in Appendix 1, and any other relevant scientific information, including additional indicators of Ecosystem Health set out in Appendix 2, and recommend in writing to the consent holders that opening the lagoon to the sea is necessary to manage the risk of a significant adverse ecological effect on the lagoon; taking into account

iii. Any request in writing from a member of the public to the Consent Authority or to the Consent Holders that the lagoon be opened to protect water quality and ecosystem health.

*Note: Science Advisory Group means the group established in accordance with **Condition 8**.*

6. Lagoon Opening - for the purpose of providing fish passage:

a) The Lagoon may be opened to the sea to provide for passage for diadromous fish species, provided that:

i. The opening takes place between 1 April and 30 November; and

ii. The lagoon has not been opened in the previous 24 months, or if the lagoon was opened during the past 24 months, where the timing of the open period did not support upstream migration of threatened or at-risk fish species, and

iii. The Science Advisory Group, has considered the lagoon water quality and ecosystem health indicators listed in Appendix 1 and 2, and any other relevant scientific and cultural information, and has advised the Consent Holders and Consent authority that opening the lagoon to the sea is necessary to enable fish passage.

*Note: Science Advisory Group means the group established in accordance with **Condition 8**.*

7. Notification of Lagoon Opening:

a) Prior to opening the Lagoon under **Conditions 4, 5, or 6**, and at least 24 hours in advance, the consent holders must:

i. Notify in writing via email:

- Fish & Game New Zealand;
- The Lake Waituna Control Association;
- Landowners adjacent to the lagoon;
- The Consent Authority.

ii. Notify the public of the opening on the Environment Southland website.

b) The notices in **Condition 7(a)(i) and (ii)** must include:

i. The date of the opening;

ii. The purpose of the opening in accordance with **Conditions 4,5 or 6**;

iii. the current water level at the Lagoon and average daily water levels for the previous seven days; and

iv. a note of the prevailing wind conditions (direction and strength) , and comment whether or not there is any reason to suspect that the water level is only temporarily raised at the gauge board by strong wind conditions; and

v. any lagoon monitoring information necessary to show compliance with the opening criteria specified in **Conditions 4, 5, or 6**. This must include:

- A copy of the written advice from the Science Advisory Group of the reason for opening as specified in **Condition 5** if the opening is in accordance with **Condition 5**;
- A copy of the written advice from the Science Advisory Group of the reason for opening as specified in **Condition 6** if the opening is in accordance with **Condition 6**.

Science Advisory Group

8. The consent holders shall establish a Science Advisory Group. The purpose of the Science Advisory Group is to:

(a) Act as an advisory group to the consent holders; and
(b) Make recommendations to the consent holders under **Conditions 5 and 6**.

9. Decisions of the Science Advisory Group must be made unanimously or if a decision cannot be made unanimously by majority.

10. All organisations represented in the Science Advisory Group will bear their own cost of their representative. The cost of additional experts is to be shared by the consent holders.

11. The Science Advisory Group:

(a) must include suitably qualified representatives of:

i. the Director-General of Conservation;

ii. Awarua Rūnaka;

iii. Environment Southland;

b) May include:

i. A suitably qualified representative of the Lake Waituna Control Association with scientific or cultural knowledge of coastal lagoon ecosystems, if one is nominated within six months of the consent approval. The consent holders must provide the Lake Waituna Control Association an opportunity to nominate a suitably qualified technical expert as its representative of the Science Advisory Group and accept the nominee, provided the nominee is a suitably qualified technical expert;

ii. Other technical experts with scientific or cultural knowledge of coastal lagoon ecosystems approved by the consent holders.

12. The Science Advisory Group must advise the consent holders in writing whether opening the lagoon to the sea is recommended to manage the risk of a significant adverse ecological effect on the lagoon. This must occur as soon as reasonably practicable but not later than ten working days of the consent holders notifying the Science Advisory Group that monitoring in accordance with **Condition 14** demonstrates that one or more of the Primary lagoon water quality and ecosystem health indicators has reached its Critical Indicator Level.

Communications

13. The consent holder must provide the Consent Authority with a Communication Management Plan within six months of commencement of this consent. The purpose of this plan is to inform interested parties of matters related to the Waituna lagoon including but not limited to lagoon openings and monitoring data.

Monitoring and Reporting Conditions

14. The consent holders must monitor and record the following information:

a) changes in the primary and secondary indicators of lagoon water quality and ecosystem health in **Appendix 1 and Appendix 2**;

b) when and where the lagoon is opened to the sea;

c) the water level in the lagoon at the time it was opened;

d) information to demonstrate compliance with the opening **Conditions 4, 5, and/or 6**;

e) how long the lagoon is open to the sea, and when it closes (to the nearest week)

15. Information gathered under **Condition 13** shall be provided in writing to the Consent Authority:

    a) Annually on [insert date]; and

    b) on request.

16. No later than [insert date – 5 years from grant], and thereafter at 5-yearly intervals, the Consent Holders must submit a 5-year review of the effectiveness of the permit (a Consent Review) in protecting lagoon health, to the Consent Authority, which as a minimum must assess:

    a) whether any amendments to the permit are required to better protect lagoon and ecosystem health and cultural values;

    b) whether the conditions of the permit are adequate to deal with any adverse effect on the environment, including cumulative effects, which may arise from the exercise of the permit, and which it is appropriate to deal with at a later stage, or which become evident after the date of commencement of the permit, including effects on fish populations, and the effects of climate change;

    c) the effectiveness of the monitoring programme to inform the exercise of the permit; and

    d) whether any amendments to the lagoon water quality and ecosystem health indicators are necessary.

Accidental Discovery and Spill Response Conditions

17. In the event of the discovery, or suspected discovery, of a site of cultural importance (Wāhi Taonga/Tapu), the consent holders must immediately cease works in that location and inform Te Ao Marama Inc and the Consent Authority. Works may recommence at a time as agreed upon in writing with the Consent Authority. The discovery of Koiwi (human skeletal remains) or Taonga or artefact material (e.g. pounamu/greenstone) would indicate a site of cultural importance. **Appendix 3** to this consent outlines the process that must be followed in the event of such a discovery. Note the consent holder is agreeable to use Environment Southlands standard condition in replacement of this condition.

18. In the event of an accidental spill of contaminants, such as fuel or oil spilt from the digger during the lagoon opening, the consent holders shall remove the contaminants immediately from the site and notify, without undue delay, the Consent Authority (email: escompliance@es.govt.nz or phone 03 211 5115) and the Operations Manager (Murihiku) of the Department of Conservation. Note the consent holder is agreeable to use Environment Southlands standard condition in replacement of this condition.

Lagoon Opening Location

19. Should the Consent Holder seek to open the lagoon at an alternative location to Walkers Bay, a risk assessment must be submitted to the Consent Authority for certification and must assess as a minimum:
    (a) The risk to ecological and cultural values of the Lagoon, including: habitat for submerged and emergent aquatic plants, habitat and migration pathways for fish species, and fringing wetlands,
    (b) The suitability of the location for managing poor water quality, and protecting the ecological and cultural values of Lagoon, and
    (c) The overall environmental benefits of the proposed location, relative to Walker's Bay, and taking into account the recommendations of the Science Advisory Group.

Consent Review

20. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holders of its intention to review the conditions of this consent on [insert date], or on receiving annual monitoring results or the 5-yearly Consent Review (required by **Condition 15**), or within two months of any enforcement action being taken by the Consent Authority in relation to the exercise of this consent for the purposes of:

    a) Determining whether the conditions of this permit are adequate to deal with any adverse effect on the environment, including cumulative effects, which may arise from the exercise of the permit, and which it is appropriate to deal with at a later stage, or which become evident after the date of commencement of the permit, including the effects of climate change.

    b) Ensuring the conditions of this consent are consistent with any National Environmental Standards Regulations, relevant plans and/or Policy Statement.

    c) Amending the monitoring programme.

Appendix 1
Primary Indicators Levels for Waituna Lagoon

	Water quality, biosecurity or ecosystem health indicator	Warning indicator level	Critical indicator level
PRIMARY indicators	Chlorophyll-a (a sustained visible algal bloom* over a period of 14 days or longer)	0.012 - 0.06 mg/L	≥ 0.06 mg/L
	Cyanobacteria	Biovolume great than 5mm3/L (and more than 50% of phytoplankton biovolume present as toxic or potentially toxic cyanobacteria	Biovolume greater than 10mm3/L (and more than 80% of phytoplankton biovolume present as toxic or potentially toxic cyanobacteria)
	Bottom water dissolved oxygen concentration	< 2 and ≥ 0.5 mg/L	< 0.5 mg/L
	Incursion of a new non-native species that is a significant biosecurity risk	Incursion of worrisome species but low risk of proliferation	High risk species incursion (eDNA or positive sighting or capture of new non-native species)
Interpretation	* A “visible algal bloom” shall be identified by: (i)A chlorophyll-a concentration and/or (ii) An observations by an appropriately qualified and experienced person. These observations shall include the location and approximate extent and intensity of the visible algal bloom on each day of observation.		

Appendix 2
Secondary Indicators Levels for Waituna Lagoon

	Water quality or ecosystem health indicator	Warning indicator level	Critical indicator level
SECONDARY indicators	Total phosphorus concentration	≥ 0.05 and < 0.1 mg/L	≥ 0.1 mg/L
	Total nitrogen concentration	≥ 0.75 and < 1.5 mg/L	≥ 1.5 mg/L
	Water clarity (Secchi disc depth)	≥ 0.5 m and < 1 m	< 0.5 m
	Nuisance epiphytes or benthic algae**	>10% cover	>30% cover
	Macrophytes**	<30% lagoon wide cover abundance	<20% lagoon wide cover abundance
	Ruppia megacarpa**	Present at <20% of lagoon monitoring sites	Present at <10% of lagoon monitoring sites
	Diadromous fish (īnanga, lamprey/kanakana, eel/tuna) density (Waituna Creek)	Declines in diadromous fish populations (density and/or biomass)	Substantial declines in diadromous fish populations (density and/or biomass)
	Toxins/pathogens	Cyanotoxin producing genes in cyanobacteria present, but no cyanotoxins detected. Prolonged level of E. coli >260 cfu/100ml and not human source	Cyanotoxins detected across lagoon E. coli prolonged level above 1200 cfu/100ml

** Based on the results from annual surveys undertaken in late summer.

Appendix 3

Protocol in the event of a discovery, or suspected discovery, of a site of cultural importance (Waahi Taonga/Tapu)

1. Kōiwi tangata accidental discovery

If Kōiwi tangata (human skeletal remains) are discovered, then work shall stop immediately and the New Zealand Police, Heritage New Zealand (details below) and Te Ao Marama Inc (Ngai Tahu (Murihiku) Resource Management Consultants) shall be advised. Contact details for Te Ao Marama Inc are as follows:

Te Ao Marama Inc

P O Box 7078, South Invercargill 9844

Phone: (03) 931 1242

Te Ao Marama Inc will arrange a site inspection by the appropriate Tangata Whenua and their advisers, including statutory agencies, who will determine how the situation will need to be managed in accordance with tikanga māori.

2. Archaeological Sites

Archaeological sites are protected under the Heritage New Zealand Pouhere Taonga Act (2014), and approval is required from Heritage New Zealand before archaeological sites can be modified, damaged or destroyed.

Not all archaeological sites are known or recorded precisely. Where an archaeological site is inadvertently disturbed or discovered, further disturbance must cease until approval to continue is obtained from Heritage New Zealand. As stated above, the New Zealand Police and Te Ao Marama Inc also need to be advised if the discovery includes kōiwi tangata /human remains.

Heritage New Zealand c/o Regional Archaeologist Otago/Southland

PO Box 5467, Dunedin

Phone: (03) 477 9871 Mobile 027 240 8715 infodeepsouth@heritage.org.nz

3. Taonga or artefact accidental discovery

If taonga or artefact material (e.g. pounamu/greenstone artefacts) other than kōiwi tangata is discovered, disturbance of the site shall cease immediately and Southland Museum and Te Ao Marama Inc. shall be notified of the discovery by the finder or site archaeologist in accordance with the Protected Objects Act 1975. All taonga tuturu are important for their cultural, historical and technical value and are the property of the Crown until ownership is resolved.

4. *In-situ (natural state) pounamu/greenstone accidental discovery*

Pursuant to the Ngāi Tahu (Pounamu Vesting) Act 1997, all natural state pounamu/greenstone in the Ngāi Tahu tribal area is owned by Te Rūnanga o Ngāi Tahu. Ngāi Tahu Pounamu Management Plans provide for the following measures:

- any *in-situ* (natural state) pounamu/greenstone accidentally discovered should be reported to Te Rūnanga o Ngai Tahu staff as soon as is reasonably practicable. Te Rūnanga o Ngāi Tahu staff will in turn contact the appropriate Kaitiaki Papatipu Rūnanga;
- in the event that the finder considers the pounamu is at immediate risk of loss such as erosion, animal damage to the site or theft, the pounamu/greenstone should be carefully covered over and/or relocated to the nearest safe ground.

The find should then be notified immediately to the Group Head – Strategy and Environment, at Te Rūnanga o Ngāi Tahu. Their details are as follows:

Te Rūnanga o Ngāi Tahu, c/o Group Head - Strategy and Environment

Te Whare o Te Wai Pounamu

15 Show Place, P O Box 13-046, Ōtautahi/Christchurch 8021

Phone: (03) 366 4344 Web: www.ngaitahu.iwi.nz

Appendix D: Walker's Bay Opening Location

Waituna Lagoon Opening Location

N

1:50,000

Appendix E: Photographs of Lagoon Opening

2019 Opening at Walker's Bay

Digger opening the lagoon on 15.10.2019

Lagoon mouth the day after opening, looking into lagoon

Lagoon mouth the day after opening looking to the sea

Lagoon mouth four days after opening

January 2024 Opening

Appendix F: Assessment of Restoration Plan Requirements

Appendix F: Assessment of Restoration Plan Requirements

Restoration Plan under Restricted Discretionary Regulation 39

Clauses 39(5) and (6), set out that an application for a restricted discretionary activity must include a restoration plan that includes the information set out in Schedule 2 of the NESFW, and must impose a condition that requires compliance with the restoration plan.

The applicant considers these matters have been addressed through the Resource Consent Application, parts of this plan refer to the consent application and associated technical documents.

Note. not all requirements of this plan are required for this activity.

1 Details of activity site and natural inland wetland

The following information:

a) *the physical address of the site of the activity*:

The physical address of the site, being Waituna Bar and the possible opening site.

b) *the names of the owners of the site*:

His Majesty the King, with the scientific reserve administered by the Department of Conservation on behalf of the Crown.

c) *the contact details for the owners*:

Operations Manger C/- Department of Conservation, Murihiku District Office, 7th floor, CUE on Don, 33 Don Street, Invercargill, P O Box 743, Invercargill 9840

d) *the legal description of the site, including the estate or interest held by the owners and any legal status or designation that applies to the site*:

Legal description of the site: Waituna Wetlands Scientific Reserve, Crown Land, section 29 Block XIII Oteramika HUN

e) *a map showing the location and boundaries of the natural inland wetland*:

This is included on Page 34 (Figure 5) of the Resource Consent Application.

f) *the details of the legal status of the natural inland wetland under any enactment or plan*:

Scientific reserve under the Reserves Act 1977, part of a scheduled Ramsar site, Statutory Acknowledgement site under the Ngāi Tahu Claims Settlement Act 1998, Outstanding Natural Landscape or feature under the Southland District Plan.

g) *the details of any management partners, including tangata whenua or key stakeholders, involved in the restoration plan.*

The management partners are the co-applicants, being Awarua Rūnanga, DOC and Environment Southland.

2 Features and values of natural inland wetland

A description of the features and values of the natural inland wetland that are relevant to a restoration plan, including the following information:

a) *the type of natural inland wetland*:

See section 4 of Appendix B to the Resource Consent Application- Technical review of Conditions for Opening Waituna Lagoon.

b) *the vegetation in the natural inland wetland, including the dominant types of vegetation and any species of note (for example, rare species, invasive weeds, or unusual plant communities)*:

See section 4 (Table 1) of Appendix B to the Resource Consent Application- Technical review of Conditions for Opening Waituna Lagoon

c) *the hydrology of the natural inland wetland, including—*
   i. *its water sources and flows (for example, streams, rivers, seeps, or solely rain)*:
   ii. *its water levels (for example, permanent open water of more than 1 m depth, shallow water of 5 cm to 1 m depth, or conditions of being saturated with water of -5 to +5 cm depth, seasonally saturated, generally dry, or dry)*:
   iii. *any modifications (for example, drains, weirs, culverts, canals, or stop banks)*:

For Water Quality, See Section 5.2 of Appendix B to the Resource Consent Application- Technical review of Conditions for Opening Waituna Lagoon.

For Water levels and Hydrology see section 5.2.3 of the Resource Consent Application.

d) *the types of soil in the natural inland wetland*:

The soil orders withing the Waituna Catchment include Brown Soils predominantly in the north of the catchment and gley, podzol, and organic soils predominantly in the south with minor recent soils close to the coast. Variability in the soil orders reflect different parent materials, landform ages and wetness.
The proportion of slowly permeable soils in the Waituna Catchment is 36% with and additional 61% of the catchment with moderate over slow drainage.

e) *any artificial features in the natural inland wetland (for example, roads, electricity lines, buildings, and access points)*:

These include Waghorn Road and Bridge, associated boat ramp, the Waituna Lagoon loop track and viewing platform, and approximately 15-20 recreational structures.

f) *any fauna known to use the natural inland wetland or its surrounding area*:

See section 5.2 of the Resource Consent application.

g) *any special features of the natural inland wetland (for example, sites of cultural significance such as archaeological features, areas of cultural harvest, historic sites, or recreational areas).*

See Cultural Values Report Appendix G to the Resource Consent Application.

3 Issues with natural inland wetland

The following information:

a) *a description of the current state or condition of the features and values of the natural inland wetland*:

See section 4 of Appendix B to the Resource Consent Application- Technical review of Conditions for Opening Waituna Lagoon.

b) *a discussion of the threats to the natural inland wetland and the opportunities for restoring its features and values.*

See section 5.2 of the Resource Consent Application. The application and associated SAR report describe the current state and condition of the lagoon and discusses the threats and opportunities for restoring its features and values.

4 Management objectives for natural inland wetland

The specific objectives for managing the natural inland wetland based on its features, values, and issues, and taking into account—

a) *its legal status under any enactment or plan; and*
b) *any existing or required resource consents or agreements with landowners or other relevant persons.*

This application is for a new lagoon opening regime to maintain and restore the ecological health and cultural values of the lagoon ecosystem in accordance with Te Mana o te Wai, and the purpose of wetland restoration and maintenance under the National Policy Statement for Freshwater Management 2020.

A history of artificial lagoon openings and nutrient and sediment inputs associated with land use in the catchment have affected the lagoon's ecology and water quality. Awarua Rūnanga, DOC, and Environment Southland seek to transition the management of water levels within the lagoon to a more ecologically optimal opening regime which supports ecological and cultural values,

The proposed consent conditions (check) set management objectives for Waituna Lagoon and take into account its legal status. There are no existing resource consents for this activity, and those required are addressed by the application. Agreements with some landowners (e.g. Te Wai Pārera Trust) are addressed in supporting letters. Other landowners have been consulted as part of the application process as members of the Lake Waituna Control Association.

5 Operational details for achieving management objectives

An outline of the activities that will be carried out to achieve the objectives for managing the natural inland wetland, including the following:

a) *the timelines for the activities and the persons responsible for resourcing and delivering them*:

The Resource Consent Application is for a 20 year term, with a transitional regime to higher lagoon levels. The lagoon will be periodically opened depending on the condition of the lagoon. Therefore, a timeline of work cannot be accurately provided.

In terms of resourcing and delivery, this will be the co-applicants, being Awarua Rūnanga, DOC and Environment Southland.

b) *scale plans showing the operational areas*:

This is included on Page 60 (Figure 16) of the Resource Consent Application.

c) *the planting to be done, including—*
   i. *a diagram showing the general areas for planting:*
   ii. *the species to be used within specific areas (for example, areas of standing water, wetter margin areas, or drier areas):*
   iii. *the spacing of the plants:*
   iv. *the sources of the plants (for example, local native plant nurseries or locally-sourced seed):*
   v. *the approach to releasing the plants (including how often, for how many years, and by what method weeding will be done around the plants):*

Not applicable. No planting is to take place under this resource consent.

d) *any vegetation to be removed, including species and methods of removal (for example, cutting, digging, or spraying):*

We expect some vegetation to be removed when the lagoon is opened. However this is not the purpose of the application, this will be a secondary outcome of the lagoon being mechanically opened.

e) *any machinery to be used and the purpose of its use:*
f) *a description of the approach to water management, including—*
   i. *any changes to water levels or movement of water during and after the restoration works:*
   ii. *if water will be dammed or diverted,—*

See section 3.2 of the Resource Consent Application for an outline of how the works will be carried out, it is worth noting that the activity itself will result in the levels of the wetland changing, this is the purpose of opening the lagoon. There will also be a diversion of water.

a) *how that will restore or enhance the natural inland wetland:*
b) *any structures that will be installed:*
c) *the time of year when the works will be carried out:*
d) *the methods to be used to minimise effects on flora and fauna*
e) *the approach to managing erosion and sediment to be used during all of the works:*
f) *any animal pest control to be carried out, including—*
   i. *which animal pests are present:*
   ii. *how often, and for how many years, the animal pest control will be carried out:*
   iii. *the method by which the animal pest control will be carried out:*
   iv. *a description of the actions to be taken to minimise any adverse effects on fauna or to enhance values for fauna.*

See section 3.2 of the Resource Consent application for an outline of how the works will be carried out. There will be no structures placed. There will be no pest control carried out as part of this consent process. The application includes the diversion and discharge of water and sediment from Waituna Lagoon to the sea, the discharge of seawater and sediment to the lagoon.

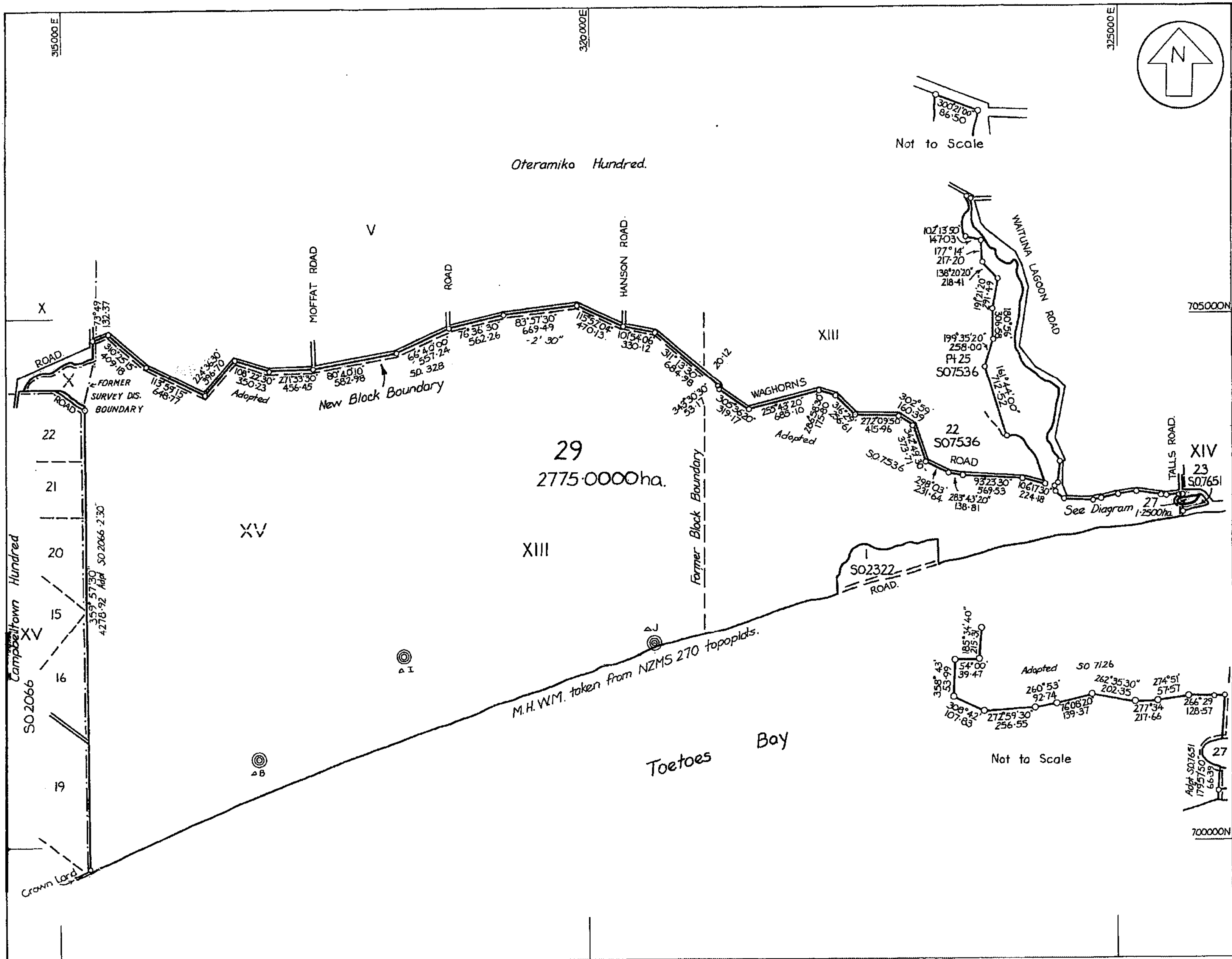
6 Review and reporting

A description of the approach for assessing progress against the restoration plan and reporting that progress to the consent authority, including—

a) *timelines for reporting progress; and*
b) *how any requirement to report under a resource consent will be met.*

See section 3 of the Resource Consent application for information related to the Monitoring of the lagoon, noted also that whilst not directly part of this consent there are several organisations that also undertake monitoring of the lagoon regularly.

Appendix G: Survey Plan



Approvals

Datum: Geodetic 1949.
Origin of Coordinates
Observation Spot. Bluff Circuit
700000 mN
300000 mE

Note: All Roads Legal.

Total Area 2776·2500 ha.

Comprised in Gaz 1971 p 364

~~I, of Registered Surveyor and holder of an annual practising certificate hereby certify that this plan has been made from Surveys executed by me or under my direction; that both plan and Survey are correct and have been made in accordance with the regulations under the Surveyors Act 1966~~

~~Dated at this day of 19 Signature~~

Field Book —— p. —— Traverse Book —— p. ——

Reference Plans 50.328, 7126, 7536, 7651, 2322 2066

Examined BMMcKenzie Correct B.Ewen

Approved as to Survey
26 / 1 /83 Dep. Chief Surveyor

~~Deposited this~~ day of 19

District Land Registrar

LAND DISTRICT Southland
SURVEY BLK.& DIST. XIII, XIV Oteramika Hd.
NZMS 261 SHEET No. E47, F47

Section 29 Blk XIII and Section 27 Blk XIV

LOCAL AUTHORITY Southland County
Surveyed by Compiled in Survey Office
Scale 1:25000 Date Nov. 1982

File 8/7/4
Received 2·12·82
Instructions

SO 10326

P. D. HASSELBERG, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1980
I. F. Stirling, Surveyor-General, Department of Lands and Survey, Wellington.
LGS FORM N 93

Appendix H: Cultural Values Report

Mana whenua values, associations, and connection to Waipārera

For Waituna Lagoon Opening Regime Consent Application, 2023

Prepared by Te Ao Marama Inc. for Te Rūnanga o Awarua.

Toitu te marae o Tane

Toitu te marae o Tangaroa

Toitu te Iwi

When the land and waters are well, so are the people.

This report has been collated from various documents with the support of the Te Ao Marama Inc team. This report has been subject to internal peer review and reviewed by Papatipu Rūnanga representatives.

Content

Executive summary

Mana oranga, Mana tangata, Mana ki uta, Mana ki tai, Mana Waituna.

Ensuring the wellbeing of the people, the land, the waters, the ecosystems, and the life-force of the Waituna catchment and lagoon, for now and for future generations through a partnership approach. Whakamana te Waituna, Strategy and Action Plan for Waituna, 2015

The purpose of this report is to highlight Ngāi Tahu ki Murihiku values and connection to Waituna Lagoon. It supports the position of Te Rūnanga o Awarua (hereby Awarua Rūnanga) to be a co-applicant, alongside Environment Southland and the Department of Conservation, for a resource consent to periodically open the Waituna Lagoon. Environment Southland, the Department of Conservation, and Awarua Rūnanga are three of the partners of the Whakamana te Waituna Trust through which they have a shared interest in restoring the mana, cultural and ecological health of the Waituna Lagoon and its surrounds.

Ngāi Tahu ki Murihiku have a long association with Waipārera, the correct name for Waituna Lagoon, with tūpuna utilising the area for the abundance of mahinga kai and resources. The name Waipārera means the water body of the grey duck, which was found in great quantity and gathered by mana whenua. Despite the change in relationship with the landscape over time, this has not affected mana whenua connection and obligations as kaitiaki of the wai and whenua. The following values have been identified as key to mana whenua and their connection to Waipārera:

1. **Kaitiakitanga** – the exercise of guardianship and stewardship by tangata whenua to continue to protect cultural associations and values of an area and resources.
2. **Mahinga kai** - is about mahi ngā kai, to work the food and is about places and ways of gathering resources. It is central to Ngāi Tahu wellbeing and identity.
3. **Wai** - water is a taonga and it is the responsibility of tangata whenua to ensure that this taonga is available for future generations in as good as, if not better, quality.
4. **Mauri** –defined as life force or essence, is a central component of the Māori perspective on the environment and represents the essence that binds the physical and spiritual elements of all things together, generating and upholding all life.

Although many of these values have been diminished for mana whenua over time, this does not diminish them in their entirety. They can be given mana again, and to restore the mauri of Waipārera recommendations are as follows:

- Cultural frameworks, values, rights and interests and the environment are inextricably intertwined.
- Awarua Rūnanga should be enabled and supported to exercise kaitiakitanga and rangatiratanga over Waipārera and be actively involved in the restoration and enhancement of Waipārera.

- Kaupapa Māori monitoring should be undertaken by and for Awarua Rūnanga throughout Waipārera and feeding waterbodies to ascertain a baseline for cultural health and then continue to do so to monitor the efficacy of any implemented measures.
- Cultural values, rights, interests and uses should be recognised and provided for to reconnect mana whenua to the area.
- It is necessary for an opening regime to prioritise the health of Waipārera and the taonga species that rely on it.

Mana whenua

Te Rūnanga o Ngāi Tahu is the tribal representative body of Ngāi Tahu whānui, established under the Te Rūnanga o Ngāi Tahu Act 1996. There are 18 Papatipu Rūnanga that constitute the membership of Te Rūnanga o Ngāi Tahu. The Te Rūnanga o Ngāi Tahu Act 1996 and the Ngāi Tahu Claims Settlement Act 1998 give recognition of the status of Papatipu Rūnanga as the repositories of the kaitiaki and mana whenua status of Ngāi Tahu Whānui over the natural resources within their takiwā boundaries.

In Murihiku there are four Papatipu Rūnanga whose members hold mana whenua status within the region. Te Rūnanga o Ngāi Tahu (Declaration of Membership) Order 2001 describes the takiwā of these four as follows:

- Waihōpai Rūnaka - centres on Waihopai and extends northwards to Te Mata-au sharing an interest in the lakes and mountains to the western coast with other Murihiku Rūnanga and those located from Waihemo southwards.
- Te Rūnanga o Awarua - centres on Awarua and extends to the coasts and estuaries adjoining Waihopai sharing an interest in the lakes and mountains between Whakatipu-Waitai and Tawhititarere with other Murihiku Rūnanga and those located from Waihemo southwards.
- Te Rūnanga o Oraka Aparima - centres on Oraka and extends from Waimatuku to Tawhititarere sharing an interest in the lakes and mountains from Whakatipu-Waitai to Tawhititarere with other Murihiku Rūnanga and those located from Waihemo southwards.
- Te Rūnanga o Hokonui - centres on the Hokonui region and includes a shared interest in the lakes and mountains between Whakatipu-Waitai and Tawhitarere with other Murihiku Rūnanga and those located from Waihemo southwards.

Te Ao Marama Inc. represents the interests of these four rūnanga on matters pertaining to the management of natural resources under the Resource Management Act 1991 and the Local Government Act 2002.

The takiwā of Te Rūnanga o Awarua includes Waipārera, therefore Te Rūnanga o Awarua hold kaitiaki status over Waipārera.

Ngāi Tahu historical and contemporary association to Waipārera

Ngāi Tahu has a long association with Waipārera. In a pre-colonial society an area like Waipārera were regarded as, and still are, a valuable resource, collectively owned, and allocated by communities. To tūpuna, Waipārera was, and still is, a major food basket utilised by nohoanga and permanent settlements located in the immediate and distant vicinity of the wetlands for its wide variety of resources and mahinga kai. Ngāi Tahu had and still have an intimate knowledge of the resources available to them and utilised this knowledge to develop a seasonal cycle of harvesting of mahinga kai. The wetlands are home to many taonga species and are important kōhanga grounds for many indigenous fish species, including, but not limited to, giant and banded kōkopu, varieties of flatfish, tuna, kanakana, inaka, waikākahi and waikōura. Around and within the fringes of Waipārera other taonga species include several breeds of ducks, gulls, spoonbill, kōtuku, oystercatcher, dotterels, terns, and fernbirds. Harakeke, raupō, mānuka, tōtara and tōtara bark, and pingao were also regularly harvested cultural materials. Paru or black mud was particularly sought after for dyeing textiles.

The name Waipārera means the body of water for grey duck, which was found in abundance and collected. The western end where the lagoon breaks out to the sea is known as Kā-puna-wai. Waituna creek and Waihao creek (common name is Currans creek) both flow into Waipārera and are both named after tuna. The wahi ingoa reinforce the value and importance of Waipārera to mana whenua still to this day and reflect the availability of mahinga kai[1]. Ara Tawhito (traditional trails) were utilised by tūpuna to navigate to and around Waipārera, these trails linked settlements to each other and to the resources of Waipārera.

Wahi tapu and wahi taonga are found along the shores of Waipārera due to the many years of occupation and use. There have been some archaeological sites recorded in recent times, with the items found mostly associated with collecting and cooking mahinga kai. Tūpuna had considerable knowledge of whakapapa, traditional trails and tauranga waka, places for gathering kai and other taonga, ways in which to use the resources of Waipārera, the relationship of people with the lake and their dependence on it, and tikanga for the proper and sustainable utilisation of resources. Although the area is not utilised the same as it once was for tūpuna, these values remain important to Ngāi Tahu today[2].

By the time Te Tiriti o Waitangi was signed in 1840, Ngāi Tahu were well accustomed to European ways as they were forced to through colonisation, causing turmoil and unease for Ngāi Tahu ki Murihiku. Resources that once were in abundance were no longer there or were in a state of decline. With the Treaty as the founding document, Ngāi Tahu believed

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1 Whaanga, D. 2013

2 Ngāi Tahu Claims Settlement Act 1998

that while they had sold land during the land sales of 1844 to 1864, their rangatiratanga over their mahinga kai and other taonga would be protected and maintained. This was not the case as the Crown failed to honour many obligations under these land purchase agreements. This removed tangata whenua from place and ostracisation from their land,creating disconnection and suppression of their knowledge, language, and way of life, with these effects still felt by Ngāi Tahu today[3].

The Waituna Catchment is a significant cultural landscape to Ngāi Tahu because of historical and contemporary associations. There is much tribal history embedded in Waipārera and the wetlands, rivers and lands that surround it with these associations acknowledged through whakapapa, connecting Ngāi Tahu to place at present[4].

"…..I remember Waipārera as it was then, and it has certainly deteriorated over time with changing patterns of land use, but its present management is functionally useless as a mahika kai site because there is no regular tidal flow." Tā Tipene O'Regan, Waitangi Day, 2021.

Waipārera is, and will always be, considered taonga to Ngāi Tahu ki Murihiku. Hence the importance of reconnecting tangata whenua to place in contemporary times. In 2021, Awarua Rūnanga, through its Te Wai Pārera Trust, strategically purchased a 404-hectare sheep and beef farm in the heart of Waipārera which was lost to the Crown[5]. The purchasing and retiring of some of the farmland affected by inundation at higher lagoon levels has enabled an increase of the maximum allowed water level in Waipārera with the aim of maintaining and enhancing a broad range ecological and cultural values[6].

A vision of Whakamana Te Waituna Trust[7] is to re-establish Awarua Rūnanga connection and role as Kaitiaki. This purchase has established new areas of land for Awarua Rūnanga and Ngāi Tahu whānau to access the area for mahinga kai, educational and capacity building programmes within a Te Ao Māori frame. Kaupapa such as this enables kaitiakitanga and rangatiranga at place, while supporting and uplifting the traditional relationship that Ngāi Tahu has with their ancestral lagoon.

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3 Cain, A & Manihera, D, 2021

4 Nelson, P & Te Rūnanga o Awarua, 2022

5 Te Rūnanga o Ngāi Tahu, 2021

6 Robertson et al., 2021

7 Whakamana te Waituna Trust was set up in February 2018 to coordinate activities of the partners involved in working to restore the mana of the Waituna Lagoon and Catchment - Te Runanga o Awarua/Te Runanga o Ngāi Tahu; Department of Conservation; Environment Southland; Southland District Council; Fonterra (joint Living Water programme with DOC)

Background

Waipārera is part of the internationally recognised Awarua Wetland and is one of the best remaining examples of a natural coastal lagoon in New Zealand, being recognised for its diverse ecological characteristics and cultural values. Waipārera contains important habitat for resident and migratory birds including nationally critical and endangered species, as well as many freshwater taonga species. Waipārera covers an area of 1,350 hectares and gained international recognition as a Ramsar site in 1976, later gaining Scientific Reserve status nationally in 1983[8]. The Ramsar site was amended in 2008 to include the wider wetland area. The cultural significance of Waipārera to Ngāi Tahu whānui was recognised as a Statutory Acknowledgement under the Ngāi Tahu Settlement Act 1998. The full text of this acknowledgement is included as **Appendix A**.

Since the early 1900's there have been many years of artificial drainage, clearance of indigenous vegetation and intensification of land use that has put Waipārera and its tributaries under stress. The development of land to increase agricultural productivity in the Waituna catchment has resulted in an increase in the transfer of nutrients and sediment to Waipārera. This change in land use intensity has coincided with changes that have destabilised Waipārera[9].

In recent years as environmental monitoring has occurred, the level of western scientific knowledge available has provided valuable information regarding the ecological health of Waipārera to stakeholders, iwi, agencies, and the surrounding community. However, relationships between land use and lagoon openings have continued to dominate decision making until recently and now are being balanced with measures to prioritise the protection and enhancement of the mana and mauri of Waipārera[10].

Ki uta ki tai

As stated in Te Tangi a Tauira, 2008, "Ki Uta Ki Tai is a culturally based natural resource framework developed by and for Ngāi Tahu Whānui and has been advocated as a key tool in assisting Ngāi Tahu achieve more meaningful rangatiratanga and kaitiakitanga in natural resource management". It reflects an indigenous understanding of the environment that can be used to help address the wide range of issues Rūnanga face with regards to environmental management.

Ki Uta Ki Tai is based on the notion that if the realms of ngā Atua are sustained, then the people will be sustained. It reflects the interconnectedness of resources from the mountains to the sea, and everything in between and they must be managed as such. It is about

8 Taumoepeau, A., de Winton, M., Zabarte-Maeztu, I., 2023

9 Lagoon Technical Group, 2013

10 Whaanga, D. 2013

standing on the land and looking in each direction and knowing the effects of an activity both upstream and downstream.

Essentially, the environmental impacts within the Upper Waituna Catchment will eventually affect the Lower Catchment and vice versa. The Kaupapa indicates that we belong to the environment and are only borrowing the resources from our generations that are yet to come, and the environment must be sustained in a way that resources are in a better state for future generations to come.

Cultural Values

Kaitiakitanga

Ngāi Tahu Vision Statement, Mō tātou, ā, mō kā uri ā muri ake nei, For us and our children after us

Kaitiakitanga can be described as the exercise of guardianship/stewardship by the tangata whenua of an area and resources in accordance with tikanga Māori, and kaitiaki are the interface between the natural and spiritual realm of resource management[11]. Guardianship and advocacy are fundamental to the relationship between Ngāi Tahu and the environment.

It is an intergenerational responsibility and right of mana whenua to take care of the environment and the resources upon which we depend. The responsibility of Kaitiakitanga is the protection of mauri and a duty to ensure to pass the environment to the future generations in the state that is as good or better than the current state[12]. Kaitiakitanga is central to Ngāi Tahu and is key to their mana whenua.

By exercising kaitiakitanga, Ngāi Tahu ki Murihiku actively work to ensure that spiritual, cultural and mahinga kai values are upheld and sustained for future generations. Kaitiakitanga in this context includes ensuring the protection, restoration, enhancement, and ability to use all the natural resources valued by Ngāi Tahu ki Murihiku[13].

Waituna context

As recognised under the Ngāi Tahu Claims Settlement Act 1998 Ngāi Tahu has strong cultural, spiritual, historic, and traditional and contemporary associations to Waipārera, its taonga species and Te Ara a Kiwa, the moana that borders Waipārera.[14]

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11 Te Tangi a Tauira, 2008

12 Cain, A & Arnold, J, 2023

13 Nelson, P & Te Rūnanga o Awarua, 2022

14 Appendix A sets out the Waituna Wetland Statutory Acknowledgment, Appendix B sets out the Te Ara a Kiwa Stautory Acknowledgement. Appendix C sets out the Taonga Species Statutory Acknowledgement

Waipārera has long been a place where Ngāi Tahu ki Murihiku exercise their tūrangawaewae, that is, their right to stand on a particular piece of land and speak and to be heard on matters affecting them and their relationship to that land and its resources[15].

Through many colonial mechanisms, the right for Ngāi Tahu to exercise kaitiakitanga has been prohibited, resulting in loss of intergenerational responsibility for the environment as well as loss of mauri of Waipārera and its people.

Recognising and providing for Ngāi Tahu values and uses

Awarua Rūnanga must be provided opportunities to exercise kaitiakitanga over Waipārera to enable the active protection of the whenua, hapua, and taonga species. The past colonial management of the catchment and lagoon cannot continue if the mauri and ecological health of Waipārera is to be prioritised. Resources must be cared for and managed in a sustainable way, and it is the kaitiaki duty of mana whenua to ensure they are in a better state for future generations.

Enabling kaitiakitanga and rangatiratanga can have positive outcomes for mana whenua by creating pathways to reconnect with their whenua and to exercise cultural rights and mahinga kai through Kaupapa such as Whakamana te Waituna.

Mahinga kai

Mahinga kai is a pillar of Te Kerēme as the ninth tall tree – the historical Ngāi Tahu Treaty Claim and is defined in the Ngāi Tahu Claims Settlement Act 1998 as “the customary gathering of food and natural materials, and the places where those resources are gathered” (s. 167). Mahinga kai was and is still central to the Ngāi Tahu ki Murihiku way of life. The collection and processing of mahinga kai is an important social and economic activity. Mahinga kai is about mahi ngā kai – to work the food and it is about places, ways of gathering resources and resources that sustain the people.

Mahinga kai practices rely on thriving and abundant biodiversity, safe and healthy places to practice, and the active transfer of knowledge between people. Biodiversity of flora and fauna are dependent on the sustainable management of many other natural resources in the takiwā, especially waterbodies.

There has been a significant loss to the customary use of mahinga kai and is due to many factors including habitat degradation, resource depletion, legislative barriers that impede access and changes in land use that affect the ability to access resources[16].

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15 Tau et al., 1990

16 Cain, A & Arnold, J, 2023

Waituna context

Mahinga kai is considered by Ngāi Tahu as a key 'environmental indicator' in natural systems. If mahinga kai is not present, is unsafe or unable to be harvested, then that natural system is under stress and requires remedial action. Ngāi Tahu ki Murihiku have been disconnected from mahinga kai at Waipārera not by choice, and this has had detrimental intergenerational impacts on Ngāi Tahu identity, as well as the active transfer of mātauranga and kaitiakitanga at place. Through many legal barriers access to Waipārera for mana whenua has been impeded, such as when it was given the status of Scientific reserve in 1983. This barred (and is still a barrier today) mana whenua from exercising their right of customary use of the area for mahinga kai, although still permitting the sport fishing of brown trout and game bird shooting[17]. Legal structures such as this have directly resulted in an inability for Ngāi Tahu ki Murihiku to exercise their cultural rights and interests.

Recognising and providing for Ngāi Tahu values and uses

It is important to take a holistic approach that considers the opportunities to enhance habitat, mahinga kai and addressing poor water quality, as well as consider the effects of land use on lagoon health and taonga species. It is key for Ngāi Tahu to be actively involved in the restoration and enhancement of Waipārera as well as having access to utilise the area for customary use for mahinga kai, as this will begin to restore the connection of people to place. Continuation of these practices is an important means of actively passing mātauranga down to tamariki and mokopuna (children and grandchildren), ensuring its survival through generations.

Wai

Water is a taonga, or treasure of the people. It is the kaitiaki responsibility of mana whenua to ensure that this taonga is available for future generations in as good as, if not better, quality. Water has the spiritual qualities of mana, mauri and wairua. The continued well-being of these qualities is dependent on the physical health of the water. Water is the lifeblood of Papatūānuku and must be protected. It must be understood that humans cannot live without healthy water and the effects on water quality have a cumulative effect on mahinga kai and other resources, and in turn on ourselves[18]. Both tangible and intangible aspects of water and waterways feature in all aspects of Ngāi Tahu culture, and waterways provide links between the spiritual world of tūpuna and tangata whenua. They feature in pūrākau, wāhi ingoa, moteatea and waiata which consistently reflect symbolic and important messages[19].

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17 Ngāi Tahu ki Murihiku, 2019

18 Te Tangi a Tauira, 2008

19 Kitson, J, 2023

Waituna context

The history of intermittent opening and closing of Waipārera to the sea, alongside the high nutrient and sediment input from the catchment, are features that strongly influences ecology and water quality of Waipārera. Waipārera is closed from sea by a gravel bar, historically a mouth has broken naturally through the bar when high water level coincides with favourable sea conditions. With the introduction of farming around Waipārera and within the catchment, a mechanical opening of the gravel bar has regularly occurred to assist with land drainage over the last 100 year.[20]

Over the last decade or so, species that characterise a healthy lagoon environment have reduced and been replaced by species that are more commonly associated with enriched and degraded systems[21]. The mechanical opening of Waipārera to facilitate land drainage has contributed to the notable decline over time to Waipārera health and quality of wai and whenua in the catchment, which is of great concern to Ngāi Tahu.

Recognising and providing for Ngāi Tahu values and uses

The Vegetation Status report[22] demonstrates that all six ecological targets were achieved for Waipārera as identified by Waipārera Technical Group in 2023. In total Waipārera was closed for 16.6 months, which improved the ecological target of more than 30 to 60% cover for Ruppia vegetation across the whole lagoon, which is a well-known indicator species of water quality.

The results support the need for closed lagoon conditions during key growing seasons through spring-summer to enhance the high macrophyte species diversity and vegetation development. The decline of Waipārera has been seen and experienced by mana whenua for decades, and it is important to Awarua Rūnanga and Ngai Tahu whanui to ensure that this decline in mauri ceases. The active involvement of mana whenua will ensure the health of Waipārera by continuing to ensure that the wai has priority.

Mauri

Mauri, defined as life force or essence, is a central component of the Māori perspective on the environment and represents the essence that binds the physical and spiritual elements of all things together, generating and upholding all life. All elements of the natural environment possess a life force, and all forms of life are interrelated, acknowledging the interconnectedness of all things, tangible, and intangible. Mauri is a critical element of the spiritual relationship of Ngāi Tahu Whanui with the coastal area.

20 Robertson et al., 2021

21 LTG, 2013

22 Taumoepeau, A., de Winton, M., Zabarte-Maeztu, I., 2023

The presence of mauri in all things entrusts people to value and respect that resource therefore overuse, depletion, or desecration of natural resources is not acceptable. Tikanga regulates activities concerning the sustainable use and conservation of natural resources to protect the mauri[23].

It is important to Māori to exercise kaitiakitanga to protect and maintain the mauri of taonga.

Waituna context

Inappropriate human interactions within the catchment and lagoon have resulted in the diminishment of mauri of the wai and the mauri of Waipārera. It has been identified that appropriate measures can be implemented to improve the mauri of the wai that many taonga species rely on. In 2017, Waituna Science Advisory Group produced a report[24] to set a maximum lagoon level for managing the ecological health of Waipārera, as well as the level required to flush nutrients out. The recommendations from this report supported raising Waipārera level trigger value to 2.5 metres to avoid spring – summer openings which is detrimental to the health of Waipārera. In addition, the new trigger level will improve the health of the fringing wetland plant community.

Recognising and providing for Ngāi Tahu values and uses

These findings support mana whenua position and cultural frameworks and values, as raising Waipārera level trigger will enhance the mauri of Waipārera by creating better habitat and spawning sites for taonga species to thrive. Further, Ngāi Tahu are unable to use Waipārera as tūpuna once did for customary use and this has diminished the mauri of Waipārera and people.

Therefore, to enhance the mauri it is important for mana whenua to continue to reestablish a meaningful connection with Waipārera to enhance the mana and mauri of Waipārera and mana whenua through kaitiakitanga and can be achieved through the recommendations provided.

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23 Te Tangi a Tauira, 2008

24 Schallenberg, M & Robertson, H, 2017

Conclusion

This report has identified the following values as key to mana whenua connection to Waipārera:

- **Kaitiakitanga** –the exercise of guardianship and stewardship by tangata whenua to continue to protect cultural associations and values of an area and resources.
- **Mahinga kai** - is about mahi ngā kai, to work the food and is about places and ways of gathering resources. It is central to Ngāi Tahu wellbeing and identity.
- **Wai** - water is a taonga and it is the responsibility of tangata whenua to ensure that this taonga is available for future generations in as good as, if not better quality
- **Mauri** – defined as life force or essence, is a central component of the Māori perspective on the environment and represents the essence that binds the physical and spiritual elements of all things together, generating and upholding all life.

This report has identified the following recommendations that need to be taken into account to ensure that the cultural and ecological values of Waipārera are recognised and provided for:

- Cultural frameworks, values, rights and interests and the environment are inextricably intertwined.
- Awarua Rūnanga should be enabled and supported to exercise kaitiakitanga and rangatiratanga over Waipārera and be actively involved in the restoration and enhancement of Waipārera.
- Kaupapa Māori monitoring should be undertaken by and for Awarua Rūnanga throughout Waipārera and feeding waterbodies to ascertain a baseline for cultural health and then continue to do so to monitor the efficacy of any implemented measures.
- Cultural values, rights, interests and uses should be recognised and provided for to reconnect mana whenua to the area.
- It is necessary for an opening regime to prioritise the health of Waipārera and the taonga species that rely on it.

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Appendix A: Statutory acknowledgement for Waituna Wetland

Statutory area

The statutory area to which this statutory acknowledgement applies is the wetland known as Waituna, the location of which is shown on Allocation Plan MD 58 (SO 12260).

Preamble

Under section 206, the Crown acknowledges Te Rūnanga o Ngāi Tahu's statement of Ngāi Tahu's cultural, spiritual, historic, and traditional association to Waituna, as set out below.

Ngāi Tahu association with Waituna

Intermittently open to the sea, Waituna wetland (with the western end, where Waipārera breaks out to sea known as Kā-puna-wai) was a major food basket utilised by nohoanga and permanent settlements located in the immediate vicinity of the wetlands, and further away, for its wide variety of reliable mahinga kai. The great diversity of wildlife associated with the complex includes several breeds of ducks, white heron, gulls, spoonbill, kōtuku, oyster-catcher, dotterels, terns and fernbirds. The wetlands are important kōhanga (spawning) grounds for a number of indigenous fish species. Kaimoana available includes giant and banded kōkopu, varieties of flatfish, tuna (eels), kanakana (lamprey), inaka (whitebait), waikākahi (freshwater mussel) and waikōura (freshwater crayfish). Harakeke, raupō, mānuka, tōtara and tōtara bark, and pingao were also regularly harvested cultural materials. Paru or black mud was available, particularly sought after as a product for making dyes.

The tūpuna had considerable knowledge of whakapapa, traditional trails and tauranga waka, places for gathering kai and other taonga, ways in which to use the resources of Waituna, the relationship of people with the lake and their dependence on it, and tikanga for the proper and sustainable utilisation of resources. All of these values remain important to Ngāi Tahu today.

As a result of this history of use and occupation of the area, there are wāhi tapu and wāhi taonga all along its shores. It is also possible that particular sections of the wetland were used for waiwhakaheketūpāpāku (water burial).

Urupā and wāhi tapu are the resting places of Ngāi Tahu tūpuna and, as such, are the focus for whānau traditions. These are places holding the memories, traditions, victories and defeats of Ngāi Tahu tūpuna, and are frequently protected by secret locations.

The mauri of Waituna represents the essence that binds the physical and spiritual elements of all things together, generating and upholding all life. All elements of the natural environment possess a life force, and all forms of life are related. Mauri is a critical element of the spiritual relationship of Ngāi Tahu Whānui with the area.

Appendix B: Statutory acknowledgement for Rakiura/Te Ara a Kiwa (Rakiura/Foveaux Strait Coastal Marine Area)

Schedule 104

Statutory acknowledgement for Rakiura/Te Ara a Kiwa (Rakiura/Foveaux Strait Coastal Marine Area)

ss 205, 312, 313

Statutory area

The statutory area to which this statutory acknowledgement applies is Rakiura/Te Ara a Kiwa (Rakiura/Foveaux Strait Coastal Marine Area), the Coastal Marine Area of the Hokonui and Awarua constituencies of the Southland region, as shown on SO 11505 and 11508, Southland Land District, as shown on Allocation Plan NT 505 (SO 19901).

Preamble

Under section 313, the Crown acknowledges Te Rūnanga o Ngāi Tahu's statement of Ngāi Tahu's cultural, spiritual, historic, and traditional association to Rakiura/Te Ara a Kiwa as set out below.

Ngāi Tahu association with Rakiura/Te Ara a Kiwa

Generally the formation of the coastline of Te Wai Pounamu relates to the tradition of Te Waka o Aoraki, which foundered on a submerged reef, leaving its occupants, Aoraki and his brother to turn to stone. They are manifested now in the highest peaks of the Kā Tiritiri of Te Moana (the Southern Alps). The bays, inlets, estuaries and fiords which stud the coast are all the creations of Tū Te Rakiwhānoa, who took on the job of making the island suitable for human habitation.

The naming of various features along the coastline reflects the succession of explorers and iwi (tribes) who travelled around the coastline at various times. The first of these was Māui, who fished up the North Island, and is said to have circumnavigated Te Wai Pounamu. In some accounts the island is called Te Waka o Māui in recognition of his discovery of the new lands. A number of coastal place names are attributed to Māui, particularly on the southern coast. Māui is said to have sojourned at Ōmaui (at the mouth of the New River Estuary) for a year, during which time he claimed the South Island for himself. It is said that in order to keep his waka from drifting away he reached into the sea and pulled up a stone to be used as an anchor, which he named Te Puka o Te Waka o Māui (Rakiura or Stewart Island).

The great explorer Rakaihautu travelled overland along the coast, identifying the key places and resources. He also left many place names on prominent coastal features. When Rakaihautu's southward exploration of the island reached Te Ara a Kiwa, he followed the coastline eastwards before heading for the east coast of Otago.

Particular stretches of the coastline also have their own traditions. Foveaux Strait is known as Te Ara a Kiwa (the pathway of Kiwa), the name relating to the time when Kiwa became tired of having to cross the land isthmus which then joined Murihiku (Southland) with Rakiura (Stewart Island). Kiwa requested the obedient Kewa (whale) to chew through the isthmus and create a waterway so Kiwa could cross to and fro by waka. This Kewa did, and the crumbs that fell from his mouth are the islands in Foveaux Strait, Solander Island being Te Niho a Kewa, a loose tooth that fell from the mouth of Kewa.

The waka Takitimu, captained by the northern rangatira (chief) Tamatea, travelled around much of Te Wai Pounamu coast, eventually breaking its back at the mouth of the Waiau River in Murihiku. Many place names on the coast can be traced back to this voyage, including Monkey Island near Ōrepuki which is known as Te-Punga (or Puka)-a-Takitimu. While sailing past the cliffs at Ōmaui it is said that Tamatea felt a desire to go ashore and inspect the inland, and so he turned to the helmsman and gave the order “Tārere ki whenua uta” (“swing towards the mainland”), but before they got to the shore he countermanded the order and sailed on. Subsequently the whole area from Ōmaui to Bluff was given the name of Te Takiwā o Tārere ki Whenua Uta. In olden days when people from the Bluff went visiting they were customarily welcomed on to the hosts' marae with the call, “haere mai koutou te iwi tārere ki whenua uta”. One of the whare at Te Rau Aroha marae in Bluff if also named “Tārere ki Whenua uta” in memory of this event.

The Takitimu's voyage through the Strait came to an end and when the waka was overcome by three huge waves, named Ō-te-wao, Ō-roko and Ō-kaka, finally coming to rest on a reef near the mouth of the Waiau (Waimeha). According to this tradition, the three waves continued on across the low lying lands of Murihiku, ending up as permanent features of the landscape.

For Ngāi Tahu, traditions such as these represent the links between the cosmological world of the gods and present generations. These histories reinforce tribal identity and solidarity, and continuity between generations, and document the events which shaped the environment of Te Wai Pounamu and Ngāi Tahu as an iwi.

Because of its attractiveness as a place to establish permanent settlements, including pā (fortified settlements), the coastal area was visited and occupied by Waitaha, Ngāti Mamoe and Ngāi Tahu in succession, who through conflict and alliance, have merged in the whakapapa (genealogy) of Ngāi Tahu Whānui. Battle sites, urupā and landscape features bearing the names of tūpuna (ancestors) record this history. Prominent headlands, in particular, were favoured for their defensive qualities and became the headquarters for a succession of rangatira and their followers.

The results of the struggles, alliances and marriages arising out of these migrations were the eventual emergence of a stable, organised and united series of hapū located at permanent or semi-permanent settlements along the coast, with an intricate network of mahinga kai (food gathering) rights and networks that relied to a large extent on coastal resources.

Mokamoka (Mokomoko or Mokemoke) was one such settlement, in a shallow inlet off the Invercargill estuary. It was here that Waitai was killed, the first Ngāi Tahu to venture this far south, well out of the range of his own people, then resident at Taumutu. This settlement was sustained by mahinga kai taken from the estuary and adjoining coastline, including shellfish and pātiki (flounder).

Ōue, at the mouth of the Ōreti River (New River Estuary), opposite Ōmaui, was one of the principal settlements in Murihiku. Honekai who was a principal chief of Murihiku in his time was resident at this settlement in the early 1820s, at the time of the sealers. In 1850 there were said to still be 40 people living at the kaik at Ōmaui under the chief Mauhe. Honekai's brother, Pukarehu, was a man who led a very quiet life, and so was little known. He is remembered, however, in the small knob in the hills above Ōmaui which bears his name. When he passed away he was interred in the sandhills at the south end of the Ōreti Beach opposite Ōmaui. Ōue is said to have got its name from a man Māui left to look after his interests there until his return. It was also here that the coastal track to Riverton began. From Ōue to the beach the track was called Te Ara Pakipaki, then, when it reached the beach, it was called Mā Te Aweawe, finally, at the Riverton end, it was known as Mate a Waewae.

After the death of Honekai, and as a consequence of inter-hapū and inter-tribal hostilities in the Canterbury region, many inhabitants of Ōue and other coastal villages on Foveaux Strait relocated to Ruapuke Island, which became the Ngāi Tahu stronghold in the south. The rangatira Pahi and Tupai were among the first to settle on the island. Pahi had previously had one of the larger and oldest pā in Murihiku at Pahi (Pahia), where 40 to 50 whare (houses) were reported in 1828. The Treaty of Waitangi was signed at Ruapuke Island by Tuhawaiki and others. No battles however occurred here, the pā Pā-raki-ao was never fully completed, due to the realisation that Te Rauparaha could not reach this far south.

Other important villages along the coast included: Te Wae Wae (Waiau), Taunoa (Ōrepuki), Kawakaputaputa (Wakaputa), Ōraka (Colac Bay), Aparima (Riverton—named Aparima after the daughter of the noted southern rangatira Hekeia, to whom he bequeathed all of the land which his eye could see as he stood on a spot at Ōtaitai, just north of Riverton), Turangiteuaru, Awarua (Bluff), Te Whera, Toe Toe (mouth of the Mataura River) and Waikawa.

Rarotoka (Centre Island) was a safe haven at times of strife for the villages on the mainland opposite (Pahi, Ōraka and Aparima). Numerous artefacts and historical accounts attest to Rarotoka as having a significant place in the Ngāi Tahu history associated with Murihiku.

Rakiura also plays a prominent part in southern history, the "Neck" being a particularly favoured spot. Names associated with the area include: Kōrako-wahine (on the western side of the peninsula), Whare-tātara (a rock), Hupokeka (Bullers Point) and Pukuheke (the point on which the lighthouse stands). Te Wera had two pā built in the area called Kaiarohaki, the one on the mainland was called Tounoa, and across the tidal strip was Kā-Turi-o-Whako.

A permanent settlement was located at Port Pegasus, at the south-eastern end of Rakiura, where numerous middens and cave dwellings remain. Permanent settlement also occurred on the eastern side of Rakiura, from the Kaik near the Neck, south to Tikotaitahi (or Tikotatahi) Bay. A pā was also established at Port Adventure.

Mahinga kai was available through access from the coastal settlements to Te Whaka-a-te-Wera (Paterson Inlet), Lords River and, particularly for waterfowl, to Toi Toi wetland. In addition, the tītī islands off the northeastern coast of the island, and at the mouth of Kōpeka River and the sea fishery ensured a sound base for permanent and semi-permanent settlement, from which nohoanga operated.

Te Ara a Kiwa, the estuaries, beaches and reefs off the mainland and islands all offered a bounty of mahinga kai, with Rakiura and the tītī islands being renowned for their rich resources of bird life, shellfish and wet fish. The area offered a wide range of kaimoana (sea food), including tuaki (cockles), paua, mussels, toheroa, tio (oysters), pūpū (mudsnails), cod, groper, barracuda, octopus, pātiki (flounders), seaweed, kina, kōura (crayfish) and conger eel. Estuarine areas provided freshwater fisheries, including tuna (eels), inaka (whitebait), waikōura (freshwater crayfish), kōkopu and kanakana (lamprey). Marine mammals were harvested for whale meat and seal pups. Many reefs along the coast are known by name and are customary fishing grounds, many sand banks, channels, currents and depths are also known for their kaimoana.

A range of bird life in the coastal area also contributed to the diversity of mahinga kai resources available, including tītī, seabirds such as shags and gulls, sea bird eggs, waterfowl, and forest birds such as kiwi, kākā, kākāpō, weka, kukupa and tieke. A variety of plant resources were also taken in the coastal area, including raupō, fern root, tī kōūka (cabbage tree), tutu juice and kōrari juice. Harakeke (flax) was an important resource, required for the everyday tasks of carrying and cooking kai. Black mud (paru) was gathered at Ocean Beach for use as dye. Tōtara bark was important for wrapping pōhā in, to allow safe transport of the tītī harvest. Pōhā were made from bull kelp gathered around the rocky coast.

The numerous tītī islands are an important part of the Ngāi Tahu southern economy, with Taukihepa (Te Kanawera) being the largest. Tītī were and are traded as far north as the North Island. The "Hakuai" is a bird with a fearsome reputation associated with the islands. No one has ever seen this bird, which appears at night, but it once regularly signalled the end to a birding season by its appearance at night. Known for its distinctive spine-chilling call, the hakuai was a kaitiaki that could not be ignored. At the far western edge of Foveaux Strait is Solander Island (Hau-tere), an impressive rock pinnacle rising hundreds of feet out of the sea, on which fishing and tītī gathering occurred.

The coast was also a major highway and trade route, particularly in areas where travel by land was difficult. Foveaux Strait was a principal thoroughfare, with travel to and from Rakiura a regular activity. There was also regular travel between the islands Ruapuke, Rarotoka and other points.

The tītī season still involves a large movement across the Strait to the islands, in addition large flotillas of Ngāi Tahu once came south from as far afield as Kaikōura to exercise their mutton-birding rights. Whenua Hou (Codfish Island) and the Ruggedy Islands were important staging posts for the movement of birders to the tītī islands off the south-west coast of Rakiura. Whenua Hou had everything that the birders required: shelter, proximity to the tītī islands, kai moana, manu (birds) and ngahere (bush). From Whenua Hou, the birders would camp at Miniti (Ernest Island), at the end of Mason Bay, where the waka-hunua (double-hulled canoes, or canoes with outriggers) were able to moor safely, ready for the final movement to the various tītī islands. Waka-hunua were an important means of transport on the dangerous and treacherous waters of Foveaux Strait and the Rakiura coast. After dropping birders and stores on the tītī islands the waka hunua generally returned immediately to Aparima and other tauranga waka along the mainland of Foveaux Strait, due to the paucity of safe anchorages among the tītī islands.

Travel by sea between settlements and hapū was common, with a variety of different forms of waka, including the southern waka hunua (double-hulled canoe) and, post-contact, whale boats plying the waters continuously. Hence tauranga waka occur up and down the coast, including spots at Pahi, Ōraka and Aparima, and wherever a tauranga waka is located there is also likely to be a nohoanga (settlement), fishing ground, kaimoana resource, rimurapa (bull kelp - used to make the pōhā, in which tītī were and still are preserved) and the sea trail linked to a land trail or mahinga kai resource. Knowledge of these areas continues to be held by whānau and hapū and is regarded as a taonga. The traditional mobile lifestyle of the people led to their dependence on the resources of the coast.

The New River Estuary contains wāhi tapu, as do many of the coastal dunes and estuarine complexes for the length of the Foveaux Strait. Many urupā are located on islands and prominent headlands overlooking the Strait and the surrounding lands and mountains. The rangatira Te Wera, of Huriawa fame, is buried at Taramea (Howells Point), near Riverton. There are two particularly important urupā in Colac Bay, as well as an old quarry site (Tīhaka). From Colac Bay to Wakapatu, the coastal sandhills are full of middens and ovens, considered to be linked to the significant mahinga kai gathering undertaken in Lake George (Urewera). Urupā are the resting places of Ngāi Tahu tūpuna and, as such, are the focus for whānau traditions. These are places holding the memories, traditions, victories and defeats of Ngāi Tahu tūpuna, and are frequently protected in secret locations.

The mauri of the coastal area represent the essence that binds the physical and spirtual elements of all things together, generating and upholding all life. All elements of the natural environment possess a life force, and all forms of life are related. Mauri is a critical element of the spiritual relationship of Ngāi Tahu Whānui with the coastal area.

Appendix C: Statutory acknowledgement for Taonga species

Birds

Name in Māori	**Name in English**	**Scientific name**
Hoiho	Yellow-eyed penguin	*Megadyptes antipodes*
Kāhu	Australasian harrier	*Circus approximans*
Kākā	South Island kākā	*Nestor meridionalis meridionalis*
Kākāpō	Kākāpō	*Strigops habroptilus*
Kākāriki	New Zealand parakeet	*Cyanoramphus* spp
Kakaruai	South Island robin	*Petroica australis australis*
Kakī	Black stilt	*Himantopus novaezelandiae*
Kāmana	Crested grebe	*Podiceps cristatus*
Kārearea	New Zealand falcon	*Falco novaeseelandiae*
Karoro	Black-backed gull	*Larus dominicanus*
Kea	Kea	*Nestor notabilis*
Kōau	Black shag	*Phalacrocorax carbo*
	Pied shag	*Phalacrocorax varius varius*
	Little shag	*Phalacrocorax melanoleucos brevirostris*
Koekoeā	Long-tailed cuckoo	*Eudynamys taitensis*
Kōparapara *or* Korimako	Bellbird	*Anthornis melanura melanura*
Kororā	Blue penguin	*Eudyptula minor*
Kōtare	Kingfisher	*Halcyon sancta*
Kōtuku	White heron	*Egretta alba*
Kōwhiowhio	Blue duck	*Hymenolaimus malacorhynchos*
Kūaka	Bar-tailed godwit	*Limosa lapponica*
Kūkupa/Kererū	New Zealand wood pigeon	*Hemiphaga novaeseelandiae*
Kuruwhengu/Kuruwhengi	New Zealand shoveller	*Anas rhynchotis*
Mātā	Fernbird	*Bowdleria punctata punctata* and *Bowdleria punctata stewartiana* and *Bowdleria punctata wilsoni* and *Bowdleria punctata candata*
Matuku moana	Reef heron	*Egretta sacra*
Miromiro	South Island tomtit	*Petroica macrocephala macrocephala*
Miromiro	Snares Island tomtit	*Petroica macrocephala dannefaerdi*
Mohua	Yellowhead	*Mohoua ochrocephala*

Name in Māori	Name in English	Scientific name
Pākura/Pūkeko	Swamp hen/Pūkeko	*Porphyrio porphyrio*
Pārera	Grey duck	*Anas superciliosa*
Pateke	Brown teal	*Anas aucklandica*
Pīhoihoi	New Zealand pipit	*Anthus novaeseelandiae*
Pīpīwharauroa	Shining cuckoo	*Chrysococcyx lucidus*
Pīwakawaka	South Island fantail	*Rhipidura fuliginosa fuliginosa*
Poaka	Pied stilt	*Himantopus himantopus*
Pokotiwha	Snares crested penguin	*Eudyptes robustus*
Pūtakitaki	Paradise shelduck	*Tadorna variegata*
Riroriro	Grey warbler	*Gerygone igata*
Roroa	Great spotted kiwi	*Apteryx haastii*
Rowi	Ōkārito brown kiwi	*Apteryx mantelli*
Ruru koukou	Morepork	*Ninox novaeseelandiae*
Takahē	Takahē	*Porphyrio mantelli*
Tara	Terns	*Sterna* spp
Tawaki	Fiordland crested penguin	*Eudyptes pachyrhynchus*
Tete	Grey teal	*Anas gracilis*
Tīeke	South Island saddleback	*Philesturnus carunculatus carunculatus*
Tītī	Sooty shearwater/Muttonbird/Hutton's shearwater Common diving petrel South Georgian diving petrel Westland petrel Fairy prion Broad-billed prion White-faced storm petrel Cook's petrel Mottled petrel	*Puffinus griseus* and *Puffinus huttoni* and *Pelecanoides urinatrix* and *Pelecanoides georgicus* and *Procellaria westlandica* and *Pachyptila turtur* and *Pachyptila vittata* and *Pelagodroma marina* and *Pterodroma cookii* and *Pterodroma inexpectata*
Tītitipounamu	South Island rifleman	*Acanthisitta chloris chloris*
Tokoeka	South Island brown kiwi	*Apteryx australis*
Toroa	Albatrosses and Mollymawks	*Diomedea* spp
Toutouwai	Stewart Island robin	*Petroica australis rakiura*
Tūī	Tūī	*Prosthemadera novaeseelandiae*
Tutukiwi	Snares Island snipe	*Coenocorypha aucklandica huegeli*

Name in Māori	Name in English	Scientific name
Weka	Western weka	*Gallirallus australis australis*
Weka	Stewart Island weka	*Gallirallus australis scotti*
Weka	Buff weka	*Gallirallus australis hectori*

Plants

Name in Māori	Name in English	Scientific name
Akatorotoro	White rata	*Metrosideros perforata*
Aruhe	Fernroot (bracken)	*Pteridium aquilinum* var *esculentum*
Harakeke	Flax	*Phormium tenax*
Horoeka	Lancewood	*Pseudopanax crassifolius*
Houhi	Mountain ribbonwood	*Hoheria lyalli* and *H. glabata*
Kahikatea	Kahikatea/White pine	*Dacrycarpus dacrydioides*
Kāmahi	Kāmahi	*Weinmannia racemosa*
Kānuka	Kānuka	*Kunzia ericoides*
Kāpuka	Broadleaf	*Griselinia littoralis*
Karaeopirita	Supplejack	*Ripogonum scandens*
Karaka	New Zealand laurel/Karaka	*Corynocarpus laevigata*
Karamū	Coprosma	*Coprosma robusta, coprosma lucida, coprosma foetidissima*
Kātote	Tree fern	*Cyathea smithii*
Kiekie	Kiekie	*Freycinetia baueriana* subsp *banksii*
Kōhia	NZ Passionfruit	*Passiflora tetranda*
Korokio	Korokio Wire-netting bush	*Corokia cotoneaster*
Koromiko/Kōkōmuka	Koromiko	*Hebe salicfolia*
Kōtukutuku	Tree fuchsia	*Fuchsia excorticata*
Kōwahi Kōhai	Kōwhai	*Sophora microphylla*
Mamaku	Tree fern	*Cyathea medullaris*
Mānia	Sedge	*Carex flagellifera*
Mānuka Kahikātoa	Tea-tree	*Leptospermum scoparium*
Māpou	Red matipo	*Myrsine australis*
Mataī	Mataī/Black pine	*Prumnopitys taxifolia*
Miro	Miro/Brown pine	*Podocarpus ferrugineus*
Ngaio	Ngaio	*Myoporum laetum*
Nīkau	New Zealand palm	*Rhopalostylis sapida*

Name in Māori	Name in English	Scientific name
Pānako	(Species of fern)	*Asplenium obtusatum*
Pānako	(Species of fern)	*Botrychium australe* and *B. biforme*
Pātōtara	Dwarf mingimingi	*Leucopogon fraseri*
Pīngao	Pīngao	*Desmoschoenus spiralis*
Pōkākā	Pōkākā	*Elaeocarpus hookerianus*
Ponga/Poka	Tree fern	*Cyathea dealbata*
Rātā	Southern rātā	*Metrosideros umbellata*
Raupō	Bulrush	*Typha angustifolia*
Rautāwhiri/Kōhūhū	Black matipo/Māpou	*Pittosporum tenuifolium*
Rimu	Rimu/Red pine	*Dacrydium cypressinum*
Rimurapa	Bull kelp	*Durvillaea antarctica*
Taramea	Speargrass, spaniard	*Aciphylla* spp
Tarata	Lemonwood	*Pittosporum eugenioides*
Tawai	Beech	*Nothofagus* spp
Tētēaweka	Muttonbird scrub	*Olearia angustifolia*
Tī rākau/Tī Kōuka	Cabbage tree	*Cordyline australis*
Tīkumu	Mountain daisy	*Celmisia spectabilis* and *C. semicordata*
Tītoki	New Zealand ash	*Alectryon excelsus*
Toatoa	Mountain Toatoa, Celery pine	*Phyllocladus alpinus*
Toetoe	Toetoe	*Cortaderia richardii*
Tōtara	Tōtara	*Podocarpus totara*
Tutu	Tutu	*Coriaria* spp
Wharariki	Mountain flax	*Phormium cookianum*
Whīnau	Hīnau	*Elaeocarpus dentatus*
Wī	Silver tussock	*Poa cita*
Wīwī	Rushes	*Juncus* all indigenous *Juncus* spp and *J. maritimus*

Marine mammals

Name in Māori	Name in English	Scientific name
Ihupuku	Southern elephant seal	*Mirounga leonina*
Kekeno	New Zealand fur seals	*Arctocephalus forsteri*
Paikea	Humpback whales	*Megaptera novaeangliae*
Parāoa	Sperm whale	*Physeter macrocephalus*

Name in Māori	Name in English	Scientific name
Rāpoka/Whakahao	New Zealand sea lion/Hooker’s sea lion	*Phocarctos hookeri*
Tohorā	Southern right whale	*Balaena australis*

Appendix I: Technical Report on Vegetation Status in Waituna Lagoon: 2009–2023

Department of Conservation
Te Papa Atawhai

NIWA
Taihoro Nukurangi





Technical Report on Vegetation Status in Waituna Lagoon: 2009–2023

Department of Conservation
Te Papa Atawhai

NIWA
Taihoro Nukurangi

Technical Report on Vegetation Status in Waituna Lagoon: 2009–2023




This report was commissioned by the Department of Conservation (DOC) and based on work under Project DOC20203.

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Contents

Introduction

This technical report accompanies the summary report on vegetation status in Waituna Lagoon in 2023 (de Winton et al. 2023). We review the lagoon conditions over the period of vegetation monitoring from 2009 to 2023. Specifically, we assess changes in vegetation status over time with water level management, comprising artificial opening to the sea for drainage, and the unpredictable, natural process of lagoon barrier closure.

As background to the summary report, this technical report describes water level, mouth opening status and duration (Section 1). The report also summarises recent lagoon conditions based on monitoring of indicators of water quality carried out by Environment Southland (Section 2). We provide descriptions of monitoring methods undertaken and present summaries of data and analyses (Sections 3, 4 and 5). Finally, we briefly conclude what the findings mean for lagoon management.

1. Water Level Regime

Methods

Water level data supplied by Environment Southland from the gauge at Waghorns Road was examined to identify lagoon openings by the onset of a sudden, substantial reduction in water level. Lagoon closure was estimated from timing of subsequent, sustained increases in level. The total time period for openings was calculated, the lagoon mouth status was confirmed and the duration of that status before each vegetation monitoring event was calculated as months (one month is 30 days).

Results

At the time of the annual monitoring of vegetation in 2023 (23–26 January 2023), the lagoon had been closed to the sea for 500 days (Figure 1, Figure 2). This closed period incorporated two consecutive spring-summer growth seasons for *Ruppia* and is the longest closed period in the 15-year dataset. Therefore, the target of three months of closed conditions prior to vegetation monitoring (Lagoon Technical Group 2013) was achieved in 2023. This target was also achieved in eight of the previous 14 monitoring years, including 2022 (Figure 1, Figure 2).

The previous lagoon opening before the 2023 monitoring was in September 2021, with this closing within days. Immediately before the 2023 monitoring, water level had mostly remained above normal level (average +0.5 m) for the previous 240 days. This followed a prolonged period (267 days) following the last lagoon opening when water levels were below normal levels (average -0.5 m) during closed lagoon conditions, with these low levels being a result of drought conditions in Southland. Water levels over the three months before the 2023 sampling dropped steadily from about 0.90 m from above normal to 0.3 m below normal. All monitoring sites were underwater at the time of the 2023 survey. This followed the 2022 year where drought conditions meant approximately 15% of monitored sites were dry or nearly dry.

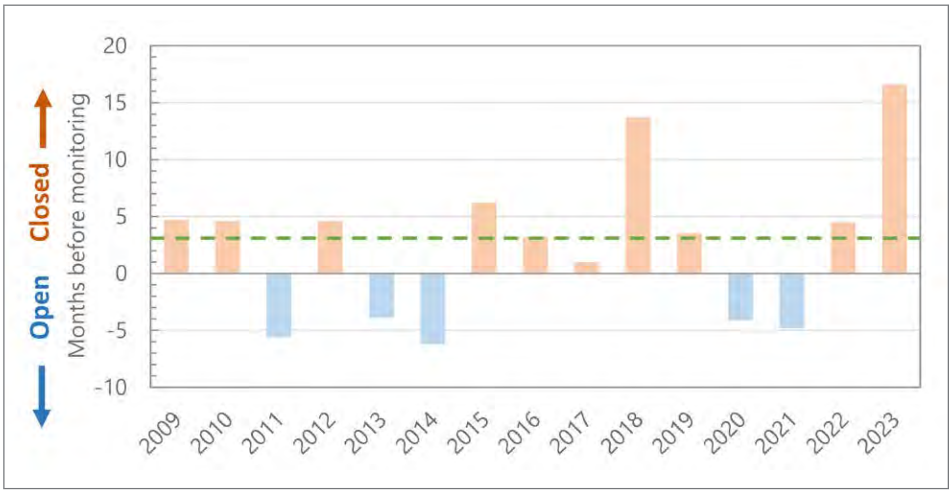


Figure 1: Diverging bar plot showing the number of months for which Waituna Lagoon was open or closed prior to monitoring (as indicated by the y axis). The dotted line indicates the ecological target of three months of lagoon closure before monitoring.

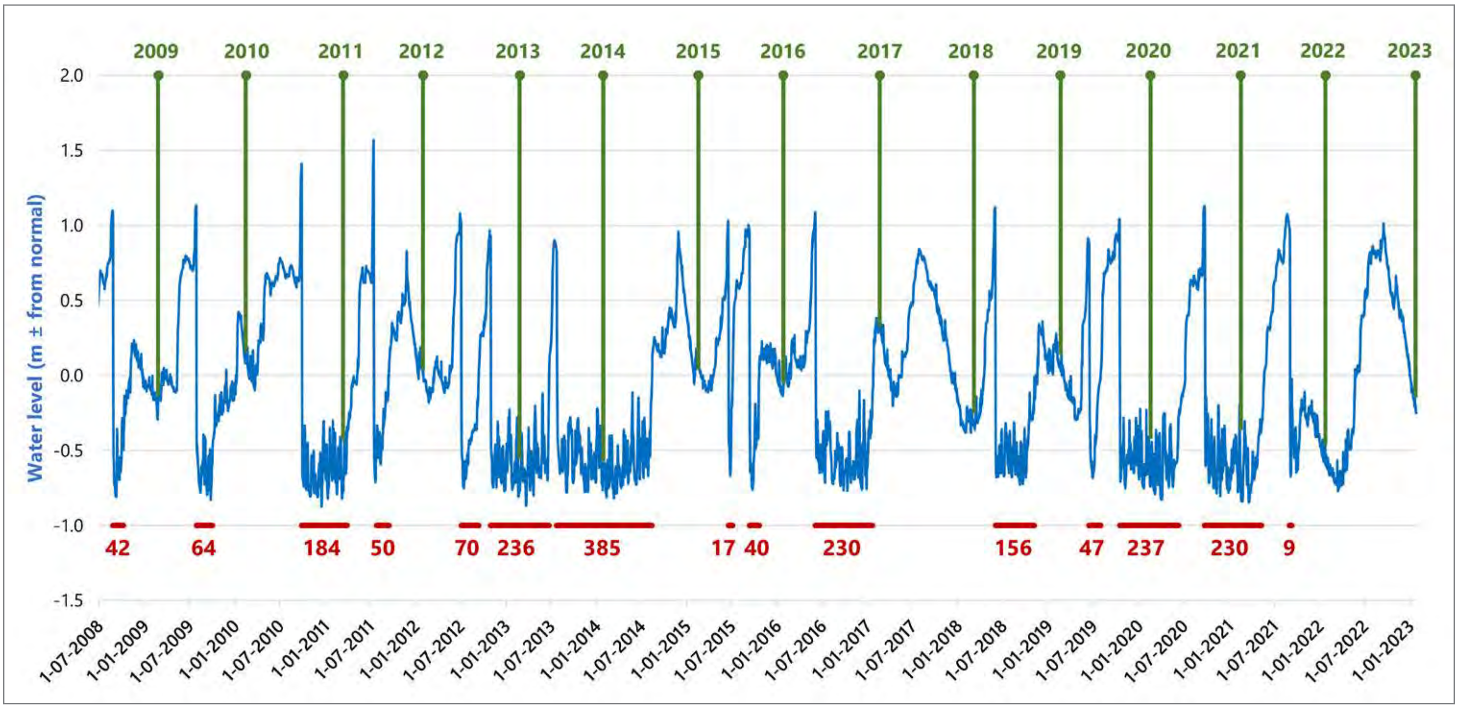


Figure 2: Plot showing the continuous water level time series for Waituna Lagoon, measured at Waghorn Road. Water level of 0 m on the graph is equivalent to 1.2 m a.s.l. Periods of lagoon opening are indicated by horizontal red lines. The number of days during which the lagoon was open correspond to the red numbers. Finally, the annual summer vegetation monitoring events are indicated by green vertical lines.

Discussion

Waituna Lagoon has been mechanically opened to the sea for land drainage purposes approximately once a year over the last c. 100 years. Lagoon closure is a natural process, driven by the effect of tides, currents and waves on redistribution of the gravel in the coastal barrier.

The last opening prior to the 2023 monitoring was in early September 2021 under conditions of the Resource Consent (20146407-01). Consent conditions permitted opening at a level of 2 m above sea level (a.s.l.) in winter, favouring early openings where there was opportunity for closure before the main spring/summer growth season for *Ruppia*. Openings over spring to autumn required a higher level of 2.2 m a.s.l. Closure of the lagoon after the 2021 opening was rapid and the lagoon has not been opened since. The coastal permit providing for openings of Waituna Lagoon expired in early 2022[1], and an application for consent renewal has been subsequently withdrawn[2].

Over the past 12 months, water level was ≥2 m a.s.l. for 70 days in winter (in July to September 2022), but only exceeded 2.2 m a.s.l. for two days. Water level in a closed lagoon is controlled by inflows, evaporation and drainage to the sea by percolation through the coastal barrier. The absence of extreme water levels fluctuations in the lagoon are likely to relate to the dryer climatic conditions experienced in Southland over the past two years according to the New Zealand Drought Index[3]. For instance, extremely dry conditions in April 2022 contributed to an extensive fire within 1370 ha of the Awarua Wetlands west of Waituna Lagoon.

Under a natural water level regime, the lagoon would have been closed to the sea with openings occurring in the decadal to century time scales (Hume et al. 2016). Periods where the barrier opened would have been short-lived in comparison. The barrier would have only breached naturally when sufficient pressure built from high water levels in the lagoon, and/or when severe storm waves overtopped the barrier. The regime of artificial openings have led to longer periods when the lagoon was open to the sea.

[1] https://www.waituna.org.nz/about-waituna-lagoon/resources/lagoon-managment
[2] https://www.es.govt.nz/environment/consents/notified-consents/2022/lake-waituna-control-association
[3] New Zealand Drought Index.

2. Temporal Physico-chemical Conditions

Methods

Water quality monitoring data for Waituna Lagoon was obtained from Environment Southland from 2009 to 2023. Data from the central lagoon sampling site was used to indicate changes in conditions over time to simplify temporal patterns. Seven parameters were plotted between 2009 and 2023:

1. Chlorophyll-*a* (Chl-*a*, mg l^{-1}).
2. Salinity (Practical Salinity Unit, PSU).
3. Total Nitrogen (TN, g m^{-3}).
4. Total Phosphorus (TP, g m^{-3}).
5. Total Suspended Solids (TSS, g m^{-3}).
6. Turbidity (NTU).
7. Temperature (°C).

Where water quality parameters were reported below detection limits, we plotted a value equal to half that detection limit. Timing and duration of lagoon openings is indicated in relation to water quality parameters.

Results

Salinity levels in Waituna Lagoon are generally related to the opening regime. Salinity showed a steady drop over the nine months prior to the 2023 vegetation monitoring (late January), to a value of 0.9 PSU in early January (Figure 3a). Similar salinity declines are seen for extended closed periods, while after opening events salinity could approach the value of seawater (Figure 3a).

Water temperature increased by almost 15°C between August 2022 and early January 2023, to a value of 19.2°C prior to vegetation monitoring. Water temperature maxima prior to the 2023 monitoring were similar to 2018 to 2022 (>15°C), but warmer than temperature between 2016 to 2017 and 2013 to 2014, according to the Environment Southland data (Figure 3a).

In the 12 months before the vegetation monitoring in late January 2023, Chl-*a* concentration was low (<0.01 mg l^{-1}) without some of the higher peaks (>0.2 mg l^{-1}) seen in 2009, 2012, 2015 and 2018 to 2021. Although TN levels over the last year showed similar patterns to previous years with winter peaks, TP concentrations were constrained to a lower range of <0.05 g m^{-3} (Figure 3b). Both TSS and turbidity measurements in the lagoon had dropped in the 12 months before the 2023 vegetation monitoring to levels of c. 2 g m^{-3} TSS and 2.5 NTU (Figure 3c). This reduction is possibly related to increased sediment trapping capacity of *Ruppia* plants with the development of vegetation (Section 5).

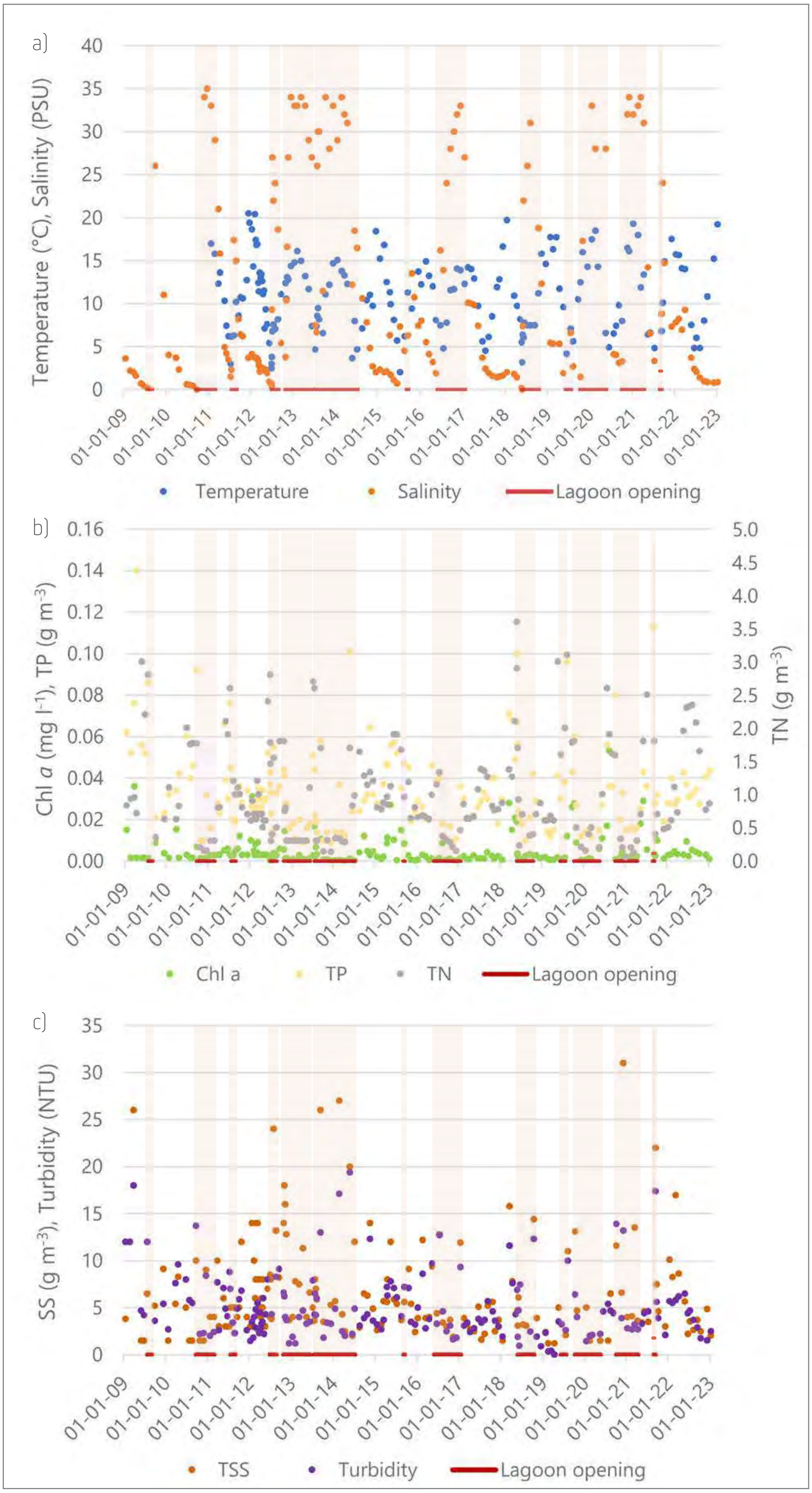


Figure 3: a) Timeseries of temperature and salinity, b) Chlorophyll-*a* (Chl-*a*), total phosphorus (TP), and total nitrogen (TN), and c) Total suspended solids (TSS) and turbidity at the lagoon centre sampled over 2009 to 2023.

Discussion

A closed lagoon over much of the *Ruppia* growing season was previously associated with lowered salinity and total suspended solids, but increased temperature and nutrients compared to an open lagoon status (de Winton and Mouton 2018a). In 2023, these associations generally held, apart from lower levels of TP (Figure 3b). It may be that reduced inputs of phosphorus resulted from reduced surface water inputs under catchment drought conditions over 2022 to 2023. A well developed vegetation in 2023 could also have reduced TP via enhanced sedimentation of suspended solids, and plant uptake.

Lagoon mouth status and the timing of lagoon openings proved major drivers of chemical conditions in the lagoon, but seasonal signals were also strong for temperature, nutrients and suspended solid concentrations (Schallenberg and Tyrell 2006, Schallenberg et al. 2010, Hodson 2017, de Winton and Mouton 2018a). In turn, these physico-chemical conditions will influence the spatio-temporal development of aquatic vegetation in Waituna Lagoon (Robertson and Funnell 2012, Lagoon Technical Group 2013, de Winton and Mouton 2018a).

In the following section (Section 3), we describe the physico-chemical conditions at the time of monitoring in 2023 and compare with previous annual monitoring over a range of mouth status.

3. Annual Physico-chemical Monitoring

Methods

The location of 47 monitoring sites are shown in Figure 4.

At each monitoring site, measurements were made from 2009 to 2023 of:

- Water depth (m).
- Visual clarity as black disk distance (m).

A calibrated multi-sensor meter (Horiba or YSI Exo 1) measured parameters at the water surface and bottom (where depth allowed) that included:

- Temperature (°C).
- Dissolved oxygen (DO, mg l^{-1}).
- Salinity (PSU).
- Turbidity (NTU).

Black disk, DO and turbidity commenced in 2011.

The surface and bottom water quality measurements were previously found to be highly correlated (Spearman r >0.9, de Winton and Mouton 2018a). We therefore employed average values for each parameter. In 2020, 2021 and 2022, where sites were dry we took water quality measurements close by if possible. The data is illustrated using box plots for each year (each annual monitoring event).

Figure 4: Monitoring sites in Waituna Lagoon. Transects are numbered from 1 to 10 from East to West. The numbers of each transect were allocated on ascending order from North to South.

Results

In 2023, all sites were monitored for water quality, although bottom water readings for some parameters could not be measured at seven sites due to restricted water depth. The low salinity (average <1 PSU) in the most recent monitoring was similar to previous closed lagoon years (<5 PSU) apart from those with recent closure in 2016, 2017, 2019 and the drought year of 2022 (Figure 5). Much higher salinity (average >15 PSU) was observed when the lagoon was open to the sea in 2011, 2014, 2020 and 2021, but an open lagoon in 2013 was associated with low salinity.

The average water depth in 2023 was 0.76 m but ranged from 0.2 to 1.9 m at sites (Figure 5). Average water level in 2023 was higher than the monitoring occasions when the lagoon was open in 2011, 2013, 2014, 2020 and 2021, but was also higher than monitoring events in the drought years of 2018 and 2022 when the lagoon was closed at the time of monitoring. The average water temperature of 17.8°C in 2023 was similar to the 16°C to 18°C average for the majority of monitoring years (Figure 5). Most sampled sites were between 16.4 and 18.5°C, with outliers recorded along the shallow northern shore (Figure 4).

An average dissolved oxygen (DO) concentration of 10.6 mg l^{-1} in 2023 was the second highest of all monitoring years (Figure 6). Dissolved oxygen levels were supersaturated at 83% of sites, likely due to very high *Ruppia* covers (Section 5) and only two sites recorded slightly less than 80% DO. The lowest recorded DO value was 7.6 mg l^{-1} (Figure 6).

Average turbidity (NTU) was low in 2023 at a value of 3.9 (Figure 6). The highest turbidity measurements of c. 15 NTU were recorded in shallow water at two sites along the northern shoreline (Figure 4), possibly resulting from resuspension of bottom sediments by wind driven wave action.

Dense vegetation obscured black disc measurements at two sites in 2023. Elsewhere, the average black disk reading was 1.18 m (Figure 6). This value is similar to the monitoring years of 2015 to 2017, but lower than 2019 and higher than other years (Figure 6).

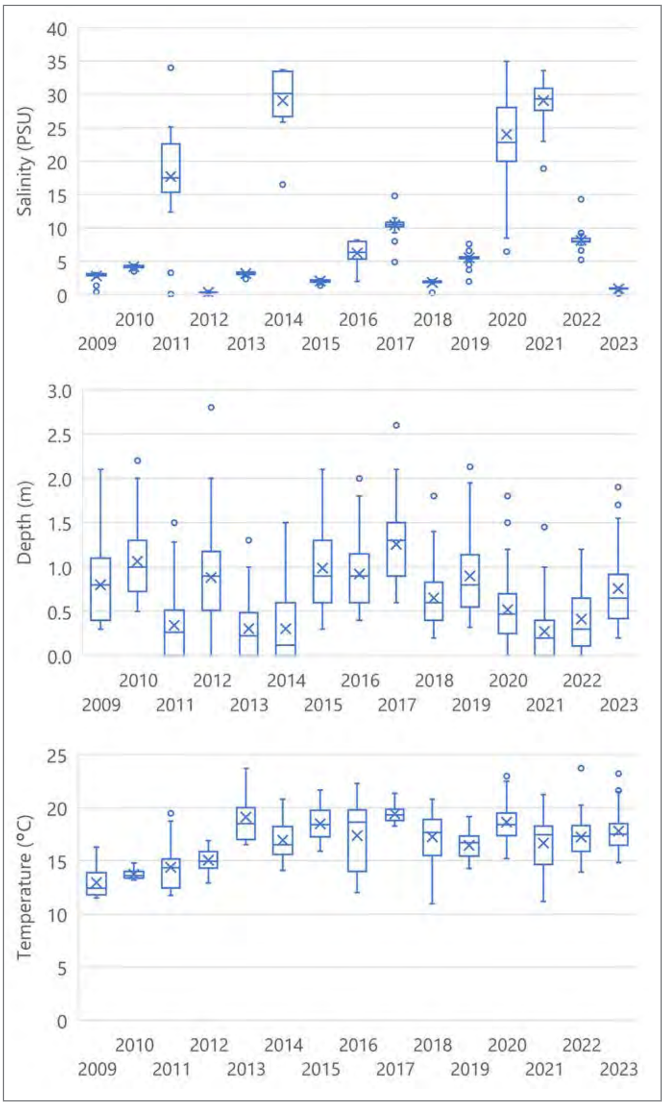


Figure 5: Box and whisker plots of salinity (top), depth (middle) and temperature (bottom) over all monitoring years. (n = 47).

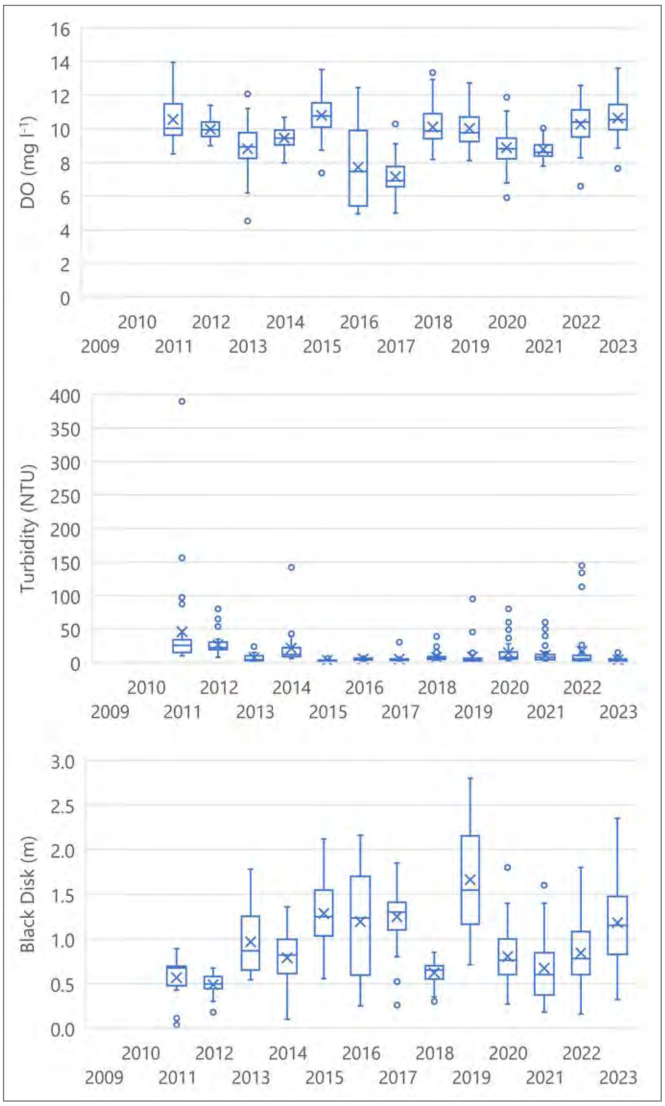
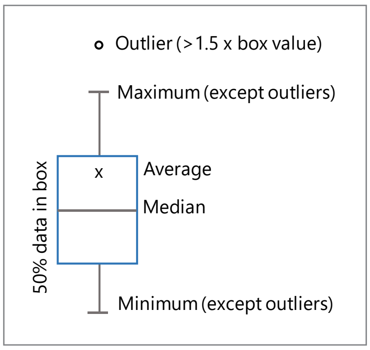


Figure 6: Box and whisker plots of DO (top), turbidity (middle) and black disk (bottom) at the monitoring sites (n = 47), from 2011 to 2023.



The legend shows features that are plotted on the graphs above.

Discussion

Physico-chemical measurements at the time of the 2023 annual monitoring appeared relatively typical for closed lagoon sampling, with low salinity, and moderate water depths. Supersaturated DO conditions are likely to reflect photosynthetic gas releases associated with the high *Ruppia* biomass recorded at many sites (Section 5). DO levels were generally well above levels considered necessary for healthy aquatic life.

4. Sediment Characteristics

Methods

At each monitoring site (Figure 4), four replicate samples 15 x 15 cm and 6 cm deep were cut from the lake-bed, using a flat based garden hoe, and carefully lifted to the surface.

Each sample was assessed for:

- Substrate type (described as combinations of soft or firm mud, sand and gravel), was assigned a score from 1 to 10 describing increasing hardness.
- Depth (cm) to a blackened layer in the substrate, which indicates sulphide accumulation (elsewhere referred to as the redox potential discontinuity layer, Stevens and Robertson 2007). Depth was categorised into five classes: surface, >0–2, 2–4, >4 cm and layer not recorded.

Results

In 2023, the hoe substrates tended to be finer or softer (higher proportion of categories 1 to 3) than the previous year. The current monitoring year resembled the composition recorded in the monitoring years 2009–2011, 2015 and 2019, with a high proportion of soft mud/sand recorded (Figure 7). It also appeared that sand substrates had become muddier in 2023 than the previous year (Figure 7), potentially due to *Ruppia* capacity to trap suspended sediment and the increased vegetation development recently (Section 5).

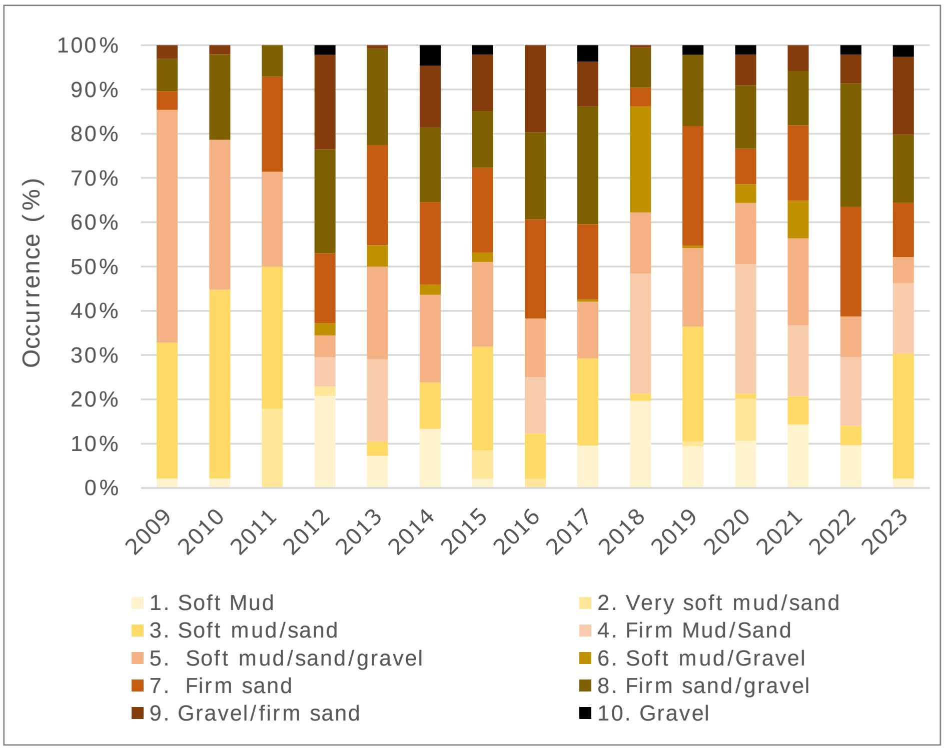


Figure 7: Bar plot illustrating the composition in substrate type (% occurrence), recorded during each of the annual monitoring surveys. Substrate types are numbered from softer to harder.

A blackened layer at the sediment surface (<1 cm depth) was recorded at only 2.7% of sampled substrates in 2023 (Figure 8), all of which comprised fine sediment of sand to mud. This was the lowest proportion for this category recorded in the last five years of monitoring. Much higher proportions of blackened surface layers were recorded in 2009, 2010, 2015 and 2019 to 2022. However, greater than 50% of substrate samples in 2023 recorded a blackened layer within the top 6 cm of sediment, a proportion greater than the previous three monitoring years (Figure 8), which likely reflects a return to greater proportions of fine substrate.

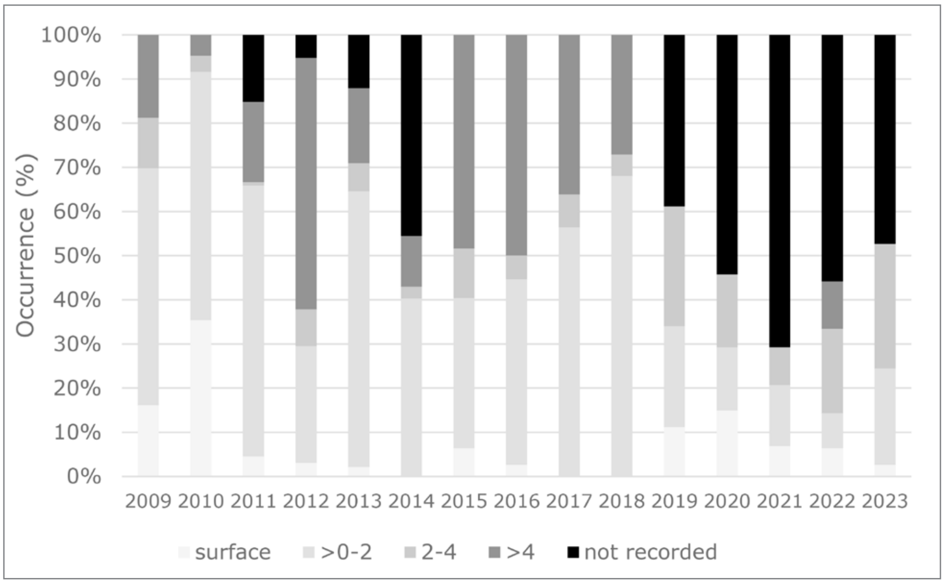


Figure 8: Substrate depth to a blackened layer shown as occurrence (% records) for five incremental depth categories.

Discussion

A redox potential discontinuity layer indicated by a blackened layer in the substrate (Stevens and Robertson 2007) suggests a reducing environment which increases oxygen consumption and, therefore, anoxic conditions as well as accumulation of phytotoxic sulphide and possible nutrient release. Therefore, increasing presence of blackened layers indicate reduced ecological health of the lagoon.

More oxidised sediments have been associated with harder substrates and indicate a better ecological condition (Stevens and Robertson 2007). Sediments had become finer and softer in 2023, possibly in association with a high biomass of vegetation under a closed lagoon which would encourage sedimentation of fines. However, substrate conditions remained similar to the previous five years, being generally oxygenated and 'healthy'. This result within generally finer substrates may reflect plant oxygen release to sediments via their roots, a recognised phenomenon of vascular aquatic plants (Thursby 1984, Kemp and Murray 1986).

5. Vegetation Development

Methods

At each site (Figure 4), four replicate samples 15 x 15 cm and 6 cm deep were cut from the sediment, using a flat based garden hoe, and carefully lifted to the surface. Each sample was assessed for:

- Presence of submerged plant species and/or macroalgae types and their % cover. Where covers were previously recorded as a cover score range[4] in 2009 and 2010, these were translated to a mid-point value.
- Height of each macrophyte species present (cm). Where heights were previously recorded as a range[5] in 2009 and 2010, these were translated to maximum value of the range.
- Life stage of *Ruppia* spp. (vegetative, flowering or post flowering).

Cover and height of *Ruppia* was averaged across the four replicates at each site. Biomass index for *Ruppia* was calculated as the product of average cover and height at each site.

From 2013 onwards, macrophyte observations were also made at each site by snorkel/SCUBA diver within a circular area of 10 m diameter. The maximum and average cover scores and height were recorded for each macrophyte species and macroalgae type present.

Results

Vegetation composition

All sites surveyed in 2023 recorded vegetation (Figure 9). *Ruppia polycarpa* was the most widespread aquatic plant recorded, being present at 45 sites. *Ruppia megacarpa* was recorded from 18 sites and extended beyond its previous typical distribution in the eastern lagoon to sites on the northern half of transect 9 (Figure 4). *Ruppia megacarpa* occurred with *R. polycarpa* at all but two of these sites. *Ruppia* species occurrence in 2023 was similar to previous high occurrence records over 2018 and 2019 of 42-45 sites for *R. polycarpa* and 14-15 sites for *R. megacarpa* (Figure 9).

Other submerged plants to increase substantially in occurrence in 2023 were the charophyte *Lamprothamnium* species[6] (23 sites) and freshwater milfoil *Myriophyllum triphyllum* (15 sites). Both species have been more conspicuous in the years that the lagoon has been closed. *Lamprothamnium* species had high frequency in 2012, 2015-2016, 2018-19 and 2022 (Figure 9). This charophytes occurrence in 2023 was the second highest after 2019 (27 sites) another year with consecutive lagoon closures during the main spring/summer growth season for macrophytes (Figure 9). *Myriophyllum triphyllum* was also frequently observed during 2018 and 2019 (15 to 20 sites), similar to 2023.

Lakeshore turf plants *Samolus repens* and *Lilaeopsis novae-zelandiae* were recorded at an increased occurrence in 2023 (Figure 9), possibly due to three previous years of low water level during summer (2020–2022) favouring these amphibious species.

By contrast to the higher plants, macroalgae were only seen at limited sites in the lagoon in 2023 (Figure 9). *Ulva intestinalis* was recorded at 10 sites, mostly in the central and western side of the lagoon. Occurrence of filamentous green algae was seen at just eight sites. Filamentous green algae were dominated by *Cladophora* species, but all algal samples collected had high numbers of sedimented diatoms (e.g., *Navicula* species). This reduction in macroalgae occurrence in 2023 contrasts with their frequency at sites over 2009 to 2022, and previously over 2015 to 2017 (Figure 9). Although hoe samples are known to incompletely sample macroalgae, wider in situ observations by divers (section 'Macroalgal cover') confirmed the limited nature of macroalgae in 2023.

[4] 1–5%, 2 = 5–10%, 3 = 10–20%, 4 = 20–50%, 5 = 50–80%, 6 = 80–100%.

[5] <5 cm, 5–15 cm, 15–30 cm, 30–50 cm, 50–80 cm, 80–100 cm.

[6] *Lamprothamnium* species taxonomy in New Zealand is currently unclear, but likely to include *L. compactum* (M. Casanova *pers* comm. 23/05/2023).

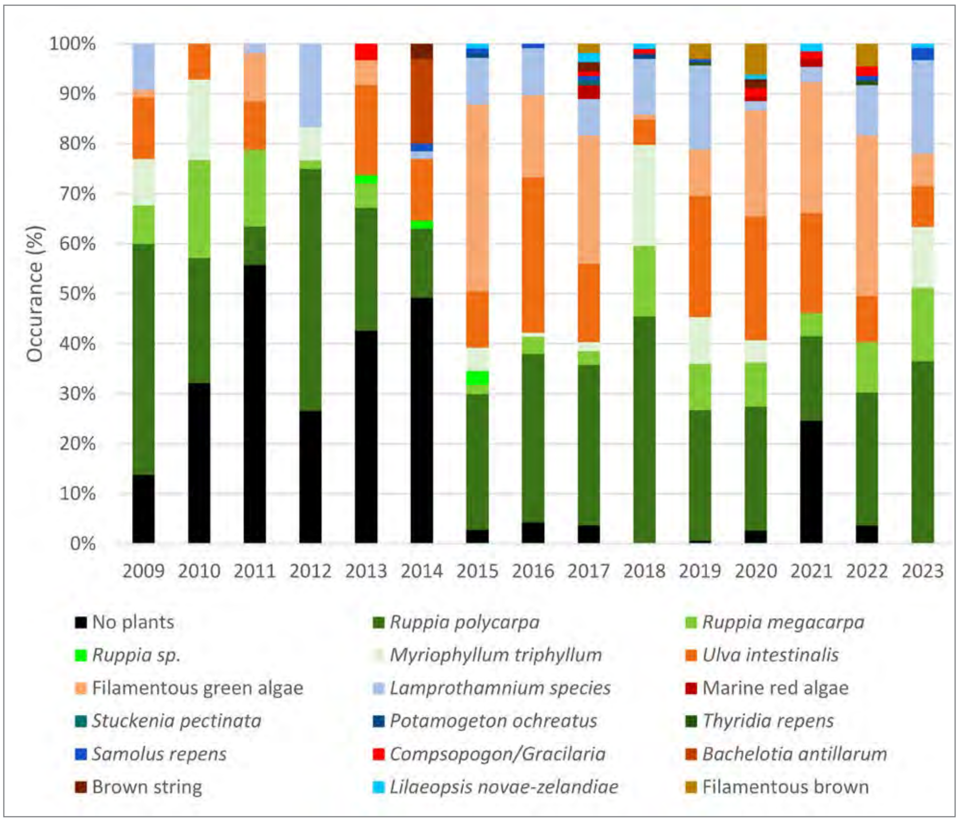


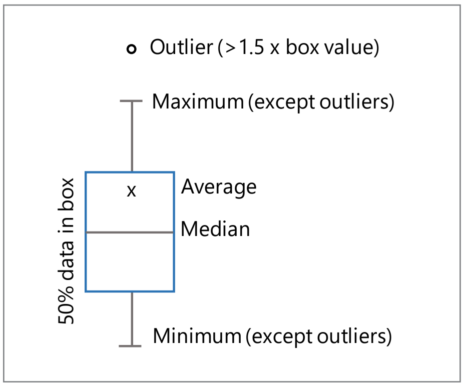
Figure 9: Vegetation composition shown as relative frequency of occurrence (sites recorded) for species or vegetation groups.

Ruppia abundance

In 2023, *Ruppia* species had the highest yet recorded average cover out of the 15 monitoring years (Figure 10a). Average cover of *Ruppia* species from hoe samples was 52% lagoon-wide (Figure 10a), compared to the next highest average of 40% recorded in 2016 and 35.6% in 2019. Both of the *Ruppia* species exhibited similar average cover for the hoe samples in 2023.

The average height of *Ruppia* plants from hoe samples in 2023, at 0.61 m, was also greater than the <0.5 m values of all previous years (Figure 10b). Together, the heights and high covers recorded contributed to a record average biomass index of 4339 (Figure 10c). The next highest average biomass index values (1000 to 2000) occurred over 2015–2016 and 2018–2019 (Figure 10c), which also represented consecutive years of a closed lagoon in the three or more months before monitoring.

High outliers in Figure 10b and 10c represent sites were dominated by *R. megacarpa*. *Ruppia megacarpa* has been disproportionately represented amongst the taller height records and higher biomass index values in all monitoring events to date.



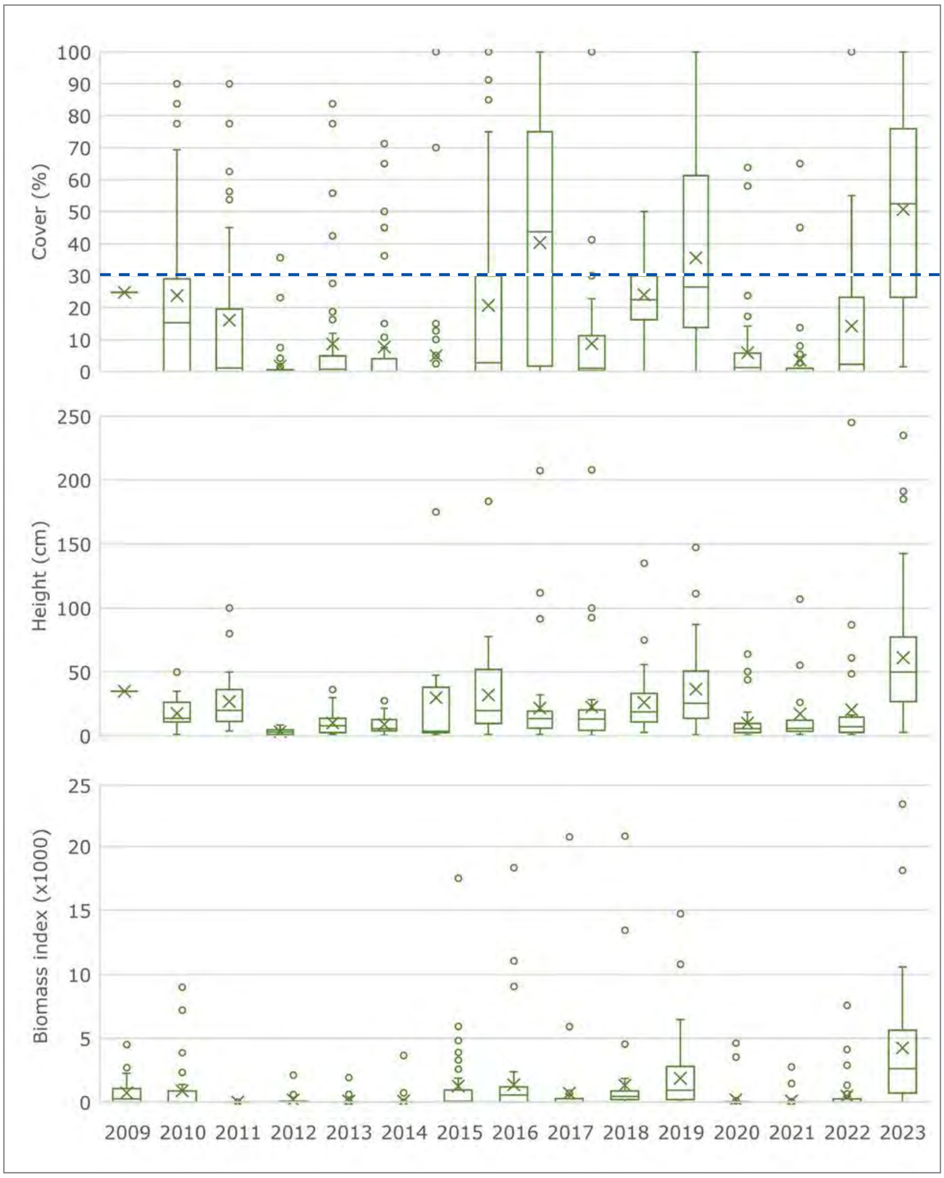


Figure 10: Box and whisker plots of *Ruppia* cover a), height b) and derived biomass index c) over monitoring years, as an average of measurements at monitoring sites (n = 47). Dotted line represents the lagoon-wide target for *Ruppia* cover of 30% identified by the Lagoon Technical Group (2013).

In 2023, *Ruppia* was observed by divers within a 10 m diameter survey area at all sites. In previous years when *Ruppia* occurrence has been much less than 100% of sites, the diver observations were more likely to detect *Ruppia* than the hoe sampling method. Diver observations of *Ruppia* covers and heights show a correlation with the hoe method (Figure 11). Average *Ruppia* cover for each method per monitoring year showed a closer correlation (R^2 = 0.94, data not shown), although the diver observations gave higher estimates than hoe measurements for 10 out of 11 years.

Diver observations of *Ruppia* in 2023 averaged 63% cover (data not shown). Again, this value was higher than previous highest average cover values observed by divers of 37% in 2016 and 50% in 2019. Diver estimates of plant height at 0.83 m in 2023 were second highest to 2019 (0.95 m). The diver method has the tendency to report taller plants than the hoe method, probably because of the larger assessed area.

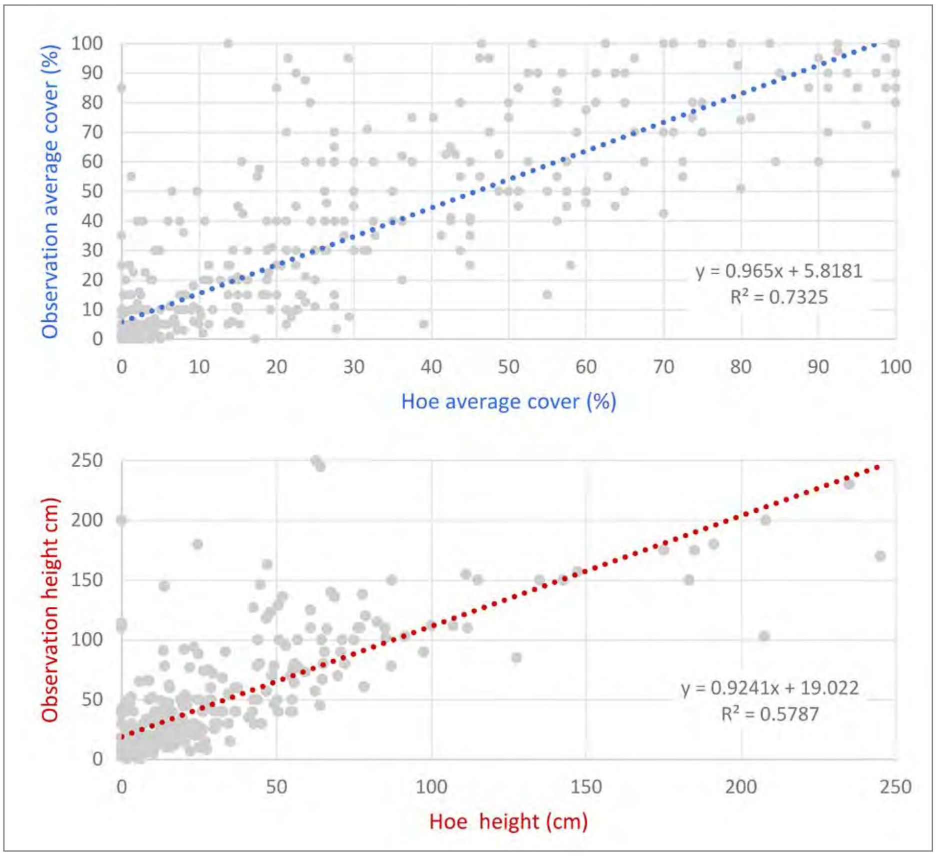


Figure 11: Relationship between *Ruppia* cover (top) and height (bottom) estimated from hoe samples and diver observations within a 10 m diameter area at each site.

Ruppia life-stage

In 2023, 85% of hoe samples (96% of sites) recorded reproductive *Ruppia* plants with flowers or developing seeds (Figure 12, Table 1). This value is higher than all the previous measures of *Ruppia* reproductive success for monitoring years. Years when the lagoon has been closed for the three months over the main *Ruppia* spring-summer growth period recorded greater than 15% hoe samples as reproductive (Figure 12, Table 1). However, a higher reproductive success was associated with the second consecutive year of closed lagoon status, for example in 2016, 2019 and 2023 (Table 1). By contrast, years with ≤10% of hoe samples recorded as reproductive were years when the lagoon was not closed for three months or more over the main growing season for *Ruppia* (2011, 2013–2014, 2017, 2020–2021, Figure 1, Table 1).

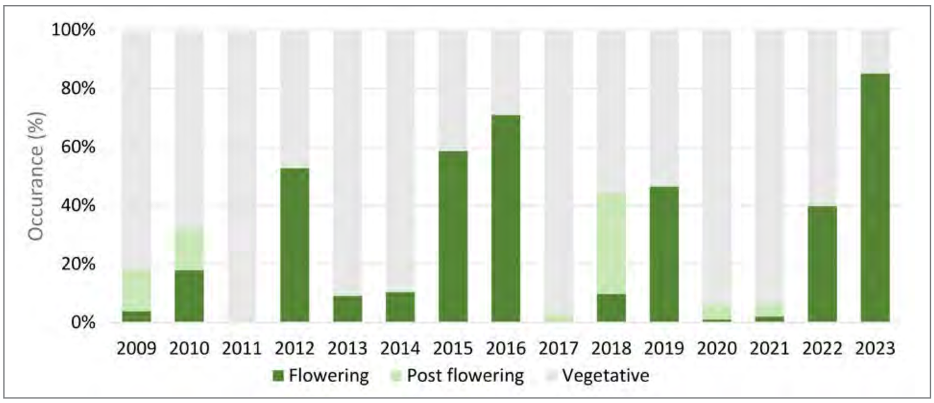
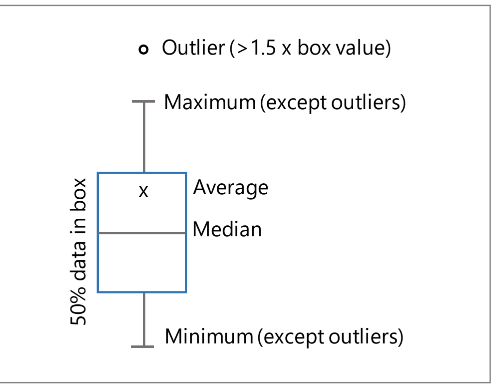


Figure 12: Life-stage category of *Ruppia* species across monitoring years as a proportion of records.

Table 1: Record of lagoon closure (months before monitoring) and reproductive success (% of hoe samples recorded as reproductive) for each monitoring year. Open lagoon shows negative value and years closed for three or more months are shaded.

Year	Months closed before monitoring	Reproduction (% samples)
2009	**4.7**	**18**
2010	**4.6**	**32**
2011	-5.6	0
2012	**4.6**	**53**
2013	-3.9	9
2014	-6.2	10
2015	**6.2**	**59**
2016	**3.2**	**71**
2017	1.0	3
2018	**13.7**	**44**
2019	**3.5**	**46**
2020	-4.1	6
2021	-4.8	6
2022	**4.5**	**40**
2023	**16.6**	**85**



Macroalgal cover

In 2023, the average macroalgae cover recorded from all hoe samples in the lagoon was low, at 5% (Figure 13). This value was low because macroalgae were only recorded at 32% of the hoe survey sites. Similar low average covers (<10%) for macroalgae cover have been recorded in 2009–2012, 2014 and 2018 (Figure 13).

Macroalgae formed covers of 100% at only one site in 2023 (Site 9.7, Figure 4). Previously in 2016, 2017, 2019 and 2022, macroalgae covers at individual sites have exceeded 100% where different macroalgae types formed overlying layers (e.g., benthic mats and surface mats).

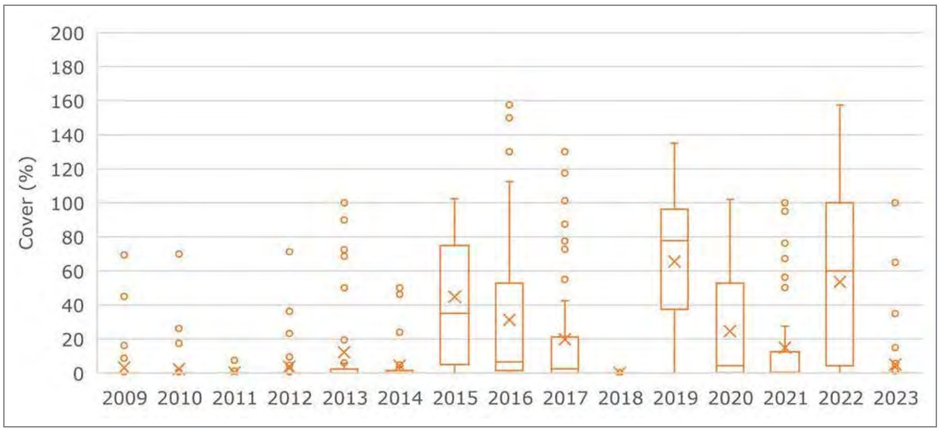


Figure 13: Box and whisker plots of macroalgae cover over monitoring years as an average of hoe measurements at monitoring sites (n = 47).

Macroalgae beds can 'lift-off' and grow as a surface mat in still, warm weather.

Dislodgment of algal cover has been observed when hoe samples were retrieved to the surface (e.g., Robertson and Stevens 2009, Stevens and Robertson 2010) and algal biomass has also been noted suspended in the water column by waves and currents and so not captured by the hoes. Therefore, an underestimation of macroalgal development is likely from hoe samples. However, diver observations over a 10 m diameter area at sampled sites in 2023 confirmed a low lagoon-wide average cover for macroalgae, with estimates of just 5.3%. The two measurements had a linear correlation ($R^2 = 0.89$) in 2023 (data not shown) that continued the relationship seen across all monitoring years (Figure 14). Average macroalgae cover for each method per monitoring year showed a closer correlation ($R^2 = 0.81$, data not shown), although the diver observations gave higher estimates than hoe measurements for 10 out of 11 years.

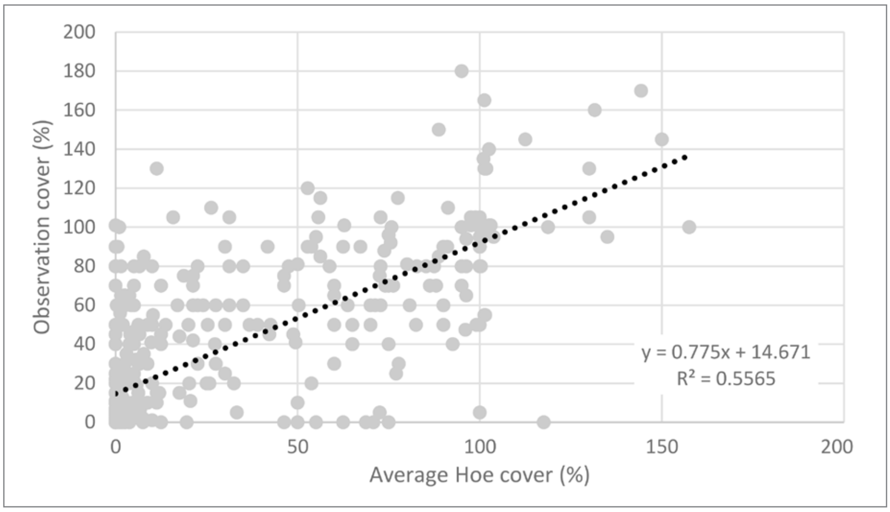


Figure 14: Relationship between macroalgal percentage cover estimated from hoe samples and diver observations within a 10 m diameter area at each site.

Discussion

The 2023 monitoring year saw records set for *Ruppia* cover, biomass index and reproductive success, with the highest average values out of the 15-year data set for annual vegetation monitoring. This 2023 year, like previous years of high *Ruppia* development in 2016 and 2019, represents the second of two consecutive years of closed lagoon over the critical growth period for *Ruppia*. Moreover, prior to the 2023 monitoring the lagoon had not experienced the disruption of a lagoon opening for 16.6 months. Dry to drought conditions recorded in Southland in 2022 avoided periods of sudden water level increase in the lagoon and possibly reduced catchment derived effects (e.g., sediment and nutrient loads). Climatic conditions also resulted in slowly falling water levels from September 2022 up until the January 2023 monitoring that would have increased light availability for plants.

Closed lagoon conditions are likely to provide conditions of sufficient water to inundate all survey sites with low, stable salinity suitable for growth. Open lagoon conditions that are detrimental to *Ruppia* development are likely to include the high and fluctuating salinity levels and tidal currents that could disturb vegetation and cause biomass loss.

The benefit of two consecutive years of closed lagoon over the critical growth period for *Ruppia* appears to provide time for vegetation colonisation to extend across the lagoon. Previously, patterns of *Ruppia* recovery in a suitable year have mainly involved the eastern sector of the lagoon, with a longer lag time apparent for the central and western lagoon. *Ruppia megacarpa* recolonisation has also lagged behind *R. polycarpa* in terms of occurrence. This longer recovery time for *R. megacarpa* means that the higher covers and biomass index associated with this species may not develop over just one year of favourable growth conditions and may require two or more consecutive years of closed lagoon conditions during the main macrophyte growth season.

In contrast to the 2023 monitoring year, an open lagoon for part of the spring to early summer growth season for *Ruppia* has previously resulted in lower vegetation development and reproductive success. *Ruppia* presence and development have been observed to decline further after two consecutive years of open lagoon status during the main growth season, for instance the 2013 to 2014 and 2020 to 2021 periods.

A major reproduction event was documented for *Ruppia* in 2023, with almost all sites (96%) recording reproductive plants. Diver's comments also indicated a large number of seeds were being produced for both of the *Ruppia* species. Addition of seed loads will replenish the seed bank, which has previously been identified as a major mechanism for vegetation recovery after long lagoon openings (de Winton and Mouton 2018b). By contrast, recovery of a related *Ruppia* species was slowed by inadequate recharging of seed banks after poor flowering success (Sinclair et al. 2020) and loss of the propagule bank was seen as a major factor restricting colonisation for an Australian *Ruppia* species (Frahn et al. 2012). Successful flowering of *Ruppia* in Waituna Lagoon is likely linked to plant biomass development (e.g., Santamaría et al. 1995). For instance, *Ruppia* plants must have sufficient energy reserves for flowering stems to reach the water surface for pollination.

Submerged plant diversity was high in the lagoon during the current years monitoring, with the highest representation by *Ruppia megacarpa* yet recorded, and second highest occurrence for the charophyte *Lamprothamnium* species and milfoil *Myriophyllum triphyllum*. Diversity was partially contributed by the appearance of freshwater macrophytes such as *Potamogeton ochreatus*.

Macroalgal development in 2023 was low in Waituna Lagoon. This result was surprising given that long closures have previously been associated with nutrient accumulation that potentially fuel macroalgal growth. It may be that reductions in surface water inflows under recent dry conditions in Southland (high drought index for 2022 and 2023[7]) have created limited nutrient availability for macroalgae in 2023. The dry year of 2018 also saw low development of macroalgae under a closed lagoon status at the time of monitoring. Although competition between abundant *Ruppia* beds and macroalgae for light and dissolved nutrients may have contributed to low macroalgae in 2023, this is not supported by results in 2019, when a high abundance of *Ruppia* was associated with the highest average cover of macroalgae recorded from 15 years of annual monitoring at Waituna Lagoon.

Also noted is that macroalgal abundance has generally been higher post-2015, despite including years of closed and open lagoon status at the time of monitoring. Overall, it appears macroalgae development is less influenced by lagoon mouth status than *Ruppia*. Macroalgae appear to respond more quickly to short-term meteorological events and their influence on catchment nutrient loading and temperature conditions in the lagoon. For instance, very rapid development of algal mats at the water surface can occur under warm, still conditions. It may also be that the amount of macroalgae that develops in one year serves as inoculum to promote levels of algal development in a subsequent year.

[7] https://niwa.co.nz/climate/information-and-resources/drought-monitor.

Informing Future Lagoon Management and Research

Ruppia is valued in Waituna Lagoon as an example of a vegetation type that is increasingly being lost in New Zealand coastal waterbodies due to water quality impacts. In Waituna Lagoon specifically, *Ruppia* is recognised as a key indicator of lagoon ecosystem health (Robertson et al. 2021) and valued as an example of intact coastal ecosystem vegetation. The current restricted distribution of *R. megacarpa* in this country means it has been designated At Risk – Nationally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).

A 15-year long dataset of annual vegetation monitoring at Waituna Lagoon provides strong evidence that artificial lagoon openings that extend into the key spring to summer growing season for *Ruppia* are undesirable. Moreover, consecutive years when opening occurs within this timeframe additionally limits biomass development and reproduction of the plants. The key impact of an open lagoon is likely to result from high and fluctuating salinity levels that limit plant growth rates (e.g., Gerbeaux 1989), acting together with loss of plant biomass under a tidally swept and disturbed system. Sensitivity to the impacts of lagoon openings is greater for *Ruppia megacarpa*, an important 'ecosystem engineer' that disproportionately contributes to vegetation height and biomass at Waituna Lagoon.

Equally, years when the lagoon is closed during the three months leading up to summer monitoring of *Ruppia* consistently have higher plant development. Consecutive years of favourable closed conditions during this period promoted greater vegetation development and reproductive success, with the highest development occurring in 2023 when two consecutive growth periods occurred without the disruption of any opening.

Artificial openings of Waituna Lagoon had been managed since 2017 by an interim Resource Consent (20146407-01), that favoured openings outside of spring-summer growth season for *Ruppia* by setting a lower water level criteria for openings in winter. However, this consent continued to result in unpredictable timing of lagoon closure, with openings that extended into the growth season.

A review of optimal opening conditions for the ecological and cultural health of the lagoon ecosystem (Robertson et al. 2021) recommended a higher water level threshold for opening the lagoon (2.5 m a.s.l.). This change would be expected to reduce the frequency of openings. Allowance for fish passage was suggested in the form of an opening at a lower water level (1.5 m a.s.l.) during winter to spring at a maximum frequency of once every three years (i.e., opened if no openings in previous 24 months). Openings at a lower water level (1.5 m a.s.l.) to disrupt algal blooms were allowed at any time of the year if critical levels for phytoplankton measurements were reached or other risk factors such as nutrient enrichment were indicated (as determined by the Technical Advisory Group[8]).

The proposed Resource Consent conditions (Robertson et al. 2021) are likely to advantage *Ruppia* populations. They would reduce the risk of successive years of an open lagoon during key growth seasons and increase the probability of reproductive success and adequate replenishment of seed banks. It is likely that replenished and persistent seed banks will enable *Ruppia* recovery under a scenario of low frequency disruptions caused by spring to summer openings (i.e., up to every three years) to meet additional conditions for fish passage or water quality. Moreover, intermittent salinity disruptions are likely to continue to promote *Ruppia* and *Lamprothamnium* species over potential freshwater plant competitors. Proposed conditions are also likely to benefit plant species diversity at the lagoon by also suiting other plant species typical of coastal lagoons such as the milfoil *Myriophyllum triphyllum*, *Potamogeton* species and possibly *Stuckenia pectinata*, *Althenia bilocularis and Zannichellia palustris.* Reduced occurrence of low lagoon levels may also contribute to safeguarding surrounding wetlands from fire and potential impacts on water quality.

Macroalgae do not respond so clearly to management of lagoon openings as *Ruppia*. Macroalgal development has been greater at the time of the summer monitoring in recent years (within last 9 years), with the notable exception of drought years 2018 and 2023, but not drought year 2022. Macroalgal development has been broadly linked to dissolved nutrient availability, however recent trophic status trend analysis of Waituna Lagoon did not suggest nutrient levels were increasing (Robertson et al. 2021). Macroalgal growth might also be less dependent on water nutrient levels than previously assumed, with evidence for algal mat access to sediment-based nutrients (McGlathery et al. 1997). Macroalgal development may also reflect the level from a previous year. For these reasons, macroalgae would appear to be less amenable to 'disruption' from lagoon openings than phytoplankton blooms. Opening the lagoon for management of nutrient levels also has unclear benefit for limiting macroalgal development. Control of catchment nutrient loads remain vital for ensuring the dominance of *Ruppia* at Waituna Lagoon. For instance, *Ruppia megacarpa* takes up nutrients from the water via its leaves less efficiently than epiphytic algae (Dudley et al. 2001), so that large catchment inputs of waterborne nutrients are likely to advantage macroalgae development (or phytoplankton blooms) over a submerged vegetation community. Reductions in catchment nutrient loads have been recommended in the order of 50% to allow the lagoon to remain in a healthy, long-term sustainable condition (Lagoon Technical Group 2013).

[8] Environment Southland, Te Ao Marama Inc., Department of Conservation.

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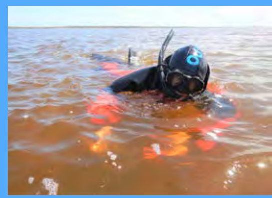
Appendix J: Summer 2023 and 2024 Vegetation Status Reports

Department of Conservation
Te Papa Atawhai

NIWA
Taihoro Nukurangi







Vegetation Status in Waituna Lagoon: Summer 2023

Department of Conservation
Te Papa Atawhai

NIWA
Taihoro Nukurangi

Vegetation Status in Waituna Lagoon: Summer 2023




This report was commissioned by The Department of Conservation (DOC) and based on work under Project DOC20203.

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Layout: Aarti Wadhwa – Spectra Design Ltd (rt@spectradesign.co.nz)

Contents

DOC commissioned NIWA to undertake the 2023 summertime Waituna Lagoon survey to document the health of submerged vegetation and to provide an inter-annual comparison of its condition. This report summarises the key findings to guide further ecological management of the lagoon.

Key findings

In 2023, all six ecological targets (in bold below) were achieved for Waituna Lagoon;

- The lagoon was closed to the sea for all the spring-summer growing season for *Ruppia*, achieving the target for **lagoon closure.**
- This the second consecutive year the target for **lagoon closure** has been achieved and comprises the longest period of closed lagoon status (16.6 months) of the 15-year monitoring data set.
- Targets for lagoon-wide ***Ruppia* cover, *Ruppia* biomass index, *Ruppia* reproductive success, *Ruppia megacarpa* status** were all achieved in 2023, with the highest values for these measurements ever recorded.
- The macroalgae cover target comprising a limit of <10% was also achieved. The low macroalgae abundance contrasts with results since 2015 when macroalgal development has usually been prominent.

Monitoring results for Waituna Lagoon in 2023 showed record vegetation development, high macrophyte species diversity, and indications of a major replenishment of seed banks for future security of the plant community. Results continue to support the need for closed lagoon conditions during the key growing seasons, preferably for consecutive years, as a means of protecting widespread *Ruppia* vegetation and the ecological benefits that submerged plants provide.

Purpose of this report

This report presents the 2023 annual summer monitoring data for submerged vegetation in Waituna Lagoon in relation to ecological targets that have been identified by the Lagoon Technical Group to guide ecological management. Results are compared to annual monitoring results since 2009.

The document is supported by a technical report[1] that describes the water level regime, water quality (physico-chemical) and substrate conditions, submerged vegetation abundance and composition and *Ruppia* life-stage.

[1] de Winton, M., Zabarte-Maeztu I., Taumoepeau, A. (2023) Technical Report on Vegetation Status in Waituna Lagoon: 2009–2023. *NIWA Publication*.

Waituna Lagoon is an internationally important example of a coastal waterbody that remains in good ecological condition.

Background

The importance of Waituna Lagoon

Waituna Lagoon on the south coast of New Zealand is included within a Ramsar Wetland of International Importance. The Lagoon is of cultural significance to Ngāi Tahu recognised by a Statutory Acknowledgement under the Ngāi Tahu Claims Settlement Act 1998[2]. It is also significant for conservation of biological diversity and as a key recreational site.

The Department of Conservation has been monitoring submerged aquatic plants (including *Ruppia* spp.) in Waituna Lagoon since 2007 under the Arawai Kākāriki Wetland Restoration Programme.

Coastal lowland lakes like Waituna Lagoon are impacted by changes in land use in the catchment including sediment and nutrient loads from upstream run-off. It is now rare to find coastal lowland lakes with an intact ecological condition, but Waituna Lagoon remains highly valued for its associated plant, wetland, fish and birdlife.

[2] Ngāi Tahu Claims Settlement Act 1998 No. 97 (as at 23 May 2008), Public Act Schedule 73 Statutory acknowledgement for Waituna Wetland – New Zealand Legislation.

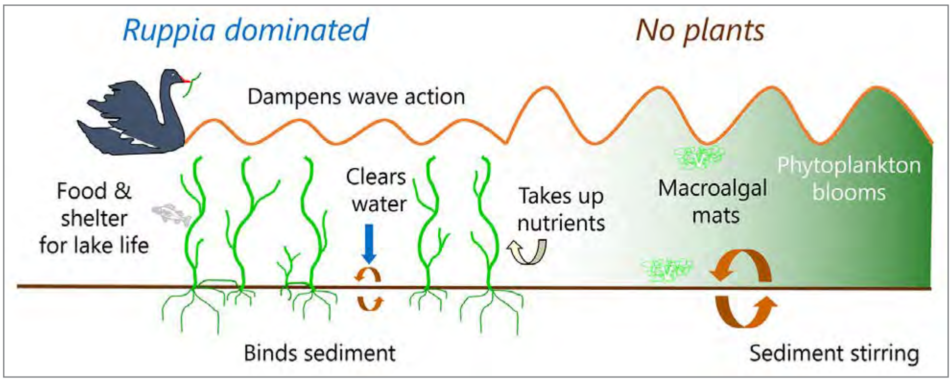
Ruppia safeguards the lagoon

When *Ruppia* grows densely in Waituna Lagoon it protects water quality, dampens wave action and stops the bed being stirred up.

Risk of Waituna Lagoon shifting to a poor ecological condition

Submerged plants have an important role in keeping shallow lakes and lagoons clean and healthy (Figure 1). If submerged plant communities become too stressed, they can collapse. The lake or lagoon then enters a new, dirty water state, with high levels of resuspended sediment and development of macroalgal mats or phytoplankton blooms instead of plants. The submerged native plant species of *Ruppia* (horse's mane) safeguard water quality in Waituna Lagoon. *Ruppia* tolerates fluctuating levels of saltwater in lagoons better than other submerged plants, but does not occur in the sea. Other plants, including a nationally rare, salinity-tolerant charophyte, also occur at Waituna Lagoon.

Figure 1: *Ruppia* vegetation can safeguard water quality in the lagoon compared to a system with no plants.



Management of water level at Waituna Lagoon

Agencies, community and iwi are working together to manage and protect Waituna Lagoon. When water levels in the lagoon rise too high for land drainage, the management response has been to mechanically open the lagoon to the sea. Lagoon openings are usually undertaken once or twice a year to prevent catchment flooding and to flush nutrients from the lagoon, but lagoon closing only occurs naturally under certain sea conditions.

Management of these artificial openings is increasingly taking into account the Lagoon's ecology. The timing and length of openings ideally should not negatively impact on the survival of *Ruppia* and other vegetation. This requires managing openings to avoid critical periods in the life-history of *Ruppia* including spring to summer growth and seed production.

Previously, the lagoon had been opened to the sea once the water level of Waituna Lagoon reached a certain trigger level[3], which varies at different times of the year and had associated conditions. The coastal permit to open the lagoon expired in 2022. More recently, the optimal Resource Consent conditions for the ecological and cultural health of the lagoon ecosystem were assessed by an expert technical panel[4] as a step towards better management of lagoon openings.

[3] Resource Consent 20146407-01, 14 February 2017.

[4] Robertson, H.A., Ryder, G., Atkinson, N., Ward, N., Jenkins, C., de Winton, M., Kitson, J., Schallenberg, M., Holmes R. (2021) Review of conditions for opening Waituna Lagoon. Supporting Information. Prepared for Whakamana Te Waituna. 29 pp.

Natural lagoon level

Once, Waituna Lagoon would have naturally breached to the sea after several years of filling with freshwater. Today it is regularly opened and infiltrated by the sea.

What do openings mean for conditions in Waituna Lagoon?

Monitoring of the waters of Waituna Lagoon over time[5] has built up a picture of the key changes caused by opening events[6]. Water level is lower and salinity higher when the lagoon is open and temperature and nutrient concentrations are both reduced with flushing by the sea (Figure 2). These changes and their duration influence the vegetation of Waituna Lagoon.

Figure 2: Key changes in the waters of Waituna Lagoon with time after opening or closing to the sea.

Catchment management

Agencies and the community aim to reduce sediment and nutrient inputs to Waituna Lagoon, focusing on strategies and initiatives for catchment management of contaminants, increasing biological processing of run-off and improving freshwater habitat. It is essential that these efforts meet the nutrient load reduction targets developed by the Lagoon Technical Group in 2013[7] to ensure the long-term persistence of *Ruppia* vegetation and safeguard the lagoon ecosystem. However, opening the lagoon to disrupt algal blooms provides a short-term solution for the ecological health of the lagoon.

[5] https://www.lawa.org.nz/explore-data/southland-region/lakes/waituna-lagoon/

[6] de Winton, M., Mouton, T. (2018) Technical Report on Vegetation Status in Waituna Lagoon: 2009–2018.

[7] Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon. *Report prepared for Environment Southland.*

What do we monitor?

Ruppia

Ruppia acts as an ecological sentinel in Waituna Lagoon, providing an early-warning system to detect deterioration. Department of Conservation oversee the monitoring of *Ruppia* and other aquatic plants and algae to determine status and trends in ecological health of the Lagoon. Monitoring supports specific resource consent conditions for lagoon opening, where opening avoids the spring to summer growth and reproduction phase for *Ruppia* although opening decisions at a lower water level may be acceptable where vegetation has been stable (key ecological targets met for a number of years), or where poor water clarity is likely to have an adverse ecological effect if the lagoon isn't opened and flushed.

Results of annual monitoring are compared with target conditions sought under the Ecological Guidelines[8] for Waituna Lagoon. Two additional targets were suggested by an analysis of all monitoring data in 2018[9]. These ecological targets are listed in Box 1.

Box 1: Ecological targets for *Ruppia* in Waituna Lagoon:

- Lagoon closed during *Ruppia* growing season (spring and summer).
- >30–60% for average % cover of *Ruppia* (and other native macrophytes[10]).
- <10% cover of benthic and epiphytic filamentous algae (macroalgae).
- >1000 average for *Ruppia* 'biomass index' (% cover x cm height).
- ≥40% of *Ruppia* samples in a flowering or post-flowering life-stage.
- ≥20% of the sites record *Ruppia megacarpa*.

[8] Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon. *Report prepared for Environment Southland*.

[9] de Winton, M., Mouton, T. (2018) Technical Report on Vegetation Status in Waituna Lagoon: 2009–2018.

[10] Other native macrophytes comprised <35% of all occurrence records for all surveys.

Monitoring methods

The lagoon is monitored each year in late summer at 47-48 sites (Figure 3a). At each site, an assessment of environmental quality includes depth and water quality measurements (Figure 3b). Substrate characteristics are measured in four samples of the lagoon bed retrieved using a garden hoe, and the composition and abundance of vegetation is also described, including *Ruppia* life-stage as flowering or vegetative. Submerged native plants and dominant macroalgae are shown in Figure 4.

Figure 3a: Map showing the location of sampling sites (47-48).

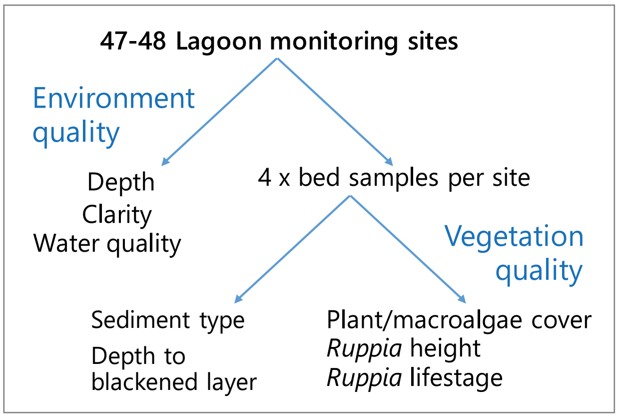


Figure 3b: Sampling design diagram.

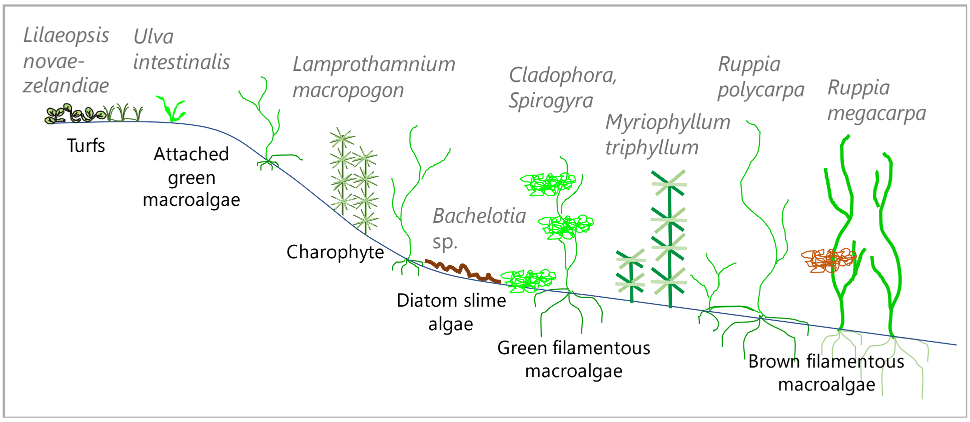


Figure 4: Common submerged plants and macroalgae types in Waituna Lagoon.

Did 2023 results achieve ecological targets for Waituna Lagoon?

The results of annual summer monitoring of the submerged vegetation in Waituna Lagoon are analysed and compared to the six ecological targets to track the health of the *Ruppia* community.

Target lagoon closure was achieved in 2023, as it was in 2009, 2010, 2012, 2015, 2016, 2018, 2019 and 2022.

1. Lagoon closure

A closed lagoon over spring and summer (defined as the three months before monitoring) is an ecological target that provides stable conditions for the *Ruppia* growing season (Box 1). Whether the lagoon is closed or open has a strong influence on conditions that affect plants, such as depth, salinity, and temperature.

Prior to the 2023 summer monitoring of *Ruppia*, the lagoon had been closed for 16.6 months (Table 1), having been last opened in September 2021. This closure well exceeds the target for closure of the lagoon (>3 months) and represents the second consecutive year where favourable closed conditions have been provided over the critical spring-summer growth period for *Ruppia* growth and reproduction (Table 1).

Table 1: Months that the lagoon has been closed (positive numbers) or open (negative numbers) prior to each monitoring event. Occasions that the target is met are shown as bold, in highlighted cells.

Year	Months closed before monitoring
2009	**4.7**
2010	**4.6**
2011	-5.6
2012	**4.6**
2013	-3.9
2014	-6.2
2015	**6.2**
2016	**3.2**
2017	1.0
2018	**13.7**
2019	**3.5**
2020	-4.1
2021	-4.8
2022	**4.5**
2023	**16.6**

2. *Ruppia* cover

A healthy *Ruppia* community occupies a large habitat area in Waituna Lagoon. This is measured by calculating the percentage cover of *Ruppia* across all sites in the Lagoon.

The ecological target of >30–60% cover for *Ruppia* across the whole lagoon (Box 1) was met in 2023 (Table 2). This is only the third time this target has been achieved since monitoring began in 2009 (Table 2, Figure 5). All three years that met this target were the second of two consecutive years of lagoon closure during the critical spring-summer growth period for *Ruppia*. *Ruppia* vegetation was recorded at all sites surveyed in 2023 (Table 2, Figure 5), with very high lagoon coverage by vegetation also recorded in 2018 and 2019.

Target lagoon-wide *Ruppia* cover was achieved in 2023, and previously 2019 and 2016.

Note: In these years the lagoon had been closed for two consecutive growing seasons for >3 months.

Table 2: *Ruppia* measurements including % sites, average cover at sites and % sites where >30% cover, and overall averaged lagoon-wide cover. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites where *Ruppia* present	Average cover (sites where present)	% Sites with >30% cover	Lagoon-wide average cover
2009	73	**33**	23	24
2010	52	**31**	21	16
2011	25	7	2	2
2012	60	14	8	9
2013	33	22	13	7
2014	19	16	2	3
2015	70	**29**	23	21
2016	87	**46**	53	**40**
2017	74	12	6	9
2018	100	26	12	26
2019	96	**37**	43	**36**
2020	68	8	4	5
2021	30	9	0	3
2022	72	19	19	13
2023	100	**52**	68	**52**

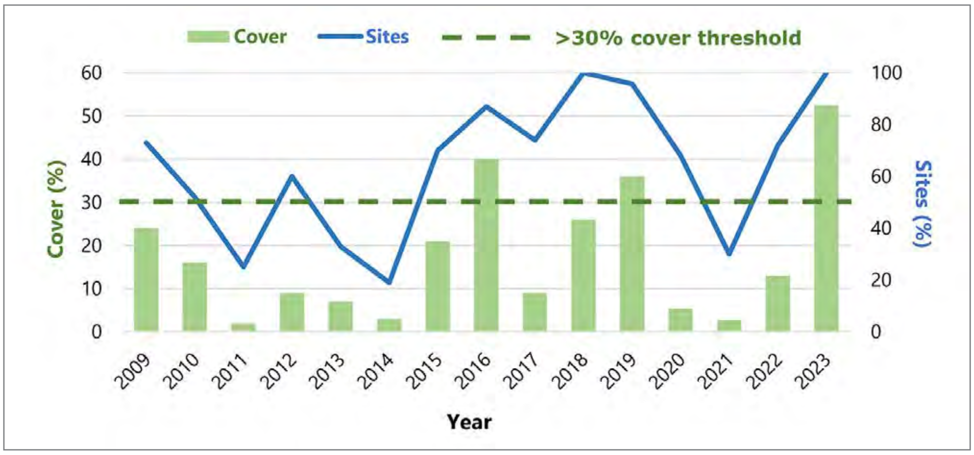


Figure 5: Lagoon-wide cover of *Ruppia* is shown as green bars and percentage of sites at which *Ruppia* was present as a blue line.

3. *Ruppia* biomass index

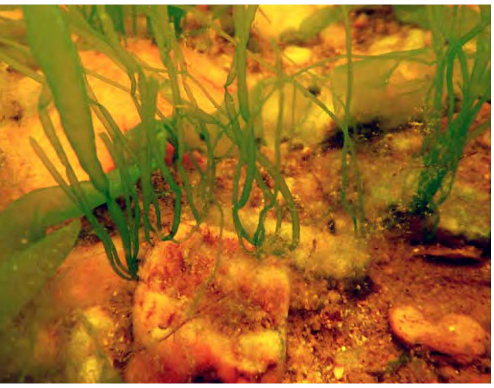
Target lagoon-wide *Ruppia* biomass index was achieved in 2023. Previous years this target was met were 2015, 2016, 2018 and 2019.

Although *Ruppia* biomass is not sampled annually, a proxy for biomass can be derived by multiplying *Ruppia* cover by height as a 'biomass index'. In a healthy *Ruppia* community a biomass index >1000 is expected (Box 1). This might be visualised as a 10% cover of plants that are 100 cm tall or by a 100% cover of plants that are 10 cm tall, and other combinations.

In 2023, the lagoon-wide *Ruppia* biomass index exceeded the target (Table 3). This biomass index was more than twice the previous highest value recorded in 2019 (Table 3). The 2023 monitoring year and four previous years where the target biomass index was achieved were also those years when the lagoon closure target was met (Table 1).

Table 3: *Ruppia* presence at sites, number of sites where target biomass index was achieved and average biomass index calculated lagoon-wide. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites where *Ruppia* present	% Sites with >1000 biomass index	Lagoon-wide average biomass index
2009	73	25	734
2010	52	21	899
2011	25	0	9
2012	60	4	177
2013	33	2	98
2014	19	2	114
2015	70	23	**1252**
2016	87	32	**1362**
2017	75	6	697
2018	100	19	**1324**
2019	96	45	**1872**
2020	68	4	199
2021	30	4	103
2022	72	4	462
2023	100	66	**4246**



Limits for lagoon-wide macroalgae cover were not exceeded in 2023, and also from 2009 to 2012, 2014 and 2018.

4. Macroalgae cover

Nutrient enrichment of waterbodies may result in excessive macroalgae growth that smothers the lake bed and shades *Ruppia* plants. One ecological target (Box 1) recognises that macroalgae on the lagoon bed (benthic), on plants (epiphytic) and floating mats should be no more than minor (<10% cover).

Lagoon-wide average macroalgae cover in 2023 met the target, being <10% (Table 4, Figure 6). This result contrasts with seven out of the previous eight years (2015 to 2022) that had relatively high macroalgae abundance (Table 4, Figure 6). Macroalgal cover (Table 4, Figure 6) has not reflected whether the lagoon closure target was met or not (Table 1).

Table 4: Percentage of sites recording macroalgae, their average cover, percentage of sites achieving <10% cover and average lagoon-wide cover. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites where macroalgae present	Average % cover (sites where present)	Sites with >10% cover (%)	Lagoon-wide average cover (%)
2009	19	17	6	**3**
2010	8	29	6	**2**
2011	17	**3**	0	**<1**
2012	23	16	8	**4**
2013	27	52	19	14
2014	27	17	11	**4**
2015	89	50	70	45
2016	79	36	49	28
2017	64	27	26	17
2018	11	**2**	0	**<1**
2019	89	73	85	66
2020	79	31	32	25
2021	25	28	12	15
2022	85	63	66	54
2023	32	16	9	**5**

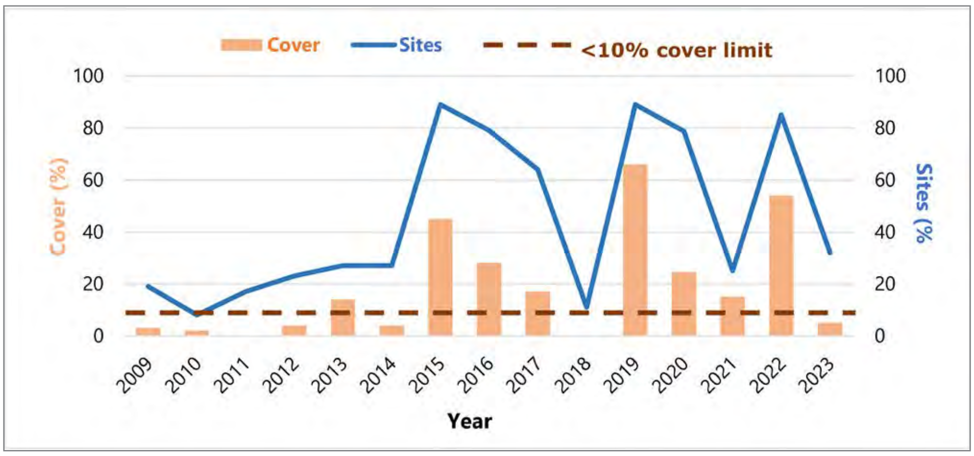


Figure 6: Lagoon-wide cover of macroalgae is shown as orange bars and percentage of sites at which macroalgae was present as a blue line.

The target for *Ruppia* reproductive success was achieved in 2023 and also in 2012, 2015, 2016, 2018 and 2019.

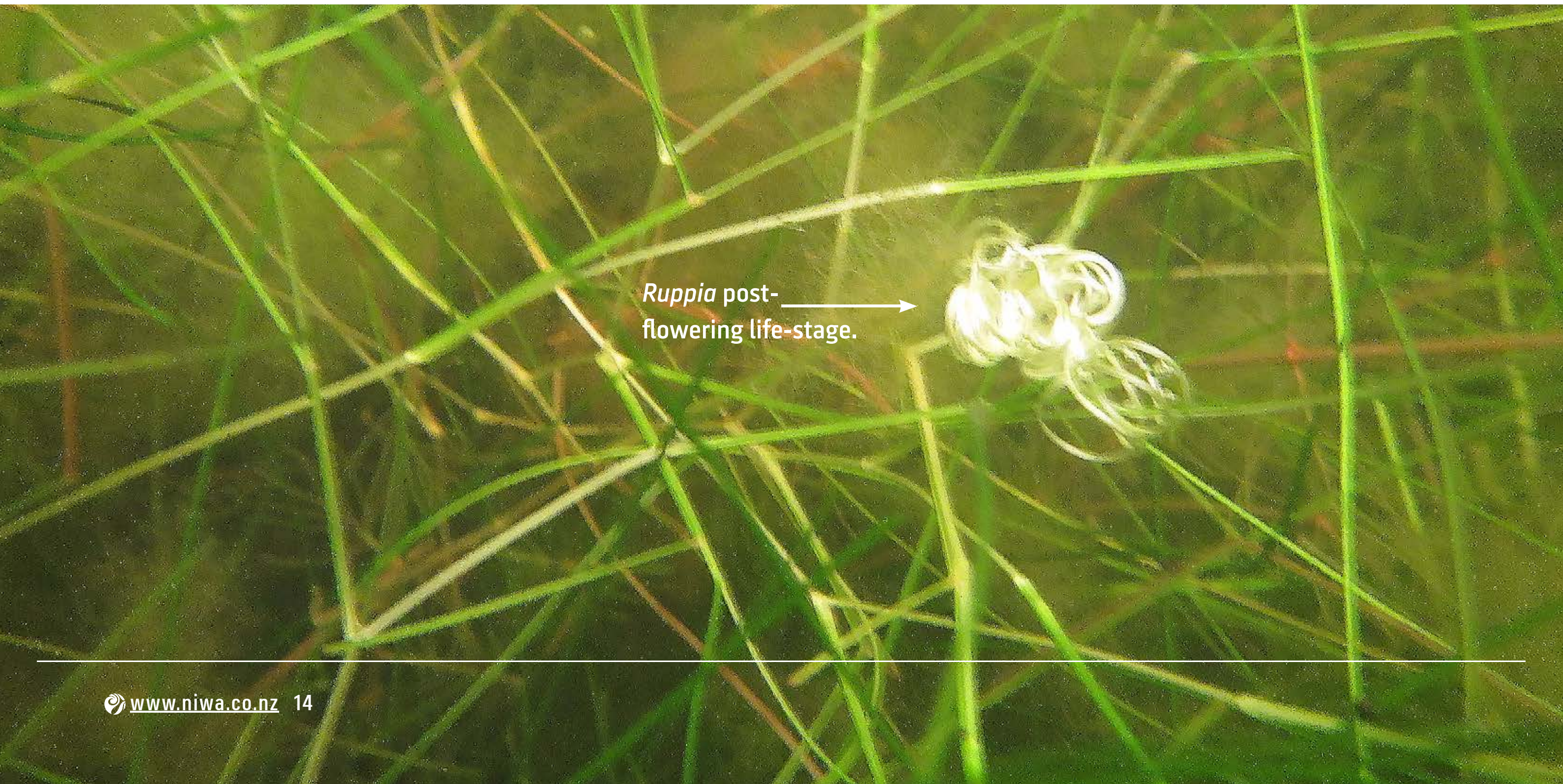
5. *Ruppia* reproductive success

This ecological target focuses on the reproductive success of *Ruppia* and the likely replenishment of the seed bank which is vital for vegetation recovery after any major disturbance (e.g., extended lagoon opening). The target is ≥40% of *Ruppia* samples at sites in a flowering or post-flowering life-stage, to incorporate sites with both *Ruppia* species (*R. polycarpa* and *R. megacarpa*).

The target for reproductive success of *Ruppia* was exceeded in 2023, with almost all of the sampling sites recording flowering or post-flowering plants (Table 5). Seed production observed at the time of the 2023 monitoring suggests a major replenishment of the lagoon seed banks.

Table 5: Percentage of sites recording reproductive success for *Ruppia* as either flowering or post-flowering status. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites recording reproduction
2009	18
2010	32
2011	0
2012	**53**
2013	9
2014	10
2015	**59**
2016	**71**
2017	3
2018	**44**
2019	**46**
2020	6
2021	4
2022	30
2023	**94**



The target for status of *Ruppia megacarpa* was achieved in 2010, 2018, 2019, 2020, 2022 and 2023.

6. Status of *Ruppia megacarpa*

Ruppia megacarpa is associated with taller, denser submerged vegetation in Waituna Lagoon. It acts as a strong 'ecosystem engineer', which subsequently supports the local environment that promotes further vegetation development. The target states ≥20% of the sites should record *R. megacarpa*. A threshold of 20% of sites is recommended because this represents known sampled areas that are favourable for this species[11].

Ruppia megacarpa exceeded the status target in 2023 (Table 6), being present at almost twice the required number of sites. This year, *R. megacarpa* had the most widespread distribution in the lagoon (38% of sites) since monitoring began in 2009 (Table 6).

Table 6: Percentage of sites recording *Ruppia megacarpa*. Occasions the target is met are shown as bold, in highlighted cells.

Year	% sites recording *Ruppia megacarpa*
2009	10
2010	**23**
2011	17
2012	2
2013	6
2014	0
2015	4
2016	9
2017	6
2018	**30**
2019	**32**
2020	**21**
2021	6
2022	**23**
2023	**38**

[11] de Winton, M. (2019) Vegetation Status in Waituna Lagoon: Summer 2019. *NIWA Publication*.

All six ecological targets were achieved in 2023.

Conclusions

Ecological targets in 2023

In 2023, all six ecological targets were achieved (Table 7), indicating a stable and self-sustaining native submerged plant population (Box 1). Widespread plant development, greater diversity of species across the lagoon and highly successful reproduction means the vegetation of Waituna Lagoon is currently in good ecological health.

This monitoring result followed an extended period (>16 months) when the lagoon has been closed, which included two consecutive *Ruppia* growing seasons. It appears that dryer than normal conditions in Southland over recent years have avoided sudden extreme increase and decrease in water level usually associated with a lagoon opening. The consecutive *Ruppia* growing seasons without a lagoon opening have resulted in record measures for four of the *Ruppia* targets in 2023 (Table 7).

Table 7: Summary of 2022 results for all ecological targets.

Ecological target	Targets met?	Comment
Lagoon closure	✓	Lagoon had been closed for two consecutive *Ruppia* growing seasons prior to monitoring.
Ruppia cover	✓	Lagoon-wide *Ruppia* cover exceeded the target (>30% cover) and was the highest cover yet monitored.
Ruppia biomass index	✓	*Ruppia* biomass index exceeded the target (>1000) and was the highest value yet monitored.
Macroalgae cover	✓	Macroalgae development was within the acceptable threshold of 10% cover.
Ruppia reproductive success	✓	The target for reproductive success (≥40% of samples flowered) was exceeded with reproductive Ruppia at almost all sites.
Status of *Ruppia megacarpa*	✓	*Ruppia megacarpa* contributed significantly to lagoon vegetation.

Ecological targets over all monitoring years

- All ecological targets were met in 2023, the first time this has been achieved in all the 15 annual monitoring years (Table 8).
- Years that did not meet the lagoon closure target (closed for 3 months prior to summer monitoring) have achieved the fewest targets (one or none). This occurred for six of the monitoring years (Table 8).
- Higher numbers of targets (≥4) tended to be achieved in the second of consecutive closed lagoon years (Table 8).
- However, the macroalgae cover target (limit of 10% cover) has not shown strong links to lagoon closure target, but exceedance of acceptable limits has been more frequent in later years (Table 8), a possible sign of nutrient enrichment.

Table 8: Summary of results for six ecological targets over all monitoring years. Darker rows indicate greater numbers of targets were met.

Year	Lagoon closure	*Ruppia* cover	*Ruppia* biomass index	Macroalgae cover	*Ruppia* reproductive success	Status of *Ruppia megacarpa*	Targets met
2009	✓	✗	✗	✓	✗	✗	2
2010	✓	✗	✗	✓	✗	✓	3
2011	✗	✗	✗	✓	✗	✗	1
2012	✓	✗	✗	✓	✓	✗	3
2013	✗	✗	✗	✗	✗	✗	0
2014	✗	✗	✗	✓	✗	✗	1
2015	✓	✗	✓	✗	✓	✗	3
2016	✓	✓	✓	✗	✓	✗	4
2017	✗	✗	✗	✗	✗	✗	0
2018	✓	✗	✓	✓	✓	✓	5
2019	✓	✓	✓	✗	✓	✓	5
2020	✗	✗	✗	✗	✗	✓	1
2021	✗	✗	✗	✗	✗	✗	0
2022	✓	✗	✗	✗	✗	✓	2
2023	✓	✓	✓	✓	✓	✓	6

Implications for lagoon health

- Ecological targets for Waituna Lagoon are not met when lagoon openings occur or extend over late spring to summer.
- Two or more consecutive years of openings during the main vegetation growth period should be avoided to ensure *Ruppia* can regenerate successfully.
- At least two consecutive years of a favourable closed lagoon over the main vegetation growth period enable higher *Ruppia* development.
- There may be trade-offs between a stable closed lagoon for good *Ruppia* development and risk of nutrient build-up fuelling macroalgae and phytoplankton blooms.
- Ecological targets for lagoon-wide *Ruppia* cover and biomass index are likely to be met when *Ruppia megacarpa* is more prevalent, due to its ability to form tall, high cover beds.

Summary of technical findings

The accompanying technical report[12] to this summary document outlines that:

- A long lagoon closure that incorporated two consecutive spring-summer growing seasons for *Ruppia* presented extremely favourable conditions for vegetation in Waituna Lagoon and led to record development in 2023.
- Physico-chemical characteristics of the lagoon in 2023 were generally typical of closed lagoon conditions, but Environment Southland monitoring data suggests nutrient concentrations and turbidity have tended to be low and less variable since 2022.
- Lagoon substrates tended to be softer or more silty in 2023, but remained generally oxygenated and 'healthy'.
- Macroalgae development remained low in 2023, following high prevalence over most of the previous eight years.
- Macroalgae patterns show drivers other than lagoon mouth status are important. We note that low algal development was associated with drought conditions in 2018 and 2023, but not drought conditions in 2022.
- Monitoring results in 2023 detected a very successful reproduction event for *Ruppia* species and indicate a substantial replenishment of seed banks that will contribute to plant recovery following future lagoon openings.

A long annual monitoring dataset over 15 years shows a strong pattern of greater lagoon vegetation development, species diversity and reproduction success are associated with years where favourable conditions under a closed lagoon status are provided over the critical spring to summer growth period for *Ruppia*. Ecological health of the lagoon can be protected by careful management of future lagoon openings in addition to safeguarding the system from excessive nutrient and sediment loads.

[12] de Winton, M., Zabarte-Maeztu I., Taumoepeau, A. (2023) Technical Report on Vegetation Status in Waituna Lagoon: 2009–2023. *NIWA Publication.*

Glossary

Term	Definition
Benthic	Relating to, or occurring at the bottom of a body of water.
Biomass index	An indicator of biomass for *Ruppia* species that is based on multiplying measured cover (%) by height (cm).
Catchment	The area of land bounded by watersheds draining into a basin.
Charophyte	A group of freshwater algae that superficially resemble higher submerged plants in that they are anchored to the substrate and have stems and whorls of 'branchlets'.
Ecosystem engineer	An organism that creates, significantly modifies, maintains or destroys a habitat.
Ecosystem health	A way to describe the state of a system relative to a desired management target or reference condition.
Epiphytic	Living on the surface of plants.
Life-stage	Stages in form and function through which an organism passes during its lifespan that include reproductive status.
Macroalgae	Collective term used for seaweeds and other benthic marine or freshwater algae that are generally visible to the naked eye.
Resource consent	Official permission to carry out an operation that has an environmental impact.
Run-off	The draining away of water (or substances carried in it) from the surface of an area of land.
Submerged vegetation	Plants that grow entirely beneath the surface of the water, except for flowering parts in some species, including charophytes but excluding macroalgae.

Referral links

- Awarua-Waituna Wetlands: (doc.govt.nz)
- Land, Air, Water Aotearoa (LAWA) – Waituna Lagoon
- Waituna Lagoon • Living Water
- Home – Whakamana te Waituna
- Awarua Waituna Lagoon – National Wetland Trust | Learn More

Department of Conservation
Te Papa Atawhai

NIWA
Taihoro Nukurangi





Vegetation Status in Waituna Lagoon: Summer 2024

Department of Conservation
Te Papa Atawhai

NIWA
Taihoro Nukurangi

Vegetation Status in Waituna Lagoon: Summer 2024



This report was commissioned by The Department of Conservation (DOC) and based on work under Project DOC24203.

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Layout: Aarti Wadhwa – Spectra Design Ltd (rt@spectradesign.co.nz)

Contents

DOC commissioned NIWA to undertake the 2024 summertime Waituna Lagoon survey to document the health of submerged vegetation and to provide an inter-annual comparison of its condition. This report summarises the key findings to guide further ecological management of the lagoon.

Key findings

Monitoring results for submerged vegetation in Waituna Lagoon are compared to six ecological targets (in bold below). In 2024, only one target was met;

- The target for **macroalgae cover** was achieved, being within the limit of <10% cover lagoon-wide. This is the second consecutive year of low summer macroalgae abundance.

Four targets relating to *Ruppia* status and one target relating to lagoon status were not achieved;

- Measures of lagoon-wide ***Ruppia* cover** and ***Ruppia* biomass index** were amongst the lowest values on record since 2009 and well below target levels.
- Targets for ***Ruppia* reproductive success** and ***Ruppia megacarpa* status** were not met, with measures of zero.
- The target for **lagoon closure** was not met, due to an emergency summer opening to disrupt a toxic algal bloom (cyanobacteria).

According to Environment Southland's water quality data, conditions for submerged vegetation growth were poor for months before the summer lagoon opening. The timing of declines in *Ruppia* abundance is unknown and may have started before the summer opening.

Signs of *Ruppia* germination from the seedbank were seen during the 2024 vegetation monitoring. The *Ruppia* seed bank is expected to be abundant after a very successful reproduction event in summer 2023 and vegetation recovery expected to proceed under usual lagoon conditions.

Purpose of this report

This report presents the 2024 annual summer monitoring data for submerged vegetation in Waituna Lagoon in relation to ecological targets that have been identified by the Lagoon Technical Group to guide ecological management. Results are compared to annual monitoring results since 2009.

Waituna Lagoon is an internationally important example of a coastal waterbody that remains in good ecological condition.

Background

The importance of Waituna Lagoon

Waituna Lagoon on the south coast of New Zealand is included within a Ramsar Wetland of International Importance. The Lagoon is of cultural significance to Ngāi Tahu recognised by a Statutory Acknowledgement under the Ngāi Tahu Claims Settlement Act 1998[1]. It is also significant for conservation of biological diversity and as a key recreational site.

The Department of Conservation has been monitoring submerged aquatic plants (including *Ruppia* spp.) in Waituna Lagoon since 2007 under the Arawai Kākāriki Wetland Restoration Programme.

Coastal lowland lakes like Waituna Lagoon are impacted by changes in land use in the catchment including sediment and nutrient loads from upstream run-off. It is now rare to find coastal lowland lakes with an intact ecological condition, but Waituna Lagoon remains highly valued for its associated plant, wetland, fish and birdlife.

[1] Ngāi Tahu Claims Settlement Act 1998 No. 97 (as at 23 May 2008), Public Act Schedule 73 Statutory acknowledgement for Waituna Wetland – New Zealand Legislation.

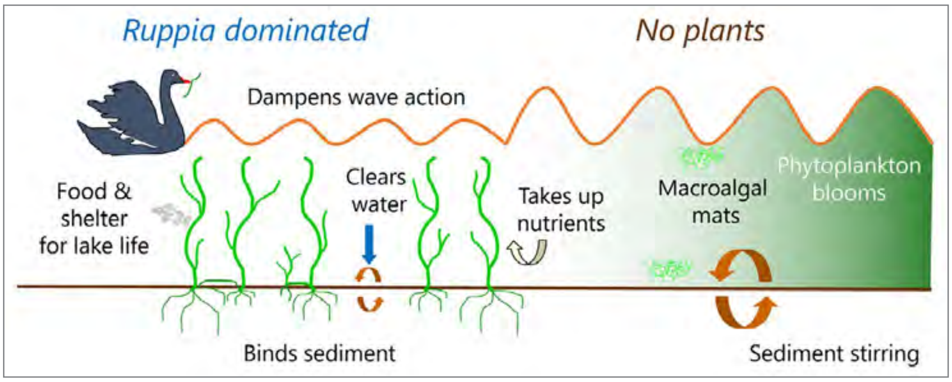
Ruppia safeguards the lagoon

When *Ruppia* grows densely in Waituna Lagoon it protects water quality, dampens wave action and stops the bed being stirred up.

Risk of Waituna Lagoon shifting to a poor ecological condition

Submerged plants have an important role in keeping shallow lakes and lagoons clean and healthy (Figure 1). If submerged plant communities become too stressed, they can collapse. The lake or lagoon then enters a new, dirty water state, with high levels of resuspended sediment and development of macroalgal mats or phytoplankton blooms instead of plants. The submerged native plant species of *Ruppia* (horse's mane) safeguard water quality in Waituna Lagoon. *Ruppia* tolerates fluctuating levels of saltwater in lagoons better than other submerged plants, but does not occur in the sea. Other plants, including a nationally rare, salinity-tolerant charophyte, also occur at Waituna Lagoon.

Figure 1: *Ruppia* vegetation can safeguard water quality in the lagoon compared to a system with no plants.



Management of water level at Waituna Lagoon

Agencies, community and iwi are working together to manage and protect Waituna Lagoon. When water levels in the lagoon rise too high for land drainage, the management response has been to mechanically open the lagoon to the sea. Lagoon openings are usually undertaken once or twice a year to prevent catchment flooding and to flush nutrients from the lagoon, but lagoon closing only occurs naturally under certain sea conditions.

Management of these artificial openings is increasingly taking into account the Lagoon's ecology. The timing and length of openings ideally should not negatively impact on the survival of *Ruppia* and other vegetation. This requires managing openings to avoid critical periods in the life-history of *Ruppia* including spring to summer growth and seed production.

Previously, the lagoon had been opened to the sea once the water level of Waituna Lagoon reached a certain trigger level[2], which varied at different times of the year and had associated conditions. The coastal permit to open the lagoon expired in 2022. More recently, the optimal Resource Consent conditions for the ecological and cultural health of the lagoon ecosystem were assessed by an expert technical panel[3] as a step towards better management of lagoon openings.

[2] Resource Consent 20146407-01, 14 February 2017.

[3] Robertson, H.A., Ryder, G., Atkinson, N., Ward, N., Jenkins, C., de Winton, M., Kitson, J., Schallenberg, M., Holmes R. (2021) Review of conditions for opening Waituna Lagoon. Supporting Information. Prepared for Whakamana Te Waituna. 29 pp.

What do openings mean for conditions in Waituna Lagoon?

Monitoring of the waters of Waituna Lagoon over time[4] has built up a picture of the key changes caused by opening events[5]. Water level is lower and salinity higher when the lagoon is open and temperature and nutrient concentrations are both reduced with flushing by the sea (Figure 2). These changes and their duration influence the vegetation of Waituna Lagoon.

Figure 2: Key changes in the waters of Waituna Lagoon with time after opening or closing to the sea.

Natural lagoon level

Once, Waituna Lagoon would have naturally breached to the sea after several years of filling with freshwater. Today it is regularly opened and infiltrated by the sea.

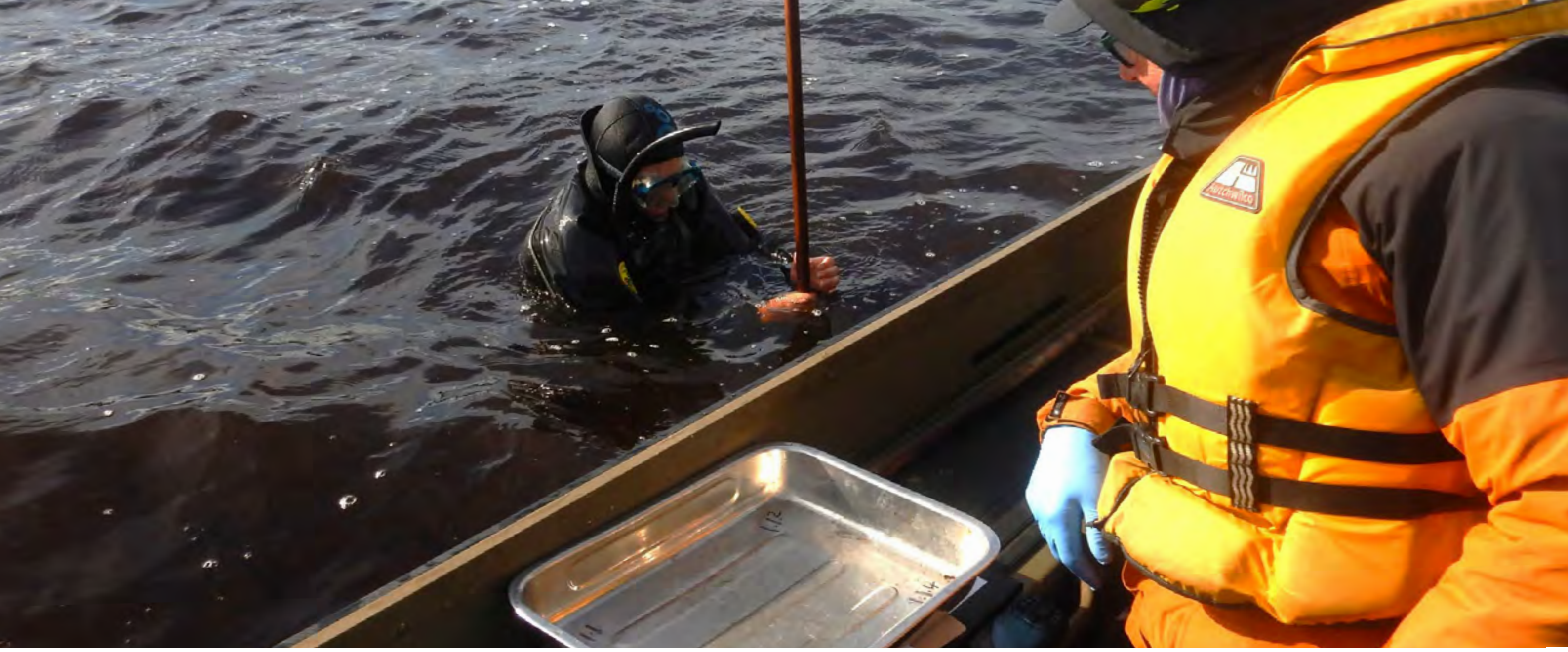
Catchment management

Agencies and the community aim to reduce sediment and nutrient inputs to Waituna Lagoon, focusing on strategies and initiatives for catchment management of contaminants, increasing biological processing of run-off and improving freshwater habitat. It is essential that these efforts meet the nutrient load reduction targets developed by the Lagoon Technical Group in 2013[6] to ensure the long-term persistence of *Ruppia* vegetation and safeguard the lagoon ecosystem. However, opening the lagoon to disrupt algal blooms provides a short-term solution for the ecological health of the lagoon.

[4] https://www.lawa.org.nz/explore-data/southland-region/lakes/waituna-lagoon/

[5] de Winton, M., Mouton, T. (2018) Technical Report on Vegetation Status in Waituna Lagoon: 2009–2018.

[6] Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon. *Report prepared for Environment Southland.*



What do we monitor?

Ruppia

Ruppia acts as an ecological sentinel in Waituna Lagoon, providing an early-warning system to detect deterioration. Department of Conservation oversee the monitoring of *Ruppia* and other aquatic plants and algae to determine status and trends in ecological health of the Lagoon. Monitoring supports specific resource consent conditions for lagoon opening, where opening avoids the spring to summer growth and reproduction phase for *Ruppia* although opening decisions at a lower water level may be acceptable where vegetation has been stable (key ecological targets met for a number of years), or where poor water clarity is likely to have an adverse ecological effect if the lagoon isn't opened and flushed.

Results of annual monitoring are compared with target conditions sought under the Ecological Guidelines[7] for Waituna Lagoon. Two additional targets were suggested by an analysis of all monitoring data in 2018[8]. These ecological targets are listed in Box 1.

Box 1: Ecological targets for *Ruppia* in Waituna Lagoon:

- Lagoon closed during *Ruppia* growing season (spring and summer).
- ▪>30–60% for average % cover of *Ruppia* (and other native macrophytes[9]).
- <10% cover of benthic and epiphytic filamentous algae (macroalgae).
- ▪>1000 average for *Ruppia* 'biomass index' (% cover x cm height).
- ≥40% of *Ruppia* samples in a flowering or post-flowering life-stage.
- ≥20% of the sites record *Ruppia megacarpa*.

[7] Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon. *Report prepared for Environment Southland*.

[8] de Winton, M., Mouton, T. (2018) Technical Report on Vegetation Status in Waituna Lagoon: 2009–2018.

[9] Other native macrophytes comprised <35% of all occurrence records for all surveys.

Monitoring methods

The lagoon is monitored each year in late summer at 47-48 sites (Figure 3a). At each site, an assessment of environmental quality includes depth and water quality measurements (Figure 3b). Substrate characteristics are measured in four samples of the lagoon bed retrieved using a garden hoe, and the composition and abundance of vegetation is also described, including *Ruppia* life-stage as flowering or vegetative. Submerged native plants and dominant macroalgae are shown in Figure 4.

Figure 3a: Map showing the location of sampling sites (47-48).

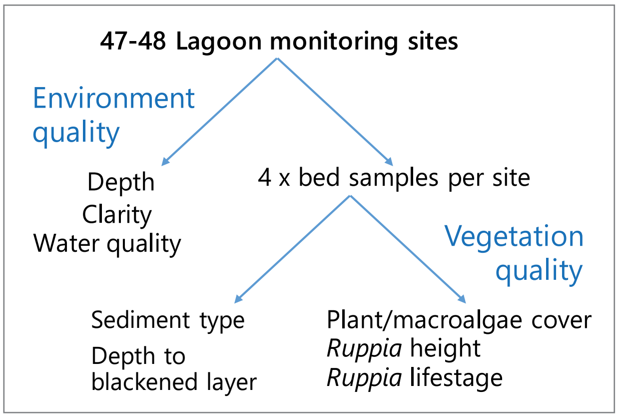


Figure 3b: Sampling design diagram.

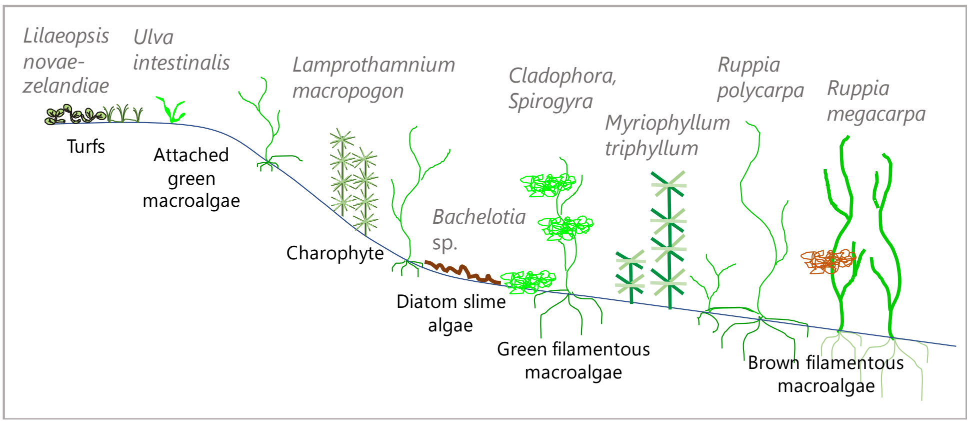


Figure 4: Common submerged plants and macroalgae types in Waituna Lagoon.

Did 2024 results achieve ecological targets for Waituna Lagoon?

The results of annual summer monitoring of the submerged vegetation in Waituna Lagoon are analysed and compared to the six ecological targets to track the health of the *Ruppia* community.

Target lagoon closure was not achieved in 2024, nor was it in 2021, 2020, 2017, 2014, 2013 and 2011.

1. Lagoon closure

A closed lagoon over spring and summer (defined as the three months before monitoring) is an ecological target that provides stable conditions for the *Ruppia* growing season (Box 1). Whether the lagoon is closed or open has a strong influence on conditions that affect plants, such as depth, salinity, and temperature.

In 2024, the lagoon closure target was not met (Table 1). Over summer 2024, the lagoon was opened to the sea by Environment Southland under emergency works powers, to disrupt a toxic algal bloom (cyanobacteria). This resulted in the lagoon remaining open for two months and it closed just 15 days before the *Ruppia* monitoring. Therefore, closed conditions were not achieved over the critical spring-summer growth period for *Ruppia* growth and reproduction (Table 1).

Table 1: Months that the lagoon has been closed (positive numbers) or open (negative numbers) prior to each monitoring event. Occasions that the target is met are shown as bold, in highlighted cells.

Year	Months closed before monitoring
2009	**4.7**
2010	**4.6**
2011	-5.6
2012	**4.6**
2013	-3.9
2014	-6.2
2015	**6.2**
2016	**3.2**
2017	1.0
2018	**13.7**
2019	**3.5**
2020	-4.1
2021	-4.8
2022	**4.5**
2023	**16.6**
2024	0.5

The target lagoon-wide *Ruppia* cover was not achieved in 2024, and previously has only been achieved in 2023, 2019 and 2016.

2. *Ruppia* cover

A healthy *Ruppia* community occupies a large habitat area in Waituna Lagoon. This is measured by calculating the percentage cover of *Ruppia* across all sites in the Lagoon. The ecological target is >30–60% cover for *Ruppia* across the whole lagoon (Box 1).

In 2024, lagoon-wide cover of *Ruppia* was only 2% (Table 2) and did not meet the ecological target. *Ruppia* was recorded at fewer than half of the monitoring sites and cover exceeded 30% at only one site. The occasions when the *Ruppia* cover target has been met are shown as bold, in highlighted cells in Table 2. The years 2016, 2019 and 2023 that met this target (Table 2, Figure 5) were the second of two consecutive years of lagoon closure during the critical spring-summer growth period for *Ruppia*.

Table 2: *Ruppia* measurements including % sites, average cover at sites and % sites where >30% cover, and overall averaged lagoon-wide cover. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites where *Ruppia* present	Average cover (sites where present)	% Sites with >30% cover	Lagoon-wide average cover
2009	73	**33**	23	24
2010	52	**31**	21	16
2011	25	7	2	2
2012	60	14	8	9
2013	33	22	13	7
2014	19	16	2	3
2015	70	**29**	23	21
2016	87	**46**	53	**40**
2017	74	12	6	9
2018	100	26	12	26
2019	96	**37**	43	**36**
2020	68	8	4	5
2021	30	9	0	3
2022	72	19	19	13
2023	100	**52**	68	**52**
2024	40	6	2	2

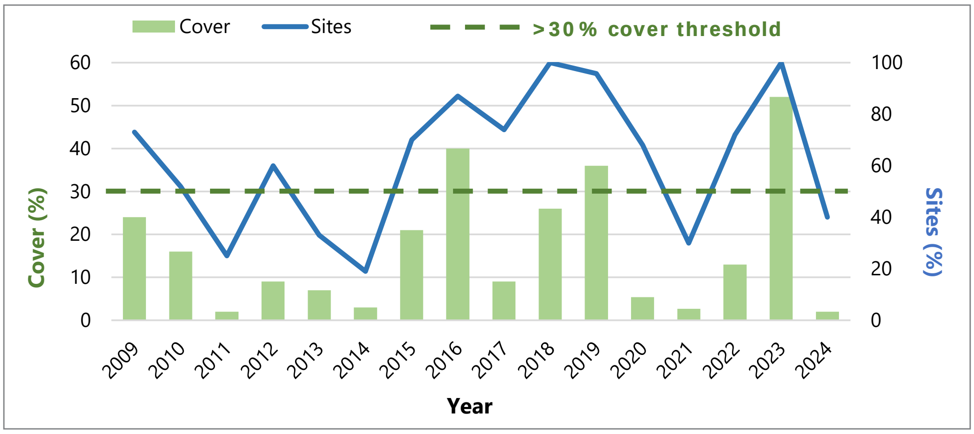


Figure 5: Lagoon-wide cover of *Ruppia* is shown as green bars and percentage of sites at which *Ruppia* was present as a blue line.

3. *Ruppia* biomass index

Although *Ruppia* biomass is not sampled annually, a proxy for biomass can be derived by multiplying *Ruppia* cover by height as a 'biomass index'. In a healthy *Ruppia* community a biomass index >1000 is expected (Box 1). This might be visualised as a 10% cover of plants that are 100 cm tall or by a 100% cover of plants that are 10 cm tall, and other combinations.

Target lagoon-wide *Ruppia* biomass index was not achieved in 2024. Previous years this target was met were 2015, 2016, 2018, 2019 and 2023.

In 2024, *Ruppia* biomass index over 1000 was not recorded at any of the sites and the lagoon-wide target was not achieved (Table 3). The biomass index averaged across the lagoon was one of the lowest values recorded (Table 3).

To date, the years where the target biomass index has been achieved are also those when the lagoon closure target has been met (Table 1). In addition, consecutive years of meeting the lagoon closure target have resulted in higher values in the second year (2015–2016, 2018–2019, 2022–2023).

Table 3: *Ruppia* presence at sites, number of sites where target biomass index was achieved and average biomass index calculated lagoon-wide. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites where *Ruppia* present	% Sites with >1000 biomass index	Lagoon-wide average biomass index
2009	73	25	734
2010	52	21	899
2011	25	0	9
2012	60	4	177
2013	33	2	98
2014	19	2	114
2015	70	23	**1252**
2016	87	32	**1362**
2017	75	6	697
2018	100	19	**1324**
2019	96	45	**1872**
2020	68	4	199
2021	30	4	103
2022	72	4	462
2023	100	66	**4246**
2024	40	0	53

Limits for lagoon-wide macroalgae cover were met in 2024, and also from 2009 to 2012, 2014, 2018 and 2023.

4. Macroalgae cover

Nutrient enrichment of waterbodies may result in excessive macroalgae growth that smothers and shades *Ruppia* plants. One ecological target (Box 1) recognises that macroalgae on the lagoon bed (benthic), on plants (epiphytic) and floating mats should be no more than minor (<10% cover).

In 2024, the target for macroalgae cover was met (Table 4) and this year was one of the lowest values yet recorded. It is the second year in a row the target has been met, following four years (2019–2022) of high summer macroalgal development (Table 4, Figure 6). There is no pattern of high or low macroalgal development with the status of the lagoon closure target (Table 1).

Table 4: Percentage of sites recording macroalgae, their average cover, percentage of sites achieving <10% cover and average lagoon-wide cover. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites where macroalgae present	Average % cover (sites where present)	Sites with >10% cover (%)	Lagoon-wide average cover (%)
2009	19	17	6	**3**
2010	8	29	6	**2**
2011	17	**3**	0	**<1**
2012	23	16	8	**4**
2013	27	52	19	14
2014	27	17	11	**4**
2015	89	50	70	45
2016	79	36	49	28
2017	64	27	26	17
2018	11	**2**	0	**<1**
2019	89	73	85	66
2020	79	31	32	25
2021	25	28	12	15
2022	85	63	66	54
2023	32	16	9	**5**
2024	13	**<1**	0	**<1**

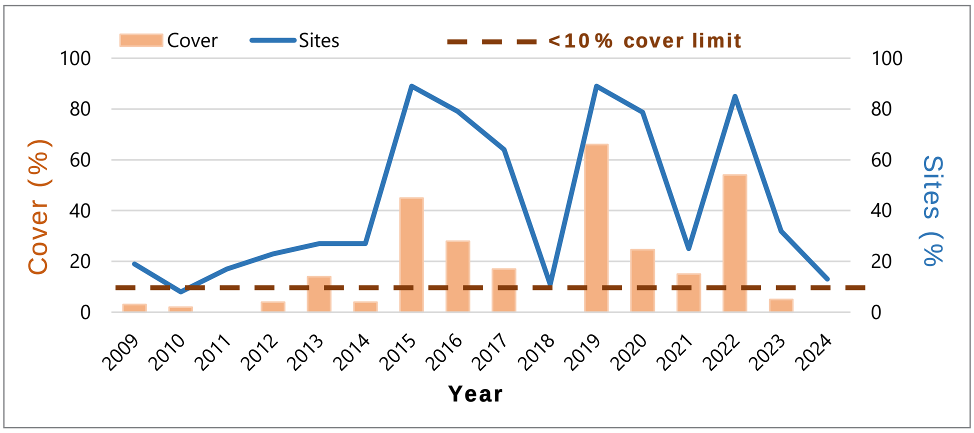
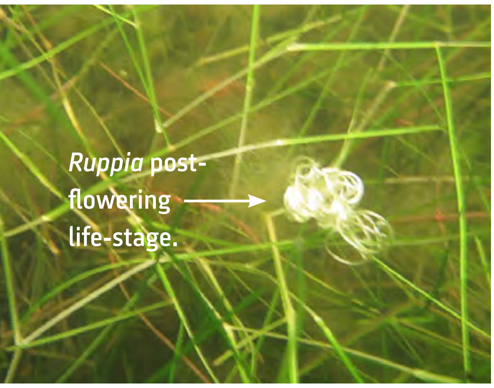


Figure 6: Lagoon-wide cover of macroalgae is shown as orange bars and percentage of sites at which macroalgae was present as a blue line.



5. *Ruppia* reproductive success

This ecological target focuses on the reproductive success of *Ruppia* and the likely replenishment of the seed bank which is vital for vegetation recovery after any major disturbance (e.g., extended lagoon opening). The target is ≥40% of *Ruppia* samples at sites in a flowering or post-flowering life-stage, to incorporate sites with both *Ruppia* species (*R. polycarpa* and *R. megacarpa*).

The reproductive success target was not achieved in 2024 (Table 5). All *Ruppia* plants that were surveyed were vegetative. This year follows the results in 2023 when a very high reproductive success was observed (Table 5).

Table 5: Percentage of sites recording reproductive success for *Ruppia* as either flowering or post-flowering status. Occasions the target is met are shown as bold, in highlighted cells.

Year	% Sites recording reproduction
2009	18
2010	32
2011	0
2012	**53**
2013	9
2014	10
2015	**59**
2016	**71**
2017	3
2018	**44**
2019	**46**
2020	6
2021	4
2022	30
2023	**94**
2024	0

The target for *Ruppia* reproductive success was not met in 2024, but was earlier met in 2012, 2015, 2016, 2018, 2019 and 2023.

6. Status of *Ruppia megacarpa*

Ruppia megacarpa is associated with taller, denser submerged vegetation in Waituna Lagoon. It acts as a strong 'ecosystem engineer', which subsequently supports the local environment that promotes further vegetation development. The target states ≥20% of the sites should record *R. megacarpa*. A threshold of 20% of sites is recommended because this represents known sampled areas that are favourable for this species[10].

Ruppia megacarpa was not recorded in 2024 and the target was not met (Table 6). This follows 2023 as the year *R. megacarpa* had the most widespread distribution recorded in the lagoon (Table 6).

The target for status of *Ruppia megacarpa* was not met in 2024 but was achieved in five of the previous six years.

Table 6: Percentage of sites recording *Ruppia megacarpa*. Occasions the target is met are shown as bold, in highlighted cells.

Year	% sites recording *Ruppia megacarpa*
2009	10
2010	**23**
2011	17
2012	2
2013	6
2014	0
2015	4
2016	9
2017	6
2018	**30**
2019	**32**
2020	**21**
2021	6
2022	**23**
2023	**38**
2024	0

[10] de Winton, M. (2019) Vegetation Status in Waituna Lagoon: Summer 2019. *NIWA Publication*.

Conclusions

Ecological targets in 2024

One ecological target was achieved in 2024, out of the six targets.

In 2024, just one of the six ecological targets was achieved (Table 7). This was the **macroalgae cover** target that reflected very low abundance of macroalgae, being within the acceptable limit for the lagoon.

Failure to achieve further targets reflected the poor ecological conditions apparent in the lagoon during the 2023/24 summer. A toxic algal bloom (cyanobacteria) saw the lagoon opened by Environment Southland under emergency powers with the aim of preventing imminent, severe ecological harm. The lagoon remained open for two months and at the time of monitoring, the lagoon had been closed for just 15 days. Therefore, the **Lagoon closure** target was not met (Table 7). Moreover, none of the four *Ruppia*-related targets were met (Table 7), suggesting conditions stemming from the bloom and/or the summer opening were detrimental to persistence of the submerged vegetation.

The toxic algal bloom delayed vegetation monitoring by c. 1 to 2 months due to health concerns, however, seasonality would not explain the low abundance of *Ruppia* in 2024. Earlier monitoring[11] established that *Ruppia* vegetation is perennial if lagoon conditions permit.

Table 7: Summary of 2024 results for all ecological targets.

Ecological target	Targets met?	Comment
Lagoon closure	✗	Lagoon was opened for two months over the summer *Ruppia* growing season.
Ruppia cover	✗	Lagoon-wide *Ruppia* cover did not meet the target (>30% cover).
Ruppia biomass index	✗	*Ruppia* biomass index did not meet the target (>1000).
Macroalgae cover	✓	Macroalgae development did not exceed the limit of 10% cover.
Ruppia reproductive success	✗	All *Ruppia* recorded was vegetative.
Status of *Ruppia megacarpa*	✗	No *Ruppia megacarpa* was recorded.

[11] de Winton, M., Mouton, T. 2018. Seasonal monitoring of submerged vegetation at Waituna Lagoon: 2014 to 2017. *NIWA Client Report* No: 2018284HN, prepared for Department of Conservation. 32 pp.

Ecological targets over all monitoring years

- Only one ecological target was met in 2024 (Table 8). Similar poor performance against targets (one or none achieved) has been recorded in six previous years (Table 8).
- These seven occasions when only one or no targets have been met (Table 8) were also those years that did not meet the lagoon closure target (closed for 3 months prior to summer monitoring).
- Higher numbers of targets (≥4) tended to be achieved in the second of consecutive closed lagoon years (Table 8).
- The target of macroalgae cover (limit of <10% cover) has not shown strong links to lagoon closure target (Table 8).

Table 8: Summary of results for six ecological targets over all monitoring years. Darker rows indicate greater numbers of targets were met.

Year	Lagoon closure	*Ruppia* cover	*Ruppia* biomass index	Macroalgae cover	*Ruppia* reproductive success	Status of *Ruppia megacarpa*	Targets met
2009	✓	✗	✗	✓	✗	✗	2
2010	✓	✗	✗	✓	✗	✓	3
2011	✗	✗	✗	✓	✗	✗	1
2012	✓	✗	✗	✓	✓	✗	3
2013	✗	✗	✗	✗	✗	✗	0
2014	✗	✗	✗	✓	✗	✗	1
2015	✓	✗	✓	✗	✓	✗	3
2016	✓	✓	✓	✗	✓	✗	4
2017	✗	✗	✗	✗	✗	✗	0
2018	✓	✗	✓	✓	✓	✓	5
2019	✓	✓	✓	✗	✓	✓	5
2020	✗	✗	✗	✗	✗	✓	1
2021	✗	✗	✗	✗	✗	✗	0
2022	✓	✗	✗	✗	✗	✓	2
2023	✓	✓	✓	✓	✓	✓	6
2024	✗	✗	✗	✓	✗	✗	1

Implications for lagoon health

- Widespread plant development across the lagoon plant diversity and successful reproduction according to identified targets indicate Waituna Lagoon's vegetation is in good ecological health.
- Ecological targets for Waituna Lagoon are not met when lagoon openings occur or extend over late spring to summer.
- Two or more consecutive years of openings during the main vegetation growth period should be avoided to ensure *Ruppia* can regenerate successfully.
- At least two consecutive years of a favourable closed lagoon over the main vegetation growth period enable higher *Ruppia* development.
- Ecological targets for lagoon-wide *Ruppia* cover and biomass index are likely to be met when *Ruppia megacarpa* is more prevalent, due to its ability to form tall, high cover beds.
- A 'super-fruiting' event for *Ruppia* in 2023 will have replenished the seed bank and will improve vegetation establishment potential.
- There are trade-offs between a stable closed lagoon for good *Ruppia* development and risk of nutrient build-up fuelling macroalgae and phytoplankton blooms.
- The need to address severe phytoplankton blooms by emergency openings should be a priority over the risk for *Ruppia*, as extended blooms are also likely to impact on vegetation.
- Drivers for phytoplankton blooms, as occurred in 2024, do not appear to be the same as for macroalgal blooms. Alternatively, macroalgae development is deleteriously impacted by phytoplankton blooms.

Related information

A deterioration in water quality was reported for Waituna Lagoon over mid-2023 to summer 2024[12]. Nutrient levels and phytoplankton pigments increased from June 2023, a cyanobacteria bloom (reaching record levels) developed from December 2023, and low water clarity resulting in restricted light penetration into the lagoon. These factors would represent stresses for submerged vegetation even before the lagoon was opened in summer. Therefore, we cannot determine if a vegetation decline preceded the lagoon opening or was subsequent, or both. Regardless, the large decline in *Ruppia* vegetation by summer 2024, directly after its substantial development in summer 2023, shows this ecological system remains unstable and vulnerable.

The artificial opening of the lagoon in 2024 was in the eastern sector for the first time during the 16 years of vegetation monitoring. Once the lagoon was open, the public warning for the toxic algal bloom was removed within 1.5 months and other water quality parameters were seen to improve. The lagoon closed after 2 months, 15 days before the vegetation monitoring.

Vegetation monitoring less than one month after the lagoon closed showed most of the remnant *Ruppia* vegetation in the south-west sector of the lagoon, away from the eastern lagoon opening site. When the lagoon has been opened at the previous south-west site, remnant vegetation has tended to persist at the eastern sector.

New seedlings of *Ruppia* were seen during monitoring. Vegetation recovery is expected to proceed from the seedbank following its replenishment by successful fruiting in 2023, under usual lagoon conditions. If the algal bloom had not been disrupted by a lagoon opening, poor conditions for *Ruppia* recovery would have continued through the summer and retarded germination.

[12] Monitored by Environment Southland.

Glossary

Term	Definition
Benthic	Relating to, or occurring at the bottom of a body of water.
Biomass index	An indicator of biomass for *Ruppia* species that is based on multiplying measured cover (%) by height (cm).
Catchment	The area of land bounded by watersheds draining into a basin.
Charophyte	A group of freshwater algae that superficially resemble higher submerged plants in that they are anchored to the substrate and have stems and whorls of 'branchlets'.
Ecosystem engineer	An organism that creates, significantly modifies, maintains or destroys a habitat.
Ecosystem health	A way to describe the state of a system relative to a desired management target or reference condition.
Epiphytic	Living on the surface of plants.
Life-stage	Stages in form and function through which an organism passes during its lifespan that include reproductive status.
Macroalgae	Collective term used for seaweeds and other benthic marine or freshwater algae that are generally visible to the naked eye.
Resource consent	Official permission to carry out an operation that has an environmental impact.
Run-off	The draining away of water (or substances carried in it) from the surface of an area of land.
Submerged vegetation	Plants that grow entirely beneath the surface of the water, except for flowering parts in some species, including charophytes but excluding macroalgae.

Referral links

- Awarua-Waituna Wetlands: (doc.govt.nz)
- Land, Air, Water Aotearoa (LAWA) – Waituna Lagoon at Lagoon Centre
- Waituna Lagoon • Living Water
- Home – Whakamana te Waituna

Appendix K: Impacts and Implications of Climate Change on Waituna Lagoon 2019

2019

SCIENCE FOR CONSERVATION SERIES 335

Impacts and implications of climate change on Waituna Lagoon, Southland

Andrew Tait and Petra Pearce

Department of Conservation
Te Papa Atawhai

New Zealand Government

Cover: Waituna Lagoon. *Photo: Mary Beech*.

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CONTENTS

Impacts and implications of climate change on Waituna Lagoon, Southland

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Abstract

Waituna Lagoon, near Invercargill, South Island, New Zealand, is a land-locked freshwater lagoon. It supports a variety of threatened species and is part of the ecologically significant Awarua Wetland Ramsar site. Periodically, the gravel lagoon barrier is manually opened to facilitate drainage of surrounding farmland and flushing of nutrient-rich water, turning the lagoon into an estuarine state until the barrier naturally closes. This report provides an assessment of potential climate change-related impacts on the lagoon, based on existing information. Projected increases in rainfall, freshwater inflows, flood events and inundation of surrounding land over the next several decades are likely to contribute to lower lagoon-bed light levels and higher levels of nutrients and sediment entering the lagoon. Such changes may increase algae growth and inhibit the growth of *Ruppia* spp., desirable native aquatic grasses. Nutrient and sediment inputs are known drivers of lagoon regime shifts (from a desirable macrophyte (freshwater plants)-dominated state to an undesirable algal-dominated state) and are closely linked to declines in water quality. If freshwater inflows increase as predicted, the lagoon will either need to be opened more frequently or the threshold for opening will need to be raised. This raises issues about land use around the lagoon and the long-term sustainability of the current manual opening regime. With ongoing sea level rise, the boundary of the lagoon is likely to shift landward and the intertidal zone is likely to shrink, which may affect wading birds that forage in the intertidal zone. Due to the complexity of the lagoon system, uncertainties about the trajectories of change in climate and sea level and the responses of the lagoon ecosystem, further research and ongoing monitoring is recommended as well as an adaptative management approach. This could include a variety of strategies for managing the lagoon and its biodiversity under both increasing freshwater inflow and saltwater inundation conditions.

Keywords: Waituna Lagoon, climate change, ecological implications, water level management

Tait, A.; Pearce, P. 2019: Impacts and implications of climate change on Waituna Lagoon, Southland. *Science for Conservation 335*. Department of Conservation, Wellington. 26 p.

1. Introduction

1.1 Purpose of this report

This report provides an assessment of potential climate change-related impacts on Waituna Lagoon, Southland, based on existing information. Projected changes in rainfall, air temperature, sea level and freshwater inflows to the end of this century are used to assess potential changes to the lagoon water temperature, water level, lagoon-bed light level and lagoon spatial extent. The ecological and management implications of these projected changes are considered and future research questions are identified and prioritised.

The information arising from this assessment is being provided to Waituna Lagoon stakeholders (Whakamana te Waituna, Living Water, and Arawai Kākāriki) to be used to evaluate the long-term viability of catchment management strategies. The report also provides a case study for rapid desktop assessments of potential climate change impacts on other coastal hydrosystems in New Zealand.

1.2 Climate change impacts on coastal hydrosystems

Coastal hydrosystems (including lagoons, estuaries and wetlands) are particularly susceptible to the impacts of climate change as they will be affected by changes to freshwater inflows, air temperature, rainfall, wind patterns as well as sea level rises (Lundquist et al. 2011; Rodriguez et al. 2017). The response of hydrosystems to these changes will be highly dependent upon the nature of the systems, the local topography and hydrological regimes and the potential for adaptive management interventions.

Recent work in New Zealand has focused on the classification of coastal hydrosystems (Hume et al. 2016) and the identification of climate change-related research gaps and needs in the coastal environment (Kettles & Bell 2016). A principal identified need is for a stocktake of New Zealand information and overseas best practice relevant to climate change impacts on coastal hydrosystems. This study on the impacts and implications of climate change on the Waituna Lagoon, and future work based on a similar methodology, will positively contribute to such a national stocktake.

1.3 Waituna Lagoon

Waituna Lagoon (1350 ha) (Figs 1, 2, 3) is part of the internationally recognised Awarua Wetland Ramsar site (19 500 ha). The lagoon also forms part of the Waituna Wetland Scientific Reserve (Kirk & Lauder 2000). The lagoon is of very high cultural significance for Ngāi Tahu and has important ecological and recreational values (Waituna Lagoon Technical Group 2013).

An initial assessment of the Awarua Wetland Ramsar site confirmed that the ecosystem is likely to undergo significant shifts in composition and habitat quality by 2100 as a result of climate change-related[1] changes in sea level, rainfall, river flows and air and water temperature (Finlayson et al. 2017).

Whakamana te Waituna, a coordinated catchment management effort that aims to maintain and enhance the Waituna Lagoon ecosystem, has been established. This initiative is driven by a partnership between the Department of Conservation (DOC), Environment Southland, Southland District Council, Te Rūnanga o Ngāi Tahu, Fonterra and Te Rūnanga o Awarua.

[1] Workshop on Adapting Wetland Policy and Management for Internationally Important Coastal Wetlands under Climate Change, Brisbane, Australia (31 July – 4 August 2017).

Figure 1. Top: map of the wider area surrounding Waituna Lagoon in Southland, New Zealand. Bottom: aerial photograph of Waituna Lagoon (photo taken when lagoon barrier was open). Source: LINZ.

Whakamana te Waituna also builds on two national freshwater projects DOC is leading in partnership with others: the Living Water[2] programme (a partnership between DOC and Fonterra) which includes the Waituna catchment as well as a number of other estuaries that are downstream of catchments with a high intensity of dairying, and Arawai Kākāriki[3], which encompasses the wider Awarua wetlands, including Waituna Lagoon.

[2] https://www.livingwater.net.nz/

[3] https://www.doc.govt.nz/our-work/arawai-kakariki-wetland-restoration/

Figure 2. Waituna Lagoon in 2015, showing the manually opened gravel barrier in the process of closing by natural wave action. *Photo: Sarah Crump.*

Figure 3. Farmland surrounding Waituna Lagoon in 2015. *Photo: Sarah Crump.*

New Zealand coastal hydrosystems have recently been classified into 11 main types, with Waituna Lagoon assigned the typology of a 'Waituna-type lagoon, sub-class A' (Hume et al. 2016). This type of estuary is reasonably rare, with examples in New Zealand including Lake Ellesmere (Te Waihora), Washdyke and Wainono Lagoons (Canterbury) and Ohuia Lagoon (Hawke's Bay). The distinguishing characteristics of this hydrosystem type are:

- Large (several km^2), shallow (mean depth 2–3 m) coastal lagoons barred from the sea by a barrier or barrier beach (no tidal inflow);

- Typically freshwater, fed by small streams, with brackish pockets in time or space;
- Drainage to the sea is generally by percolation through the barrier;
- Most frequent state is closed to the sea;
- Short-lived openings to the sea occur when water levels build sufficient hydraulic pressure in the lagoon to breach the enclosing barrier, generally due to high river inflows and/or severe storm waves overtopping the barrier;
- Sustained openings to the sea are rare (decadal–century time scales) unless created artificially;
- Tidal inflows may occur for short periods (1–2 tidal cycles) after natural barrier breaches, although recent observations indicate that artificial breaches can result in openings that lead to tidal ingress for up to several weeks (e.g. Lake Ellesmere (Te Waihora));
- Wind waves and wind-induced currents are important agents for water mixing in the lagoon;
- Observations of historical lagoon ridges suggest that these wind-generated agents were even more important in pre-human times when depth and fetch of the waterbodies were greater than today;
- Situated on wave-dominated high-energy mixed sand/gravel coasts;
- Dominant lagoon substrate is very fine sand and mud;
- Sometimes incorrectly labelled as ICOLLs (Intermittently Closed and Opened Lakes and Lagoons, after Haines et al. 2006). However, Waituna barriers typically comprise coarser sediment and are therefore more permeable than those of ICOLLs. This, for most of the time, allows the lake to drain by percolation through the barrier, preventing build-up of water and hydraulic pressure. Hence the barrier breaches less often than in the case of ICOLLs.

The Waituna Lagoon is located within a catchment that has experienced substantial land use intensification over the last century. Large-scale development of the 20 000-ha catchment commenced in the 1960s, and dairy farming and other pastoral land uses now use more than 70% of the total land area in the catchment (Fig. 3). Since the early 20th century, local authorities have periodically opened the Waituna Lagoon to the sea. Initially this was to facilitate a productive trout fishery, but since the 1950s the main driver has been drainage of surrounding farmland which has a high natural water table and poor soil permeability, leading to rapid flooding during periods of heavy rain (Jackson et al. 2001; Johnson & Partridge 1998). Lagoon opening also allows for flushing of the increasingly nutrient-rich lagoon water, helping prevent regime shift to an algae-dominated state with even worse water quality. Currently, a resource consent allows manual opening (via excavation) of the gravel lagoon barrier when the water level at the Waghorns Road bridge staff gauge reaches 2.0 m in winter and 2.2 m in spring, summer and autumn (Measures & Horrell 2013; Walsh et al. 2016). Natural coastal sedimentation processes eventually close the opening, with the process taking anywhere from a couple of weeks to a year depending on sediment supply and wave, tide and wind conditions (Larkin 2013). Figure 4 shows the number of days the lagoon has been open per year since 1972. The Whakamana te Waituna partnership aims to remove land drainage as a reason to open the lagoon and manage opening primarily for ecological purposes (i.e. the drainage of nutrient-rich water).

The current trophic level (which reflects water nutrient concentrations) of the Waituna Lagoon coupled with increased land-use intensification in the catchment has raised concern over the potential for the lagoon to switch from a macrophyte (freshwater plants)-dominated state to an algal-dominated state (Sutherland et al. 2014). A macrophyte-dominated state typically has high biodiversity and aesthetic, recreational and tourist values and is usually the desired state. In contrast, an algal-dominated state can often lead to decreased values and increased risk of toxic blooms. The process by which a lagoon moves from one state to the other can be quite rapid and is termed ‘flipping’. Once a lagoon flips from a macrophyte-dominated to an algal-dominated state it is often difficult to reverse and it becomes the new stable state.

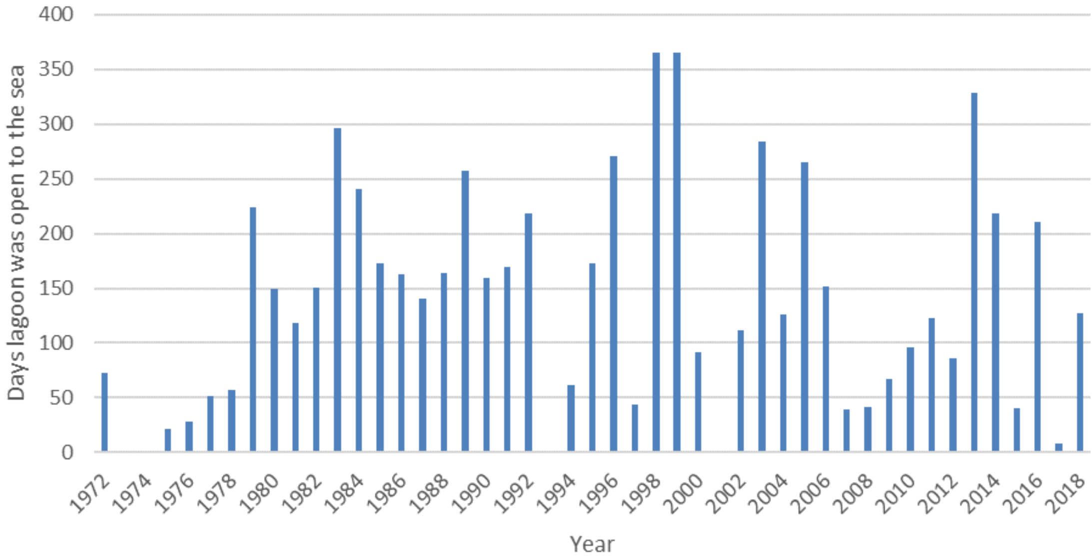

Figure 4. Number of days per year that Waituna Lagoon has been open to the sea since 1972. The days the lagoon is open are sometimes spread over multiple opening events per year. Data source: Environment Southland.

Waituna Lagoon supports beds of the macrophyte ruppia (*Ruppia magacarpa* and *R. polycarpa*), a native freshwater plant that is salt-tolerant (Robertson & Funnell 2012). Ruppia is essential for healthy lagoon functioning, as it holds sediment, absorbs nutrients and releases oxygen. It also creates habitat and a food source for fish and aquatic invertebrates. Ruppia is sensitive to changes in water level and salinity – it requires low salt concentrations during the spring germination period. When the barrier is closed, the lagoon generally has low salinity. However, salinity increases significantly when it is open (Larkin 2013). Therefore, the manual opening regime of the lagoon, which switches it to an estuarine state, threatens the extent of ruppia.

Waituna is an important habitat for waterfowl, migratory birds, coastal birds and native fish. Over 80 different species of birds have been recorded in the Waituna Lagoon and wetland complex, including both internationally and internally migratory waders. A number of nationally threatened species have been recorded in the lagoon area, including the New Zealand dotterel (*Charadrius obscurus*), white heron (*Ardea modesta*), black-fronted tern (*Chlidonias albostriatus*), banded dotterel (*Charadrius bicinctus*) and white-fronted tern (*Sterna striata*) (Rance & Cooper 1997). Some of these birds, such as the eastern bar-tailed godwit (*Limosa lapponica*), migrate from their breeding grounds in western Alaska to seek food in New Zealand during the southern hemisphere summer.

In the past, when the lagoon was open to the sea more frequently, there were considerable intertidal mudflats that provided habitat for waders throughout the year. This key habitat has diminished with build-up of the gravel lagoon barrier. What remain of the intertidal mudflats are therefore particularly important habitat for waders.

Eighteen freshwater and estuarine fish species have been identified in the Waituna catchment and lagoon, including native and introduced species. Common bully (*Gobiomorphus cotidianus*), longfin (*Anguilla dieffenbachia*) and shortfin (*Anguilla australis*) eels, trout, and giant (*Galaxias argenteus*) and banded (*Galaxias fasciatus*) kōkopu have all been found in the catchment (Atkinson 2008).

2. Methodology

This assessment of the impacts of climate change on Waituna Lagoon is based on existing information available in published reports and scientific papers. Primarily, we draw on the climate and sea level rise projections published by the Ministry for the Environment (MfE 2017, 2018) and projections of changes to freshwater inflows to Waituna Lagoon published in Collins & Zammit (2016). Access to these climate and hydrological datasets can be requested by contacting NIWA.

Digital elevation model (DEM) data for the Waituna catchment was derived from LiDAR[4] data and has been made available to DOC under Land Information New Zealand (LINZ) licensing arrangements.

The ecological and water-level management implications of the projected climate change-related impacts are based on current practices, previous modelling results and expert knowledge.

3. Results

3.1 Projected changes to rainfall and temperature

Future projections for climate change were analysed using greenhouse gas emission scenarios, called Representative Concentration Pathways (RCPs), described by the Intergovernmental Panel on Climate Change (IPCC 2013). The four RCPs range from RCP2.6 (strong reduction in global greenhouse gas emissions by 2100) to RCP8.5 (continued growth in emissions at current rates). Six global climate models were downscaled to a 5 km resolution and averaged together to understand potential future changes over New Zealand (MfE 2018).

Mean annual rainfall for Southland is projected to increase by approximately 0–15% (low emissions; RCP2.6) and 5–30% (high emissions, RCP8.5; Fig. 5) by the end of this century, compared with the period 1986–2005 (MfE 2018). For the Waituna catchment, the projected range of increase is 5–10% (low emissions) to 15–20% (high emissions).

Mean annual air temperature for Southland (and the region including Waituna Lagoon) is projected to rise by between approximately 0.5°C (low emissions) and 2.5°C (high emissions; Fig. 6) by the end of this century, compared with the period 1986–2005 (MfE 2018).

3.2 Projected changes to lagoon inflows

Collins and Zammit (2016) assessed climate change impacts on hydrological regimes of rivers and streams throughout New Zealand[5] using downscaled global climate change projections (MfE 2018) and NIWA's national water model (NZWaM-Hydro[6]). Similar to the climate projections discussed above, the assessment was driven by a combination of four emission scenarios (RCPs) and six global climate models, but it was run over the period 1971–2099.

These NZWaM-Hydro projected flows were included in a subsequent report for Environment Southland on Climate Change Impacts for the Southland Region (Zammit et al. 2018). Maps were produced showing colour-coded projected median[7] changes from the baseline period 1986–2005

[4] https://oceanservice.noaa.gov/facts/lidar.html

[5] 43 862 catchments total with an average catchment area of approximately 6 km^2.

[6] https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/nz-water-model-hydrology-nzwam-hydro

[7] Changes to inflows are presented based on the median change over the six climate model runs.

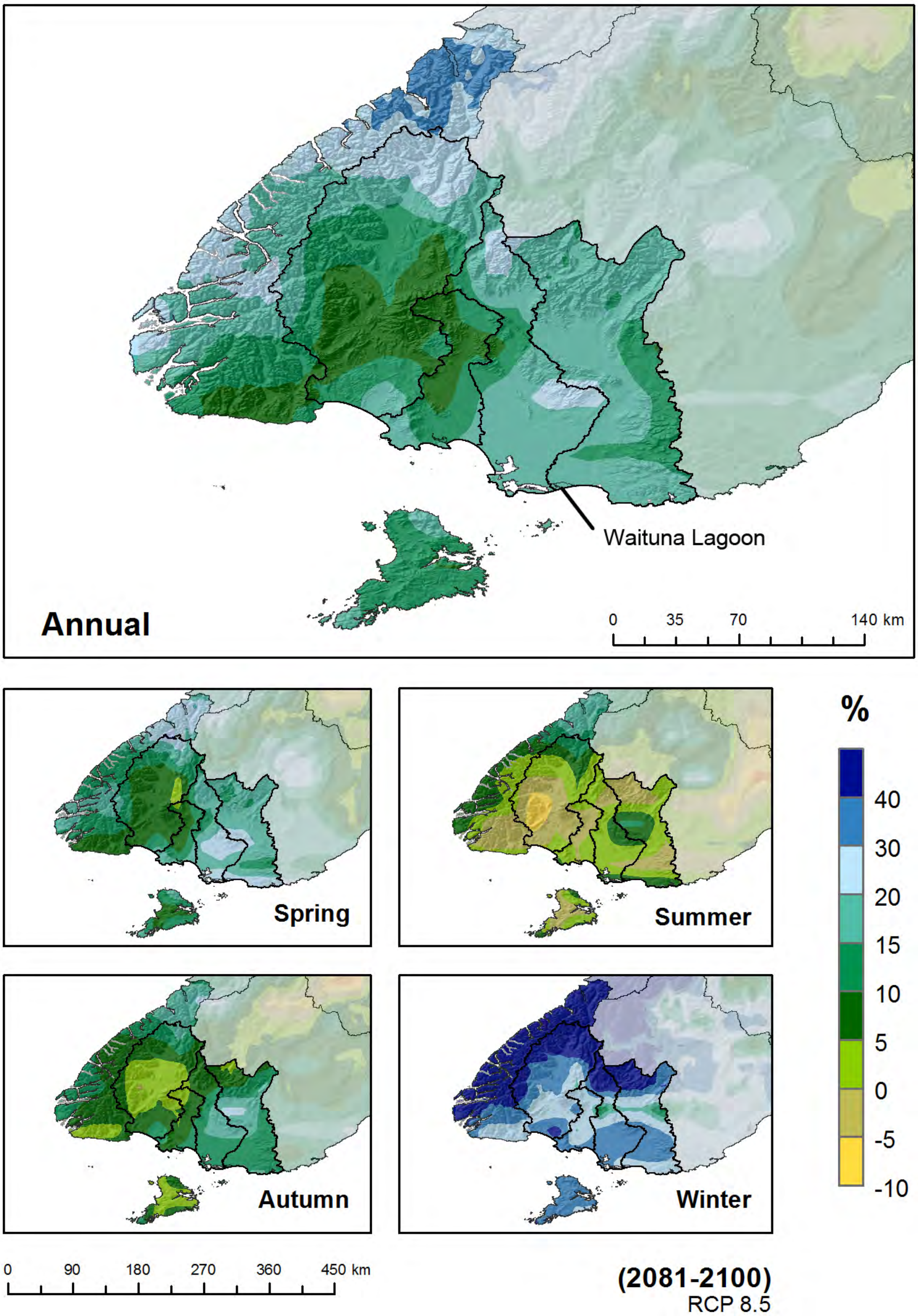

Figure 5. Projected percentage change to Southland mean annual and seasonal rainfall by 2080–99 compared with 1986–2005, based on a high global greenhouse gas emission scenario (RCP8.5) and the average of six global climate models (after Zammit et al. 2018).

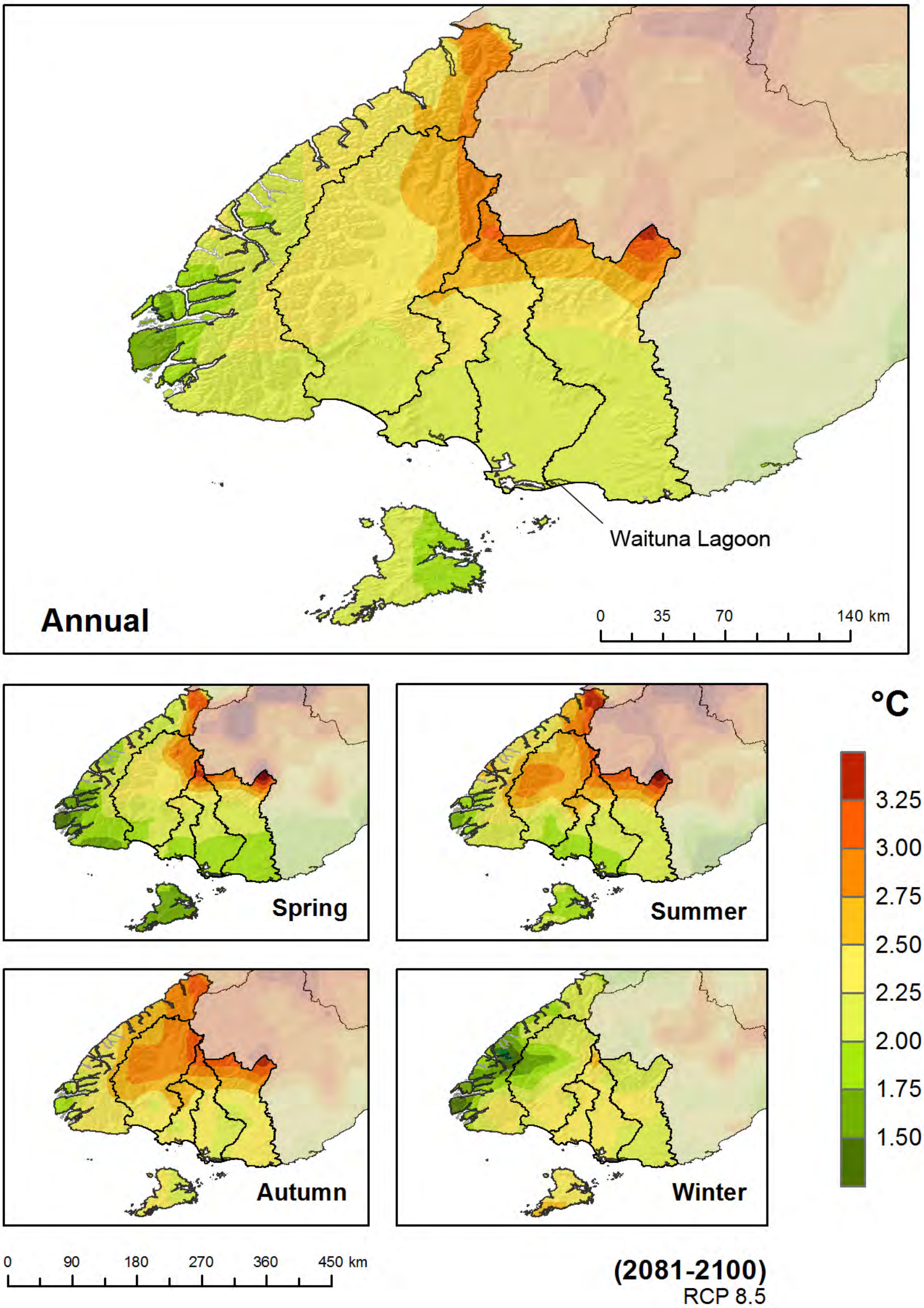

Figure 6. Projected change to Southland mean annual and seasonal temperature (in °C) by 2080–99 compared with 1986–2005, based on a high global greenhouse gas emission scenario (RCP8.5) and the average of six global climate models (after Zammit et al. 2018).

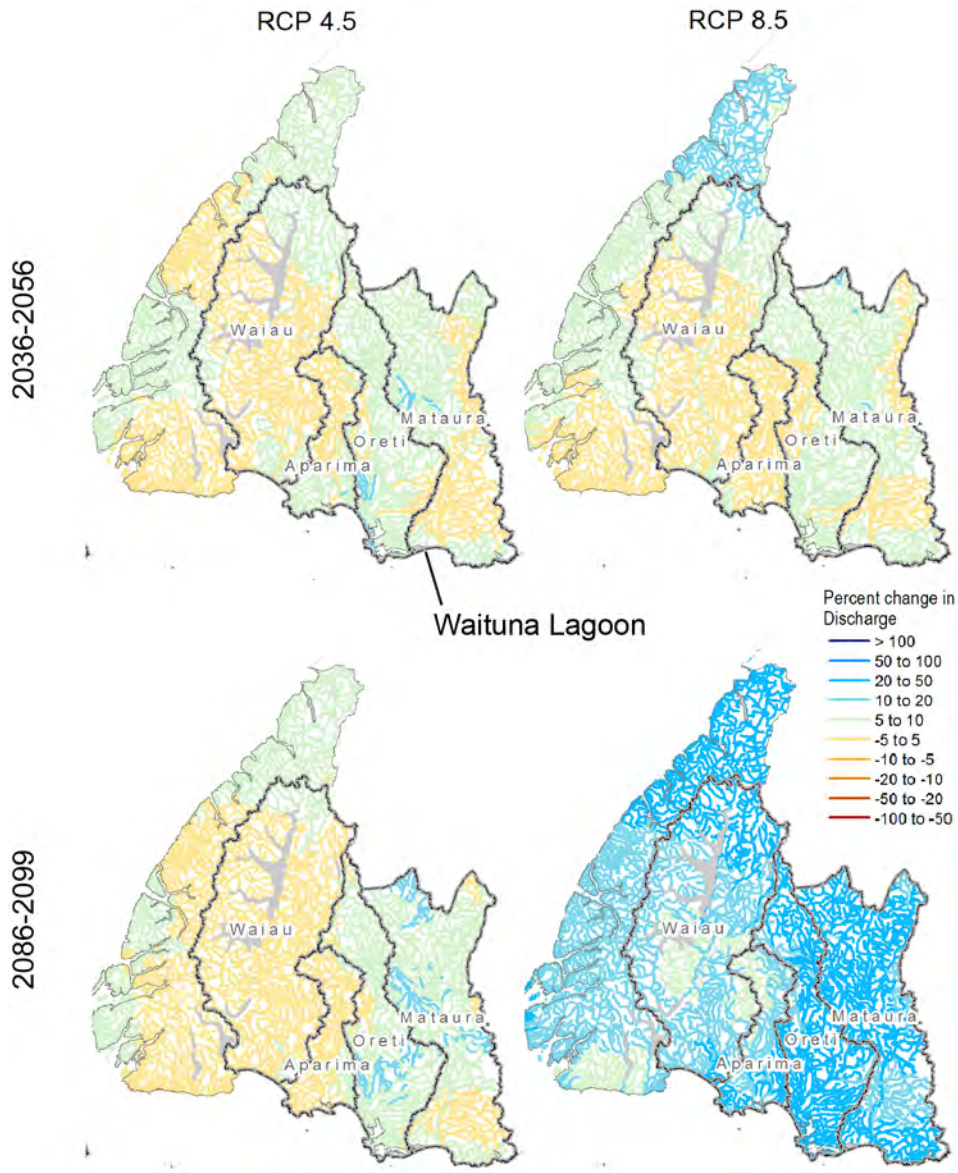

Figure 7. Southland Region multi-model median changes in Mean Annual Discharge (%) for mid (top) and late-century (bottom) and for medium (left) and high (right) emission scenarios (after Zammit et al. 2018).

to mid-century (2036–2056) and end-century (2086–2099), based on two emission scenarios (RCP4.5 = mid-range emissions and RCP8.5 = high emissions), for hydrological parameters of streams and rivers including:

- Mean annual discharge
- The Q95% low flow (flow that is exceeded 95% of the time)
- Mean annual flood (MAF) – the mean of the largest peak flows for each year. For New Zealand rivers, this flow is typically exceeded less than 1% of the time and has a return period of 2–3 years.

For this study, projected changes to the above three parameters associated with inflows to Waituna Lagoon were derived from the Zammit et al. (2018) maps. All changes to the parameters are described as percentage change.

Mean annual water discharge into Waituna Lagoon is projected to increase by up to 10% by the middle of this century and by more than 50% by the end of this century for the high emission scenario, compared with the present-day (Fig. 7). Most of this increase will be in autumn, winter and spring (Zammit et al. 2018). The Q95% low flow for the Waituna catchment is projected to

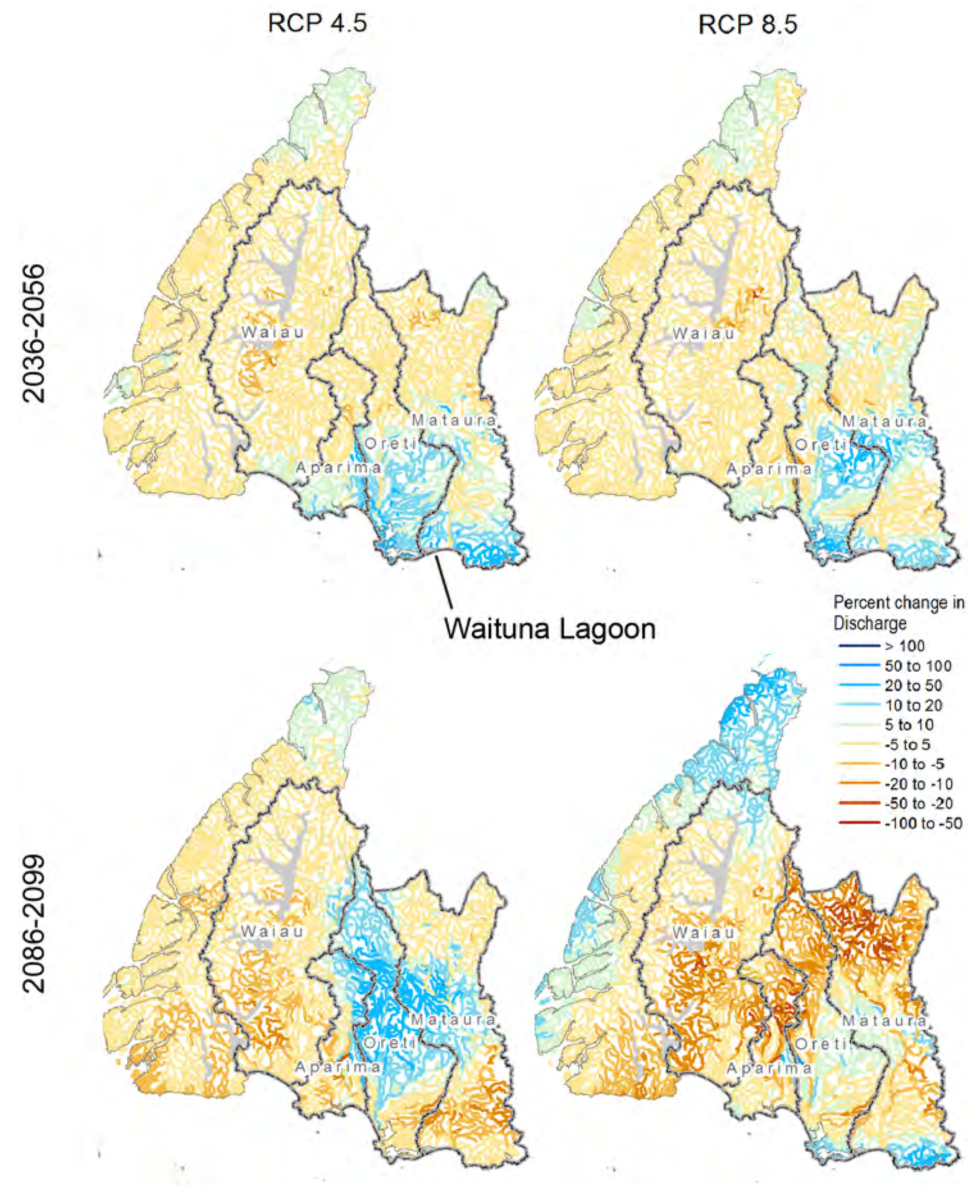

Figure 8. Southland Region multi-model median changes in Mean Summer Discharge (%) for mid (top) and late-century (bottom) and for medium (left) and high (right) emission scenarios (after Zammit et al. 2018).

increase by up to 20% by mid-century but decrease by up to 20% by the end of the century for the high emission scenario, related to drier summers (Figs 5, 8 and 9). Mean annual flood (MAF) is projected to increase for the Waituna catchment, by 20–100% by the end of the century under both medium and high emission scenarios (Fig. 10).

All these projections are dependent upon the greenhouse gas emission scenario. It is also recognised that there is significant uncertainty in the downscaled regionalised precipitation projections from climate models, hence the projected changes in flows are also uncertain (Collins & Zammit 2016).

3.3 Projected sea level rise

Sea level around New Zealand, relative to vertical land movement, has risen by around 0.2 m over the last 100 years. Sea level around New Zealand (including the Southland coast) is expected to continue to rise by an additional 0.2–0.3 m by 2040 and 0.4–0.9 m by 2090, depending upon global greenhouse gas emissions (MfE 2017).

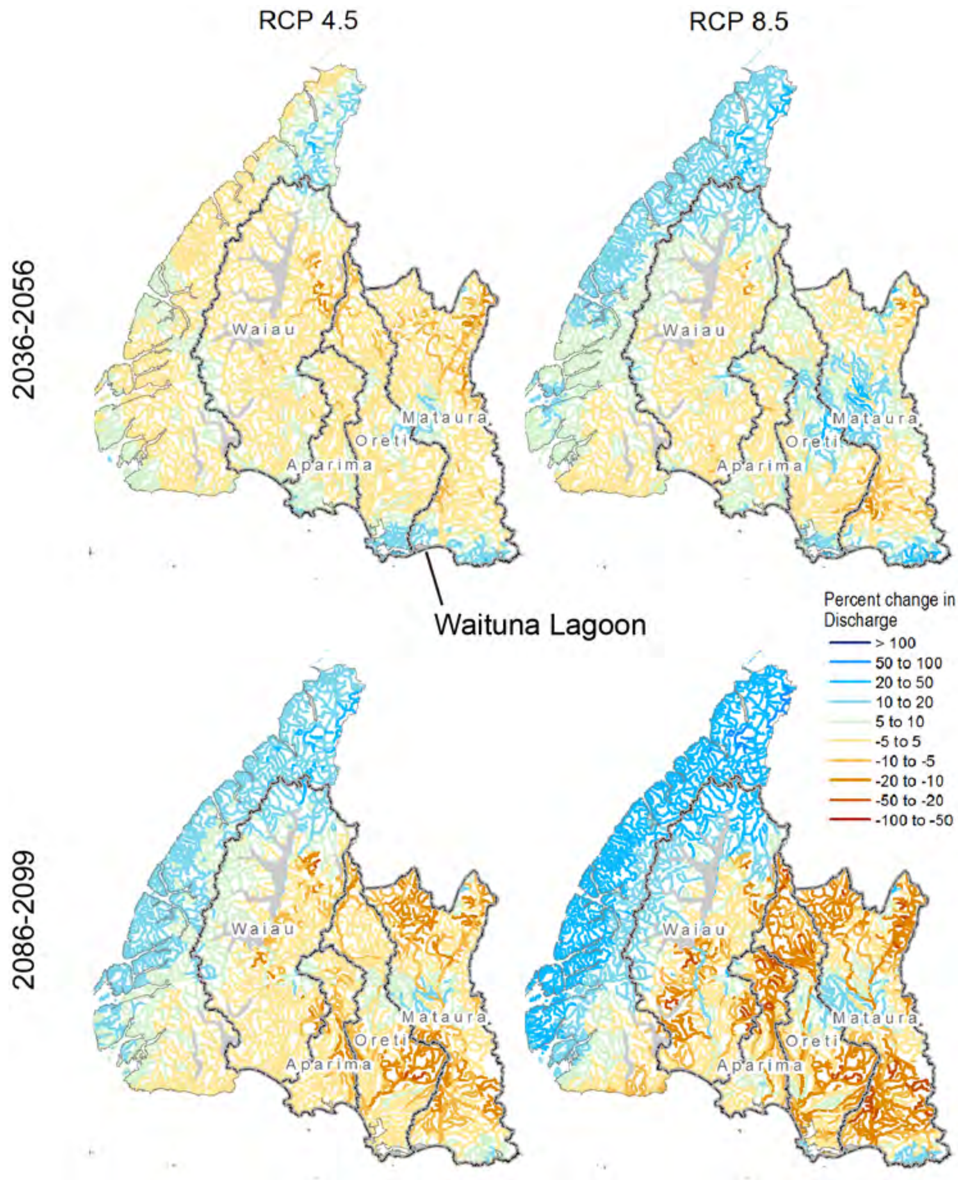

Figure 9. Southland Region multi-model median changes in Q95% Low Flow (%) for mid (top) and late-century (bottom) and for medium (left) and high (right) emission scenarios (after Zammit et al. 2018).

3.4 Impacts of sea level rise on lagoon water levels and intertidal area

Lagoon spatial extent associated with low- and high-tide levels at times when the lagoon is open to the sea were mapped for the current sea level as well as six sea level rise scenarios (Table 1). For each of these seven sea level elevations the lagoon area at low and high tide and the area of the intertidal zone was calculated using GIS software and a LiDAR-based digital elevation model[8] (DEM). The DEM defined the extent of shoreward expansion of the lagoon with different elevations of sea level.

Currently, when the lagoon is manually opened to the sea, the water level drops from the opening threshold of around 2 m above datum to close to sea level within a few days (Schallenberg et al. 2017). The lagoon becomes tidal with water level fluctuations controlled by sea levels and lagoon opening conditions. The lagoon level fluctuates approximately 0.2–0.4 m on each tide, and typically sits in the range 0.2–0.8 m above datum. Water levels are raised as high as 1.1 m above

[8] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/digital-elevation-models

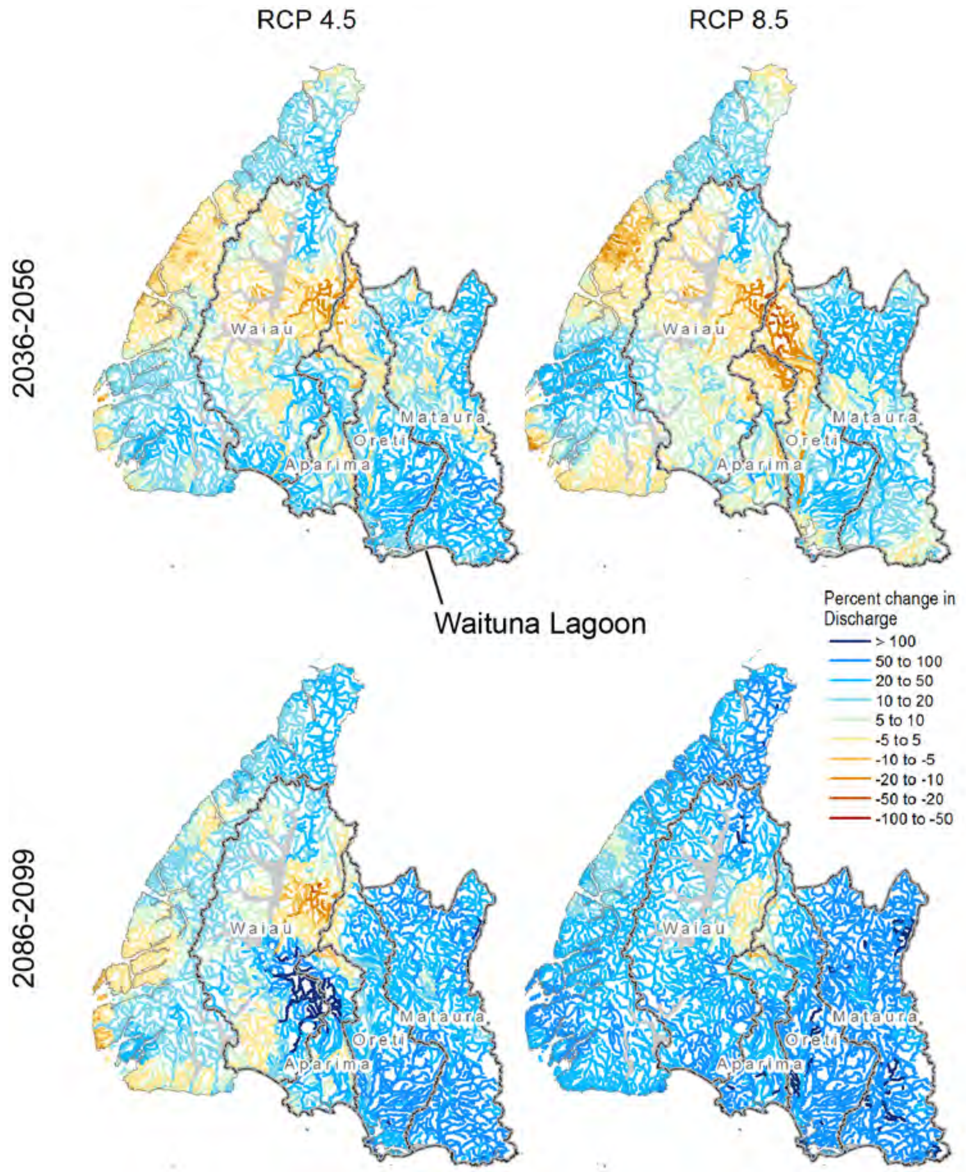

Figure 10. Southland Region multi-model median changes in Mean Annual Flood, MAF (%) for mid (top) and late-century (bottom) and for medium (left) and high (right) emission scenarios (after Zammit et al. 2018).

Table 1. Sea level rise elevations mapped for Waituna Lagoon, and when these elevations may occur under medium-to-high greenhouse gas emission scenarios.

SEA LEVEL RISE ELEVATIONS (m)	WHEN THIS SEA LEVEL RISE MAY OCCUR UNDER MEDIUM-TO-HIGH GREENHOUSE GAS EMISSION SCENARIOS*
+0.2	2040–2050
+0.4	2060–2080
+0.6	2080–2100
+0.8	2100–2120
+1.0	2110–2130
+1.2	2120–2140

* These projected dates are highly dependent the response of large ice masses (e.g. the Greenland ice sheet) to global warming and may be much earlier if the rate of ice melt accelerates.

datum during high winds and when the lagoon opening is constricted by waves. The water levels recorded at Waghorns Road water level recorder during an extended opening in 2013–14 are shown in Figure 11.

For the purposes of this climate change analysis we have assumed that the 0.6 m range from 0.2 to 0.8 m above datum is representative of the typical tidal range. It is assumed that this range will not change with sea level rise, as the height and shape of the coastal barrier will also change in response to sea level rise[9]. However, there will be a rise in the actual low and high tide lagoon levels above datum in accordance with sea level rise. For example, with 0.2 m of sea level rise the new low and high tide lagoon levels will be approximately 0.4 and 1.0 m above datum (i.e. an increase of 0.2 m to both levels, with no change to the tidal vertical level range).

Table 2 and Figure 12 show the projected lagoon area (enclosed water below mean high water springs (MHWS)) and intertidal area (between MHWS and mean low water springs (MLWS)) when the lagoon is open to the sea, associated with the current sea level and six future sea level rise scenarios.

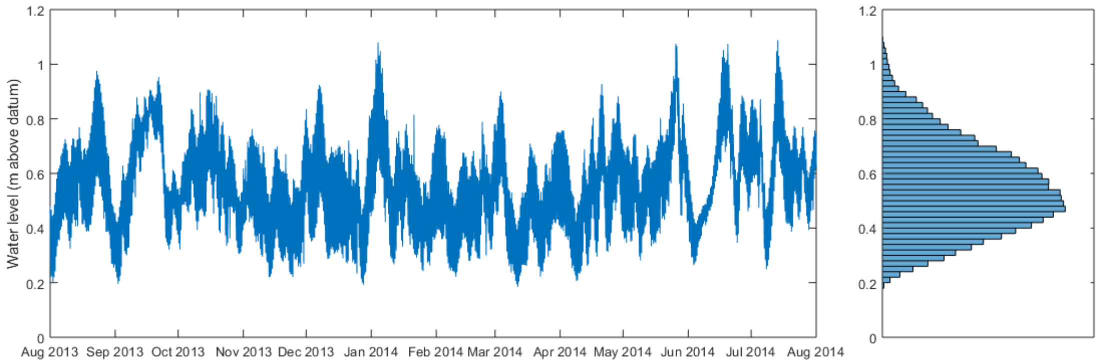

Figure 11. Water level recorded at Waghorns Road water level recorder during an extended lagoon opening in 2013–14. Histogram to the right shows the frequency with which different water levels occur. Levels greater than 0.8 m above datum are generally associated with a constricted lagoon opening.

Table 2. Surface water extent in Waituna Lagoon for approximate average low and high tides and intertidal area under current conditions and six scenarios of sea-level rise (SLR). *Note, these areas are only relevant when the lagoon is open to the sea.*

SCENARIO	TIDE (low or high)	LAGOON LEVEL (m above datum)	LAGOON AREA (ha)	INTERTIDAL AREA (ha)
Current	low	0.2	612.23	687.72
	high	0.8	1299.95	
SLR 0.2 m	low	0.4	812.90	399.62
	high	1.0	1212.53	
SLR 0.4 m	low	0.6	1028.82	405.84
	high	1.2	1434.66	
SLR 0.6 m	low	0.8	1299.95	231.62
	high	1.4	1531.57	
SLR 0.8 m	low	1.0	1212.53	392.50
	high	1.6	1605.03	
SLR 1.0 m	low	1.2	1434.66	250.64
	high	1.8	1685.30	
SLR 1.2 m	low	1.4	1531.57	232.11
	high	2.0	1763.67	

[9] The implication of this assumption is that there will continue to be a barrier between the lagoon and the sea at least to the end of this century (i.e. the lagoon is not expected to transition into an estuary). This is a research question that could be further investigated.

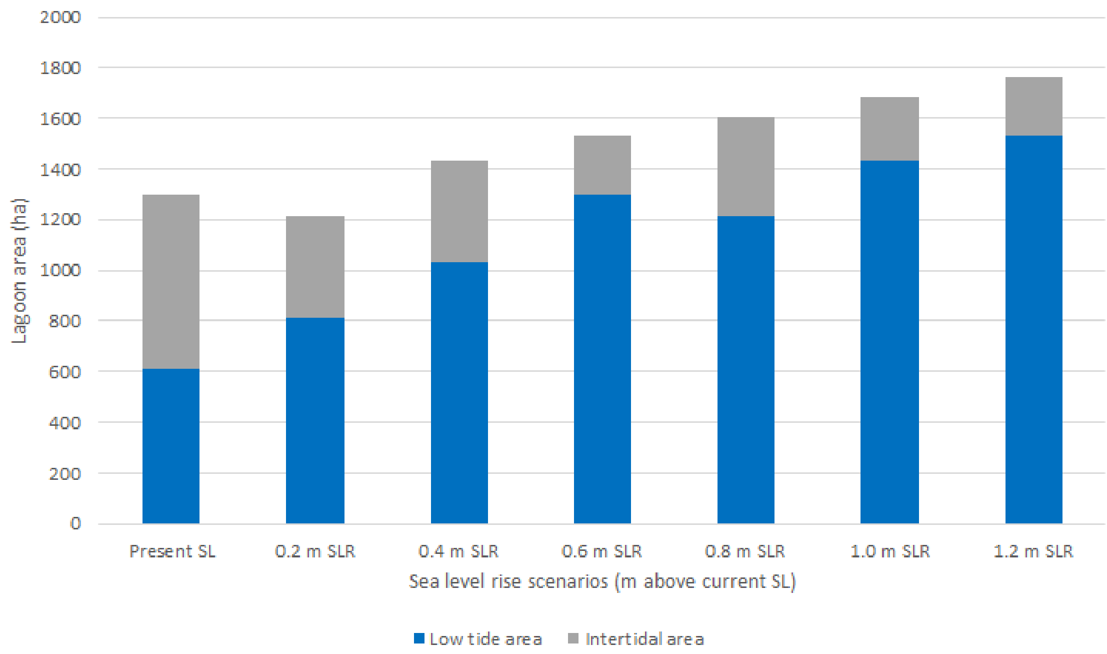

Figure 12. Waituna Lagoon area under current conditions and six scenarios of sea level rise. The average high tide level is the total height of each bar (i.e. low tide area + intertidal area). *Note, these areas are only relevant when the lagoon is open to the sea.*

Lagoon water surface area is projected to increase for both low and high tidal levels under sea level rise, but low tide area is projected to increase more than high tide area, resulting in a decline in the intertidal area from around 700 ha currently to around 400–230 ha, depending upon the sea level rise scenario. Decline in intertidal area occurs even at the modest 0.2 m increase in sea level.

Figure 13 shows the change in intertidal zone with 0.4 m and 1 m of sea level rise[10], compared with present-day conditions. With 1 m of sea level rise the intertidal zone shifts from its current location to beyond the current high tide extent.

4. Discussion

4.1 Implications of changes to inflows

The impact of changes to freshwater inflows depends on whether the lagoon is open to the sea or not. The projected increase in inflows into the lagoon in autumn, winter and spring under both mid range and high emission scenarios, would raise the lagoon level more swiftly when the lagoon is closed to the sea. If the lagoon is open to the sea, the increase in discharge would not impact the lagoon level as this is modulated by the sea level and tide. However, when the lagoon is closed the increased inflow would result in the lagoon being deeper for longer periods, reducing the light environment of the lagoon bed, and likely leading to an increased frequency of manual lagoon opening events (i.e. when the resource consent threshold for manual opening of 2.2 m water depth at the Waghorns Road bridge gauge is reached; see section 4.2).

Increases in the mean annual flood (MAF) of 20–100% by the end of the century under both emission scenarios would greatly increase the risk of inundation of the low-lying land surrounding the lagoon and its tributary creeks. Flooding of this land from the lagoon is only

[10] This analysis can be done for any sea level rise, but here we only show +0.4 m and +1.0 m for demonstration purposes.

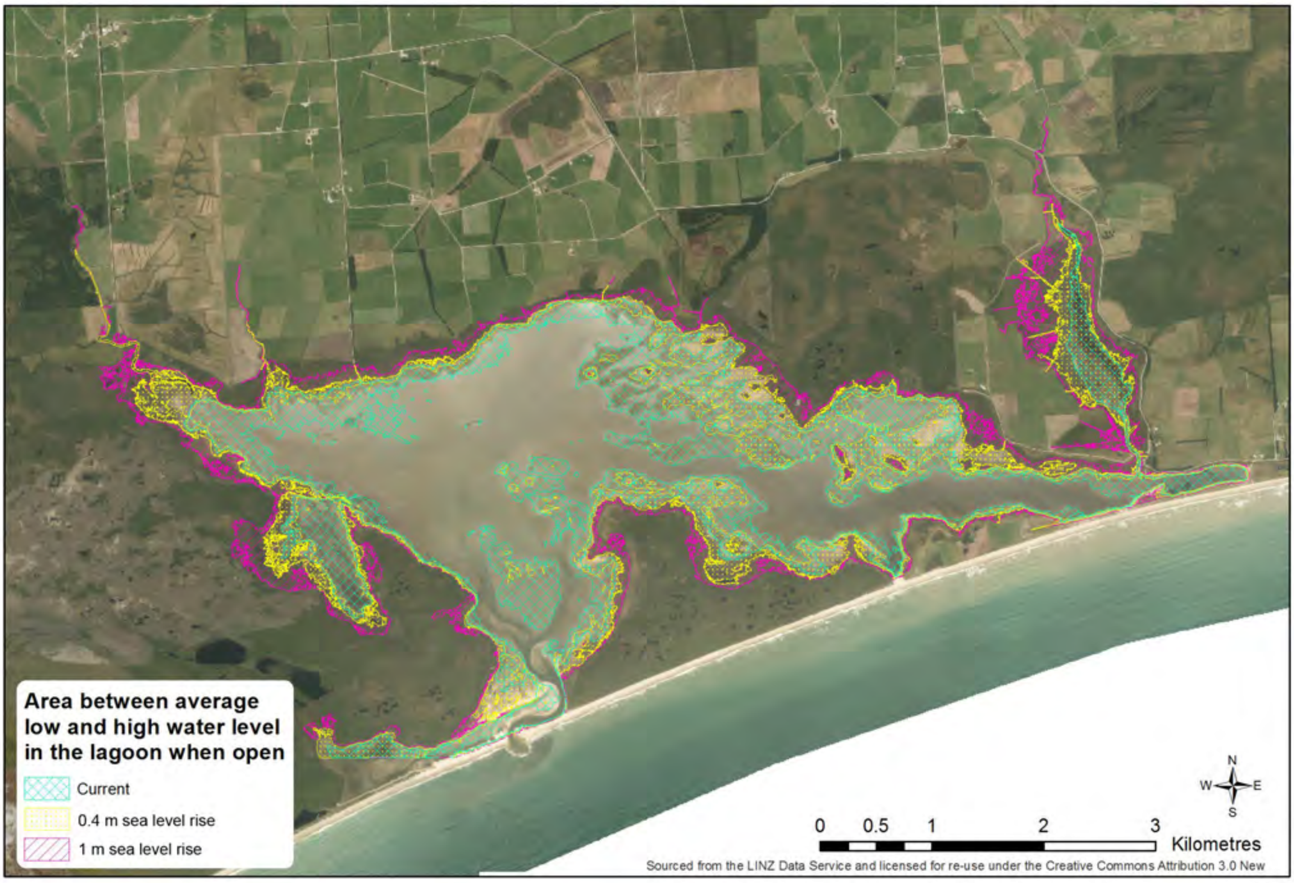

Figure 13. Waituna lagoon intertidal zone for approximate average current conditions plus two sea level rise scenarios of +0.4 m and +1.0 m. *Note, these mapped areas are only relevant when the lagoon is open to the sea*.

likely when the lagoon is closed. Sediment and nutrient transport during flood events would also be increased. Greater flow rates may also increase sedimentation, reduce salinity, lower water temperature and affect turbidity and mixing of the lagoon[11].

Decreases in rainfall and the even lower low inflows projected for summers later in the century would have opposite effects to those associated with increased inflows described above, with lagoon levels rising more slowly, lagoon bed light levels remaining high, and water temperature being higher than for deeper water conditions. An increase in lagoon temperature in summer would likely have a greater ecological impact on the lagoon than the decrease in temperature that may be associated with higher inflows over the winter months. Sea level rise would affect the lagoon level only when the lagoon is open to the sea. The high- and low-tide lagoon water level will rise in accordance with sea level rise. The lagoon area at high and low tide would also increase but the magnitude of change will be affected by the topography of the surrounding land. With 1 m of sea level rise, the high-tide lagoon area is projected to increase by 30%, compared with the high-tide area at present, while the projected increase of the low-tide lagoon area is 134%, compared with the low-tide area at present. This differential increase means that the intertidal lagoon area (i.e. mudflats) would decrease by 64% with a 1 m sea level rise, compared with present. This projected decrease in mudflat area would have considerable impacts on the wading bird population in the lagoon.

[11] Water temperature of lagoons are also highly correlated to the temperature of the overlying air (Schibuola & Tambani 2012). Thus, the Waituna Lagoon water temperature is likely to increase along with projected increases in air temperature. However, deeper water will warm less than shallow water.

4.2 Implications for the lagoon opening/closing regime

The lagoon is currently manually opened by excavation of the gravel barrier when its water level exceeds 2.0 m above a datum at the Waghorns Road bridge gauge during winter and 2.2 m during spring, summer and autumn (Measures & Horrell 2013; Walsh et al. 2016). Currently, this results in an approximately annual opening frequency. If the mean discharge into the lagoon increases, then these two triggering water levels will likely be reached more often (accepting that in summer the mean discharge may decrease). The implication is that the timing of lagoon openings may change, and the lagoon may need to be opened more often. Additional research using detailed modelling is required to fully assess this potential impact (see Appendix 1).

Sea level rise also causes reductions in the efficacy of lagoon openings, due to the following processes:

- When the lagoon is opened, the amount of drawdown of the lagoon water level available would be reduced by sea level rise, because the sea level will be closer to the lagoon water level which is currently higher in elevation.
- With sea level rise the lagoon water level will also rise and the mouth will close at higher lagoon levels than it currently does, increasing the likelihood of more saline intrusion to the lagoon.
- Further, there would be a reduction in storage volume of the lagoon between lagoon mouth closure and the two opening thresholds, reducing the hydraulic gradient between the lagoon and sea[12].
- The reduced hydraulic gradient would also reduce the stored energy available for the water to erode an effective mouth channel (i.e. after a channel is manually cut with a bulldozer the outflow of water widens and deepens the channel).
- Currently it is relatively easy to open the lagoon, but this is likely to become progressively more difficult with sea-level rise as the hydraulic gradient between lagoon level and sea level will be reduced[13].
- In addition, the degree that opening events flush suspended sediment and nutrients will likely be reduced, although this water quality risk may be offset by the increased frequency of opening events.

Eventually (potentially by 2150) the high-tide level may not be much lower than the current lagoon opening threshold. At this time the threshold level would need to be higher than today's level to generate enough hydraulic gradient to flush the lagoon. This, of course, would have significant implications on the spatial extent and depth of the lagoon, leading to surrounding low-lying land being flooded. This highlights the need for efforts (such as those under the Whakamana te Waituna initiative) to explore options to enable this land to be transitioned away from agricultural production.

4.3 Implications for the lagoon ecosystem

Research on the state and functions of, and pressures and impacts on, the Waituna Lagoon ecosystem is ongoing and supported by Whakamana te Waituna, Living Water, Arawai Kākāriki and additional partners. It is undoubtedly a complex ecosystem, particularly due to the interactions between managed land and water uses, human interventions and natural environment variability. There is a pressing need to better understand the potential long-term implications of climate change for this complex system.

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[12] The 'hydraulic gradient' is the amount of water pressure between two bodies of water at different elevations. When the two bodies are connected then the rate of flow of water between them is affected by the magnitude of the hydraulic gradient (i.e. greater pressure results in higher flows, and vice versa).

[13] This is already an issue with manual openings at Lake Ellesmere (Te Waihora).

Here, we summarise the likely[14] response of the ecosystem components to the projected climate changes described above. Our summary is based on published literature and expert opinion and is intended to initiate further discussion and research.

Table 3 presents the potential impacts on a selection of ecosystem components. Three main risks to the lagoon and surrounding farmland can be deduced from this analysis:

- Significant increases in rainfall (autumn-spring), flood events and inundation of surrounding land are likely to contribute higher levels of nutrients and sediment flowing into the lagoon than are currently experienced.
- Decreases in summer rainfall and inflows, as well as increases in temperature, may favour algae growth in the lagoon due to increased water temperature and light levels.
- These changes could both contribute to a regime shift within the lagoon by favouring undesirable algae growth and inhibiting favourable ruppia[15] growth.
- Sea level rise may reduce the available habitat area for species that use the intertidal mudflats and bordering wetland vegetation, as well as cause more regular inundation of surrounding farmland.

Table 3. Summary of likely Waituna Lagoon ecosystem responses to projected climate and sea level changes. Red boxes highlight the impacts that may be severe in nature and contribute or lead to the lagoon ecosystem flipping into an algal-dominated state. Orange boxes highlight impacts that may be moderate, affecting species but unlikely to lead to a regime shift. Green boxes highlight potential benefits to the lagoon ecosystem or species.

ECOSYSTEM COMPONENT	LIKELY RESPONSE TO INCREASE IN WATER INFLOWS AND HIGHER LAGOON WATER LEVELS IN AUTUMN TO SPRING			LIKELY RESPONSE TO DECREASE IN INFLOWS AND LOWER LAGOON WATER LEVELS IN SUMMER		LIKELY RESPONSE TO SEA-LEVEL RISE (WHEN LAGOON IS OPEN)	
	Increased sediment and nutrient loading	**Reduced light levels / deeper water**	**Increased salinity from more frequent lagoon openings**	**Increased water temperature**	**Increased light levels / shallower water**	**Decreased inter-tidal area**	**Increased lagoon area (at high and low tide)**
Ruppia	Reduction in abundance (due to sedimentation of lake bed)	Reduction in growth	Reduction in germination over spring/ summer	Decrease in ruppia biomass due to reduced water depth	Increased growth/ abundance	No impact	Changes in available habitat (based on depth)
Algae	Increased abundance	Decreased abundance	Change in community composition	Increased abundance	Increased abundance	No impact	Increasing available habitat
Fish (native and introduced)	Reduction in habitat quality	Possible reduction in food availability	Reduced larval fish (e.g. giant kōkopu) growth rates†	Reduction in habitat quality (decreased DO)	Possible increase in food availability	Unknown	Increase in available habitat
Wetlands bordering lagoon	Increased abundance of exotic plant species	No impact	Possible change in community composition	No impact	No impact	Loss of intertidal wetland vegetation	Reduced available habitat
Birds (migratory and endemic)	Possible changes to food availability and decreased habitat	Possible changes to food availability and decreased habitat	Possible changes to food availability for some species groups	Possible changes to food availability	Possible changes to food availability	Decreased habitat for waders	Decreased habitat for waders

* Ruppia (*Ruppia* spp.) is a native freshwater plant that is common in Waituna Lagoon. It is tolerant of low levels of salinity. It is desirable that ruppia is able to spread in the lagoon in the future.

† Hicks, A.S.; Jarvis, M.G.; Funnell, E.P.; Closs, G.P. unpubl. data: Non-diadromous recruitment of threatened giant kōkopu (*Galaxias argenteus*) within an intermittently closed and open coastal lagoon: benefits of larval retention and effects of artificial opening.

[14] The IPCC defines 'likely' as having greater than 66% probability of occurrence or outcome. We use this same definition here, with our assessment of likelihood based on expert opinion.

[15] Ruppia (*Ruppia* spp.) is a native freshwater plant that is common in Waituna Lagoon. It is tolerant of low levels of salinity. It is desirable that ruppia is able to spread in the lagoon in the future.

5. Knowledge gaps and lagoon management

This study has highlighted many potential impacts on, and implications for, Waituna Lagoon associated with projected climate change and sea level rise over this century. Table 4 summarises the knowledge gaps identified in previous sections which, together with the information in Appendix 1, should be considered when designing future research projects. Table 4 also provides some considerations of potential management responses which can be used to reduce the uncertainty and proactively adapt to any changes.

Table 4. Summary of future risks and potential management implications for Waituna Lagoon resulting from climate change.

AFFECTED COMPONENT	RISK	CAUSE	CONSIDERATIONS FOR FUTURE MANAGEMENT
Water in lagoon.	Decline in water quality/ regime shift from macrophyte-dominated state to algae-dominated state.	Increased sedimentation and nutrients from high inflows (autumn-spring). Reduced lagoon depth and increased temperature from low inflows (summer). Increased saline incursion. Increase in frequency of lagoon reaching 2 m depth. Reduced ability to open lagoon. Unknown impact of coastal processes on lagoon closing.	Any re-design of the drainage network in the catchment should account for higher freshwater inflows – i.e. increases in flood capacity and nutrient reduction systems are needed. Investigate how opening the lagoon more often will affect salinity levels and ruppia survival. Investigate the impact of potential changes in wave climate and coastal sediment transport on the lagoon's ability to close naturally.
Species, particularly birds, fish and macrophytes, that live in or use the lagoon.	Reduction in numbers able to survive in the lagoon.	Altered food webs. Reduced habitat quality. Less habitat available (particularly intertidal zone).	Need to better understand food web dynamics within the lagoon for zooplankton, fish and birds so that appropriate conservation management actions may be taken. Need to better understand habitat requirements for species, especially those dependent on the intertidal zone (wading birds) and lagoon (macrophytes, fish), so that appropriate conservation management actions can be taken.
Adjoining land owners/ managers.	Flooding hazard.	Increased inflows and higher frequency of inundation of surrounding land with sea level rise.	A buffer zone immediately adjacent to the lagoon should be developed by retiring land from agricultural production. Inundation modelling of the lagoon and surrounding land that includes future rainfall predictions is needed (update Walsh et al. (2016)).

6. Similar assessments for other coastal hydrosystems

Coastal hydrosystems, such as wetlands, estuaries and lagoons, are especially sensitive to climate change, as they can be affected both by changes to freshwater inflows and changes to sea level (Rodríguez et al. 2017). This has implications for threatened native species that use these ecosystems. This desktop study of the Waituna Lagoon in Southland has shown the potential for exploring these projected changes for any coastal location using existing hydrological projections in tandem with GIS-based mapping techniques. Critical to the assessment is the availability of LiDAR-based digital elevation data.

Each hydrosystem may be affected by climate change quite differently depending upon its type, local topography and hydrological regime. Ecological and management implications of any changes would also vary with location. A recommended course of action for central and local government agencies is to identify key coastal sites with available LiDAR data and carry out similar assessments to that described in this report, taking the additional research areas flagged (Appendix 1) into consideration. If necessary and if possible, more detailed studies could be undertaken using localised hydrological models and site-based assessments.

7. Conclusions

The climate of Southland (including the region around Waituna Lagoon) is projected to become wetter (except in summer, when drier conditions are predicted) and warmer over the coming several decades. These changes are likely to result in higher freshwater inflows in autumn, winter and spring and lower inflows in summer (when low flows are projected to be even lower than at present). Floods are generally expected to be larger all year round.

Increases in rainfall, freshwater inflows, flood events and inundation of surrounding land are likely to contribute to lower lagoon-bed light levels and higher levels of nutrient and sediment entering Waituna Lagoon than are currently experienced. Consequently, increased algae growth and inhibit Ruppia growth are predicted. These are known components that contribute to regime shift from a desirable macrophyte-dominated state to an undesirable algal-dominated state and are closely linked to declines in water quality. This shift would fundamentally change the ecology of the lagoon and create unsuitable habitat for many of the species that currently exist there.

With the projected increases in inflows (except in summer), the lagoon water level would increase more rapidly than under present conditions. The implication is that the lagoon would either have to be manually opened more frequently (if the present threshold depths for opening are maintained) or the thresholds for opening would need to be raised (if the opening frequency is maintained). If the latter, then more of the land surrounding the lagoon would be subject to inundation before the lagoon would be opened.

Regular opening of the lagoon to lower the water level and flush nutrients out is likely to become more difficult with sea level rise and the loss of hydraulic pressure to aid opening. Sea level rise and more frequent openings of the lagoon barrier would have significant impacts on the biodiversity of the lagoon area, particularly in relation to decreasing intertidal habitat detrimentally affecting wading birds and increased salinity reducing the abundance of the macrophytes that currently support the food web of the lagoon.

These projected changes pose a major risk to a wide variety of plants, birds and fish, many of which are threatened endemic species and a fundamental part of what gives Waituna Lagoon its high ecological status.

8. Recommendations

Based on this study we recommend the following actions:

- Climate change impacts and implications should be factored into future ecological research plans for Waituna Lagoon.
- Ongoing monitoring and research is needed to address knowledge gaps concerning the possible ecological dynamics resulting from reduced habitat quality and extent at Waituna Lagoon.
- Management and research efforts should also focus on the catchment and drainage network at Waituna Lagoon and seek to reduce the impacts of high flows and nutrient leaching on water quality within the catchment.
- All lagoon management plans for Waituna Lagoon and elsewhere should be reviewed and reassessed at least every 10 years using the latest data, research and climate projections. A 10-year rolling review should be part of a long-term strategy for the remainder of this century and potentially beyond.

9. Acknowledgements

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Appendix 1 – Additional research

Hydrological modelling

A distributed hydrological model for the Waituna catchment and lagoon has been developed and validated by Deltares and DairyNZ[A1]. The model is called WFLOW[A2], and has been integrated with a nutrient model (OVERSEER) to model water quality and nutrient loads flowing into the lagoon.

Projected daily rainfall and evapotranspiration data from NIWA's Regional Climate Model could be incorporated into the WFLOW model and the impact on water quality, nutrient loads (given no other changes), and lagoon water depth could be assessed in more detail than in the desktop study addressed in this report. This information will be useful for long-term strategies for enhancing water quality in the catchment and lagoon, and for assessing ecological impacts.

NIWA is currently enhancing the TopNet hydrological model in a project commissioned by Environment Southland in association with their Source and Flows programme. The objective of the work is to develop two hydrological models (1. A surface+simple groundwater conceptualisation – TopNet0 and 2. A coupled surface-groundwater model – TopNet-GW) for the Waituna catchment to assess:

- Water transfer between the Mataura catchment (through the Edendale area) to the Waituna catchment;
- Use of hydrogeochemistry to better inform water flux understanding across the Waituna catchment;
- Model conceptualisation impact on decision making (water allocation and ecological decision making through coupling TopNet suite and CHES tool);
- Coupling hydrological model (TopNet suite) with water quality model (CLUES suite[A3]) to provide temporal disaggregation of simple coupled quantity-quality models and integration with Freshwater Management Unit models suite (Mid Mataura model being currently developed in parallel).
- As suggested above, NIWA Regional Climate Model output could also be incorporated into these surface+groundwater models to improve the projections of potential changes to surface and groundwater flows and their impact on water quality in the Waituna Lagoon.

Changes in lagoon water level

There is potential to use lagoon water level data in combination with inflow data to model what the projected reduced flows over summer would do to water levels[A4]. The potential rate of water level rise/fall in the lagoon could also be modelled, providing valuable guidance on how much more frequently the water level would hit the trigger for opening.

[A1] van den Roovaart et al. 2014. Contact person is David Burger, Environment Manager, DairyNZ, Hamilton.

[A2] https://oss.deltares.nl/web/wflow/why-wflow

[A3] https://www.niwa.co.nz/freshwater-and-estuaries/our-services/catchment-modelling/clues-catchment-land-use-for-environmental-sustainability-model

[A4] Environment Southland may have the capacity to do this work.

Changes in wave climate

NIWA performed and updated models to project changes in the significant wave height around New Zealand (Law et al. 2016). Figure A1 shows the projected percent changes between the present-day and the end of this century for a mid-range emission scenario (RCP4.5, left) and a high-range scenario (RCP8.5, right). Both scenarios show an increase in significant wave height is projected for the south coast of New Zealand of 2–5% (noting that there is much variability between climate models). As the lagoon mouth closure process is driven by wave-driven coastal sediment transport, it would be fundamental to model how these projected changes in significant wave height could affect the mouth closure process.

Physiographic modelling

Rissmann et al. (2018) describe the application of a high-resolution physiographic approach to modelling water quality controls for the Waituna catchment. A physiographic approach seeks to understand the pathways of water through a catchment, over land and through the ground, under different rainfall conditions. The Living Water partnership is currently undertaking research on this[A5]. The approach could be expanded to estimate the effect of climate change on water quality (e.g. eutrophication (shift of the lagoon to an algae-dominated state), turbidity) and seabed (sedimentation) outcomes by deriving equations to explain the relationships between climatic drivers (e.g. soil moisture, soil temperature and rainfall) and inflows, water quality and hydrochemistry. The model could then be used to assess farmer adaptation options to mitigate any changes to water quality associated with climate changes.

Extreme events

The frequency and intensity of extreme events (e.g. storm surge, high winds, droughts and flood events in the catchment) are likely to be affected by climate change. Changes to these events would be a major factor for the long-term sustainability of the opening and closing regime at the lagoon mouth and are also likely to significantly impact on the lagoon ecosystem.

Influence of tectonics and lagoon sediment budget on relative sea-level rise

The actual impact of sea-level rise is dependent on coincident changes in land elevation and the sediment budget (from the catchment and the sea). Areas where subsidence is occurring have faster relative sea level rises than stable areas, whereas land undergoing uplift may not be impacted by sea level rise to the same extent. Sediment supply to the coast also has an impact on relative sea level rise through impacts on coastal erosion or accretion. How this applies at Waituna and elsewhere needs more study.

Changes to the lagoon typology due to climate change

It would be good to explore the potential for the typology of the hydrosystem[A6] (Hume et al. 2016) to change, e.g. an increased connection with the sea resulting from barrier erosion or more frequent overtopping with sea-level rise and increased freshwater inflows, and what this might mean for the lagoon ecosystem if it changes; for example, from a system typology of a Waituna lagoon to an ICOLL (Intermittently Closed and Open Lakes and Lagoons).

[A5] https://www.livingwater.net.nz/catchment/waituna-lagoon/physiographics-project/

[A6] http://www.mfe.govt.nz/publications/marine/classification-of-new-zealands-coastal-hydrosystems

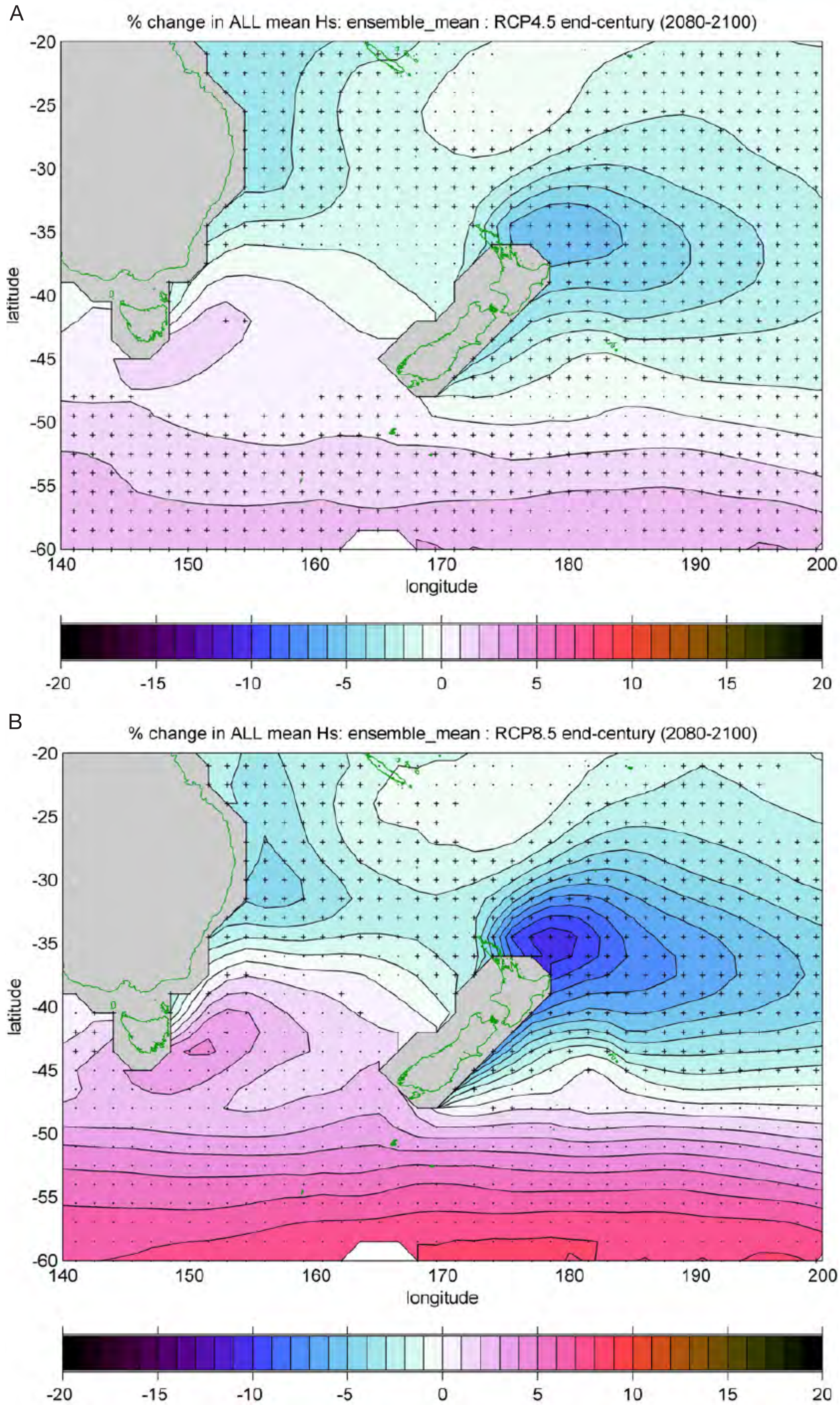

Figure A1. Multi-model average percentage change in significant wave height for mid-range emission scenario RCP4.5 (A) and high-range emission scenario RCP8.5 (B) for 2100 relative to present-day. The heavy- and lightly-stippled areas indicate respectively where all four, and three out of four, models show the same sign of change as the multi-model mean, and so indicate greater confidence in projections, whereas lack of stipules implies little confidence in either direction or magnitude of change (i.e. the Tasman Sea).

Appendix L: Previous Resource Consents

Application No: L010-001
Consent No: 97283

Cnr North Road and Price Street
(Private Bag 90116)
Invercargill

Telephone (03) 211 5115
Fax No. (03) 211 5252
Southland Freephone No. 0800 76 88 45

Coastal Permit

Pursuant to Section 105(1) of the Resource Management Act 1991, a resource consent is hereby granted by the Southland Regional Council (the "Council") to **Lake Waituna Control Association** (the "consent holder") C/- **Murray Waghorn, Waituna Lagoon Road, Gorge Road** from 19 May 1999.

Please read this Consent carefully, and ensure that any staff or contractors carrying out activities under this Consent on your behalf are aware of all the conditions of the Consent.

Details of Permit

Purpose for which permit is granted:		To open Lake Waituna to the sea
Location	- site locality	Waituna
	- map reference	F47:718-933
	- receiving environment	Lake Waituna
	- catchment	Waituna
Expiry date:		21 May 2014

Consent Amended

Conditions amended on 15 July 2011 and on 20 July 2012, as follows:

Schedule of Conditions

Consent Period and Purpose

1. This resource consent shall expire on 21 May 2014
2. This consent authorises the opening of the Waituna Lagoon to the sea.

Notification at 1.8 m

3. When the lagoon water level reaches 1.8 m, as measured on the gauge board attached to the Waghorn's Road Bridge, the consent holder shall notify, in writing, the Southland Regional Council, and the Area Manager (Murihiku) of the Department of Conservation, that the lagoon level is 1.8 m on the gauge board.

Lagoon Opening at 2.0 m

4. (a) The lagoon may be opened to the sea at a point as far west in the lagoon as practicable, but within 200 metres of map reference NZMS 260 F47:717-933 when water level in the lagoon reaches 2.0 m, as measured on the Waghorn's Road Bridge gauge board.

   (b) Subject to Condition 4(c), the lagoon may be opened to the sea at any one of the following points when water level in the lagoon is above 1.5 m, as measured on the Waghorn's Road Bridge gauge board:

   - Walker Bay, within 200m of NZ Map Grid co-ordinates 2171745E, 5393260N; or
   - Charlies Bay, within 200m of NZ Map Grid co-ordinates 2175030E, 5394565N

   (c) Opening of the lagoon in accordance with Condition 4(b) shall only occur if the following (both X & Y) apply:

   X. Environment Southland's Director of Environmental Management provides written notice to the consent holder either:

   (i) that:
   - a technical advisory group, with scientific knowledge of coastal lagoon ecosystems and convened by Environment Southland, has advised opening the lagoon to the sea is advisable to disrupt an actual or probable algal bloom in order to avoid a significant adverse ecological effect on the lagoon; or
   - the primary ecological trigger (outlined in Appendix 1 has been reached), and the secondary and tertiary indicators have been considered in conjunction with the primary indicator.

   (ii) that it is advisable to open the lagoon to the sea during the May-July period to allow:
   - flushing and dilution while inflows are high, and
   - sufficient time for the lagoon to close and fill prior to the critical growth period for aquatic plants, such as *Ruppia*

   Y. That the Area Manager (Murihiku) of the Department of Conservation and the Kaupapa Taiao Manager at Te Ao Marama Inc. have been consulted on the proposal to open the lagoon as described in Conditions 4(b) and 4(c)(X).

(d) The location of the opening to the sea in accordance with Condition 4(b) shall be advised by a technical advisory group, with scientific knowledge of coastal lagoon ecosystems and convened by Environment Southland.

(e) In the event that the lagoon is opened to the sea in accordance with Condition 4(b), the consent holder shall provide a copy of the notice specified in Condition 4(c) to the following parties:

- Kaupapa Taiao Manager, Te Ao Marama Inc., P O Box 7078, South Invercargill 9844
- The Regional Conservator, Southland Conservancy, Department of Conservation, P O Box 743, Invercargill 9840
- The Manager, Fish & Game New Zealand, P O Box 159, Invercargill 9840
- The Compliance Manager, Environment Southland

Note: it is sufficient for the purposes of this condition if a copy of the notice is provided to these parties by Environment Southland's Director of Environmental Management.

5. In the event of:

(a) the discovery, or suspected discovery, of a site of cultural importance (Waahi Taonga/Tapu), the consent holder shall immediately cease operations in that location and inform the local Iwi authority (Te Ao Marama Inc, phone (03) 214 1573, fax (03) 214 1505) and the Council's Director of Environmental Management. Operations may only recommence with the permission of the Council's Director of Environmental Management;

(b) contamination of the lagoon or foreshore, such as with fuel or oil spilt from the digger during the lagoon opening, the consent holder shall remove the contaminants immediately from the site and notify, without undue delay, the Council's Director of Environmental Management and the Area Manager (Murihiku) of the Department of Conservation.

Information Gathering Requirements

6. The consent holder shall record the following information:

(a) when and where the lagoon is opened to the sea;
(b) the water level in the lagoon at the time it was opened;
(c) how long the lagoon is open to the sea and when it closes (to the nearest week);
(d) when and at what gauge board level access across Curran's Creek bridge was lost for stock and farm vehicles and when was this access re-established.

7. When the lagoon is at a height above 2.0 m on the Curran's Creek gauge board, as reported in accordance with condition 3, the consent holder shall:

   (a) take photographs of Curran's Creek, Moffat Creek and Waituna Creek to record how far the water has backed up and how much land has been flooded;
   (b) record the height of the lagoon on the Waghorn's Road Bridge gauge board at the time the photographs are taken.

Report Information

8. The consent holder shall provide the information and copies of the photographs, specified in conditions 6 and 7, to the Area Manager (Murihiku) of the Department of Conservation within one month of the opening of the lagoon to the sea.

Study on Drainage Effects

9. (a) The consent holder shall instigate a study of the impact of the lagoon water level on farm drainage. *NB: An objective of the study shall be to establish the upstream extent of drainage impacts at various water levels up to 2.5 m, as measured at the Waghorn's Road Bridge gauge board and to quantify the amount of farmland affected.*

   (b) The extent of the study, its methodology, and how it is implemented shall be to the satisfaction of the Director of Environmental Management, in consultation with the Department of Conservation.

   (c) An outline of the proposed study shall be provided to the Southland Regional Council by 30 November 1999.

   (d) The results of the study shall be reported to the Southland Regional Council by 30 November 2000.

Consent Review and Council Charges

10. The Council may serve notice of its intention to review the conditions of this consent, in accordance with Sections 128 and 129 of the Resource Management Act, during the period 1 April to 30 June in the years 2003, 2008 and 2011, for the purposes of assessing the appropriateness of this consent in light of the monitoring data and any relevant studies.

11. The consent holder may apply for a review of the conditions of this consent, in accordance with Section 127 of the Resource Management Act, during the period 1 April to 30 June in the years 2003, 2008 and 2011.

12. The consent holder shall pay the Southland Regional Council an administration charge, set by Special Order under the Act, in advance, payable on the first day of July each year.

13. (a) With regard to the Primary indicator in Appendix 1, a 'visible algal bloom' shall be identified by:

    (i) ≥ 0.012 mg/l Chlorophyll *a* (or other figure identified in writing by the technical advisory group referred to in Condition 4[c]); and/or
    (ii) The observations of an appropriately qualified person. These observations shall include the location and approximate scale and intensity of the visible algal bloom on each day of observation.

    (b) These observations or readings are to be recorded and shall be made available to the Lagoon technical advisory group and the Director of Environment Management.

for the **Southland Regional Council**

W J Tuckey
Director of Environmental Management

Appendix 1

Primary Indicator	**Critical Trigger**
Chlorophyll *a*	a sustained visible algal bloom over a period of 14 days or longer
Secondary Indicators	Critical Indicator Levels
Total Phosphorus concentration	≥ 0.045 mg/l
Total Nitrogen concentration	≥ 0.700 mg/l
Tertiary Indicators	
Nuisance epiphytes or benthic algae	
Ruppia and other macrophytes	
RPD (Redox Potential Discontinuity) – bottom sediments	
Turbidity	
Bottom water dissolved oxygen concentration	
Aquatic and surrounding wetland life	
Algal blooms	

AUTH- 20146407-01

Cnr North Road and Price Street
(Private Bag 90116)
Invercargill

Telephone (03) 211 5115
Fax No. (03) 211 5252
Southland Freephone No. 0800 76 88 45

Coastal Permit

Pursuant to Section 104B of the Resource Management Act 1991, a resource consent is hereby granted by the Southland Regional Council to **Lake Waituna Control Association,** care of **E R Pirie, 389 Kapuka North Road, RD 3, Wyndham 9893** from **14 February 2017**.

Please read this Consent carefully, and ensure that any staff or contractors carrying out activities under this Consent on your behalf are aware of all the conditions of the Consent.

Details of Permit

Purpose for which permit is granted:	To periodically open Lake Waituna to the sea
Location - site locality	Walker's Bay and Hansen's Bay, Lake Waituna
- map reference	Between NZTM 1262340E 48311370N and 1261460E 4831000N (Walker's Bay), and about NZTM 1265350E 4832550N (Hansen's Bay)
Legal description at the site:	Section 29 Block XIII Oteramika Hundred and Crown Land (seabed)
Expiry date:	14 February 2022

Schedule of Conditions

1. This consent authorises the opening of the Waituna Lagoon to the sea through the gravel barrier at either:
   (a) Walker's Bay between NZTM 1,262,340E 4,831,360 N and 1,261,460E 4,831,000N; or
   (b) Hansen's Bay, between NZTM 1,265,305E 4,832,570N and 1,265,405E 4,832,605N

2. Except as specified in Condition 6, the openings authorised by this resource consent shall be at the Walker's Bay site specified in Condition 1(a).

(i) Openings under Condition 6 may be at either the Walker's Bay or the Hansen's Bay sites, dependent upon the recommendation of the technical advisory group as described in Condition 6(b).

3. (a) Immediately prior to lagoon opening, the consent holder must notify the Consent Authority (email: escompliance@es.govt.nz), the Kaupapa Taiao Manager at Te Ao Marama Inc and Operations Manager (Murihiku) of the Department of Conservation about the proposed opening location. The notification shall be in writing and shall include:

(i) the current water level at the Waghorn's Road bridge gauge board[1]; and

(ii) note of the prevailing wind conditions (direction and strength)[2], and comment whether or not there is any reason to suspect that the water level is only temporarily raised at the gauge board by strong wind conditions; and

(iii) information to show compliance with the opening criteria specified in Conditions 4, 5 or 6.

Note: 'in writing' may be by email.

Lagoon Opening May to 19 September inclusive

4. (a) During the months from 1 May to, and including, 31 August the lagoon may be opened to the sea when water level in the lagoon reaches 2.0 metres, as measured on the Waghorn's Road bridge gauge board.

(b) During the period 1 September to 19 September the lagoon may be opened to the sea when water level in the lagoon reaches 2.0 metres, as measured on the Waghorn's Road bridge gauge board once the lagoon has been above that level for 7 days out of a continuous period of ten days.

(c) During the month of July the lagoon may be opened when water level in the lagoon reaches 1.8 metres as measured on the Waghorn's Road bridge gauge board, if the lagoon has not been opened in the previous 12 month period.

Lagoon Opening 20 September to April inclusive

5. (a) During the months from 20 September to, and including, 30 April the lagoon may be opened to the sea when the water level in the lagoon reaches 2.2 metres, as measured on the Waghorn's Road bridge gauge board;

(b) During the months from 20 September to, and including, 30 April the lagoon may be opened to the sea when the water level exceeds 2.0 metres, as measured on the Waghorn's Road bridge gauge board, provided that:

(i) the lagoon has been above that level for 14 days out of a continuous period of twenty days; and

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[1] Continuous water level readings are available at: http://www.es.govt.nz/rivers-and-rainfall/graph/?site=Waituna-Lagoon-at-Waghorns-Road&measurement=river level&start=12-May-2016&end=19-May-2016&owner=0

[2] Wind conditions at Invercargill airport can be viewed at: http://www.metservice.com/towns-cities/invercargill?gclid=CIuft6z1gM8CFQGavAod19kAsA#!/your-weather

(ii) the mean aquatic plant (macrophyte) cover in the lagoon has exceeded 30 percent for the previous three years, as determined by annual summer surveys or monitoring by a suitably qualified person

Lagoon Opening in the case of poor water quality events

6. (a) Notwithstanding conditions 4-6 of this consent, the lagoon may be opened to the sea when water level in the lagoon is above 1.5 metres, as measured on the Waghorn's Road bridge gauge board, provided that:

   (i) a primary ecological trigger (outlined in Appendix 1) has been reached, and
   (ii) a technical advisory group, convened jointly by Environment Southland, Te Ao Marama Inc and the Department of Conservation, with scientific knowledge of coastal lagoon ecosystems, has considered the secondary and tertiary indicators (Appendix 1), and any other relevant scientific information, and has advised the consent holder and Consent Authority in writing that opening the lagoon to the sea is advisable to disrupt an actual or probable algal bloom in order to avoid a significant adverse ecological effect on the lagoon,

   (b) If the technical advisory group required by Condition 6(a)(ii) specifies a preference (in writing) for the opening to occur at one or the other of the locations specified in Condition 1, the opening in accordance with this condition shall only occur at that location.

   (c) In the event that the lagoon is opened to the sea in accordance with condition 6(a), the consent holder shall notify the following parties that a primary ecological trigger has been reached and that opening the lagoon to the sea has been recommended. The notification shall include evidence that the ecological trigger has been reached and a copy of the written advice from the technical advisory group specified in condition 6(a):

   - Kaupapa Taiao Manager, Te Ao Marama Inc, PO Box 7078, South Invercargill 9844
   - Operations Manager, Murihiku District Office, Department of Conservation, PO Box 743, Invercargill 9840
   - The Manager, Fish & Game New Zealand, PO Box 159, Invercargill 9840
   - The Consent Authority

7. (a) With regard to the Primary indicator in Appendix 1, a "visible algal bloom" shall be identified by:

   (i) $\geq$ 0.012 mg/l Chlorophyll *a* (or other figure identified in writing by the technical advisory group referred to in condition 6); and/or
   (ii) The observations of an appropriately qualified person. These observations shall include the location and approximate scale and intensity of the visible algal bloom on each day of observation.

   (b) These observations or readings are to be recorded and shall be made available to the Lagoon technical advisory group and the Consent Authority.

Responses to disturbance of artefacts or fuel spills

8. In the event of:

(a) the discovery, or suspected discovery, of a site of cultural importance (Waahi Taonga/Tapu), the consent holder shall immediately cease operations in that location and inform the local Iwi authority (Te Ao Marama Inc) and the Consent Authority Operations may recommence at a time as agreed upon in writing with the Consent Authority. The discovery of Koiwi (human skeletal remains) or Taonga or artefact material (e.g. pounamu/greenstone) would indicate a site of cultural importance. Appendix 2 to this consent outlines the process that is to be followed in the event of such a discovery.

(b) contamination of the lagoon or foreshore, such as with fuel or oil spilt from the digger during the lagoon opening, the consent holder shall remove the contaminants immediately from the site and notify, without undue delay, the Consent Authority (email: compliance@es.govt.nz or phone 03 211 5115) and the Area Manager (Murihiku) of the Department of Conservation.

Information Gathering Requirements

9. The consent holder shall record the following information:

(a) when and where the lagoon is opened to the sea;
(b) the water level in the lagoon at the time it was opened;
(c) information to show compliance with the opening criteria specified in Conditions 4, 5 or 6.
(d) when and at what gauge board level access across Carran Creek bridge was lost for stock and farm vehicles and when was this access re-established.
(e) how long the lagoon is open to the sea and when it closes (to the nearest week);

10. The consent holder shall provide the information specified in condition 9, to the Consent Authority and to the Operations Manager (Murihiku) of the Department of Conservation within one month of the opening of the lagoon to the sea, and without undue delay following closure of the channel to the sea.

Consent Review and Council Charges

11. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the conditions of this consent during the period 1 February to 30 September each year, or within two months of any enforcement action being taken by the Consent Authority in relation to the exercise of this consent, or on receiving monitoring results, for the purposes of:

(a) determining whether the conditions of this permit are adequate to deal with any adverse effect on the environment, including cumulative effects, which may arise from the exercise of the permit, and which it is appropriate to deal with at a later stage, or which become evident after the date of commencement of the permit;
(b) ensuring the conditions of this consent are consistent with any National Environmental Standards Regulations, relevant plans and/or Policy Statement;
(c) amending the monitoring programme to be undertaken; or
(d) adding or adjusting compliance limits.

Note: Under s127 of the Resource Management Act the Consent Holder can apply for a change or cancellation of a resource consent condition (other than the consent duration) at any time during the consent period.

12. The consent holder shall pay an annual administration and monitoring charge to the Consent Authority, collected in accordance with Section 36 of the Resource Management Act, 1991.

Meetings

13. The consent holder shall hold liaison meetings, at least once each year, to report and discuss available monitoring information regarding the following in Lake Waituna:
    - water level
    - water quality, particularly nutrients
    - algae, particularly chlorophyll a
    - macrophytes
    - fish

    (a) The consent holder shall invite the following to the liaison meetings:
        (i) representatives of each of the organisations in Section 3.1 of Appendix 3; and

        (ii) each of the individuals (or their representatives) in Section 3.2 of Appendix 3

        (iii) Any other person or group at the discretion of the applicant.

    (b) The consent holder shall record a summary of the attendees and discussion at each meeting, and report the summary to the consent authority within 20 working days of the meeting.

    (c) In the event that contact details for any of the individuals or organisations in Appendix 3 becomes outdated, and the consent holder has not been notified of updated contact details, the consent holder may omit invitation of that individual or organisation to the meeting.

for the **Southland Regional Council**

Vin Smith
Director of Policy, Planning & Regulatory Services

Appendix 1
Indicators

Primary Indicator	**Critical Trigger**
Chlorophyll *a*	a sustained visible algal bloom over a period of 14 days or longer
Secondary Indicators	Critical Indicator Levels
Total Phosphorus concentration	≥ 0.045 mg/l
Total Nitrogen concentration	≥ 0.700 mg/l
Tertiary Indicators	
Nuisance epiphytes or benthic algae	
Ruppia and other macrophytes	
RPD (Redox Potential Discontinuity) – bottom sediments	
Turbidity	
Bottom water dissolved oxygen concentration	
Aquatic and surrounding wetland life	
Algal blooms	

Appendix 2
Protocol in the event of a discovery, or suspected discovery, of a site of cultural importance (Waahi Taonga/Tapu)

1. *Kōiwi tangata accidental discovery*

If Kōiwi tangata (human skeletal remains) are discovered, then work shall stop immediately and the New Zealand Police, Heritage New Zealand (details below) and Te Ao Marama Inc (Ngai Tahu (Murihiku) Resource Management Consultants) shall be advised. Contact details for Te Ao Marama Inc are as follows:

Te Ao Marama Inc
Murihiku Marae, 408 Tramway Road, Invercargill
P O Box 7078, South Invercargill 9844
Phone: (03) 931 1242

Te Ao Marama Inc will arrange a site inspection by the appropriate Tangata Whenua and their advisers, including statutory agencies, who will determine how the situation will need to be managed in accordance with tikanga māori.

2. *Archaeological Sites*

Archaeological sites are protected under the Heritage New Zealand Pouhere Taonga Act (2014), and approval is required from Heritage New Zealand before archaeological sites can be modified, damaged or destroyed.

Not all archaeological sites are known or recorded precisely. Where an archaeological site is inadvertently disturbed or discovered, further disturbance must cease until approval to continue is obtained from Heritage New Zealand. As stated above, the New Zealand Police and Te Ao Marama Inc also need to be advised if the discovery includes kōiwi tangata/human remains.

Heritage New Zealand, C/- Dr M Schmidt, Regional Archaeologist
Otago/Southland
PO Box 5467, Dunedin 9058
Phone: (03) 470 2364 Mobile 027 240 8715 mschmidt@heritage.org.nz

3. ***Taonga or artefact accidental discovery***

If taonga or artefact material (e.g. pounamu/greenstone artefacts) other than kōiwi tangata is discovered, disturbance of the site shall cease immediately and Southland Museum and Te Ao Marama Inc shall be notified of the discovery by the finder or site archaeologist in accordance with the Protected Objects Act 1975. All taonga tuturu are important for their cultural, historical and technical value and are the property of the Crown until ownership is resolved.

4. ***In-situ (natural state) pounamu/greenstone accidental discovery***

Pursuant to the Ngai Tahu (Pounamu Vesting) Act 1997, all natural state pounamu/greenstone in the Ngai Tahu tribal area is owned by Te Runanga o Ngai Tahu. Ngai Tahu Pounamu Management Plans provide for the following measures:

- any *in-situ* (natural state) pounamu/greenstone accidentally discovered should be reported to Te Runanga o Ngai Tahu staff as soon as is reasonably practicable. Te Runanga o Ngai Tahu staff will in turn contact the appropriate Kaitiaki Papatipu Runanga;
- in the event that the finder considers the pounamu is at immediate risk of loss such as erosion, animal damage to the site or theft, the pounamu/greenstone should be carefully covered over and/or relocated to the nearest safe ground.

The find should then be notified immediately to the Programme Leader – Ohanga, at Te Rūnanga o Ngāi Tahu. Their details are as follows:

Te Rūnanga o Ngāi Tahu, c/o Programme Leader - Ohanga
Te Whare o Te Wai Pounamu
15 Show Place, P O Box 13-046, Otautahi/Christchurch 8021
Phone: (03) 366 4344 Web: www.ngaitahu.iwi.nz

Appendix 3
Contact details for persons identified in Condition 13

a) The following lists identify the organisations and persons to be invited to the liaison meetings.
b) The postal and email addresses are based on information in the submissions to the application but could become outdated during the term of the resource consent.

3.1 Organisations:

- Te Runanga o Awarua, C/- Te Ao Marama Inc, PO Box 7078, South Invercargill 9844 dean.whaanga@teaomarama.maori.nz
- Department of Conservation, Private Bag 4715, Christchurch Mail Centre 8140. Attn: G Deavoll gdeavoll@doc.govt.nz
- Fish & Game New Zealand, P O Box 159, Invercargill 9840 zane@southlandfishgame.co.nz
- Royal Forest & Bird Protection Society, PO Box 6230, Dunedin North 9059 s.maturin@forestandbird.org.nz
- Waituna Affected Farmers, C/- J Crack, 108 Moffat Road, RD 5, Invercargill 9875 jo@farmnews.co.nz
- Waituna Recreational Users Group, C/- B McNaughton, 502 Elles Road, Kingswell, Invercargill 9812 bevan@ocs.net.nz
- Federated Farmers New Zealand, PO Box 176, Invercargill 9840. Attn: Tanith Robb trobb@fedfarm.org.nz
- Dairy New Zealand, Private Bag 3221, Hamilton 3240 David.burger@dairynz.co.nz
- Stagger Inn Hunting Group, C/- Craig Booth, 11 Judge Road, Tisbury, Invercargill 9812

3.2 Individuals:

- S Carston, 5 /3 Fortuna Place, Gold Coast, Queensland, Australia ycats7@gmail.com
- J & D Crack, 108 Moffat Road, RD 5, Mokotua, Invercargill 9875 jo@farmnews.co.nz
- O Kelly, 433 Waituna Lagoon Road, RD 5, Invercargill 9875 oakelly@netspeed.nz
- L McCallum, 1100 Wilsons Crossing Road, RD 1, Winton 9781 lloyd.kathy@xtra.co.nz
- G McKenzie, 32 Bungalow Hill Road, RD 1, Riverton 9881 Graeme@orakafarms.co.nz
- B J McNaughton, 502 Elles Road, Kingswell, Invercargill 9812 bevan@ocs.net.nz
- R McNaughton, 168 Walker Road, RD 1, Woodlands, Invercargill 9871 roger@ocs.net.nz
- A Owen, 275 Waimatuku Township Road, RD 4, Invercargill 9874 aowen444@gmail.com
- L Paddon, 19 Manapouri Street, Invercargill 9812
- J Pannett, 113 Chelmsford Street, Invercargill 9810 john.chick@xtra.co.nz
- S Perriam, 904 Rimu Seaward Downs Road, RD 1, Waituna, Invercargill 9871 jane.shayne@woosh.co.nz
- B Pirie, 206 Drakes Hill Road, RD 1, Invercargill 9871 drakeshillfarming@gmail.com
- D J Simms, 54 Awatea Gardens, Wigram, Christchurch 8042 Don.simms@xtra.co.nz
- R W Simms, 6 /58 Douglas Street, Frankton, Queenstown 9300 sue_raysimms@xtra.co.nz
- S R Simms, 50A Bantry Street, Alexandra 9320
- R van Gool, 90 Smiths' Way, RD 3, Cromwell 9383 towyn@vodafone.co.nz
- M J Waghorn, 961 Waituna Lagoon Road, RD 5, Invercargill 9875 murraywaghorn@hotmail.com
- R C Waghon, 837 Waituna Lagoon Road, RD 5, Invercargill 9875 rcwaghorn@gmail.com
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Water Permit

Pursuant to Section 104B of the Resource Management Act 1991, a resource consent is hereby granted by the Southland Regional Council to **Lake Waituna Control Association,** care of **E R Pirie, 389 Kapuka North Road, RD 3, Wyndham 9893** from **14 February 2017**.

Please read this Consent carefully, and ensure that any staff or contractors carrying out activities under this Consent on your behalf are aware of all the conditions of the Consent.

Details of Permit

Purpose for which permit is granted:	To divert water from Lake Waituna and associated wetlands to the sea
Location - site locality	Walker's Bay and Hansen's Bay, Lake Waituna
- map reference	Between NZTM 1262340E 48311370N and 1261460E 4831000N (Walker's Bay), and about NZTM 1265350E 4832550N (Hansen's Bay)
Legal description at the site:	Section 29 Block XIII Oteramika Hundred
Expiry date:	14 February 2022

Schedule of Conditions

1. This consent authorises the diversion of water from the Waituna Lagoon and associated wetlands by opening the gravel barrier between the lake and the sea at either:
   (a) Walker's Bay between NZTM 1,262,340E 4,831,360 N and 1,261,460E 4,831,000N; or
   (b) Hansen's Bay, between NZTM 1,265,305E 4,832,570N and 1,265,405E 4,832,605N

2. This resource consent may only be exercised in conjunction and accordance with Resource Consent AUTH-20146407-01.

3. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the conditions of this consent during the period 1 February to 30 September each year, or within two months of any enforcement action being taken by the Consent Authority in relation to the exercise of this consent, or on receiving monitoring results, for the purposes of:

    (a) determining whether the conditions of this permit are adequate to deal with any adverse effect on the environment, including cumulative effects, which may arise from the exercise of the permit, and which it is appropriate to deal with at a later stage, or which become evident after the date of commencement of the permit;
    (b) ensuring the conditions of this consent are consistent with any National Environmental Standards Regulations, relevant plans and/or Policy Statement;
    (c) amending the monitoring programme to be undertaken; or
    (d) adding or adjusting compliance limits.

for the **Southland Regional Council**

Vin Smith
Director of Policy, Planning & Regulatory Services

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Coastal Permit

Pursuant to Section 104B of the Resource Management Act 1991, a resource consent is hereby granted by the Southland Regional Council to **Lake Waituna Control Association,** care of **E R Pirie, 389 Kapuka North Road, RD 3, Wyndham 9893** from **14 February 2017**.

Please read this Consent carefully, and ensure that any staff or contractors carrying out activities under this Consent on your behalf are aware of all the conditions of the Consent.

Details of Permit

Purpose for which permit is granted:	To periodically discharge water from Lake Waituna to the sea
Location - site locality - map reference	Walker's Bay and Hansen's Bay, Lake Waituna Between NZTM 1262340E 48311370N and 1261460E 4831000N (Walker's Bay), and about NZTM 1265350E 4832550N (Hansen's Bay)
Legal description at the site:	Section 29 Block XIII Oteramika Hundred
Expiry date:	14 February 2022

Schedule of Conditions

1. This consent authorises the periodic discharge of water from the Waituna Lagoon into the sea via openings in the gravel barrier at either:
   (a) Walker's Bay between NZTM 1,262,340E 4,831,360 N and 1,261,460E 4,831,000N; or
   (b) Hansen's Bay, between NZTM 1,265,305E 4,832,570N and 1,265,405E 4,832,605N

2. This resource consent may only be exercised in conjunction and accordance with Resource Consent AUTH-20146407-01.

3. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the conditions of this consent during the period 1 February to 30 September each year, or within two months of any enforcement action being taken by the Consent Authority in relation to the exercise of this consent, or on receiving monitoring results, for the purposes of:

   (a) determining whether the conditions of this permit are adequate to deal with any adverse effect on the environment, including cumulative effects, which may arise from the exercise of the permit, and which it is appropriate to deal with at a later stage, or which become evident after the date of commencement of the permit;
   (b) ensuring the conditions of this consent are consistent with any National Environmental Standards Regulations, relevant plans and/or Policy Statement;
   (c) amending the monitoring programme to be undertaken; or
   (d) adding or adjusting compliance limits.

for the **Southland Regional Council**

Vin Smith
Director of Policy, Planning & Regulatory Services

Appendix M: NIWA Inundation Study

NIWA
Taihoro Nukurangi

Waituna Lagoon level impacts on land drainage and inundation

Investigation stages 1 and 2

Prepared for Department of Conservation

February 2016

Prepared by:
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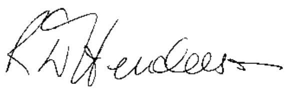
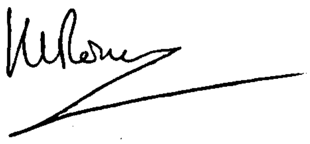
NIWA CLIENT REPORT No: CHC2016-010
Report date: February 2016 (Revised May 2017)
NIWA Project: DOC16501

Quality Assurance Statement		
	Reviewed by:	Roddy Henderson
	Formatting checked by:	America Holdene
	Approved for release by:	Helen Rouse

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Executive summary

Water tables and inundation within parts of the Waituna Lagoon catchment are influenced by water levels within the lagoon, but the extent of this effect is not fully understood. Better understanding of the area of land impacted by different lagoon levels will enable more robust decision making regarding lagoon level regimes. Mapping the area of land impacted by lagoon levels will also identify those areas most vulnerable to inundation or compromised drainage.

To inform decision making in regard to lagoon openings, the Department of Conservation commissioned NIWA, under the Arawai Kākāriki wetland restoration programme, to undertake a two-stage study to map the spatial extent of inundated land for a range of lagoon levels and to predict areas of drainage affected land. This work has been funded from Living Water, a Department of Conservation/Fonterra partnership committed to best practice management of New Zealand's waterways.

Stage 1 of the study was commissioned in September 2015, and involved simple 'bathtub' modelling of the Waituna Lagoon to provide a simple 'first-cut' mapping of the extent of farmland inundated under different lagoon levels, assuming static horizontal water levels. This work was completed in September 2015.

Stage 2 was commissioned in November 2015. This involved a hydraulic model study of the creeks feeding into the Waituna Lagoon with the aim of providing a more accurate mapping of inundated or drainage affected farmland, by including simulated backwater effects. Stage 2 was completed for Waituna and Carran Creeks in February 2016, and for Moffat Creek in May 2017.

This report documents work done and provides results for both stages.

The 'first-cut' maps of inundation extent that have been derived from the simple bathtub modelling have been included. These maps, which show inundation extent under static lagoon water levels, are useful in that they provide inundation extents around the shoreline of the lagoon. However, since they do not allow for hydraulic effects (i.e., steady-flow water level and backwater effects) they cannot be used to assess inundation extents along the main tributary channels resulting from stream flow.

In Stage 2, one-dimensional hydraulic models of Waituna Creek, Carran Creek and Moffat Creek were constructed and calibrated. The models were used to assess water levels in each creek for two flow and two plant abundance scenarios. This modelling has allowed maps of inundation extent and drainage affected farmland to be produced that incorporate steady-state hydraulic effects.

Key results for Waituna Creek:

- For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent up Waituna Creek was to around 400 m upstream of White Pine Road.
- Farmland inundated by high lagoon water levels or backwater effects from Waituna Lagoon is mainly within an area on the true left of the channel south of a farm access road off Marshall Road, about 1 km south of White Pine Road. Significant inundation of this area occurs even at low lagoon levels when the Waituna Creek channel has high plant abundance, indicating that the inundation is related to restriction of the channel rather than the lagoon level.

- At the 90 percentile high flow, the area of land where drainage is potentially affected is much more influenced by plant growth than by lagoon water level (including backwater effects). At mean flow, the lagoon water level has a more significant effect, but with more limited up-channel extent.

Key results for Carran Creek:

- For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was to 1.1 km upstream of Waituna Lagoon Road Bridge.
- The main area of land inundated by high Waituna lagoon levels is west to north-west of Little Lake Waituna. For the scenarios considered, no significant inundation occurred east of Waituna Lagoon Road or north of Hanson Road.
- A 500 m wide swath of land downstream of Waituna Lagoon Road Bridge and west of Waituna Lagoon Road is potentially drainage affected even at low lagoon level (taken as 0.5 m), although much of this land is wetland habitat, not farmland
- At mean flow, except at high lagoon levels (WL > 2.0 m), very little farmland upstream of Waituna Road Bridge is potentially drainage affected, when the river channel is clear of plant growth. If the channel has instead high plant abundance then, more farmland is potentially drainage affected.
- At the 90 percentile high flow, a fairly large area of farmland (~44 ha), upstream of Waituna Lagoon Road Bridge, is potentially drainage affected when the channel is vegetated (under all lagoon levels). This area reduces in size by about 40% if the channel is cleared.

Key results for Moffat Creek:

- For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was about 940 m downstream of Moffat Road Bridge.
- The main area of land inundated by high Waituna lagoon levels is wetland habitat, not farmland. No significant inundation of farmland is predicted.

Overall the area of land inundated by static lagoon water levels up to 2.5 m is relatively minor and generally around the mouths of the three main tributary creeks. For Waituna, Moffat and Carran Creeks the area of land affected by direct inundation and impeded drainage is a function of lagoon level, flow rate and plant growth in the creeks. The relative importance of these three factors varies spatially. The most downstream parts of the Creeks strongly affected by lagoon level but further upstream this has little or no effect and channel vegetation and flow dominate. For high flow, densely vegetated conditions, the lagoon level has less impact as Creek levels are already high. Under high flow conditions the area of farmland with potentially affected drainage is much higher as a result of a vegetated channel than as a result of a high lagoon level (for all three creeks).

While this study provides a good basis for understanding how lagoon levels impact farmland around Waituna Lagoon uncertainty could be reduced by investigating the typical depth of field drains, and conducting further water level and flow surveys in the backwater reaches under different flow and vegetation conditions.

1 Introduction

Water levels within Waituna Lagoon are influenced by lagoon inflows, losses (seepage and evaporation), openings to the ocean, and (when open) tides. The current opening regime involves opening the lagoon once the level exceeds 2 m above mean sea level. The consent which permits this opening regime to occur is up for renewal, and the potential for more flexibility with regard to openings to promote environmental benefits is being considered (for example openings at lower levels to relieve periods of prolonged algal blooms or reducing the frequency of spring/summer openings when this could be beneficial to macrophytes).

Water tables and inundation within parts of the Waituna Lagoon catchment are influenced by water levels within the lagoon, but the extent of this effect is not fully understood. Better understanding the area of land impacted by different lagoon levels will enable more robust decision making regarding lagoon level regimes. Identifying the areas most vulnerable to inundation or compromised drainage will also be useful for management.

To inform decision making in regard to lagoon openings, the Department of Conservation commissioned NIWA, under the Arawai Kākāriki wetland restoration programme, to undertake a two stage study to map the spatial extent of inundated land for a range of lagoon levels and to map drainage affected land. This work has been funded from Living Water, a Department of Conservation/Fonterra partnership committed to best practice management of New Zealand's waterways.

Stage 1 of this study, to undertake simple 'bathtub' modelling of the Waituna Lagoon, was commissioned in September 2015. This was a preliminary study, the aim of which was to provide a simple 'first-cut' mapping of the extent of farmland inundated under different lagoon levels, assuming static horizontal water levels. This work was completed in September 2015.

In December 2015, a second stage of work was commissioned (Stage 2) involving a hydraulic model study of the creeks feeding into the Waituna Lagoon. The Stage 2 study aimed to provide accuracy, by including simulated backwater effects on the creeks and mapping land which was inundated as well as land which was within 1 m of the creek water elevation and hence likely to have its drainage affected. This work was completed for Waituna and Carran Creeks in February 2016.

In October 2016 the study was extended to consider a deeper (2 m) drainage depth as it was felt that many field drains were deeper than 1 m.

In May 2017 the study was extended to include Moffat Creek, which had not been included originally due to difficulties accessing the Creek for cross-section survey.

This report has been updated to include all the work done and provides results for both Stage 1 and Stage 2 of the study.

2 Scope of the project

2.1 Stage 1: Simple 'bathtub' modelling

The scope of work for Stage 1 consisted of building a digital elevation model of the Waituna Lagoon and its surrounding area by combining data from aerial LiDAR and a bathymetry survey of the lagoon, then mapping the extent of farmland inundated under different lagoon levels. Static horizontal water levels are assumed.

The following outputs were required:

- a digital elevation model (DEM) of the lagoon and its catchment;
- maps of inundation extent for a range of static lagoon level scenarios.

2.2 Stage 2: Hydraulic Modelling

The aim of Stage 2 was to refine the analysis of inundation extents to include backwater effects along the main creeks draining into Waituna Lagoon (i.e., Waituna Creek, Moffatt Creek and Carran Creek), through steady-state hydraulic modelling of these creeks.

Tasks required to be carried out by NIWA under Stage 2 were as follows:

1. build a one-dimensional hydraulic model of each of the 3 main creeks using cross-section survey data, from a survey commissioned in December 2015;
2. calibrate the models hydraulically, to match surveyed water levels;
3. perform model runs in each creek for two flows (mean flow and a higher flow) and for a range of lagoon levels.

Outputs required included:

- 1D hydrodynamic models of the main creeks;
- a report providing a technical description of the models, their calibration, and providing information on backwater extents including maps of ground freeboard relative to lagoon water/creek water level for a range of scenarios taking into account backwater effects in the creeks.

TrueSouth Survey Services Ltd were commissioned by the Department of Conservation to undertake the cross-section survey of Waituna Creek, and Carran Creek in December 2015, and Moffat Creek in March 2017. TrueSouth surveyed 7 cross-sections in Carran Creek, 8 cross-sections in Waituna Creek, and 9 cross-sections in Moffat Creek.

3 Stage 1: Simple bathtub modelling

3.1 Methodology

The simple bathtub modelling required a digital elevation model of the Waituna Lagoon and the surrounding area to be constructed. Once constructed this model was used to obtain maps of inundated areas for static lagoon levels.

The following data sources were used to create the DEM:

- a LiDAR point cloud collected between 20-22 March 2012 by NZ Aerial Mapping for Environment Southland;
- bathymetric soundings collected in December 2011 by TrueSouth Survey Services Ltd;
- bathymetric soundings 'Charlie_Bay_Transect_1.shp', provided by Environment Southland.

The LiDAR points were interpolated into raster grids at various resolutions (2 m, 5 m, 10 m, 20 m, and 30 m). The final 'dry land' DEM from LiDAR was then generated by layering these interpolated DEMs with priority given to higher resolutions. Using this method, data gaps in higher resolution DEMs (mainly in the wetlands surrounding the lagoon) were filled with real data interpolated at lower resolutions.

The lagoon bathymetry was interpolated by using the two sets of sounding points as well as LiDAR returns within a 5m distance from the water's edge to assure a smooth transition between lagoon and land elevations.

The final DEM was generated by overlaying the bathymetric raster over the dry land DEM. Technical details of the final version supplied are as follows:

Filename: Waituna_2m_Combined_DEM_filtered.tif
Coordinates: NZTM
Vertical Datum: Bluff 1955
Resolution: 2 m

Figure 3-1 provides an overview of the data sources used. Note, the displayed cross-sections were not used in the DEM and are shown for reference only.

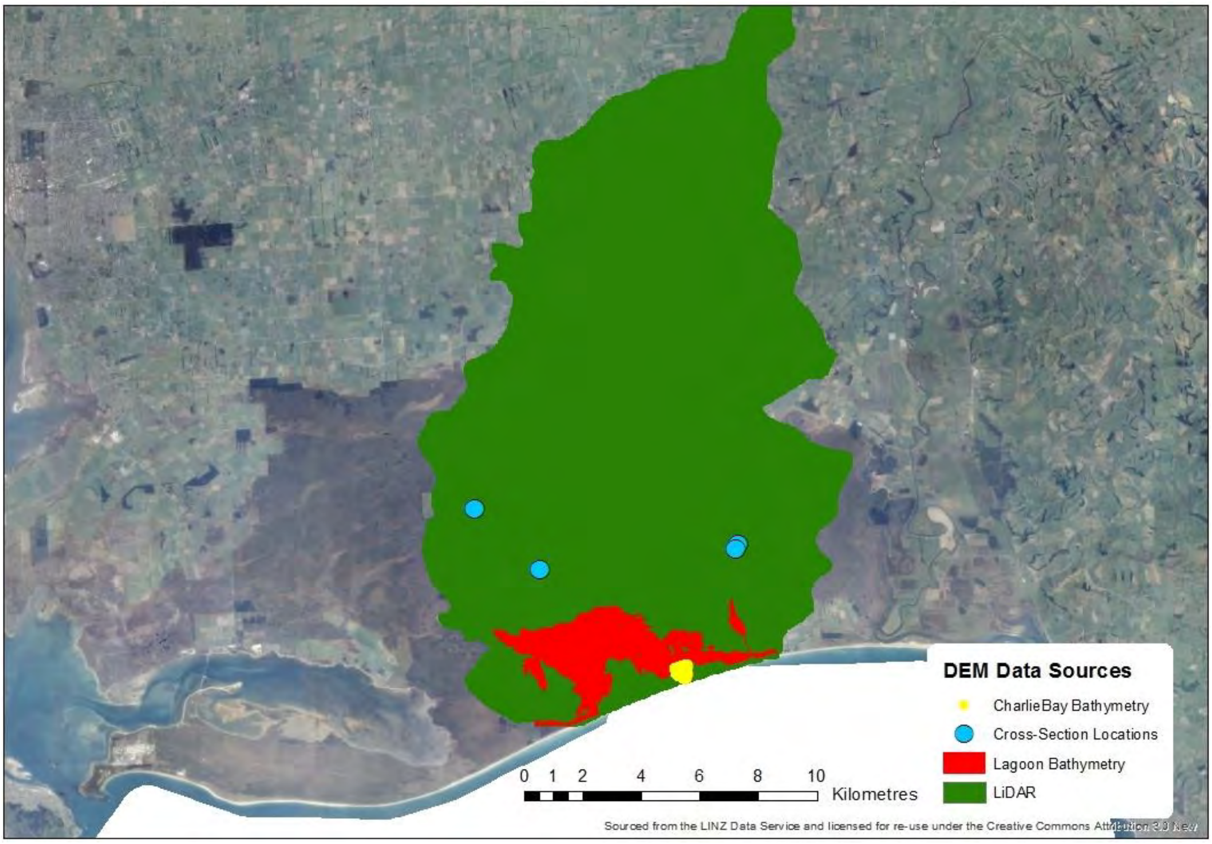


Figure 3-1: Data sources used to generate the final DEM for the simple 'bathtub' modelling.

3.2 Results

Figure 3-2 maps inundation extents derived from the simple bathtub model for Waituna Lagoon water levels from 0.5 m to 2.5 m at 0.5 m intervals. Figure 3-3 maps inundation extents for three additional lagoon water levels of specific relevance to the current or possible future management regime (1.5, 1.8 and 2.3 m).

The maps show that the area of land inundated by lagoon levels up to 2.5 m is generally confined to wetlands around the lagoon margins. The areas where the static lagoon level inundates farmland are relatively minor and generally around the mouths of the three main tributary creeks: Waituna, Moffatt and Carran. The impact of lagoon levels on land around Waituna and Carran Creeks is explored further in Stage 2.

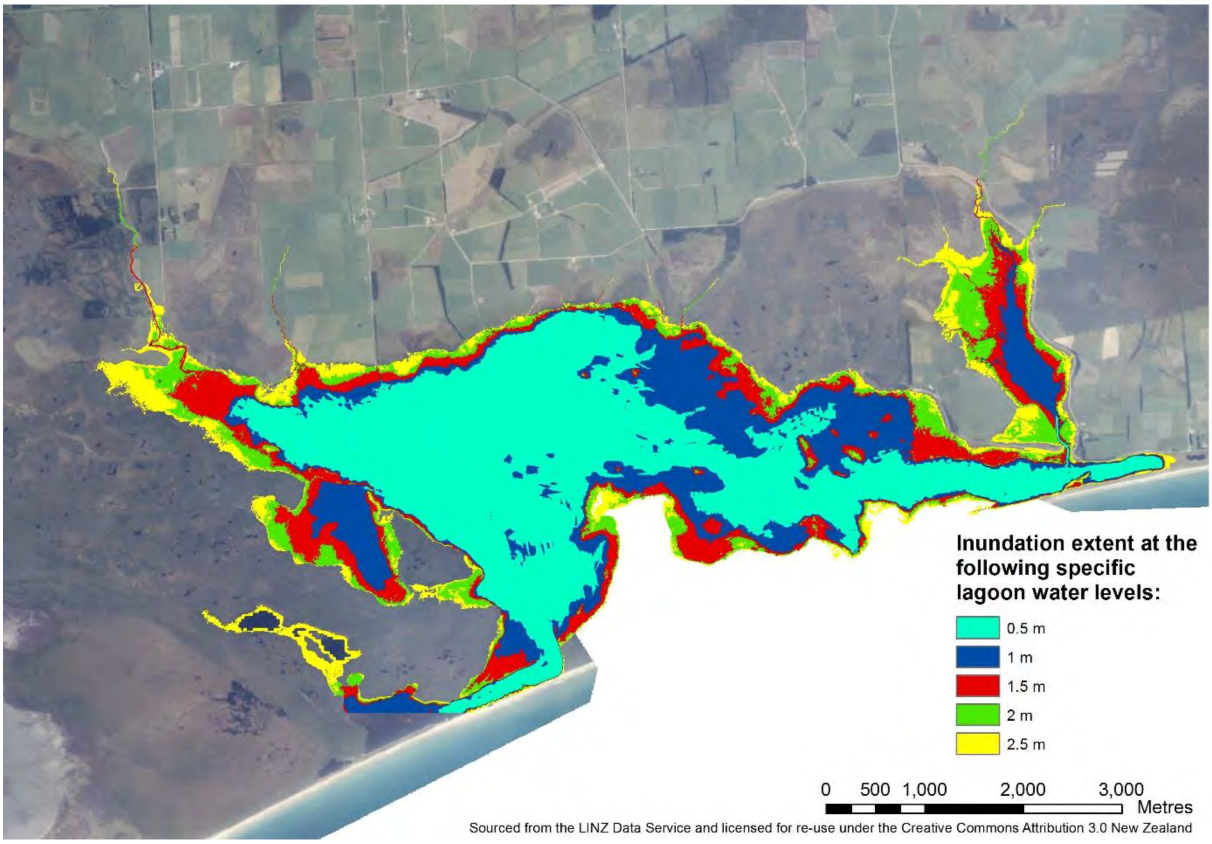


Figure 3-2: Inundation extent for Waituna Lagoon levels at 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. Inundation extents are derived from the simple 'bathtub' model.

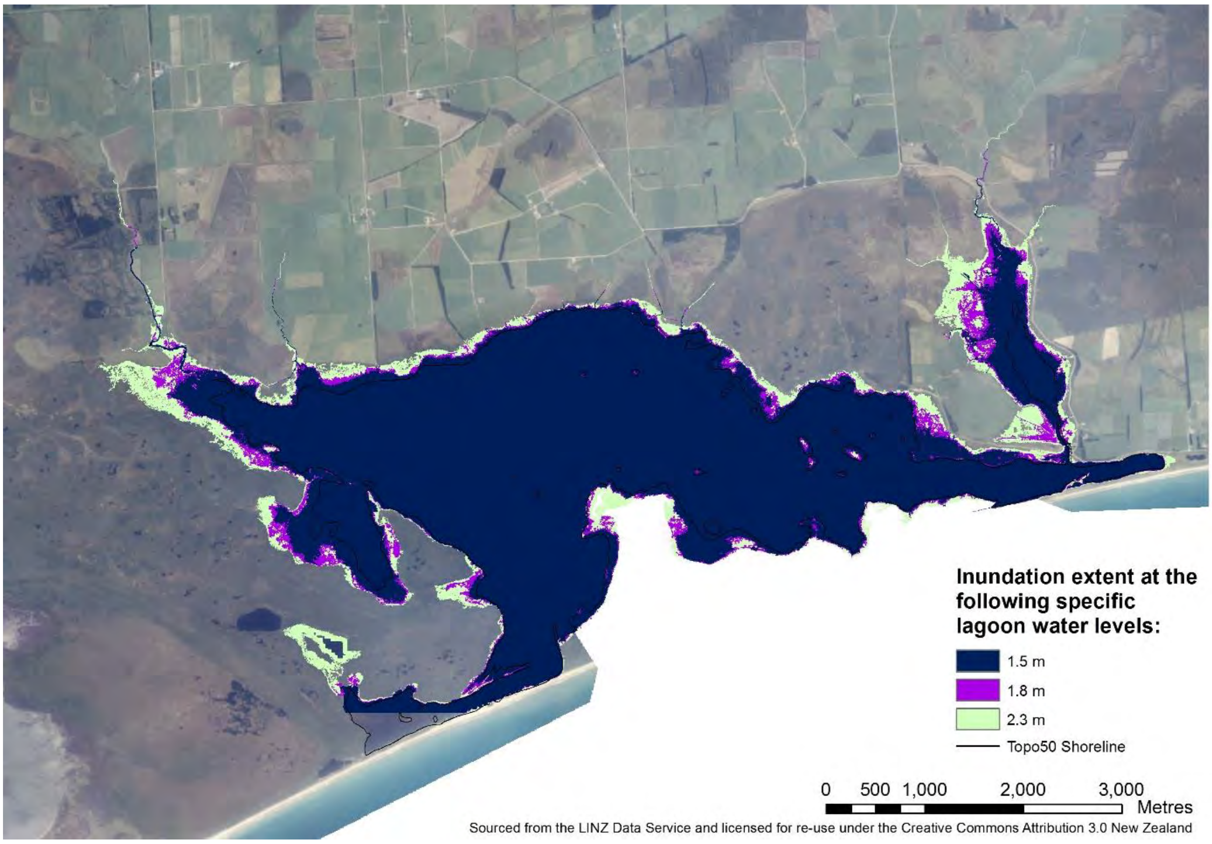


Figure 3-3: Inundation extent for Waituna Lagoon levels at 1.5 m, 1.8 m, and 2.3 m Inundation extents are derived from the simple 'bathtub' model.

4 Stage 2: Hydraulic modelling

4.1 Building the models

Modelling was carried out using DHI's MIKE HYDRO RIVER (Release 2016) modelling package which is a successor of the MIKE-11 modelling tool that is widely used both in New Zealand and internationally.

Three one-dimensional hydraulic models were constructed, one representing a 6.52 km reach of Waituna Creek from the Marshall Road hydrology recorder down to the Waituna Lagoon, another a 5.02 km reach of Carran Creek from 1.5 km upstream of Waituna Lagoon Road down to Waituna Lagoon, and a third representing a 3.95 km reach of Moffat Creek from upstream of Moffat Road down to Waituna Lagoon. Figure 4-1 shows the modelled Waituna Creek reach (bottom left plot) and modelled Carran Creek reach (bottom right plot). Locations of surveyed cross-sections used in the models and downstream chainage are also shown.

Cross-sections were derived from the following sources:

- The December 2015 survey conducted by TrueSouth Survey Services Ltd for Waituna and Carran Creeks. The surveyed cross-sections were extended where necessary using the LiDAR based DEM derived in Stage 1, to give a wider topographic representation of the stream channel and surrounds.
- The March 2017 survey conducted by TrueSouth Survey Services Ltd for Moffat Creek.
- Directly from the LiDAR DEM derived in Stage 1 (within Waituna Lagoon and Little Lake Waituna).

In Waituna Creek, TrueSouth were unable to survey closer to the lagoon than cross-section W-1 as the combination of dense plant growth and wide channel made surveying by boat or on foot very challenging. To provide definition of the channel close to its exit into the lagoon, an artificial cross-section (W1-A) was added at chainage 6.176 km. This cross-section replicates cross-section W-1 but with an adjustment to level of -1.5 m, to match the local thalweg slope between cross-sections W-1 and its nearest cross-section upstream (i.e., W-2). The model could be improved by an additional bathymetric survey between cross-section W1 and the lagoon.

Table 4-1, Table 4-2 and Table 4-3 document the location of key modelled cross-sections for the Waituna Creek, Carran Creek and Moffat Creek models, respectively. Chainage refers to the distance along the river channel from the start of the modelled reach to any given location.

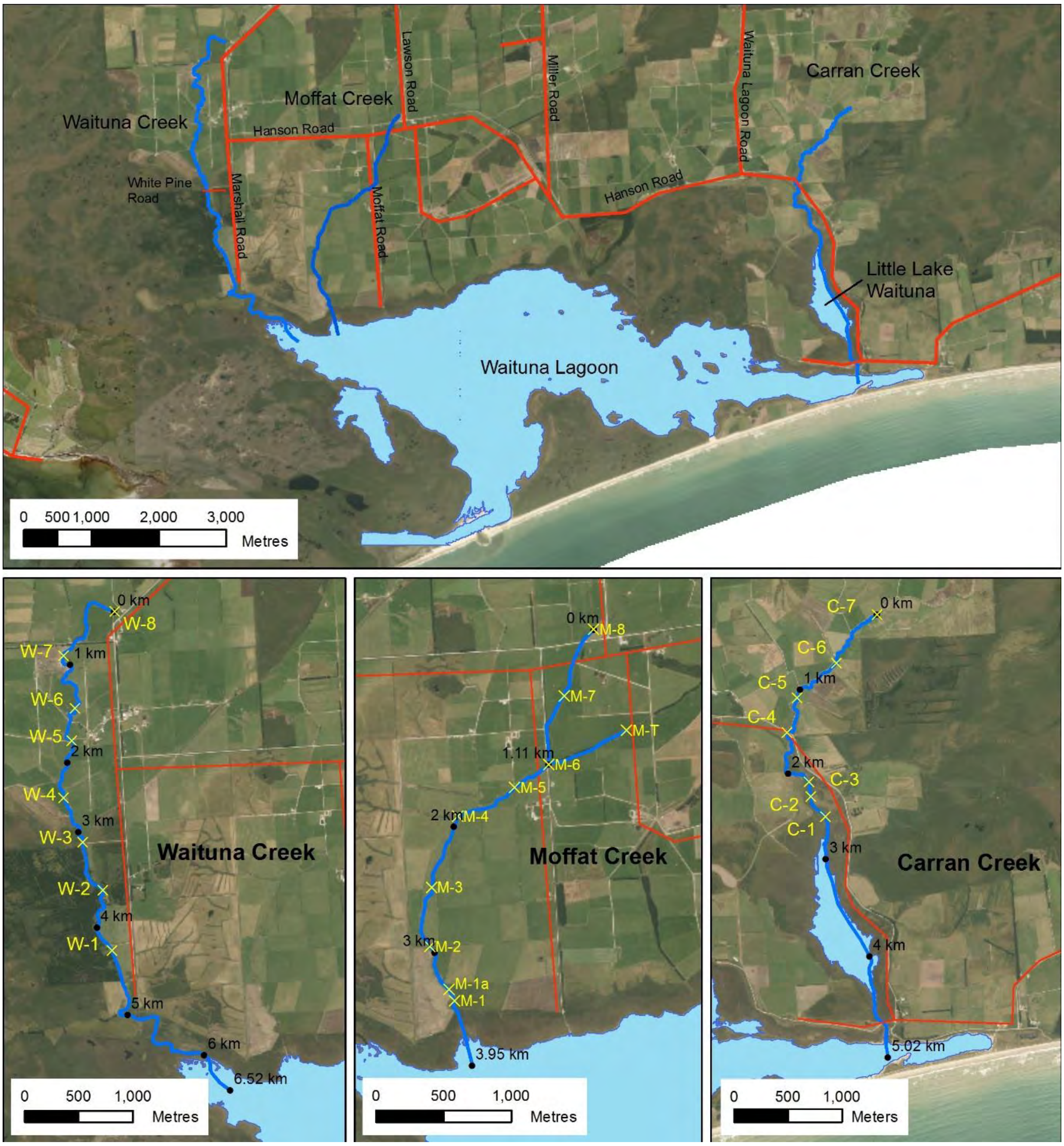


Figure 4-1: Maps of Waituna Lagoon and the modelled creeks. Blue line shows the modelled reach. Yellow crosses show the location of cross-sections surveyed by TrueSouth in December 2015. Black dots show distance from the start of the modelled reach (chainage). *Aerial imagery sourced from the LINZ Data Service https://data.linz.govt.nz/layer/1934-southland-075m-rural-aerial-photos-2005-2011/ and licensed by The Southland Consortium (Southland District Council, Gore District Council, Environment Southland, and Department of Conservation) for re-use under the Creative Commons Attribution 3.0 New Zealand licence*.

Table 4-1: Waituna Creek - location of key modelled cross-sections.

Cross-section	Chainage (km)	Location description
W-8	0.000	Marshall Road Hydrology Recorder Site
W-7	0.862	0.86 km downstream of recorder site
W-6	1.594	Marshall Road Farm Trustees Ltd
W-5	1.992	Marshall Road Farm Trustees Ltd Bridge
W-4	2.608	0.5 km upstream of White Pine Road
W-3	3.116	At White Pine Road
W-2	3.640	0.5 km downstream of White Pine Road
W-1	4.303	1 km downstream of White Pine Road
W-1A	6.176	Outlet to Waituna Lagoon
W-LG	6.520	Lagoon

Table 4-2: Carran Creek - location of key modelled cross-sections.

Cross-section	Chainage (km)	Location description
C-7	0.000	1.5 km upstream of Waituna Lagoon Road Bridge
C-6	0.549	1 km upstream of Waituna Lagoon Road Bridge
C-5	1.111	0.4 km upstream of Waituna Lagoon Road Bridge
C-4	1.527	At Waituna Lagoon Road Bridge
C-3	2.238	0.65 km downstream of Waituna Lagoon Road Bridge
C-2	2.377	0.8 km downstream of Waituna Lagoon Road Bridge
C-1	2.617	Near outflow at Little Lake Waituna
E-12	2.822	Little Lake Waituna
E-2	4.710	Little Lake Waituna
E-1B	4.856	Channel immediately upstream of outlet to Waituna Lagoon
E-1	5.020	Lagoon

Table 4-3: Moffat Creek - location of key modelled cross-sections.

Cross-section	Chainage (km)	Location description
M-8	0.000	130 m upstream of Hanson Road
M-Tributary	0	Upper tributary
M-7	0.557	0.5 km m upstream of Moffat Road
M-6	1.110	At Moffat Road Bridge
M-5	1.420	0.3 km Downstream of Moffat Road
M-4	1.914	0.8 km Downstream of Moffat Road
M-3	2.487	1.15 km downstream of Moffat Road
M-2	2.973	2 km downstream of Moffat Road
M-1a	3.343	2.4 km downstream of Moffat Road
M-1	3.437	Near outflow at Waituna Lagoon
M-OT	3.524	Channel immediately upstream of outlet to Waituna Lagoon
M-LG	3.949	Lagoon

4.2 Calibrating the models

In hydraulic modelling *roughness* represents a channels frictional resistance to flow. For the Waituna, Carran and Moffat Creek models roughness was specified at each cross-section using Manning's n coefficient, where lower values of the coefficient indicate less flow resistance (i.e. shallower faster flow will occur) and higher values of the coefficient indicate greater flow resistance (i.e. deeper slower flow). Roughness is influenced by many factors including bed material and vegetation/plant growth. Typical values of Manning's n are available from the literature but calibration is necessary in order to adjust roughness values so that the model correctly predicts observed water level for a known flow. The range of Manning's n potentially applicable to the Waituna, Carran and Moffat Creek models is given in Table 4-4 (Chow, 1959).

Table 4-4: Range of Manning's n values potentially applicable to Waituna and Carran Creek models. Based on Chow 1959 Table 5-6.

Channel description	Manning's n		
	Minimum	Normal	Maximum
Earth, straight and uniform: Clean recently dredged/excavated	0.016	0.018	0.020
Earth, straight and uniform: With short grass, few weeds[1]	0.022	0.027	0.033
Earth, winding and sluggish: Stony bottom and weedy[1] banks	0.025	0.035	0.040
Channels not maintained, weeds[1] and brush uncut: Clean bottom, brush on sides	0.040	0.050	0.080
Channels not maintained, weeds[1] and brush uncut: Dense weeds high as flow depth	0.050	0.080	0.120
Channels not maintained, weeds[1] and brush uncut: Dense brush, high flow depth	0.080	0.100	0.140
Very weedy[1] reaches, deep pools, or floodways with heavy stands of timber and underbrush	0.075	0.100	0.150

1. The term 'weeds' as used in hydraulics literature refers to any plants increasing flow resistance and does not imply invasive/alien species.

The Waituna and Carran Creek models were calibrated against water level profiles derived from water levels recorded at each cross-section by TrueSouth during the surveys. During the surveys a flow gauging was undertaken at each of the surveyed cross-sections. The flow gauging was done using an ADCP StreamPro, except at the Marshall Road Flow Recorder site (section W-8) where a Pygmy current meter was used. At each cross-section plant growth was cleared 3 m upstream and downstream of the gauging site to enable a reliable measurement of water depth and flow throughout the gauged cross-section.

These gaugings were used to assess flow inputs to the upstream boundary of the modelled reach and lateral inflows to the channel downstream throughout the reach arising from groundwater, field-drains and small tributaries. For the Waituna and Carran Creek models, the recorded water level at the Waituna Lagoon Monitoring Platform hydrometric site was used as the downstream boundary condition. The monitoring platform had ceased operation when the Moffat Creek survey was completed and the Waghorns Road lagoon water level recorder was used for the Moffat Creek downstream boundary. No allowance was made for wind setup in the lagoon. Gauging notes recorded during the survey (key metadata parameters of which are summarised in Appendix A) indicated that the wind was light to moderate at the time that gaugings were taken at sections likely to be affected by lagoon level. Given this, wind setup would not have been significant.

We note, the purpose of the modelling was to assess backwater effects at low to moderate flows, not under flood conditions. Therefore calibration at the relatively low flow conditions during the December 2015 survey is acceptable for Waituna and Carran Creek models. The calibration, however, would need to be revisited if the models were to be applied to simulate flood flows.

4.2.1 Calibrating the Waituna Creek model

Table 4-5 summarises the main channel inflow and downstream water level boundary conditions assumed for the Waituna Creek model calibration. For Waituna Creek, flow gaugings at cross-sections showed little variation through the modelled reach. On this basis, no lateral inflows are included in the model. Based on recorded water levels in the lagoon, we specified a linearly varying lagoon level water level that ramped down from 1.26 m to 1.14 m over the 7 hour gauging period on 10 December 2015.

Table 4-5: Waituna Creek model - boundary conditions for the calibration trials.

Boundary conditions/Flow inputs	River distance (km)	Flow (m^3/s)	Water Level (m)
Upstream flow boundary condition	0.00	0.477	
Downstream water level boundary condition	6.52		1.26 – 1.14 m

Figure 4-2 compares the surveyed water level profile from the 10 December 2015 survey data, with that derived from the calibrated model. In order to give a fair comparison, given that the downstream water level is variable, both measured and simulated profiles compare water levels at the recorded start time of the gauging at each gauging site. In practice, the differences in water levels over time resulting from the changing lagoon level are very slight and only affect cross-sections downstream of section W-3.

A good match is shown between the modelled and observed water levels at all cross-sections except at cross-section W-5 where the model under-predicts the water level by 0.17 m. Given that this effect is local, the calibration is considered acceptable.

Figure 4-2 also shows the calibrated Manning's n roughness values. Values are specified at the surveyed sections. Manning's n roughness values at computational nodes between cross-sections are then determined by linear interpolation. The Manning's n roughness at the channel outlet into the lagoon (i.e. at cross-section W-1A), and in the lagoon itself, have been taken as 0.05. This means that roughness ramps up from 0.05 to 0.12 between cross-sections W-1A and W-1.

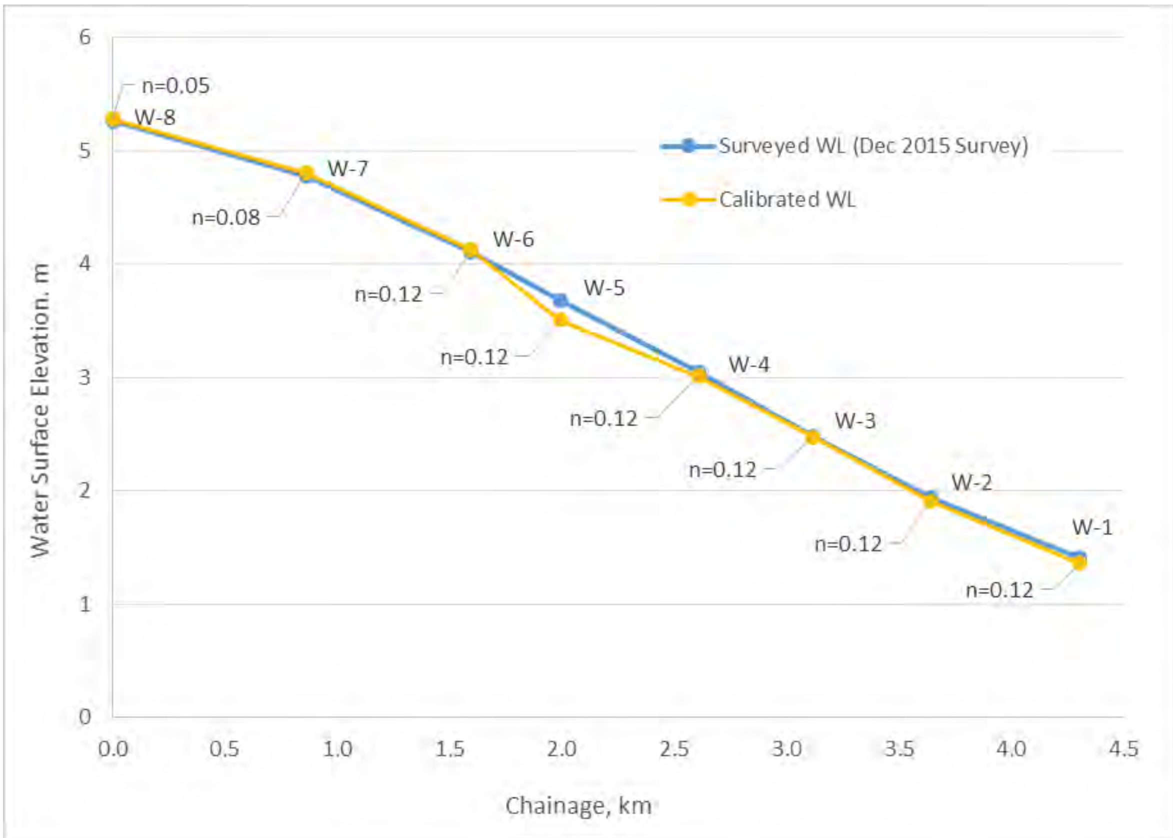


Figure 4-2: Comparison of surveyed and calibrated water surface profiles for Waituna Creek. Calibrated Manning's n roughness values are also shown.

Gauging notes (summarised in Appendix A) describe the main channel as affected by plant growth at cross-sections W-6 through to W-3. Plants in the channel cause a significant increase in roughness (e.g. see Table 4-4) and are the likely cause of the very high roughness coefficient (n=0.12) required to calibrate the model in the middle reach. Other factors which could affect the water level include local constrictions within the channel not captured by the survey (for example a partially blocked culvert or section of elevated bed acting as a weir). Unlike plant growth, which can be widespread, constrictions would only cause a relatively local effect. It is likely that the difference in water level at cross-section W-5 could be caused by a local constriction between this cross section and cross-section W-4.

In fact, dense plant growth proved to be a significant problem during the survey. An echo-sounder survey of longitudinal bed profiles had been planned as part of the survey. TrueSouth attempted this, but had to abandon it as "the infestation of thick [plants] encountered during the survey prevented the capture of reliable bed soundings" (Thompson 2015). The cover of plants ranged from minimal (at site W-1) to prolific (see Appendix A).

4.2.2 Calibrating the Carran Creek model

An initial calibration was performed using the gauging data and water level measurements collected on 9 December 2015.

Table 4-6 lists the boundary conditions and lateral flow inputs applied in the calibration, to match gauged flows during the 9 December 2015 survey. The lagoon level on the day, which was constant at around 1.285 m, is also listed.

Table 4-6: Carran Creek model - boundary conditions and lateral inflows for the initial calibration event

Boundary conditions/Flow inputs	Chainage, km	Flow, m^3/s	Water Level, m
Upstream flow boundary condition	0.00	0.09	
Downstream water level boundary condition	5.02		1.285
Lateral inflow-(C-6 – C-7)	0.00 – 0.55	0.026	
Lateral inflow-(C-5 – C-6)	0.55-1.11	0.022	
Lateral inflow-(C-4 – C-5)	1.11 – 1.53	0.009	
Lateral inflow-(C-3 – C-4)	1.53 – 2.24	0.009	
Lateral inflow-(C-2 – C-3)	2.24 – 2.38	0.031	

Figure 4-3 compares the water surface profile for the initial calibration event, in which Manning's n is set to 0.15 globally, with the surveyed water surface profile. This initial calibration works well downstream from cross-section C-4 but it significantly under-predicts water surface elevation upstream of this location.

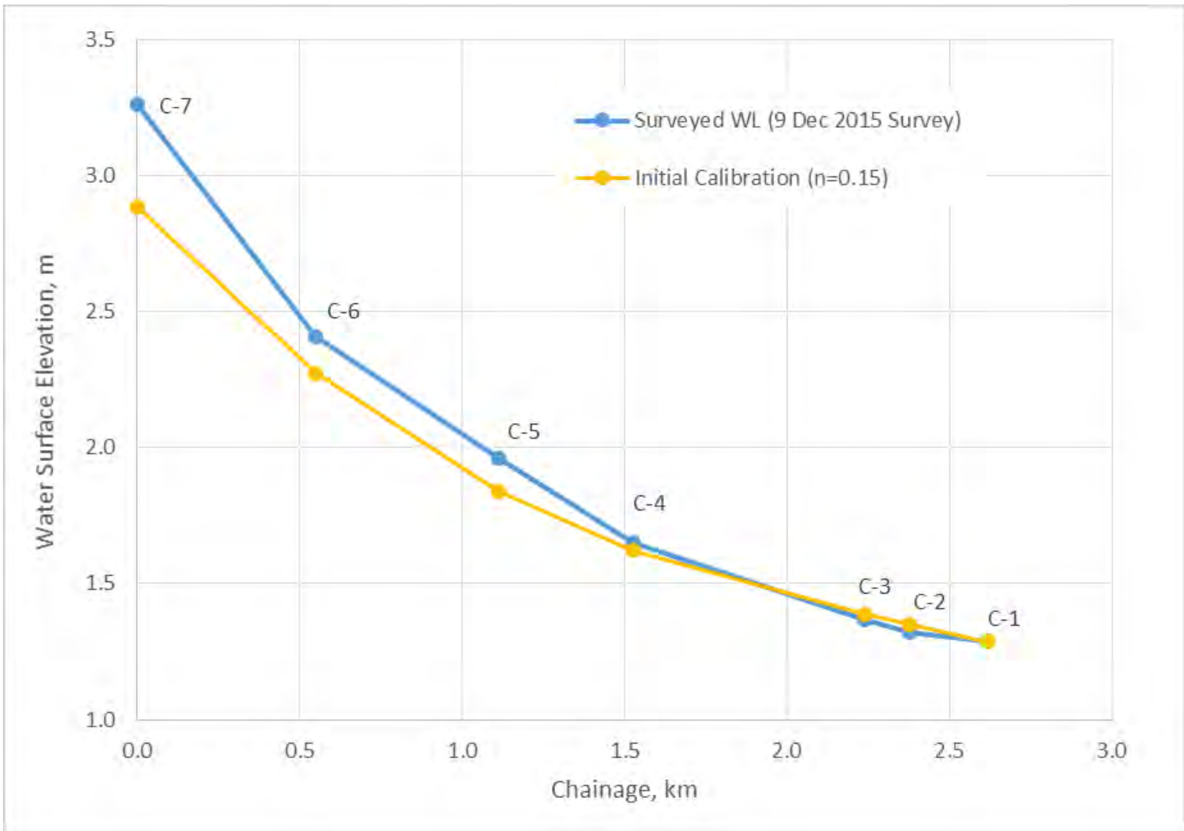


Figure 4-3: Comparison of surveyed water surface profiles with that for an initial calibration of the Carran Creek model. Manning's n roughness is set to 0.15 globally.

The poor calibration upstream of cross-section C-4 is likely due to partial blockage of the low flow channel by dense plants. This is supported by photographs taken during the survey at sites C-6 and C-7 (Figure 4-4) showing that the low flow channel is significantly narrowed by mats of reeds growing on the banks. This blockage effect would be reduced at higher flows (as the plants are flattened by the higher flow velocities) and therefore the high roughness needed to calibrate to it would be unrealistic at higher flows. Local flow constrictions not captured by the cross-section survey could also be raising the water level in the creek. This is a potential cause of difference between the modelled and observed water levels but by their nature any effects would be localised so it is unlikely that this is the cause of differences over ~1.5 km of channel.

Figure 4-4: Photographs at gauging sites C-6 (top) and C-7 (bottom) showing plant growth. The photographs were taken during the flow gauging survey on 9 Dec 2015.

Additional water level data on Carran Creek was available from a longitudinal water surface profile survey undertaken by Environment Southland on 11 July 2012. The flow in Waituna Creek at the time of the survey, based on rated flow from the Waituna at Marshall Road recorder, was steady at around 0.79 m^3/s. Applying this to Environment Southland's equation relating flow in Carran Creek to recorded flow in Waituna Creek, the flow in Carran Creek at the time of the survey is estimated to be 0.204 m^3/s. This equation gives flow at the Carran Creek telemetry site which is close to the upstream extent of the model (i.e., to cross-section C-7). This equation was calculated from a period of concurrent flow observations and has been demonstrated to be reliable for hindcasting flow in Carran Creek ($r^2 = 0.97$, pers. comm. Chris Jenkins).

We undertook a second calibration of the Carran Creek model using the 11 July 2012 water surface elevation data as a calibration profile. Table 4-7 lists the inflow and water level boundary conditions that were applied. Inflows were not gauged during 11 July 2012, so no data was available from which to directly assess lateral inflows. Instead, lateral inflows are assumed to have the same proportion to the main channel inflow as in the December 2015 survey, totalling 52% of the main channel flow.

As a check on the lateral inflows, we calculated the catchment area for the whole Carran Creek catchment to be 49.25 km^2 and the catchment downstream of cross-section C-7 to be 23.12 km^2. The proportion of the catchment below cross-section C-7 is therefore 47%, which is close to our estimate for lateral inflows totalling 52% of the main channel flow. This confirms that our estimate for lateral inflows, totalling 52% of the main channel flow, is reasonable.

Table 4-7: Carran Creek model - boundary conditions and lateral inflows for the second calibration event

Boundary conditions/Flow inputs	Chainage, km	Flow, m^3/s	Water Level, m
Upstream flow boundary condition	0.00	0.204	
Downstream water level boundary condition	5.02		0.45
Lateral inflow-(C-6 – C-7)	0.00 – 0.55	0.059	
Lateral inflow-(C-5 – C-6)	0.55-1.11	0.05	
Lateral inflow-(C-4 – C-5)	1.11 – 1.53	0.02	
Lateral inflow-(C-3 – C-4)	1.53 – 2.24	0.02	
Lateral inflow-(C-2 – C-3)	2.24 – 2.38	0.07	

Figure 4-5 compares modelled and surveyed water surface profile for the second calibration event after calibration. Manning's n has been set to 0.08 globally. Good agreement is shown over the reach for which survey data is available (i.e., from chainage 0.3 to 1.44 km).

The final roughness calibration (Table 4-8) is a combination of results from the two calibration events.

Table 4-8: Carran Creek model - final roughness calibration.

Sub Reach (Chainage to-from, km)	Manning's n	Basis
0.00 - 1.527	0.08	9 Dec 2015 Water Level Survey
1.54 - 5.02	0.15	11 Jul 2013 Water Level. Survey

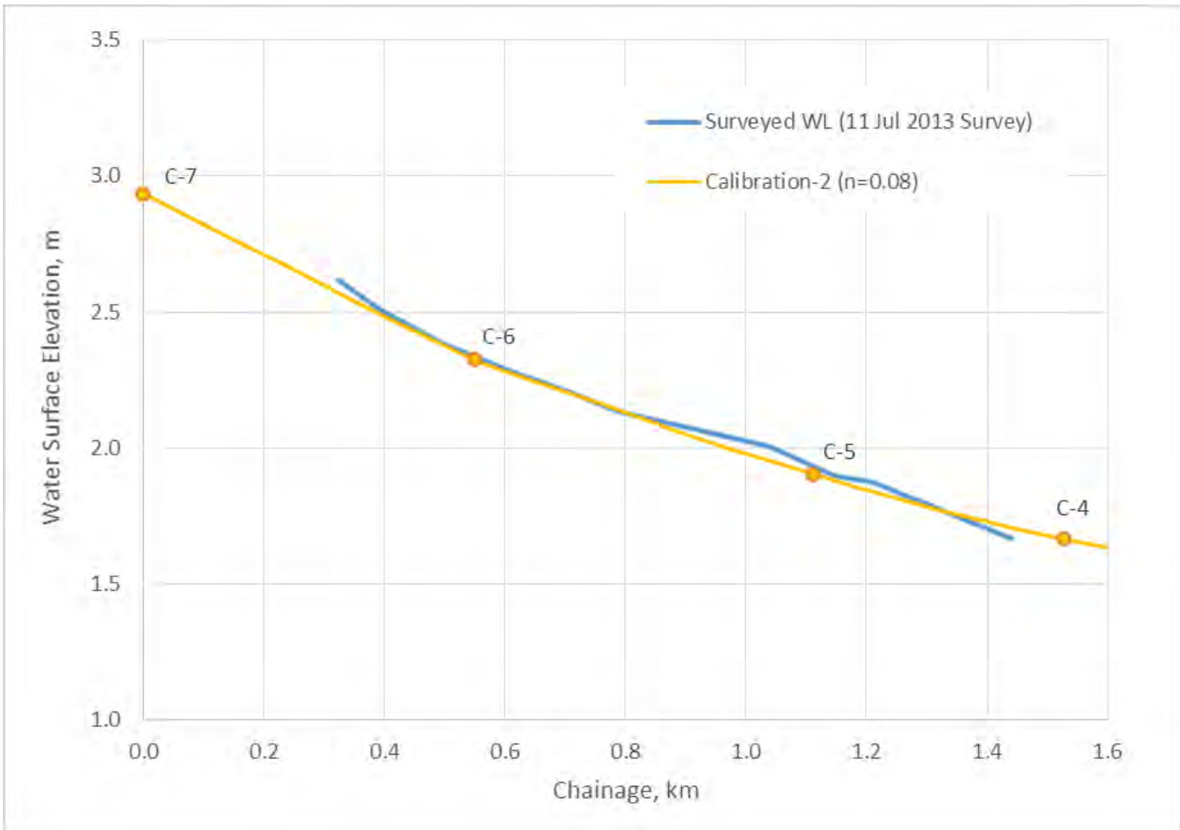


Figure 4-5: Comparison of surveyed water surface profiles with that for the second calibration of the Carran Creek model. Manning's n roughness is set to 0.08 globally.

4.2.3 Calibrating the Moffat Creek model

Table 4-9 lists the main channel inflow and downstream water boundary conditions applied in the calibration to match water surface profile during 1 and 3 March 2017 survey. The water level in the lagoon on the day of survey was constant at around 1.37 m.

Table 4-9: Moffat Creek model – boundary conditions for the calibration model.

Boundary conditions/Flow inputs	River distance (km)	Flow (m^3/s)	Water Level (m)
Upstream flow boundary condition-Moffat Creek	0	0.017	
Downstream water level boundary condition	3.73		1.37
Lateral inflow-(M-7 – M-8)	0 – 0.56	0.0035	
Upstream flow boundary condition-Moffat Tributary	0	0.0035	
Lateral inflow-(M-5 – M-6)	1.11 – 1.42	0.023	
Lateral inflow-(M-4 – M-5)	1.42 – 1.91	0.007	
Lateral inflow-(M-3 – M-4)	1.91 – 2.49	0.006	
Lateral inflow-(M-2 – M-3)	2.49 – 2.97	0.026	
Lateral inflow-(M-1a – M-2)	2.97 – 3.34	0.035	

Figure 4-6 compares calibrated model and surveyed water surface profile for the calibration event. Figure 4-6 also shows the calibrated Manning's n roughness values. Values are specified at the surveyed sections. Linear interpolation was used to determine roughness values at computational nodes between cross-sections. The Manning's n roughness at three downstream cross sections (i.e. at cross section M-2, M-1 and M-1a) have been taken as 0.2. Also, for upstream cross sections (from cross sections M-3 to M-8), Manning's n roughness of 0.35 makes good agreement between the modelled and observed water levels over the reach.

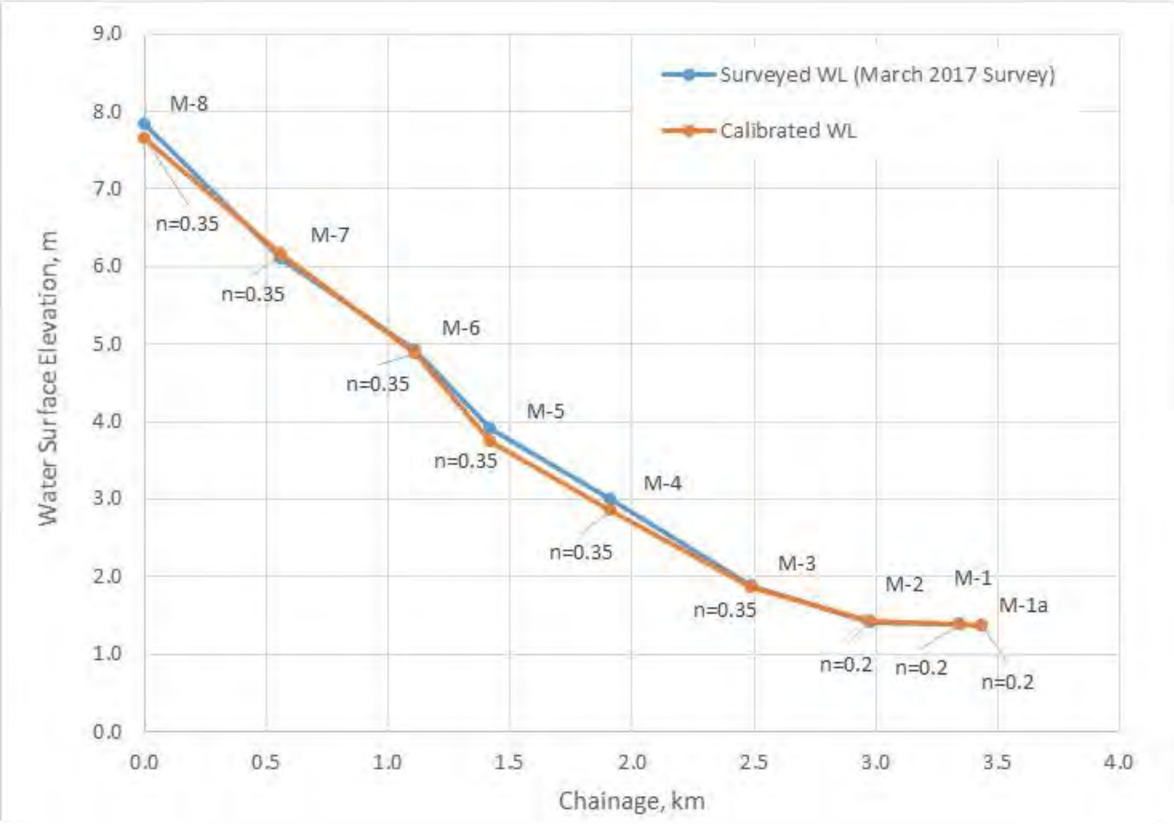


Figure 4-6: Comparison of surveyed and calibrated water surface profiles for Moffat Creek. Calibrated Manning's n roughness values are also shown.

4.3 Applying the models

Following calibration, the now calibrated hydraulic models of Waituna Creek, Carran Creek and Moffat Creek were used to assess backwater effects for four scenarios comprising two steady flows: 1) mean flow (Q_{mean}); and 2) a higher but not extreme flow, taken as the 90 percentile high flow (Q_{90}), in conjunction with two roughness categories: 1) "channel vegetated"; and 2) "channel cleared". For each scenario, steady-state backwater profiles were extracted for a range of lagoon levels.

Based on analysis of rated flow data from the Waituna Creek at Marshall Road recorder for the period from 13 August 2001 to 31 Dec 2015 (the full period of record for this site), the mean flow and 90 percentile high flow at site W-8 in Waituna Creek, were calculated to be 1.66 m^3/s and 4.15 m^3/s, respectively.

Then, applying Environment Southland's equation relating flow in Carran Creek and Moffat Creek to flow in Waituna Creek, the mean flows at site C-7 in Carran Creek and M-8 in Moffat Creek, for the same period, are estimated to be 0.300 m^3/s and 0.234 m^3/s respectively, and the 90 percentile high flows, to be 0.76 m^3/s and 0.514 m^3/s respectively.

As for the calibration runs, lateral inflows into the main channel of Waituna Creek are assumed to be negligible based on the negligible increase in flow observed during the 10 December 2015 flow gaugings. This is consistent with its large upstream catchment and relatively small catchment within the modelled reach. For Carran Creek and Moffat Creek lateral inflows are significant and were specified using the same proportions to inflow as determined from the 9 December 2015, and 8 March 2017 flow gaugings, respectively.

Lagoon levels ranging from 0.5 m to 2.5 m at 0.5 m increments were simulated. As well, three additional lagoon levels: 1.2 m, 1.8 m and 2.3 m that were of special interest, were also simulated.

Environment Southland periodically clear Waituna Creek, Moffat Creek and Carran Creek of plants, using a backhoe to scrape the sides and bottom of the channel where accessible. The model calibration highlighted the significant effect of plants on creek water levels. It is likely that the variable effect of plant growth represents the biggest source of uncertainty in this modelling study so two roughness scenarios were modelled to represent this. The two roughness categories: 1) "channel vegetated"; and 2) "channel cleared", correspond to conditions before and after channel clearing. Roughness for the two categories is defined as follows:

- For the "channel vegetated" category, the final roughness calibrations as described in Section 4.2.1 for Waituna Creek, Section 4.2.2 for Carran Creek and Section 4.2.3 for Moffat Creek, have been applied. Use of the roughness calibrations is consistent with high vegetation on the banks and sides in some reaches of Waituna and Carran creeks, as was the case at the time of the December 2015 survey (as described in flow gauging notes and shown in photographs).
- For the "channel cleared" category, a constant Manning's n roughness value of 0.05 is considered suitable and has been applied.

By comparing the results of the "channel vegetated" and "channel cleared" simulations it is possible to isolate the effects of plant growth and understand the level of uncertainty in the model results due to this source of variability.

The modelling does not consider wind set-up in Waituna Lagoon, although this may be done at a later stage. Any set-up should be added to the lagoon level, before the relationships derived here are used to estimate the effect on the creek upstream.

4.4 Results

The model results are presented using long section profiles of creek water level as well as maps showing the area of land impacted. We have mapped two different severities of impact:

1. Land which is inundated. These areas have been mapped as land where the ground level in the LiDAR derived digital elevation model is lower than the modelled water level in the creek.
2. Land which is potentially influenced by poor drainage. The maps identify farm land adjacent to the main river channel that is within a threshold distance of the water level in the main channel. The basis for this is that flow in the field drains, will start to be influenced by backwater effects when their downstream end becomes drowned. Two different depth thresholds, 1 m and 2 m, were applied in order to represent the range of depths at which field drains are likely to occur. The plots, therefore give an

indication of areas that could have reduced drainage due to lagoon level effects. It is recognised that this is a simplistic assumption for the calculation of drainage affected areas but we feel it provides a useful first-cut mapping of areas where land drainage is potentially impeded.

When interpreting the long section plots and the maps it is possible to identify the effects of lagoon level by comparing the results for a given lagoon level with the results for the low (0.5 m) lagoon level simulation. The increase in water level (long-sections) or affected area (maps) from this low lagoon level baseline represents the effect of the lagoon. This is illustrated in Figure 4-7. Reaches where the water level or affected area does not change between different lagoon levels indicate that inundation or poor drainage results from the combination of creek flow and roughness irrespective of lagoon level.

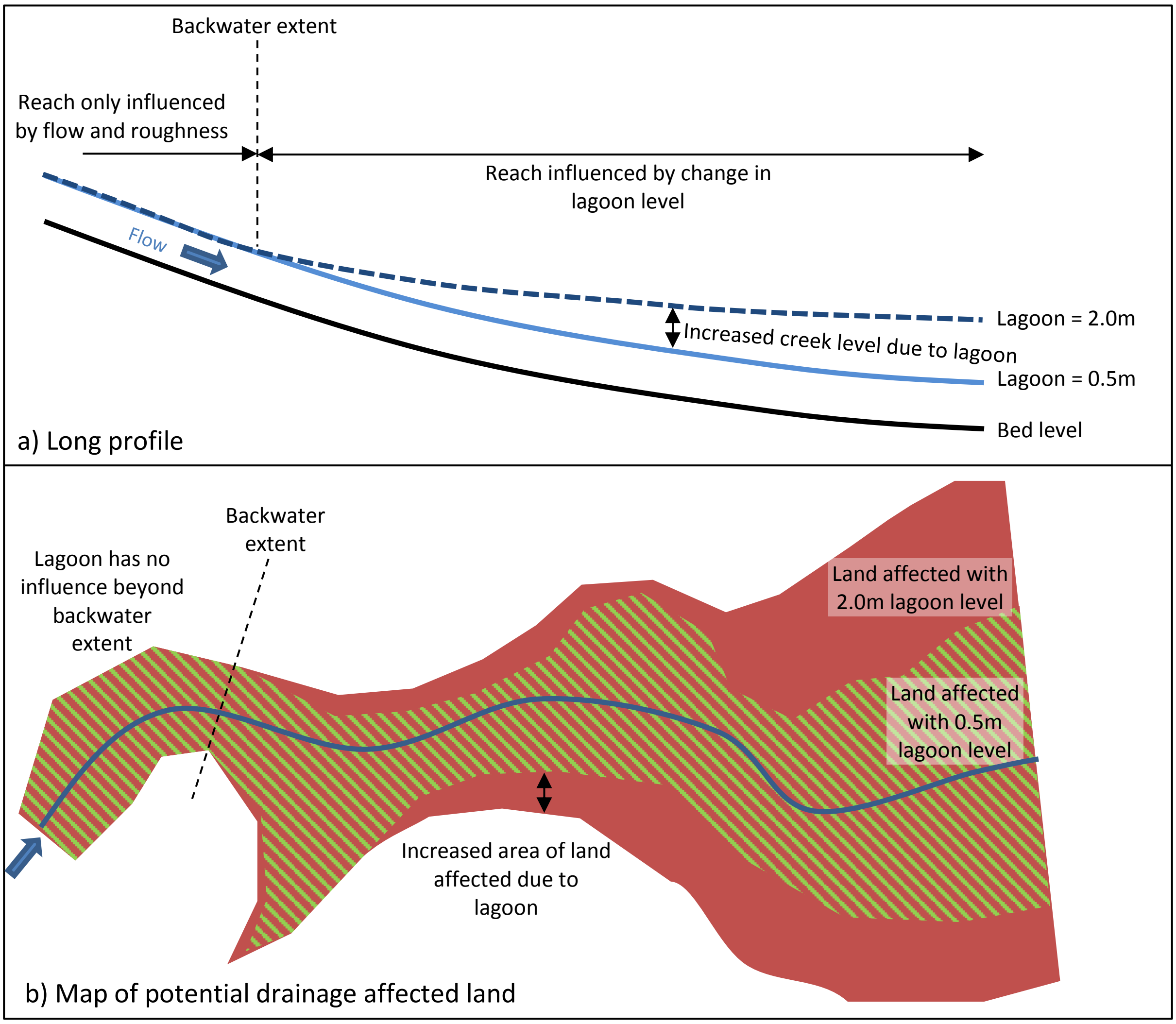


Figure 4-7: Illustration of how increase in water level above the low lagoon level scenario represents the effect of the lagoon. a) Shows long section. b) Shows map view.

The backwater extent has been tabulated and marked on the inundation maps. The backwater extent has been defined as the upstream limit of the reach where the lagoon affected creek water level is higher than the creek level under low lagoon level conditions. A consistent depth threshold of

0.02 m has been applied when calculating backwater extent i.e. upstream of the backwater extent the lagoon level has a negligible (< 0.02 m) effect on water levels.

4.4.1 Waituna Creek backwater profiles and extent

Figure 4-8 plots backwater profiles for Waituna Creek. Four plots are shown covering backwater profiles for the two flow cases (Q_{mean} and Q_{90}) and for two roughness categories ("channel cleared" and "channel vegetated"). Each plot shows water surface profiles for a range of lagoon levels from 0.5 m to 2.5 m and a bed thalweg profile. The bed thalweg level is shown as a solid line where it has been interpolated between surveyed cross-sections and as a dotted line, where it has been extrapolated.

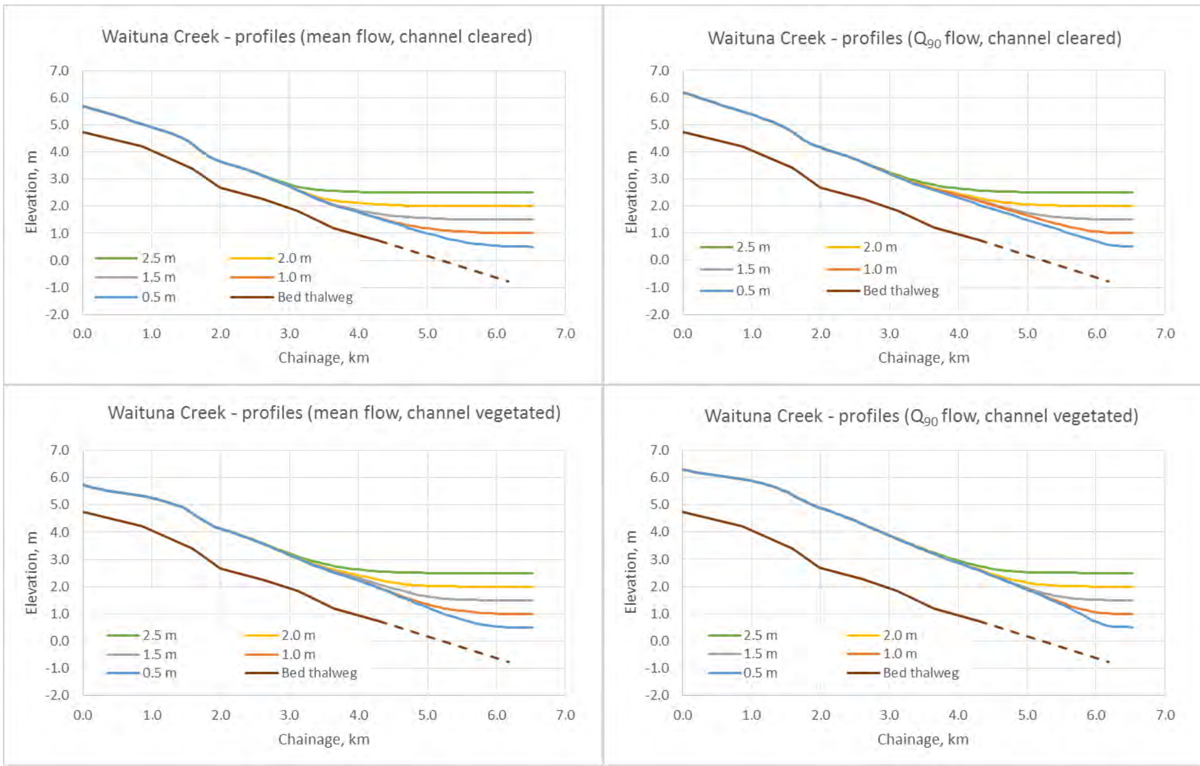


Figure 4-8: Waituna Creek backwater profiles. Left hand side plots are for mean flow and right hand side plots are for the 90 percentile high flow. Within each vertical slice, the top plot is with "channel cleared" and the bottom plot is with "channel vegetated".

As well as the backwater profiles, maps of inundation extent for lagoon water levels of 1.0 m, 1.5 m, 2.0 m and 2.5 m were created and are shown in Appendix B. Four maps are shown, one for each flow and roughness characterisation scenario. Each plot shows, as well as inundated land area, red lines indicating the backwater extent in the main channel for a range of lagoon water levels. Table 4-10 provides the same information in tabular form, with backwater extent given in terms of chainage along the channel.

Table 4-10: Waituna Creek – the chainage in kilometres of the backwater extent for the four scenarios at different Waituna Lagoon water levels. Note: Since chainage increases in a downstream direction, higher chainages represent a lesser backwater extent.

	Channel Cleared		Channel Vegetated	
Lagoon WL, m	Q_{mean}	Q_{90}	Q_{mean}	Q_{90}
1.0	4.31	3.30	4.34	5.25
1.2	4.02	3.30	3.91	5.06
1.5	3.60	3.27	3.31	4.71
1.8	3.32	3.19	3.13	4.42
2.0	3.16	3.10	3.04	4.17
2.3	2.92	2.87	2.84	3.59
2.5	2.73	2.72	2.68	3.36

Key results relating to backwater extent in Waituna Creek are:

- For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was to around chainage 2.7 km and occurred at a lagoon level of 2.5 m. At this lagoon level, three of the four scenarios have very similar backwater extents. The exception is the "Q_{90} - Channel Vegetated" scenario which, because of raised water levels drowning out some of the backwater effect, gives a reduced backwater extent.

- For each lagoon water level, the "Q_{90} -Channel Vegetated" scenario gives the least backwater extents. This is because the water level due to flow is already high in this scenario so the lagoon has little further effect. The other three scenarios give backwater extents that are higher and that are broadly similar except at low lagoon levels (WL ≤ 1.5 m), where the "Q_{90} -Channel Cleared" scenario gives backwater extents that are up to 1 km further than the other two due to the effect of the higher flow raising water levels in the channel near the lagoon, but not so much as to drown out the backwater effect.

- Farmland inundated by high lagoon static water level or backwater from the lagoon, is mainly within an area on the true left of the channel south of a farm access road with connection to Marshall Road about 1 km south of White Pine Road (downstream of chainage 4.3 km). At the 90 percentile high flow, significant inundation of this area occurs even at low lagoon level when the channel is vegetated, indicating that inundation is related to restriction of the channel rather than the lagoon level. With the channel cleared, or at mean flow, the effect of lagoon level does become important. Under these scenarios, significant inundation then occurs only when the lagoon level equals or exceeds 2.0 m.

4.4.2 Carran Creek backwater profiles and extent

Figure 4-9 plots backwater profiles for Carran Creek. Four plots are shown as described in Section 4.4.1 for Waituna Creek. Each plot shows profiles of water surface elevation for a range of lagoon levels from 0.5 m to 2.5 m and a bed thalweg profile.

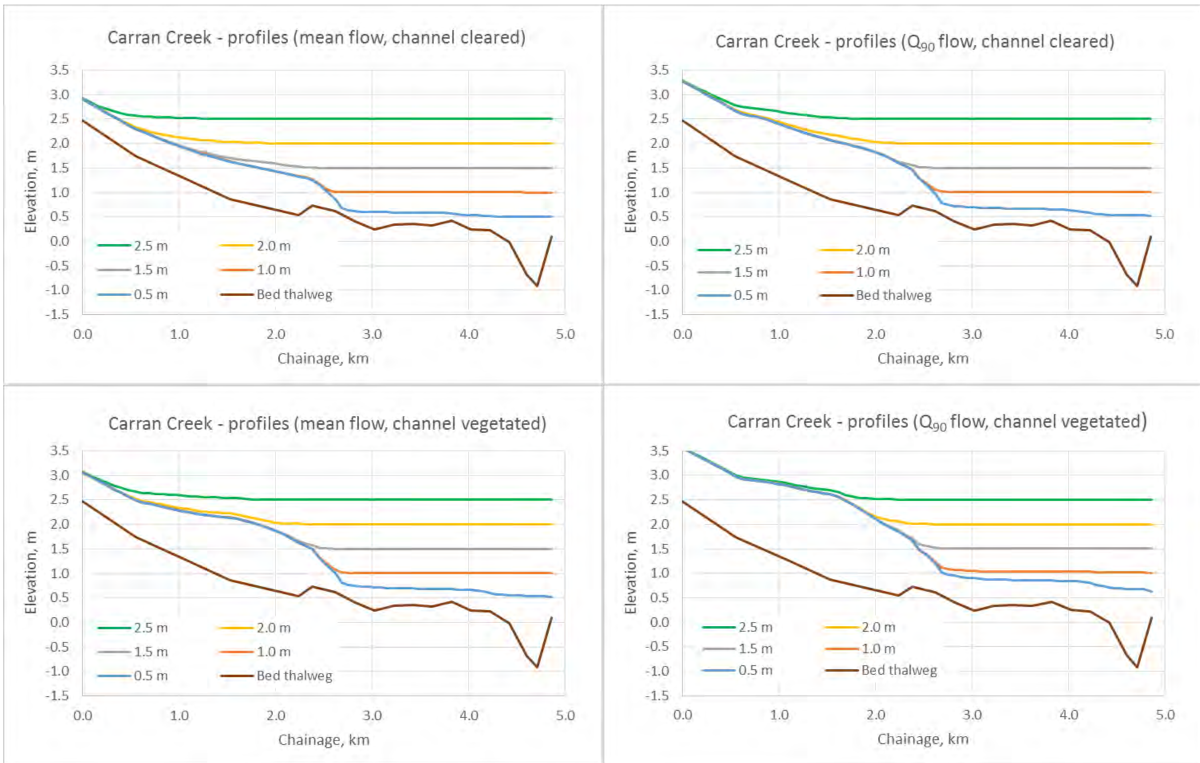


Figure 4-9: Carran Creek backwater profiles. Left hand side plots are for mean flow and right hand side plots are for the 90 percentile high flow. Within each vertical slice, the top plot is with "channel cleared" and the bottom plot is with "channel vegetated".

Maps of inundation and backwater extent have been plotted for Carran Creek as for Waituna Creek (see Section 4.4.1), and are shown in Appendix C. Table 4-11 summarises backwater extents for the four scenarios.

Table 4-11: Carran Creek – the chainage in kilometres of the backwater extent for the four scenarios at different Waituna Lagoon water levels. Note: Since chainage increases in a downstream direction higher chainages represent a lower the backwater extent.

	Channel Cleared		Channel Vegetated	
Lagoon WL, m	Q_{mean}	Q_{90}	Q_{mean}	Q_{90}
1.0	2.42	2.49	2.49	2.57
1.2	1.84	2.40	2.40	2.44
1.5	1.05	2.18	2.14	2.25
1.8	0.65	1.11	1.11	2.03
2.0	0.47	0.64	0.55	1.93
2.3	0.23	0.27	0.21	1.18
2.5	0.06	0.07	0.04	0.48

Key results relating to backwater extent in Carran Creek are:

- For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was to about 40 m downstream of cross-section C-7 (i.e. to chainage 0.04 km) and occurred at a lagoon level of 2.5 m. At this lagoon water level, three of the four scenarios have very similar backwater extents. The exception is the "Q_{90} - Channel Vegetated" scenario. As for Waituna Creek, the raised water levels that occur under this scenario drown out some of the backwater effect, thereby giving a reduced backwater extent (to chainage 0.48 km)

- A restriction in the channel at chainage 2.6 km (i.e., at surveyed cross-section C-1) acts as a control (see Figure 4-9). This combined with high roughness when the channel is vegetated raises water levels steeply upstream of this point. As a result, except at lagoon water levels greater than 1.5 m, backwater effects for the two "Channel Vegetated" scenarios, and for the "Q_{mean} - Channel Cleared" scenario, extend upstream only as far as chainage 2.14 km (i.e., to about 0.6 km downstream of Waituna Lagoon Road Bridge).

- For the range of scenarios considered, the extent of inundation (as shown in Appendix D, Figure D-1 to Figure D-8) is determined mostly by lagoon level and is only very slightly affected by plant growth and flow in the main channel. The main area of inundated land is west and north-west of Little Lake Waituna. No significant inundation occurs east of Waituna Lagoon Road or north of Hanson Road.

4.4.3 Moffat Creek backwater profiles and extent

Figure 4-10 plots backwater profiles for Moffat Creek. Four plots are shown as described in section 4.4.1 for Waituna Creek. Each plot shows water surface profiles for a range of lagoon levels from 0.5 m to 2.5 m and bed thalweg profile.

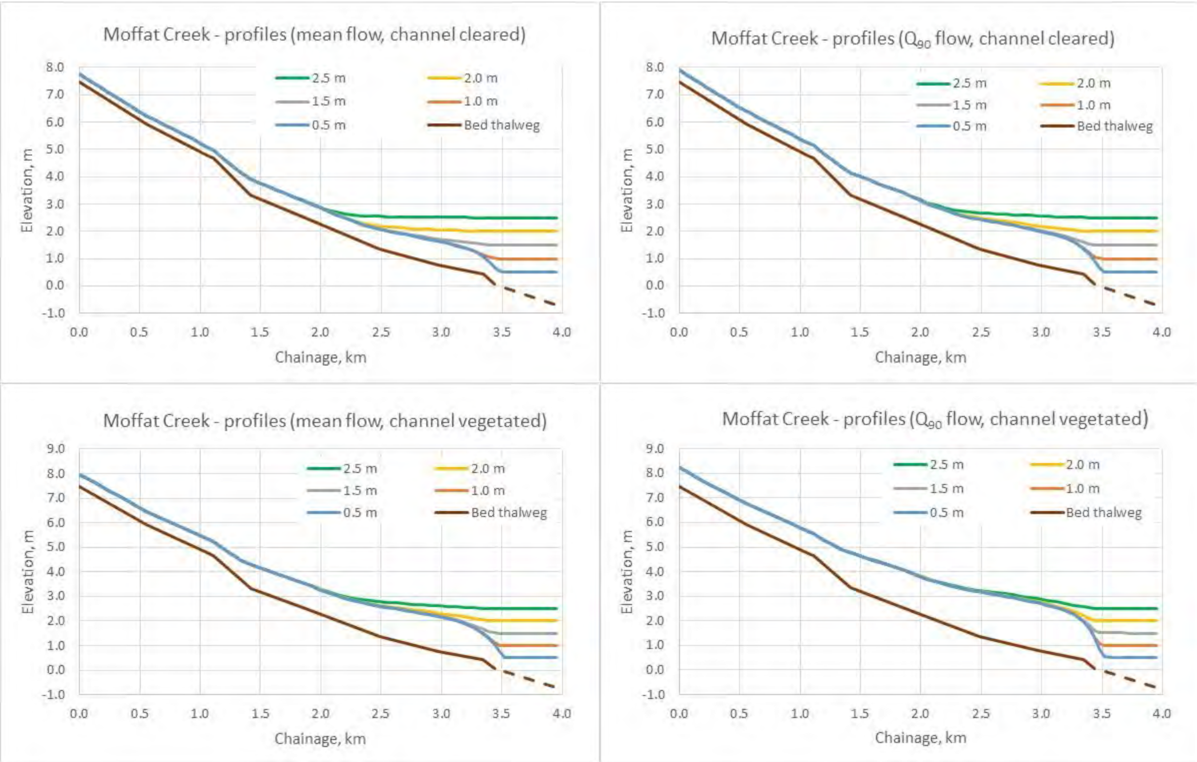


Figure 4-10: Moffat Creek backwater profiles. Left hand side plots are for mean flow and right hand side plots are for the 90 percentile high flow. Within each vertical slice, the top plot is with "channel cleared" and the bottom plot is with "channel vegetated".

Maps of inundation extent for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m were created and are shown in Appendix C. Table 4-12 provides backwater extents for the four scenarios in tabular form.

Table 4-12: Moffat Creek – the chainage in kilometres of the backwater extent for the four scenarios at different Waituna Lagoon water levels. Note: Since chainage increases in a downstream direction, higher chainages represent a lesser backwater extent.

	Channel Cleared		Channel Vegetated	
Lagoon WL, m	Q_{mean}	Q_{90}	Q_{mean}	Q_{90}
1.0	3.25	3.35	3.37	3.42
1.2	3.00	3.23	3.25	3.37
1.5	2.58	2.83	2.93	3.26
1.8	2.34	2.39	2.49	2.97
2.0	2.25	2.25	2.28	2.63
2.3	2.11	2.09	2.09	2.21
2.5	2.01	2.00	1.99	2.07

Key results relating to backwater extent in Moffat Creek are:

- For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was around chainage 2.0 km.
- For each lagoon water level, the 90 percentile high flow with a vegetated main channel scenario gives the least backwater extent. The reason is high water level due to flow in this scenario exceeds the lagoon effect.
- For the range of scenarios considered (as shown in Appendix C, Figure C-1 to Figure C-8), the main area of land inundated by high Waituna lagoon levels is wetland habitat near the Waituna lagoon, not farmland. Little direct inundation of farmland is shown for any of the scenarios.

4.4.4 Waituna Creek – maps of potential drainage affected land

Appendix E and Appendix H provide maps for Waituna Creek of land areas where drainage is potentially affected by backwater or high water effects for two threshold depths: 1.0 and 2.0 m, respectively. Eight maps are shown for each threshold depth, two for each flow-roughness characterisation scenario.

Key results relating to potentially drainage affected land in Waituna Creek are:

- At the 90 percentile high flow, the land area where drainage is potentially affected is much more influenced by high channel roughness than by lagoon water level. As evidence of this, compare the large area of drainage affected land at 1.0 m lagoon level in Figure E-7 with the extent of potentially drainage affected land at all lagoon levels in Figure E-3.
- For the lower flow case (i.e., at mean flow), lagoon water level has a larger effect on the area of potentially drainage affected land (see Figure E-1 and Figure E-5) with the area affected increasing with increase in the lagoon water level. The upstream extent of this area for a 2.5 m lagoon level, under both channel roughness scenarios, is approximately 0.5 km south of White Pine Road.
- Considering a 2m threshold rather than a 1m threshold results in a clear increase in drainage affected land identified under all scenarios, however the increase in area because of increasing lake levels is similar for the 1m and 2m drainage depth analysis.

4.4.5 Carran Creek – maps of potential drainage affected land

Appendix G and Appendix J provide maps of potentially drainage affected land for Carran Creek similar to those described in Section 4.4.4 for Waituna Creek.

Key results relating to potentially drainage affected land in Carran Creek are:

- Downstream of Waituna Lagoon Road Bridge, the dominant influence on the extent of potentially drainage affected land is the Waituna Lagoon water level. Upstream of the bridge, the lagoon level has little effect except at high lagoon levels (WL > 2.0 m), and the dominant influence is channel flow and roughness.

- A swath of land about 500 m wide downstream of Waituna Lagoon Road Bridge and west of Lagoon Road is shown to be potentially drainage affected (1m threshold) even at low lagoon level (taken as 0.5 m).
- At the 90 percentile high flow, Figure G-7 shows a fairly large area of farmland (~ 44 ha) upstream of Waituna Lagoon Road Bridge that is potentially drainage affected (1m threshold) when the channel is weedy. This area reduces in size by about 40%, if the channel is cleared (viz. Figure G-3). For both Q_{90} scenarios, the area with impeded drainage was not dramatically affected by lagoon opening or closing, as there were large areas inundated even when the lagoon was at 0.5m.
- At mean flow, except at high lagoon levels (WL > 2.0 m), very little farmland upstream of Waituna Road Bridge is potentially drainage affected under the 1m threshold, when the channel is clear of plants (viz. Figure G-1). If the channel is instead vegetated then, from Figure G-5, more farmland is potentially drainage affected.
- Considering a 2m threshold rather than a 1m threshold results in a clear increase in drainage affected land identified under all scenarios, however the increase in area because of increasing lake levels is similar for the 1m and 2m drainage depth analysis.

4.4.6 Moffat Creek – maps of potential drainage affected land

Appendix F and Appendix I provide maps for Moffat Creek of land areas where drainage is potentially affected by backwater or high water effects using 1.0 m and 2.0 m threshold depths, respectively. Key results relating to potentially drainage affected land in Moffat Creek are:

- Considering a 1 m threshold depth for the identification of potentially drainage impacted land shows that little land upstream of the lagoon backwater is affected by poor drainage.
- Using a 2 m threshold depth suggests that land further upstream is also potentially affected, but the potentially affected land is confined to an approximately 200 m wide corridor centred on the Creek (or 100 m wide corridor centred on its main tributary).
- At the 90 percentile high flow, comparing the area of drainage affected land between cleared (see Figure F-3) and vegetated (see Figure F-7) channels with 1 m threshold depth indicate that the area where drainage is potentially affected is more influenced by high channel roughness than by lagoon level. However, if a 2 m threshold depth is considered there is no significant difference in potentially drainage affected land under two scenarios of cleared (see Figure I-3) and vegetated (see Figure I-7) main channel.

4.4.7 Sensitivity analysis

A sensitivity analysis was conducted to investigate the sensitivity of the backwater extent calculation to the threshold used for defining the limit of the backwater effect.

To investigate the sensitivity of the backwater extent calculation the calculation was repeated using a 0.05 m threshold and the results compared to the originally calculation using a 0.02 m threshold. For this higher threshold, backwater extents up channel were typically: 200 to 300 m less for Waituna Creek; 70 to 180 m less for Carran Creek; and 20 to 140 m less for Moffat Creek, but the overall pattern of how the extend changed between the different scenarios did not change. The reduction in extent associated with increasing the threshold from 0.02 m to 0.05 m demonstrates how in the most upstream part of the backwater extent (as marked on the maps in Appendix B, Appendix C, Appendix D) the lagoon only a small (2-5 cm) effect on water levels.

The sensitivity of the area of drainage affected land to the depth threshold used for identifying it was investigated by comparing maps of drainage affected land identified using a 1.0 m and 2.0 m thresholds. The 2.0 m threshold was selected to be indicative of locations with very deep field drains. This comparison was done for all three Waituna, Carran and Moffat Creeks for each flow-roughness characterisation. Maps showing the results of these analyses are included in Appendix E to Appendix J and have been discussed under sections 4.4.4 to 4.4.6. In general this sensitivity analysis shows that the deeper threshold does result in a moderate increase in the area of land identified as being impacted but the overall pattern of inundation does not change.

5 Summary and recommendations

5.1 Waituna Creek

1. The furthest backwater extent of Waituna Lagoon up Waituna Creek for the range of lagoon water levels considered (i.e. up to 2.5 m) was to around 400 m upstream of White Pine Road.

2. Of the 4 scenarios modelled, the least backwater extent occurs for the "Q_{90} -Channel Vegetated" scenario. Under this scenario the creek level is very high anyway, so the lagoon level has little impact. The other three scenario gave backwater extents that are higher and broadly similar between scenarios (although varying with lagoon level) except at lower lagoon levels (WL < 1.5 m).

3. Farmland inundated by high lagoon water level or backwater effects from the lagoon is mainly within an area on the true left of the channel south of a farm access road off Marshall Road about 1 km south of White Pine Road. At the 90 percentile high flow, significant inundation of this area occurs even at low lagoon levels when the channel is vegetated, indicating that inundation is related to restriction of the channel rather than the lagoon level. With the channel cleared, or at mean flow, significant inundation occurs only when the lagoon level equals or exceeds 2.0 m.

4. At the 90 percentile high flow, the area of land where drainage is potentially affected is much more influenced by high channel roughness (due to plant growth) than by lagoon water level (including backwater effects). At mean flow, the lagoon water level has a more significant effect, but with more limited up-channel extent.

5.2 Carran Creek

1. For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was to about 400 m downstream of cross-section C-7 (i.e. to chainage 0.4 km) and occurred at a lagoon level of 2.5 m.

2. A restriction in the channel at chainage 2.6 km acts as a control, raising water levels steeply upstream of this point. This limits the extent of backwater effects when lagoon levels are less than 1.5 m, particularly when the channel is vegetated.

3. The main area of land inundated by high Waituna lagoon water levels is west to north-west of Little Lake Waituna. No significant inundation occurs east of Waituna Lagoon Road or north of Hanson Road. The extent of this inundation is due mostly to lagoon level – it is only very slightly affected by channel vegetation and flow.

4. A swath of land about 500 m wide downstream of Waituna Lagoon Road Bridge and west of Lagoon Road is potentially drainage affected even at low lagoon level (taken as 0.5 m), although much of this land is wetland habitat

5. At the 90 percentile high flow, a fairly large area of farmland, upstream of Waituna Lagoon Road Bridge (~44 ha), is potentially drainage affected when the channel is vegetated. This area reduces in size by about 40%, if the channel is cleared.

6. At mean flow very little farmland upstream of Waituna Lagoon Road Bridge is potentially drainage affected, when the channel is clear of plants, although land does start to become

affected once lagoon levels exceed approximately 1.8m. If the channel is instead vegetated then, more farmland is potentially drainage affected but lagoon level has relatively little effect.

5.3 Moffat Creek

1. For the range of Waituna Lagoon water levels considered (i.e., up to 2.5 m), the furthest backwater extent was to about 140 downstream of cross section M-4 (i.e. around 940 m downstream of Moffat Road Bridge).

2. The main area of land inundated by high Waituna lagoon water levels is wetland near the outlet of channel to Waituna Lagoon. A small area of farmland in the lower reaches can inundated due mostly to high lagoon levels rather than channel vegetation and flow.

3. At mean flow, 28 ha of farmland adjacent to the main river channel that is less than 1.0 m above the water level in the main channel is potentially drainage affected when channel is vegetated (under 2.5 m lagoon level). This area reduces to about 25.3 ha if the channel is cleared.

4. At mean flow, area of potentially drainage affected farmland adjacent to the channel with ground elevation less than 2.0 m above the channel water level when channel is vegetated is ~100.3 ha (under 2.5 m lagoon level). This area reduces in size by about 16% if the channel is cleared.

5. At the 90 percentile high flow, a larger area of farmland (~27.4 ha) is potentially drainage affected with 1 m threshold depth when the channel is clear (under 2.5 m lagoon level). This area increases to about 48.1 ha if the channel is vegetated.

6. At the 90 percentile high flow, area of farmland which potentially drainage affected with 2 m threshold depth is about 95.4 when the channel is cleared (under 2.5 m lagoon level). This area increases in size by about 18% if the channel is vegetated.

5.4 Overall summary

Bathtub inundation modelling shows the area of land inundated by static lagoon water levels up to 2.5 m is relatively minor and generally around the mouths of the three main tributary creeks: Waituna, Moffat and Carran.

For all three Waituna, Moffat and Carran Creeks the area of land affected by direct inundation and impeded drainage is a function of lagoon level, flow rate and plant growth in the creeks. The relative importance of these three factors varies spatially. The most downstream parts of the Creeks is strongly affected by lagoon level but further upstream this has little or no effect and channel vegetation and flow dominate. For high flow, densely vegetated conditions, the lagoon level has less impact as Creek levels are already high. Under high flow conditions the area of farmland with potentially affected drainage is much higher as a result of a vegetated channel than as a result of a high lagoon level (for all three creeks).

When interpreting results from this study it is important to bear in mind the various assumptions and simplifications involved in the analysis. Of particular importance is the way simple 1 m and 2 m threshold depths to lagoon/creek water levels were applied to map the area of land potentially influenced by poor drainage, and the way varying Manning’s ‘n’ roughness coefficients have been used to simulate vegetation. It should also be noted that study does not account for any wind effects on lagoon level.

5.5 Recommendations for further analysis

While this study provides a good basis for understanding how lagoon levels impact farmland around Waituna Lagoon there are a number of ways uncertainty could be reduced:

1. The uncertainties associated with the threshold used for mapping areas with impacted land drainage could be reduced by investigating/mapping the typical depth of field drains in low lying areas adjacent to the Creeks.

2. Further water level and flow gaugings in the identified backwater reaches under different flow and plant growth conditions would provide additional calibration/validation data to improve model certainty.

6 Acknowledgements

This study has been supported by flow, LiDAR and bathymetric data provided by Environment Southland.

7 Glossary of abbreviations and terms

ADCP	Acoustic Doppler Current Profiler: Instrument for conducting flow gaugings by measuring the distribution of flow velocity across a cross-section.
backwater	increase in creek water level due to downstream high water (lagoon level)
chainage	Distance along a river channel from the start of the modelled reach to any given cross-section
DEM	Digital Elevation Model: A digital map of land elevation
hydraulic roughness	Hydraulic roughness represents the frictional resistance of a channel to flow passing through it. In this study roughness is quantified using Manning's 'n' coefficient.
LiDAR	Abbreviation for Light Detection And Ranging. LiDAR data is high resolution topographic survey data collected using an aircraft mounted laser scanner
Manning's 'n'	Coefficient used to specify hydraulic roughness. A higher value of 'n' means the channel has more resistance so will require greater flow depths to pass a given flow. Conversely a lower 'n' means a channel will have faster shallower flow (for any given flow rate and slope). Typical values of n relevant to this study are given in Table 4-4.
raster grids	maps of data at a constant spatial resolution, for example a 20m resolution raster grid is a gridded data set where each 20m x 20m cell contains a single value.
wind set-up	Local increase in lagoon level on the downwind side of the lagoon caused by the wind inducing a sloping water surface

8 References

Chow V.T. (1959) *Open Channel Hydraulics*. McGraw-Hill, New York.

Thompson, C. (2015) Carran and Waituna Creek Cross Section Survey of Gaugings Sites. Survey Report December 2015. Report prepared by TrueSouth Survey Services Ltd., for Environment Southland, December 2015.

Appendix A Summary of metadata from flow gauging notes

Table A-1: Waituna Creek flow gauging metadata.

Location	Cross-section	Easting	Northing	Date	Start time	End time	Flow (l/s)	Details	Bed	Plant growth	Other notes
Marshall Rd Hydrology Recorder	W-8	1258125	4838490	10/12/2015	13:16	13:45	482	Pygmy, Wading	Gravel	Not really	
Marshall Rd Dairy Farm	W-6	1257775	4837589	10/12/2015	11:27	11:45	460	StreamPro, Wading	Gravel	Yes	Strong wind
Marshall Road Farm Trustee Ltd Bridge	W-5	1257745	4837288	10/12/2015	10:38	11:00	423	StreamPro, Wading	Gravel	Yes	Strong wind
500 m u/s of White Pine Rd	W-4	1257674	4836759	10/12/2015	9:43	10:04	473	StreamPro, Wading	Gravel	Yes	Moderate wind
White Pine Rd	W-3	1257842	4836348	10/12/2015	8:45	8:59	465	StreamPro, Wading	Gravel	Yes	
500 m d/s White Pine Rd	W-2	1258032	4835904	10/12/2015	8:02	8:19	495	StreamPro, Wading	Gravel	Not really	
1000 m d/s White Pine Rd	W-1	1258120	4835345	10/12/2015	7:19	7:32	541	StreamPro, Wading	Gravel	No	

Table A-2: Carran Creek flow gauging metadata.

Location	Cross-section	Easting	Northing	Date	Start time	End time	Flow (l/s)	Details	Bed	Plant growth	Other notes
1500 m u/s of Waituna Lagoon Rd	C-7	1267302	4837462	9/12/2015	16:53	17:18	90	StreamPro, Wading	Muddy	Very weedy[1]	Difficult to get consistent flows. Lots of sweet grass
1000 m u/s of Waituna Lagoon Rd	C-6	1267027	4837081	9/12/2015	15:38	16:05	116	StreamPro, Wading	Muddy	Choked with weeds except for narrow channel	Stage dropped 3mm while on site. Site d/s of hydrology recorder
500 m u/s of Waituna Lagoon Rd	C-5	1266664	4836756	9/12/2015	14:01	14:30	138	StreamPro, Wading	Gravel/Muddy	Very Weedy	
Waituna Lagoon Rd Bridge	C-4	1266566	4836441	9/12/2015	9:10	9:57	175	StreamPro, Wading	Gravel	Only on sides in clumps	
650 m d/s of Waituna Lagoon Rd	C-3	1266777	4835976	9/12/2015	11:54	12:09	156	StreamPro, Wading	Sand/Gravel	Very Weedy	
800 m d/s of Waituna Lagoon Rd	C-2	1266790	4835845	9/12/2015	11:13	11:21	187	StreamPro, Wading	Sand/Gravel	Very Weedy	
Outflow to Little Lake Waituna	C-1	1266935	4835657	9/12/2015	10:58	11:01	48	StreamPro, Boat	Sand/Gravel	Slightly	Unsuitable site - flow only rough estimate from 1 crossing

1. “Weedy” in the hydraulic sense is used to refer to plants blocking the flow and does not imply invasive/alien species.

Table A-3: Moffat Creek flow gauging metadata.

Location	Cross-section	Easting	Northing	Date	Start time	End time	Flow (l/s)	Details	Bed	Plant growth	Other notes
Tributary, upstream of Moffat Rd	M-8	1260941	4836654	8/3/2017	17:07	18:08	17	Ott, Wading		Very weedy	shallow but straight section with expected velocity patterns
u/s of Hansen Rd	M-7	1260693	4837401	8/3/2017	15:50	16:20	28	Ott, Wading		Extremely weed choked	Upon arrival the stream was not flowing. Straight section with slow velocity
500 m u/s Moffat Rd	M-6	1260480	4836907	8/3/2017	14:07	14:41	24	Ott, Wading	Gravel	Very weedy	Shallow creek, straight section
Moffat Creek at Moffat Rd	M-5	1260364	4836402	1/3/2017	08:26	09:01	47	Ott, Wading	Sand/gravel	Relatively weed free	Straight section, ex Hydrology site for ES
300 m d/s Moffat Rd	M-4A	1260115	4836234	1/3/2017	15:26	16:01	54	Ott, Wading	Gravel	Very weedy	Constricted stream, relatively straight section
1150 m d/s Moffatt Rd (100 m u/s survey site 3)	M-3A	1259576	4835753	1/3/2017	14:12	14:47	60	Ott, Wading	Gravel	Weedy creek	Relatively straight section
2 km d/s Moffat Rd	M-2	1259480	4835048	1/3/2017	12:30	13:30	86	Ott, Wading	Gravel	Whole creek is very weedy	Tile drain upstream discharging
600 m from lagoon	M-1A	1259626	4834728	1/3/2017	10:37	11:36	121	Ott, Wading	Gravel	Not too weedy	Deep and slow velocity (especially in bottom measurement)

Appendix B Waituna Creek inundation extent maps

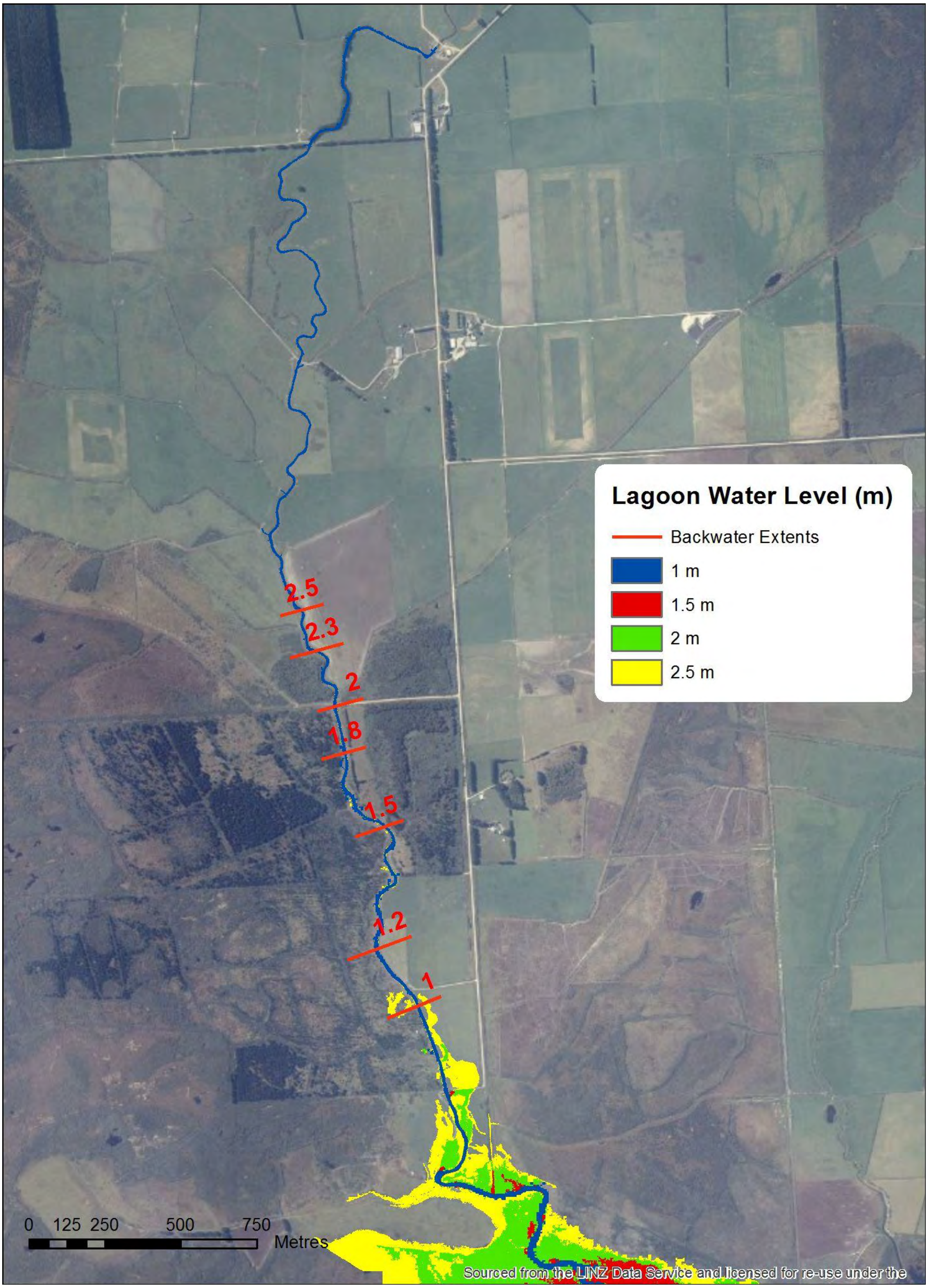


Figure B-1: Extent of Inundated land from Waituna Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{mean}-Channel Cleared". Inundated land is mapped for lagoon water levels of 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

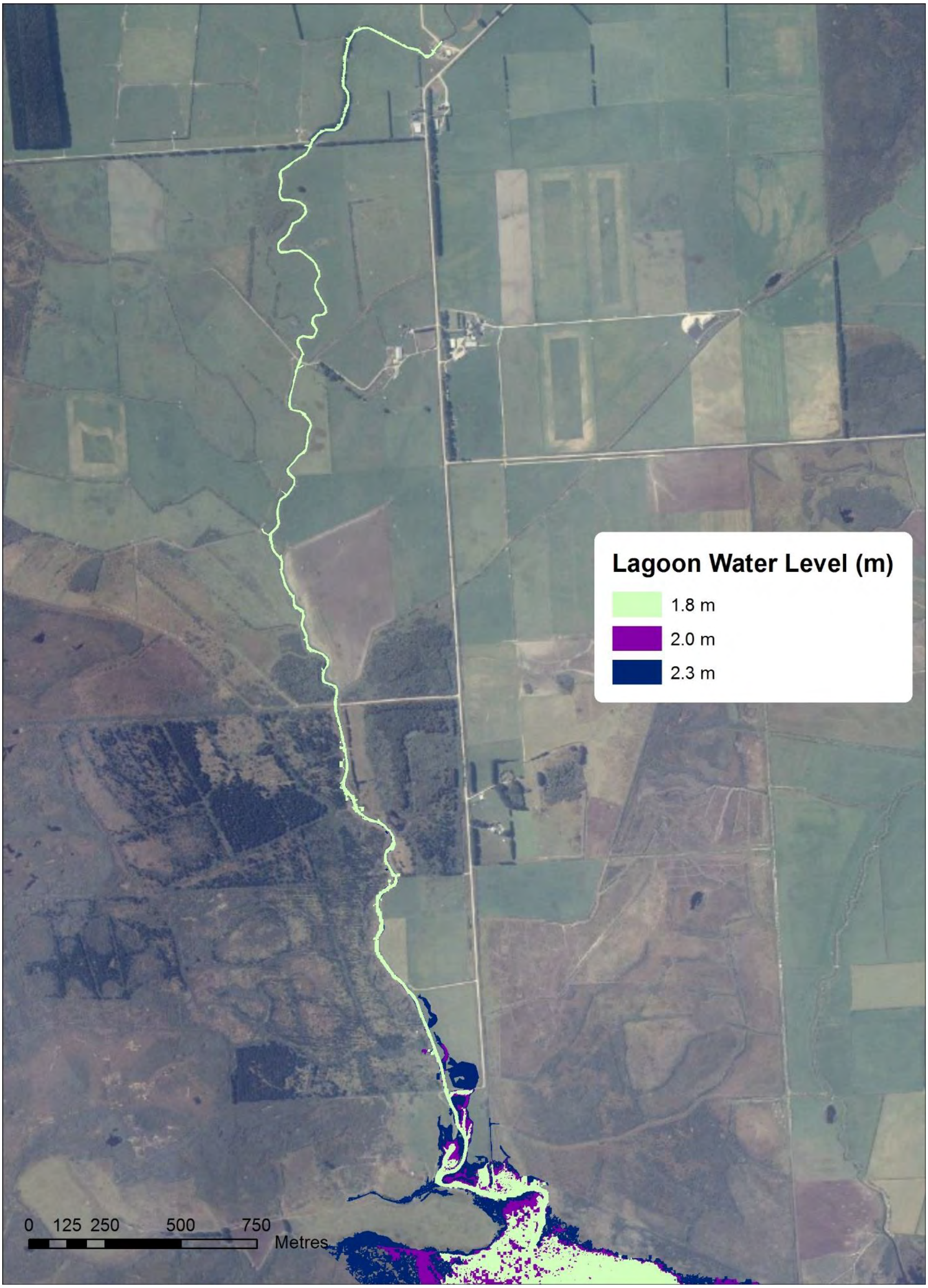


Figure B-2: Extent of Inundated land from Waituna Creek for scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

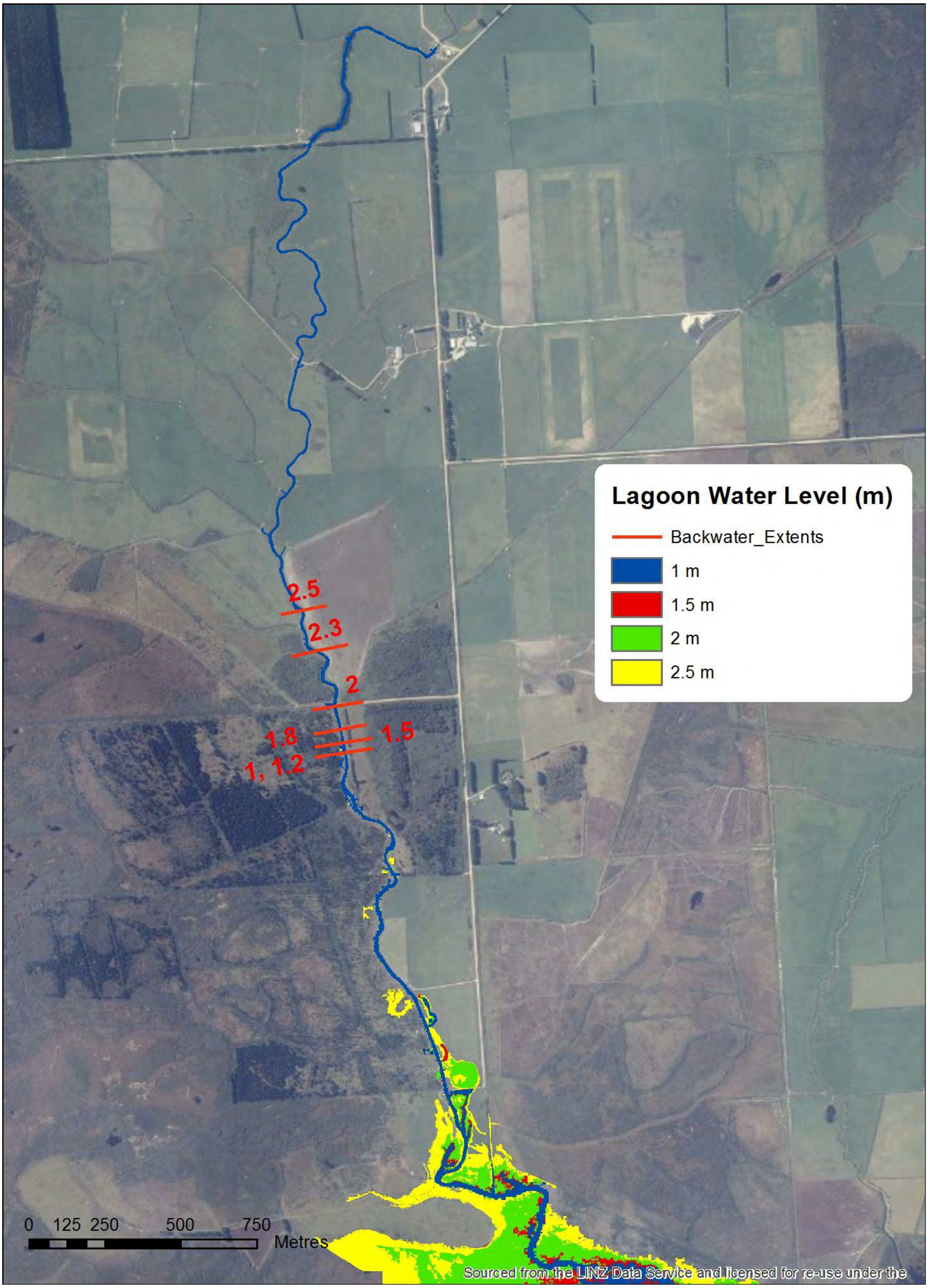


Figure B-3: Extent of Inundated land from Waituna Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{90}-Channel Cleared". Inundated land is mapped for lagoon water levels of 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

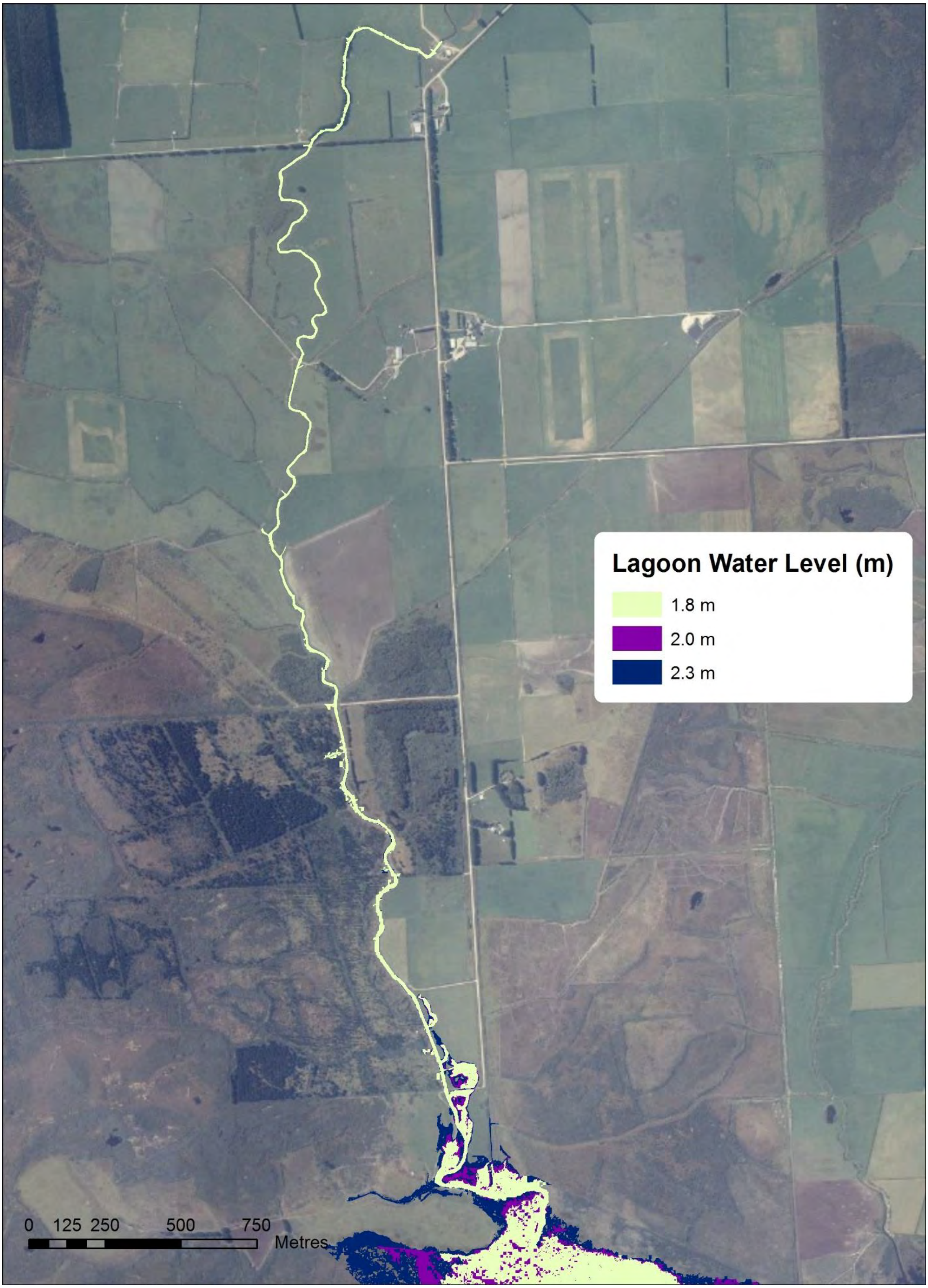


Figure B-4: Extent of Inundated land from Waituna Creek for scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

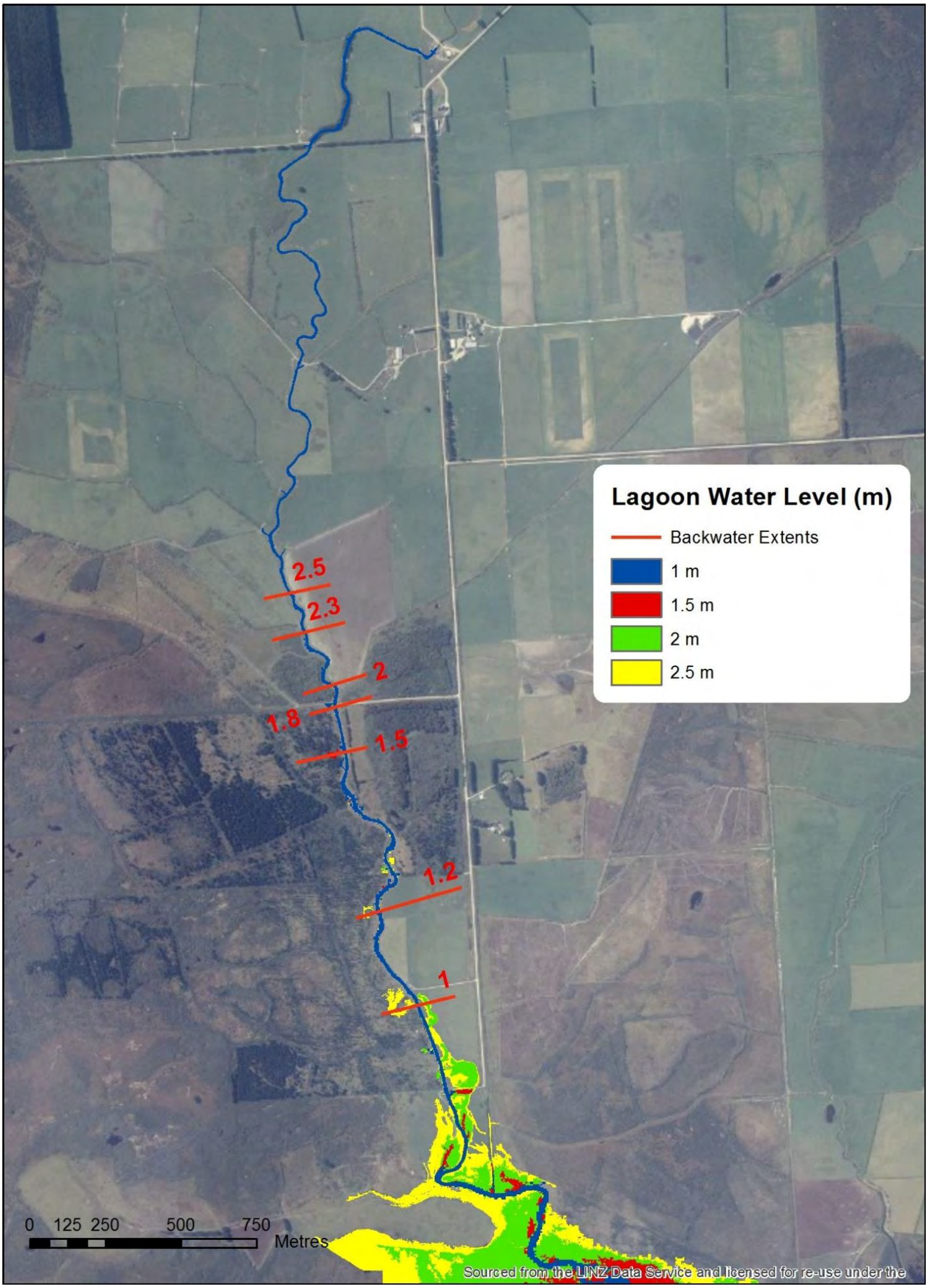


Figure B-5: Extent of Inundated land from Waituna Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{mean}-Channel Vegetated". Inundated land is mapped for lagoon water levels of 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

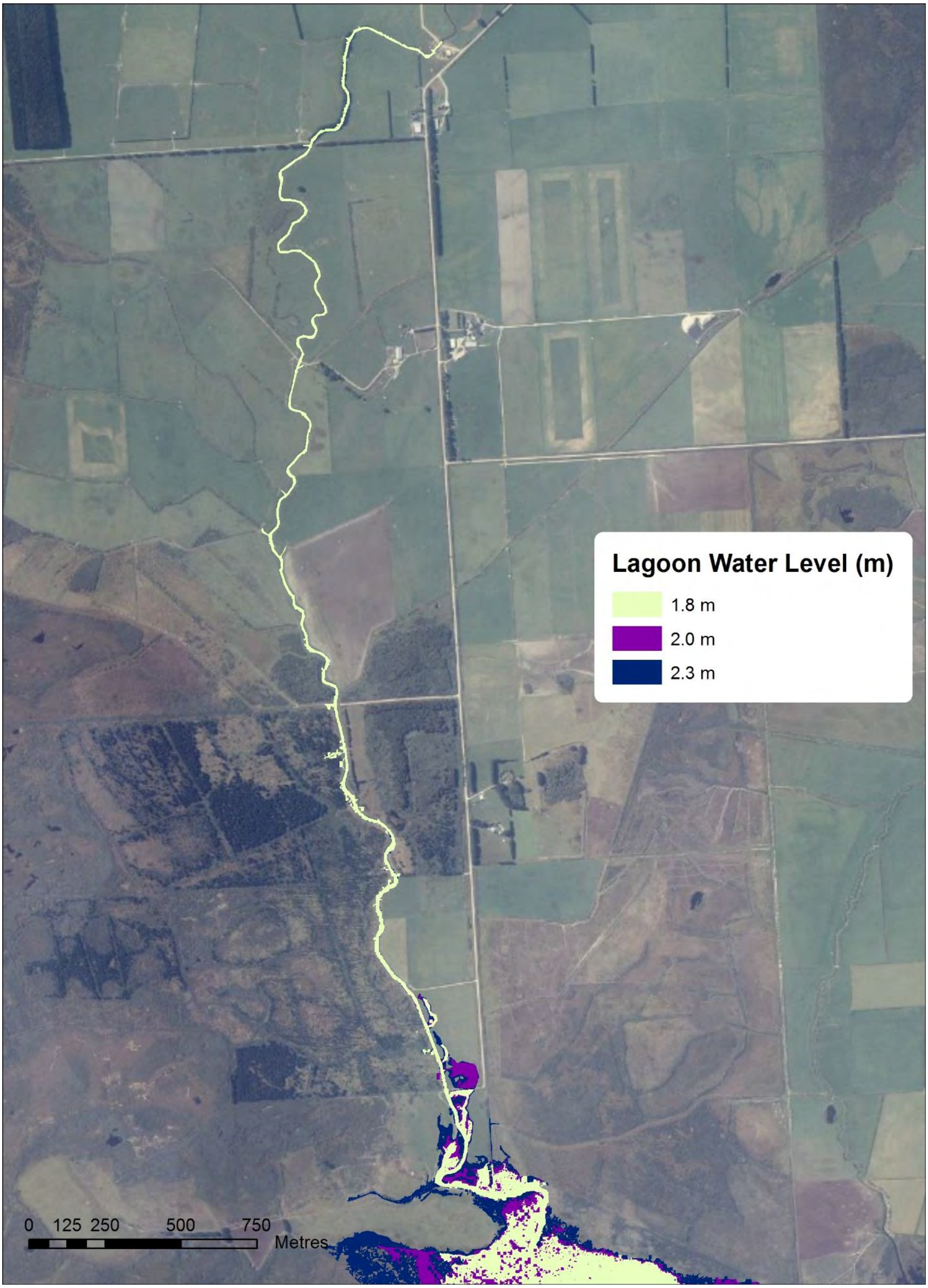


Figure B-6: Extent of Inundated land from Waituna Creek for scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

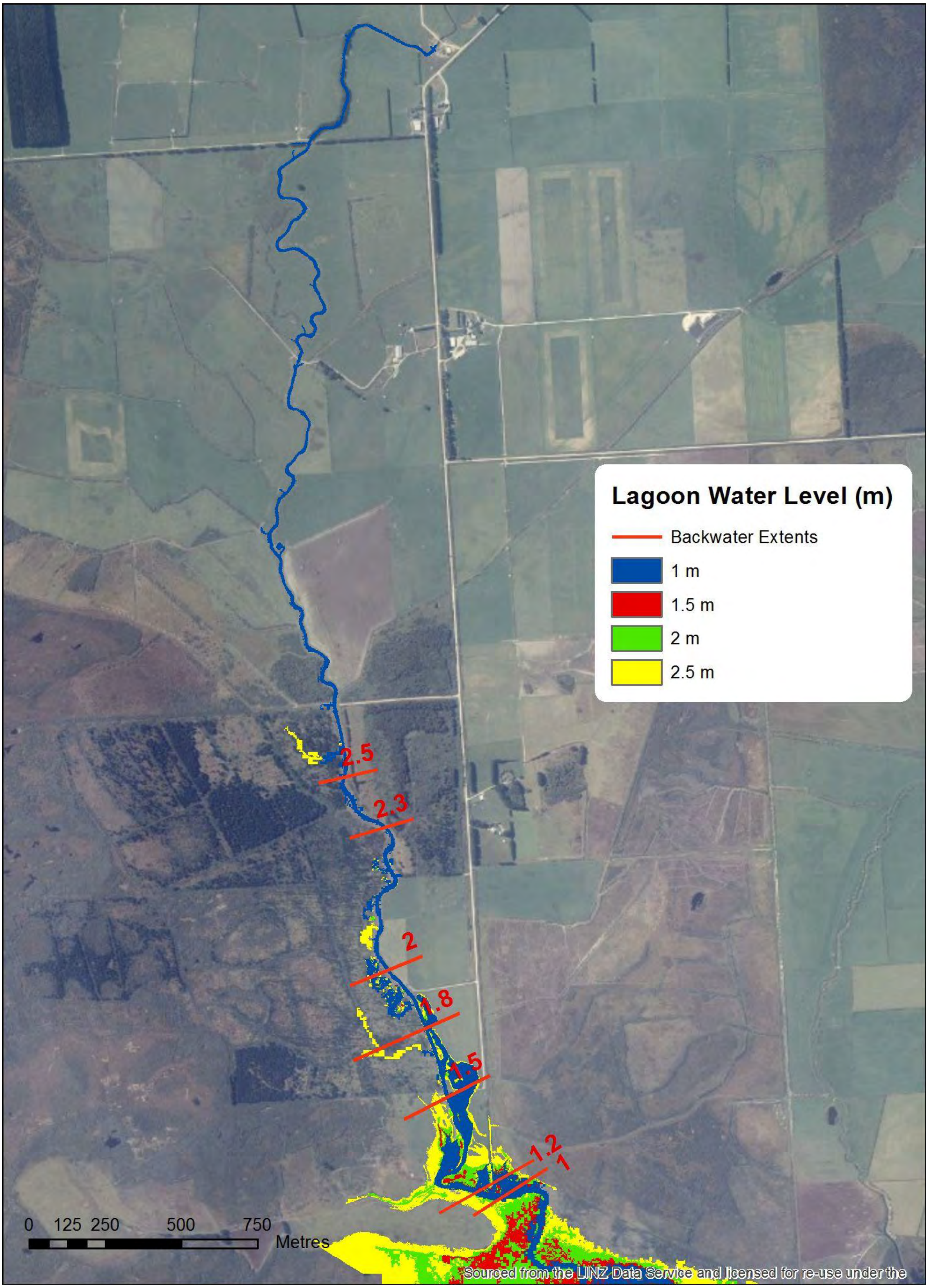


Figure B-7: Extent of Inundated land from Waituna Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{90}-Channel Vegetated". Inundated land is mapped for lagoon water levels of 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

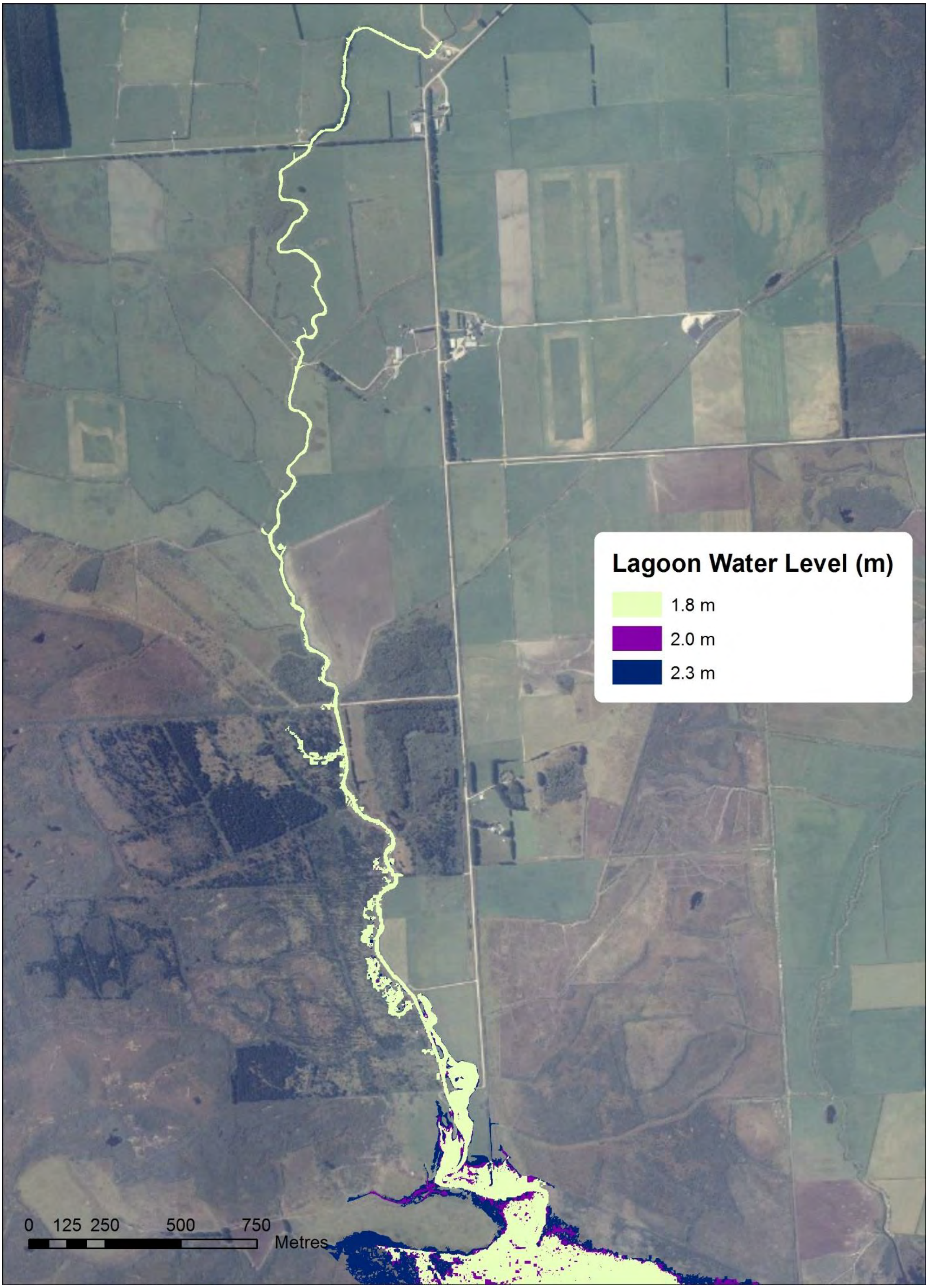


Figure B-8: Extent of Inundated land from Waituna Creek for scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

Appendix C Moffat Creek inundation extent maps

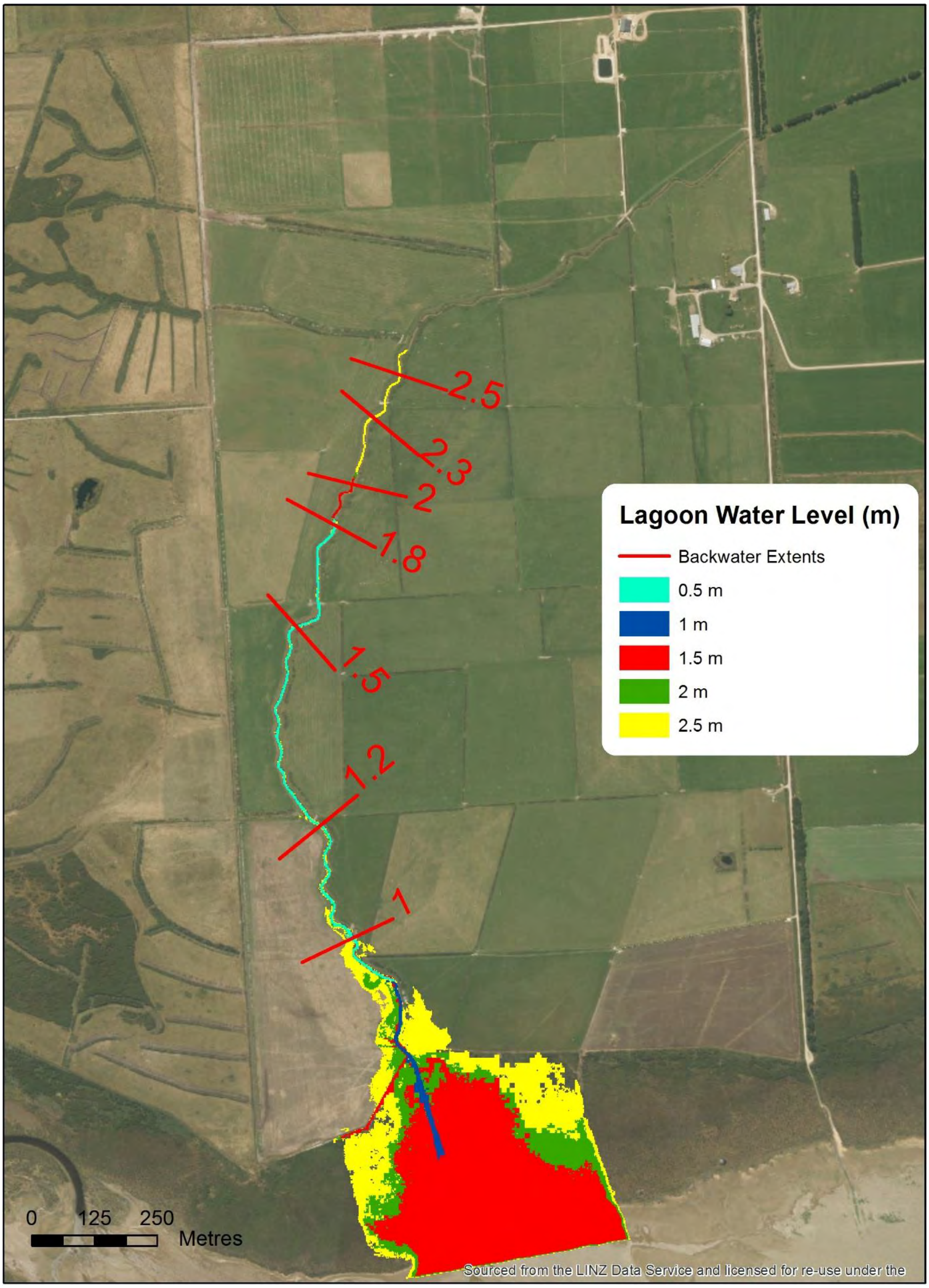


Figure C-1: Extent of Inundated land from Moffat Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{mean}-Channel Cleared". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

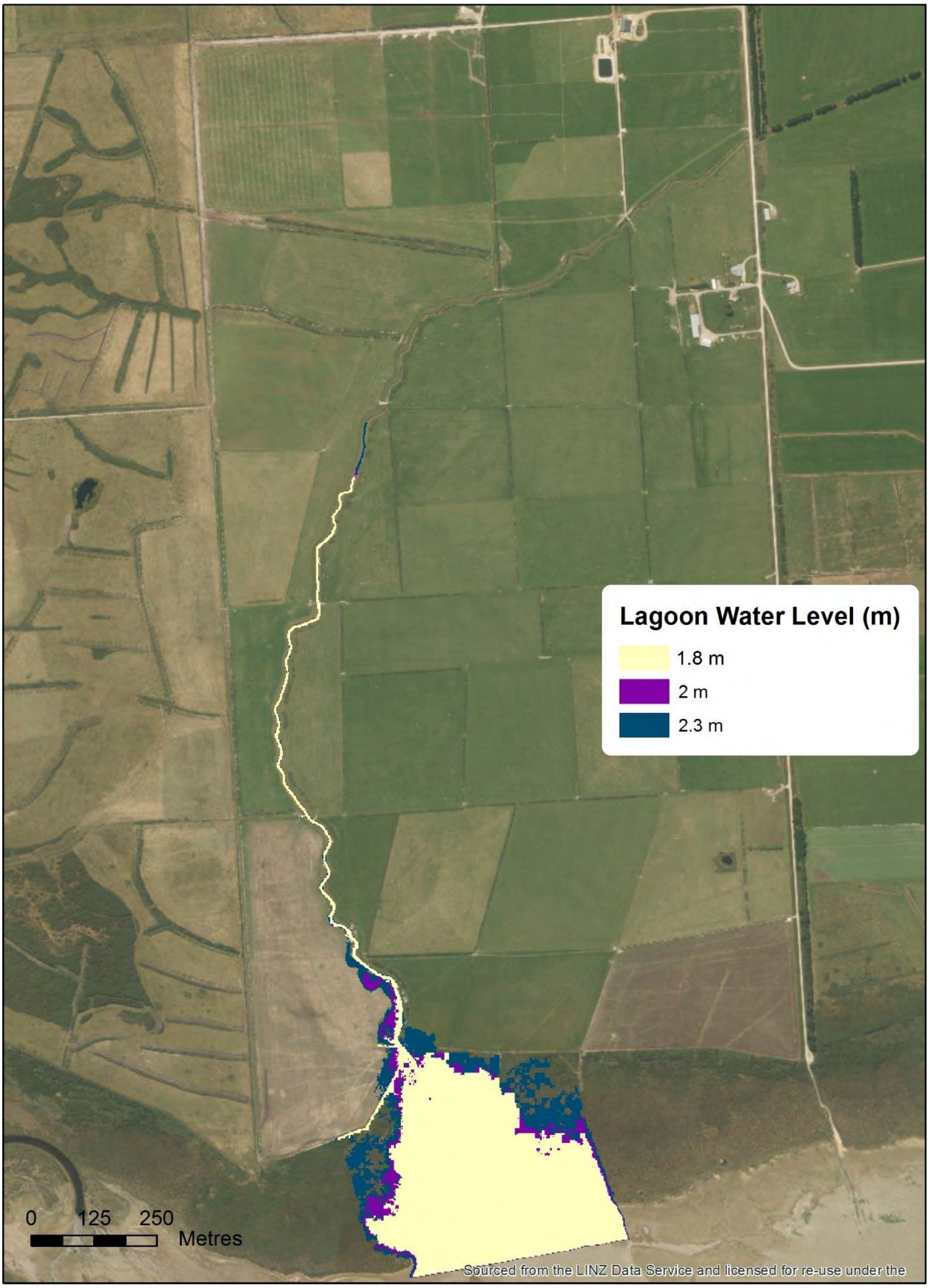


Figure C-2: Extent of Inundated land from Moffat Creek for scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

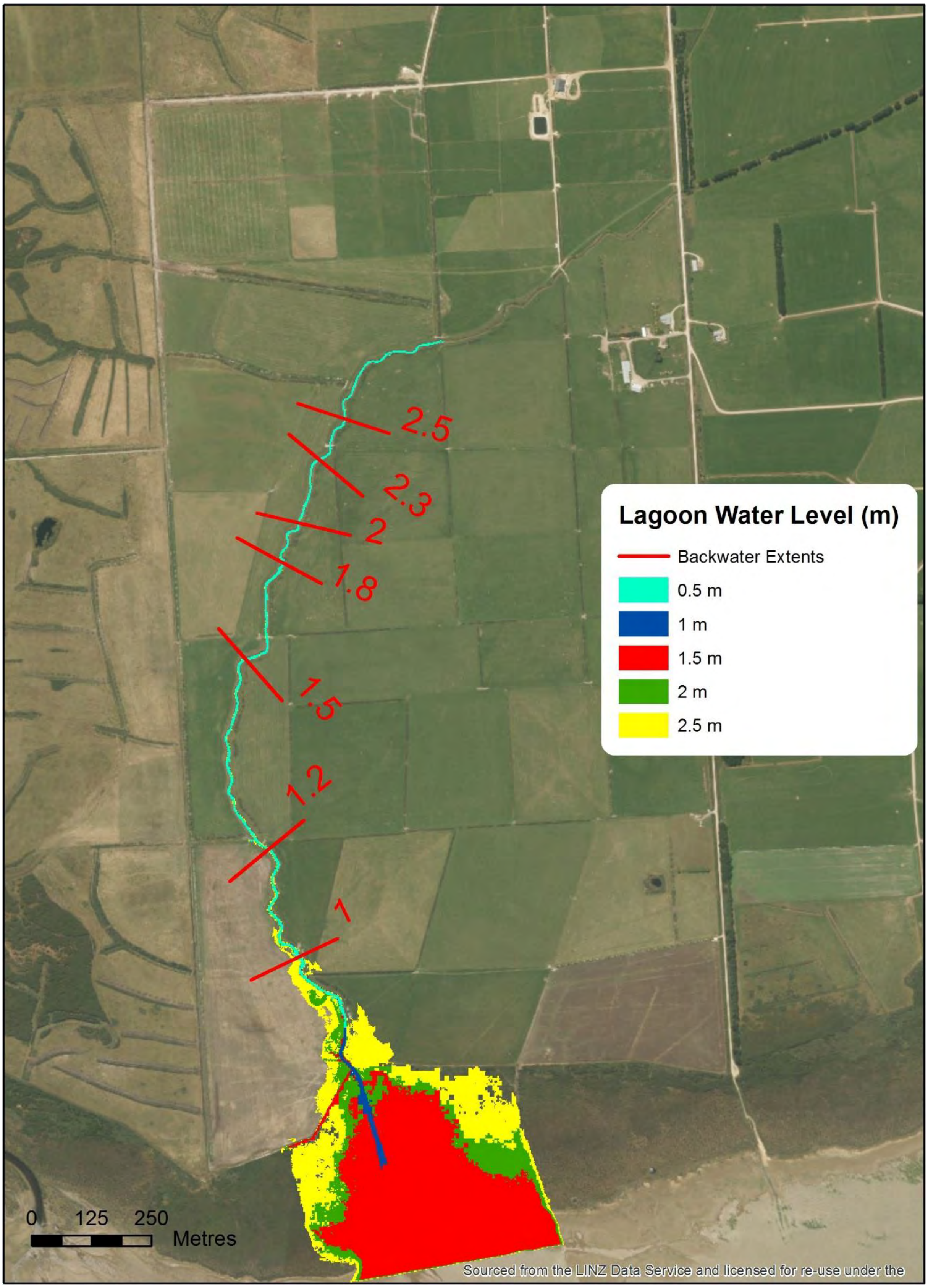


Figure C-3: Extent of Inundated land from Moffat Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{90}-Channel Cleared". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

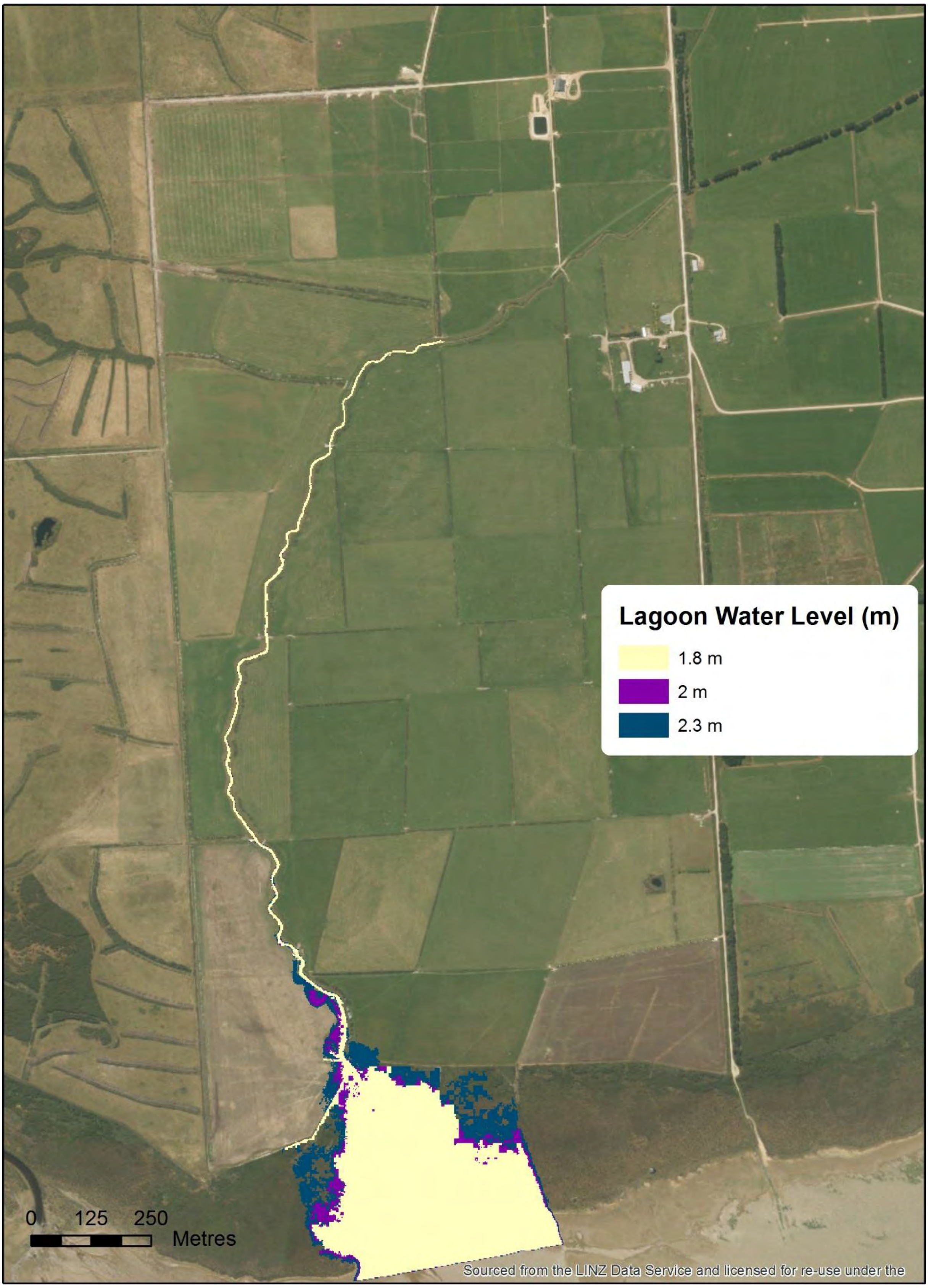


Figure C-4: Extent of Inundated land from Moffat Creek for scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 0.5 m, 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

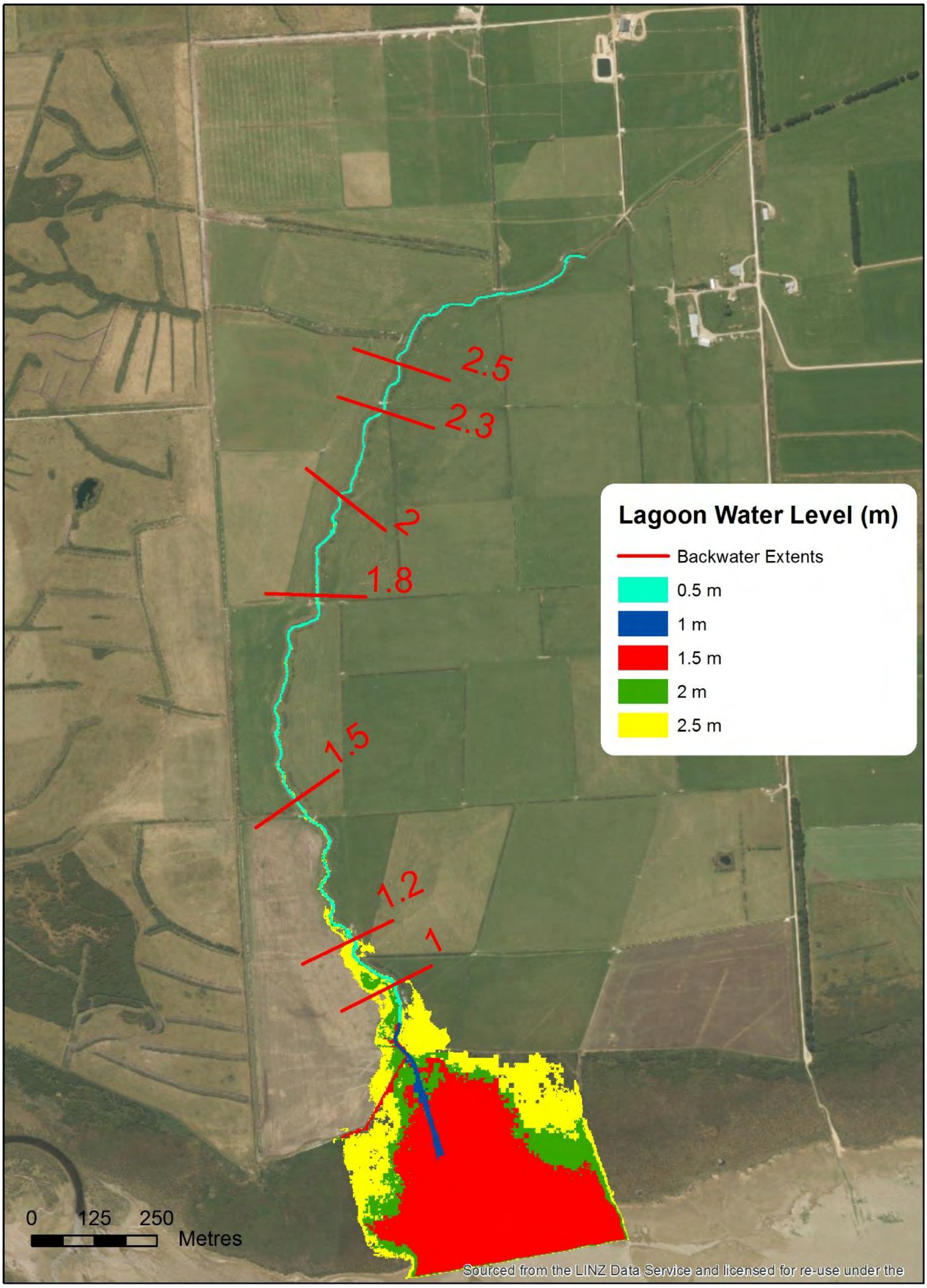


Figure C-5: Extent of Inundated land from Moffat Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{mean}-Channel Vegetated". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

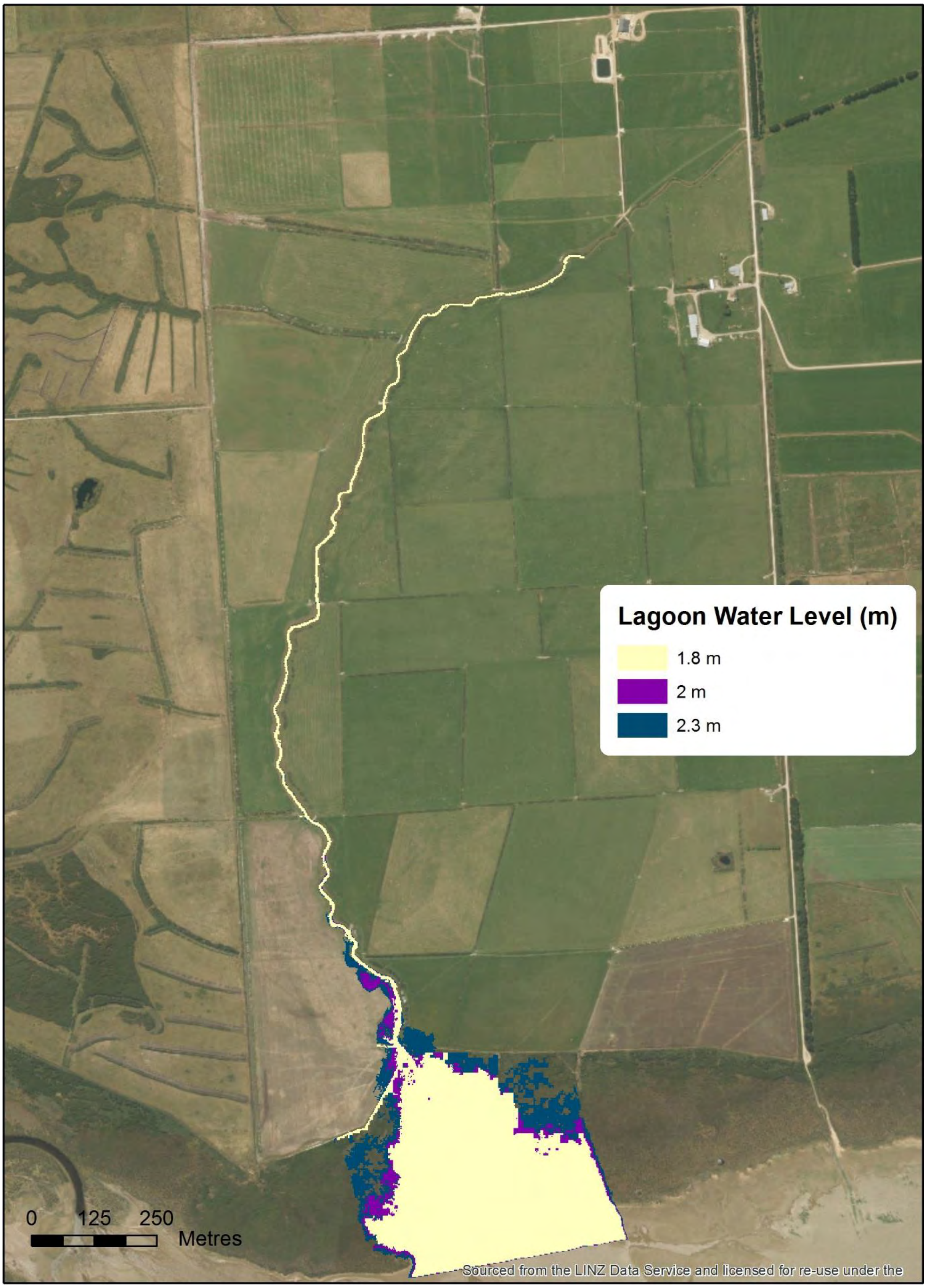


Figure C-6: Extent of Inundated land from Moffat Creek for scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

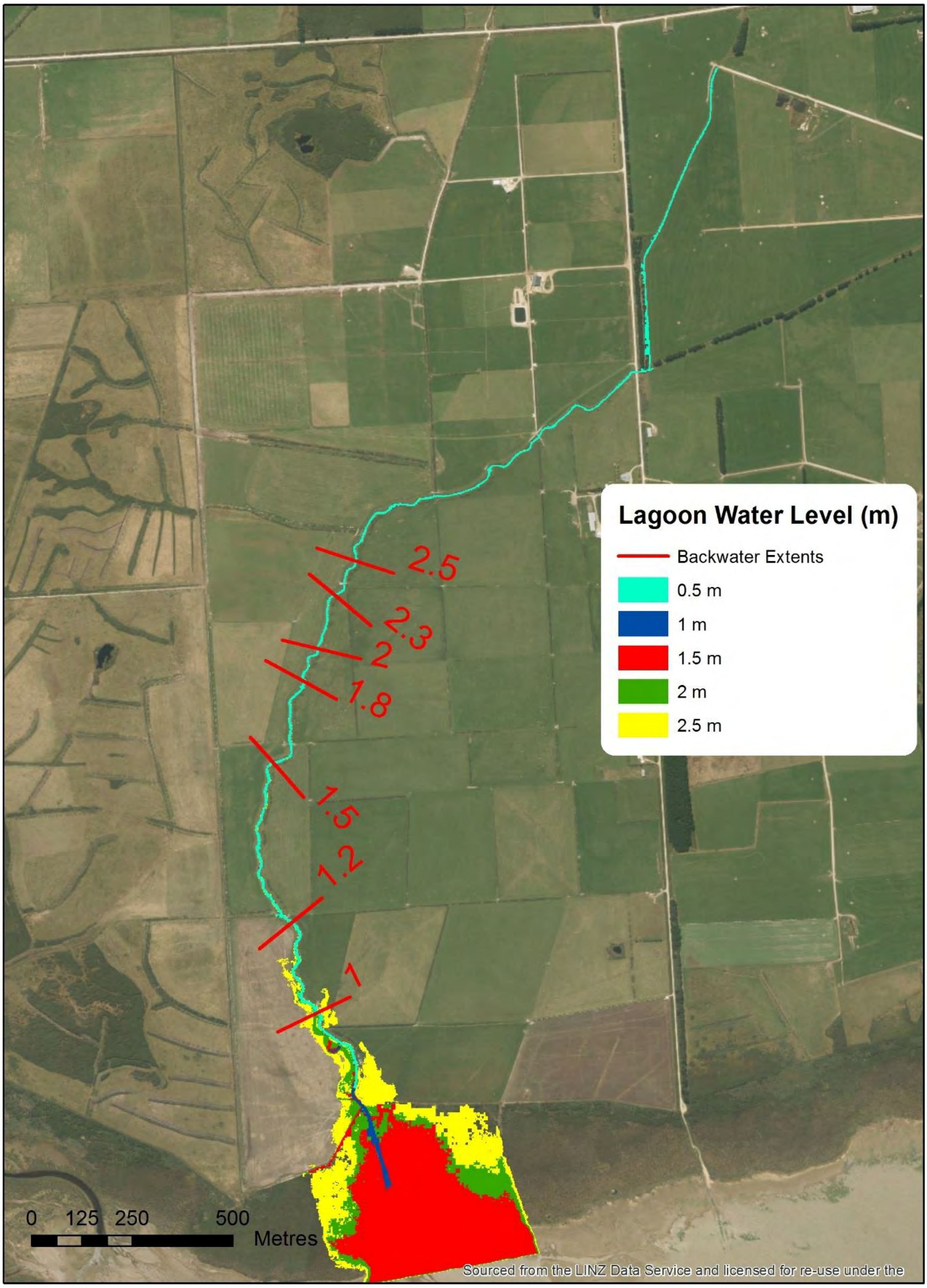


Figure C-7: Extent of Inundated land from Moffat Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{90}-Channel Vegetated". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

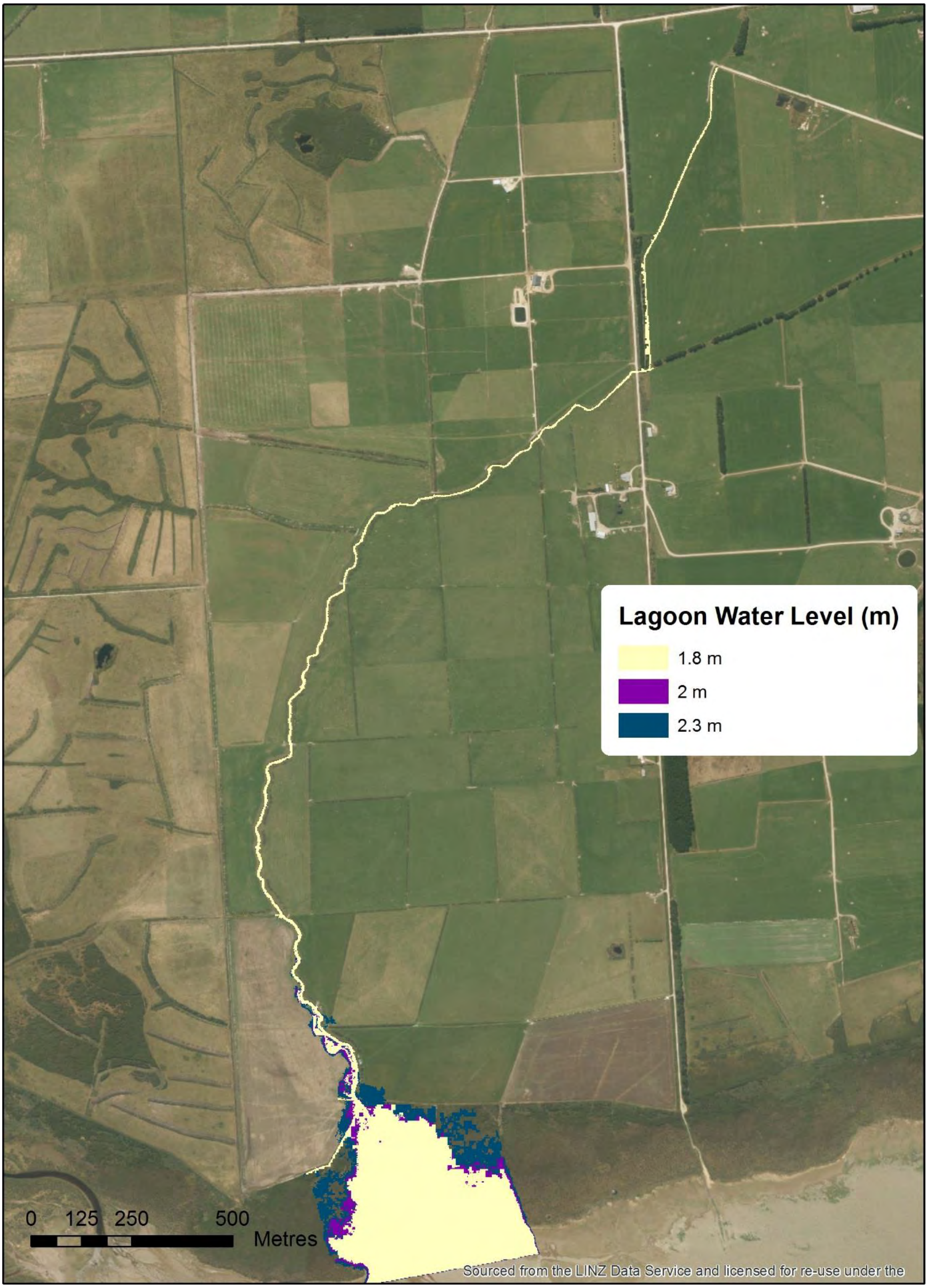


Figure C-8: Extent of Inundated land from Moffat Creek for scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

Appendix D Carran Creek inundation extent maps

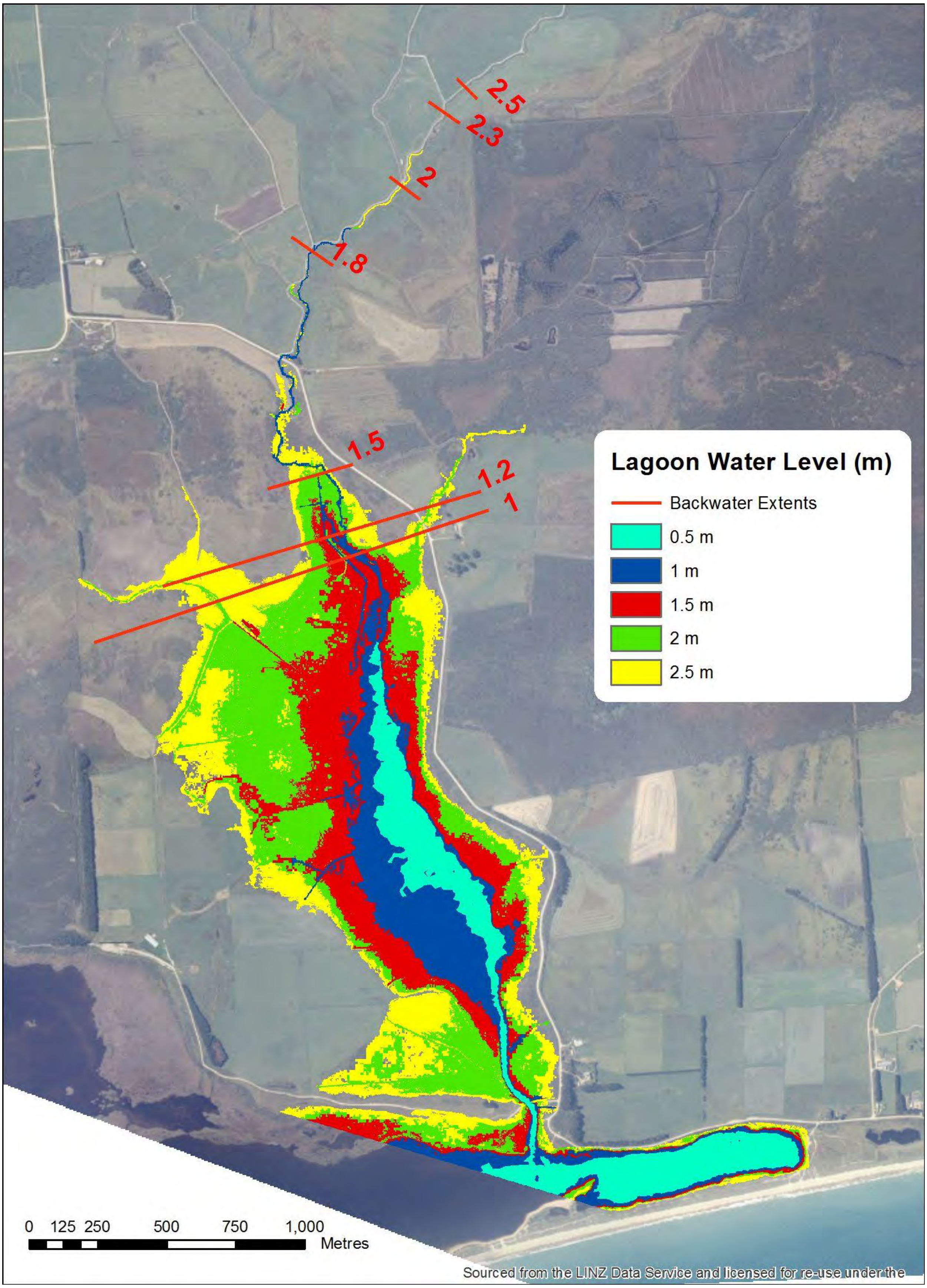


Figure D-1: Extent of Inundated land from Carran Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{mean}-Channel Cleared". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

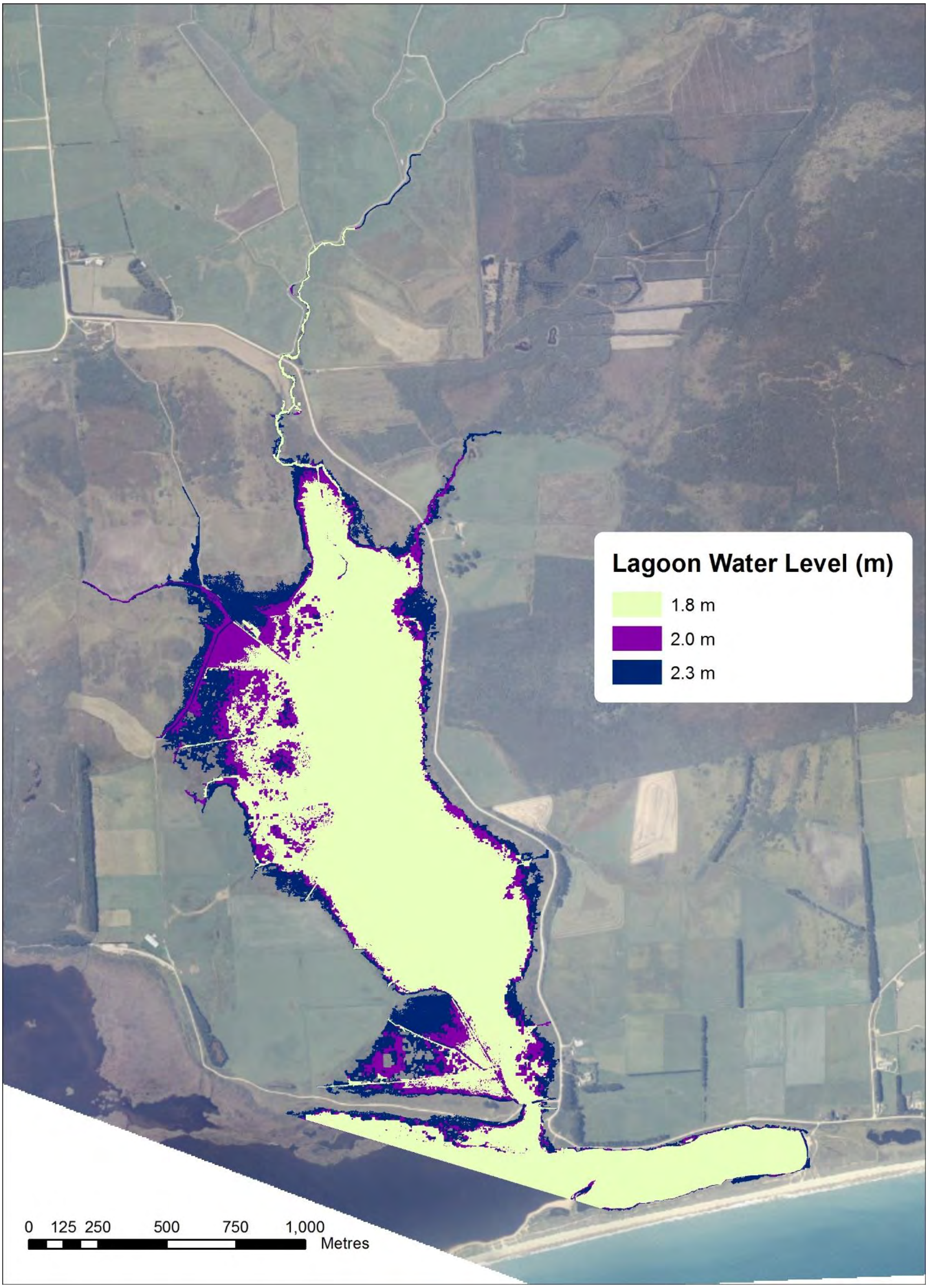


Figure D-2: Extent of Inundated land from Carran Creek for scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

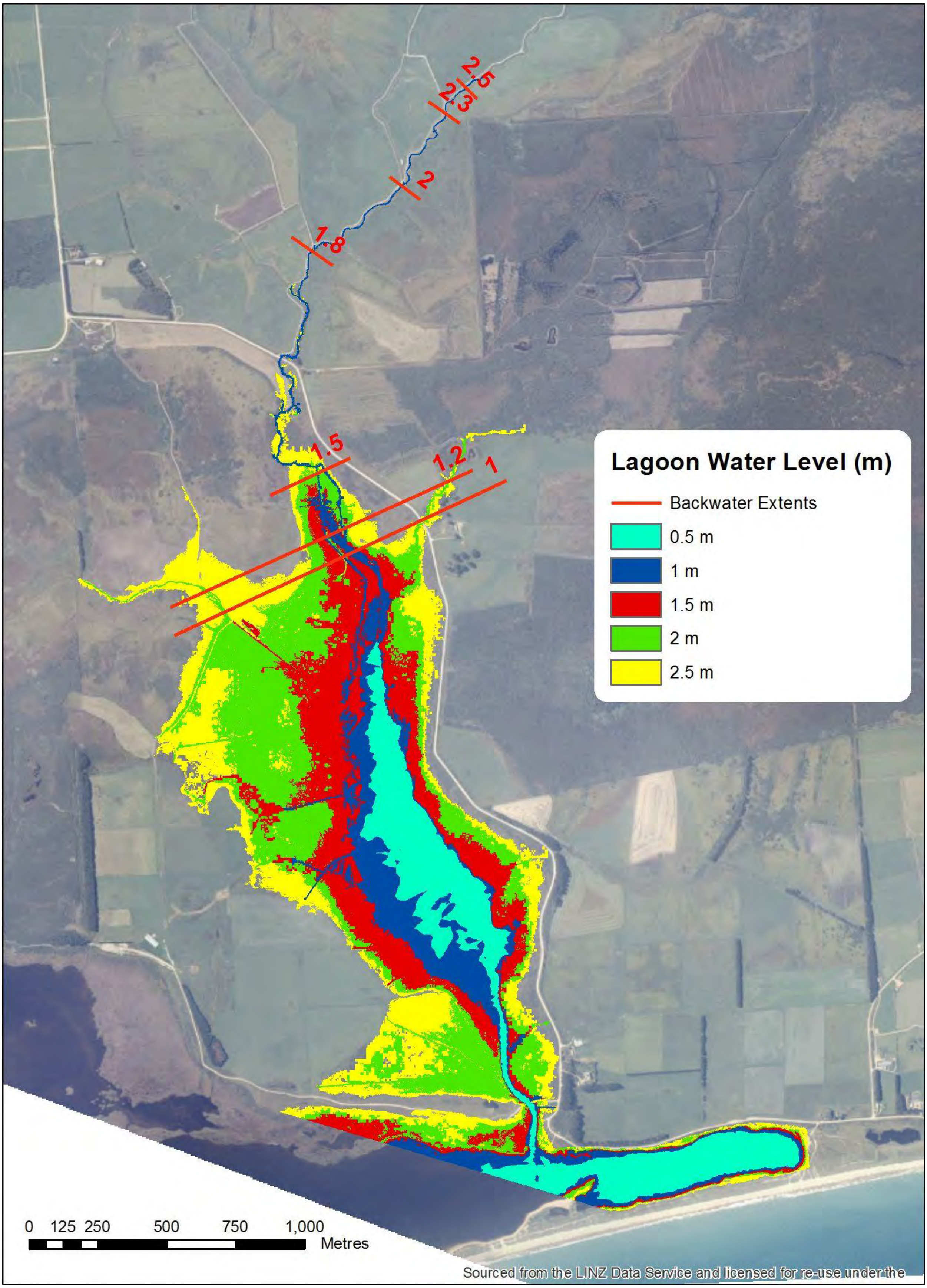


Figure D-3: Extent of Inundated land from Carran Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{90}-Channel Cleared". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

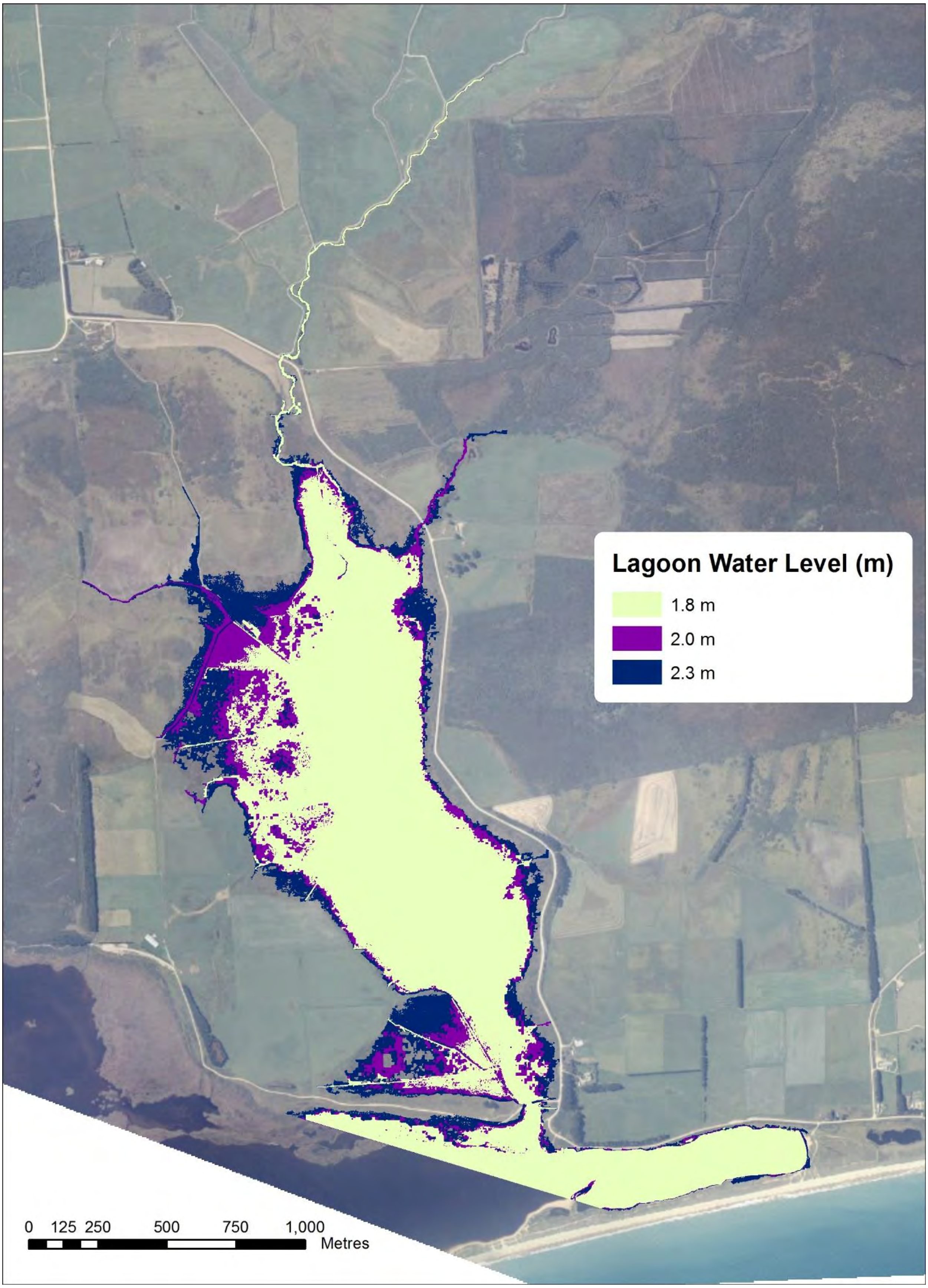


Figure D-4: Extent of Inundated land from Carran Creek for scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

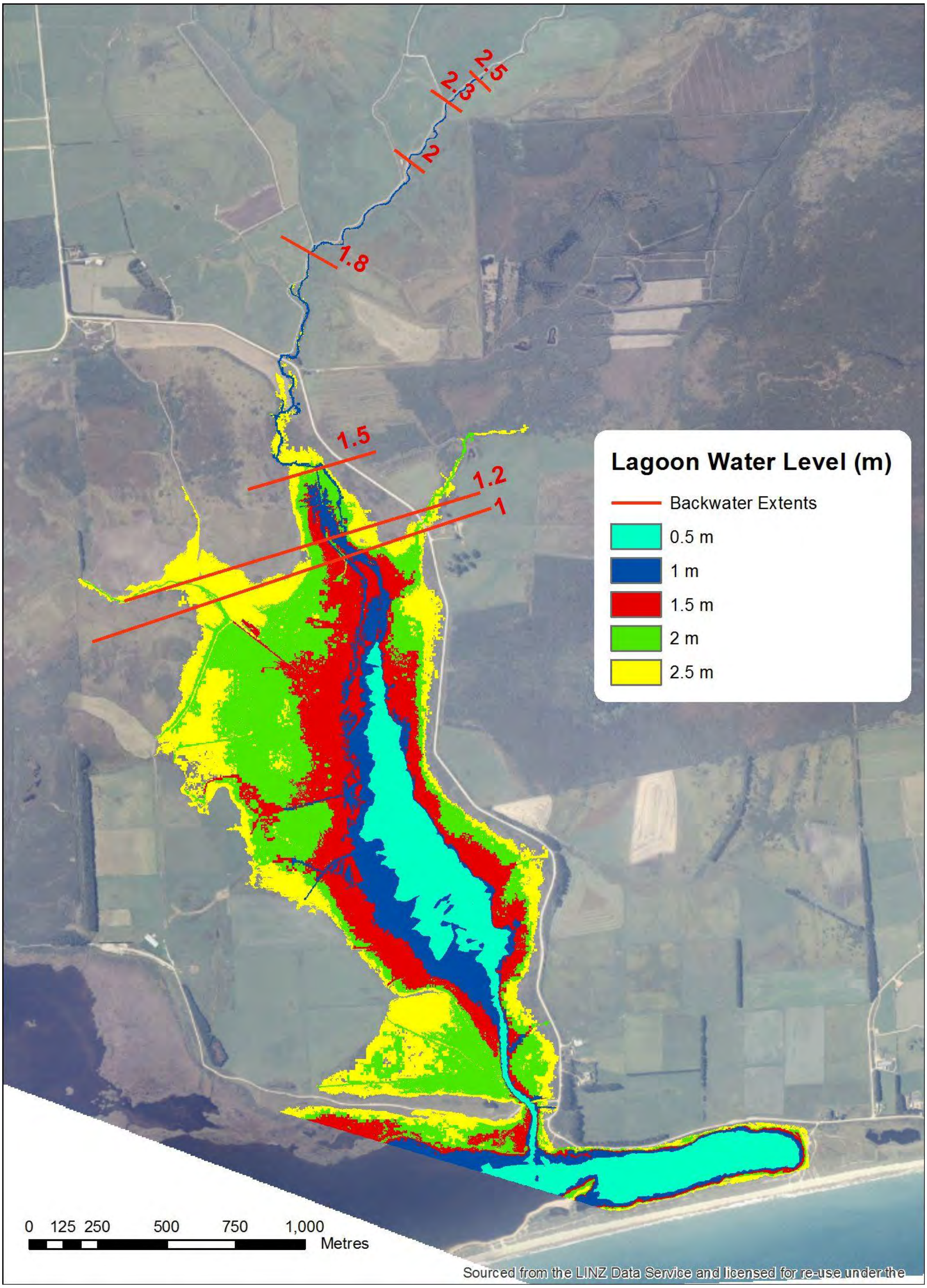


Figure D-5: Extent of Inundated land from Carran Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{mean}-Channel Vegetated". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

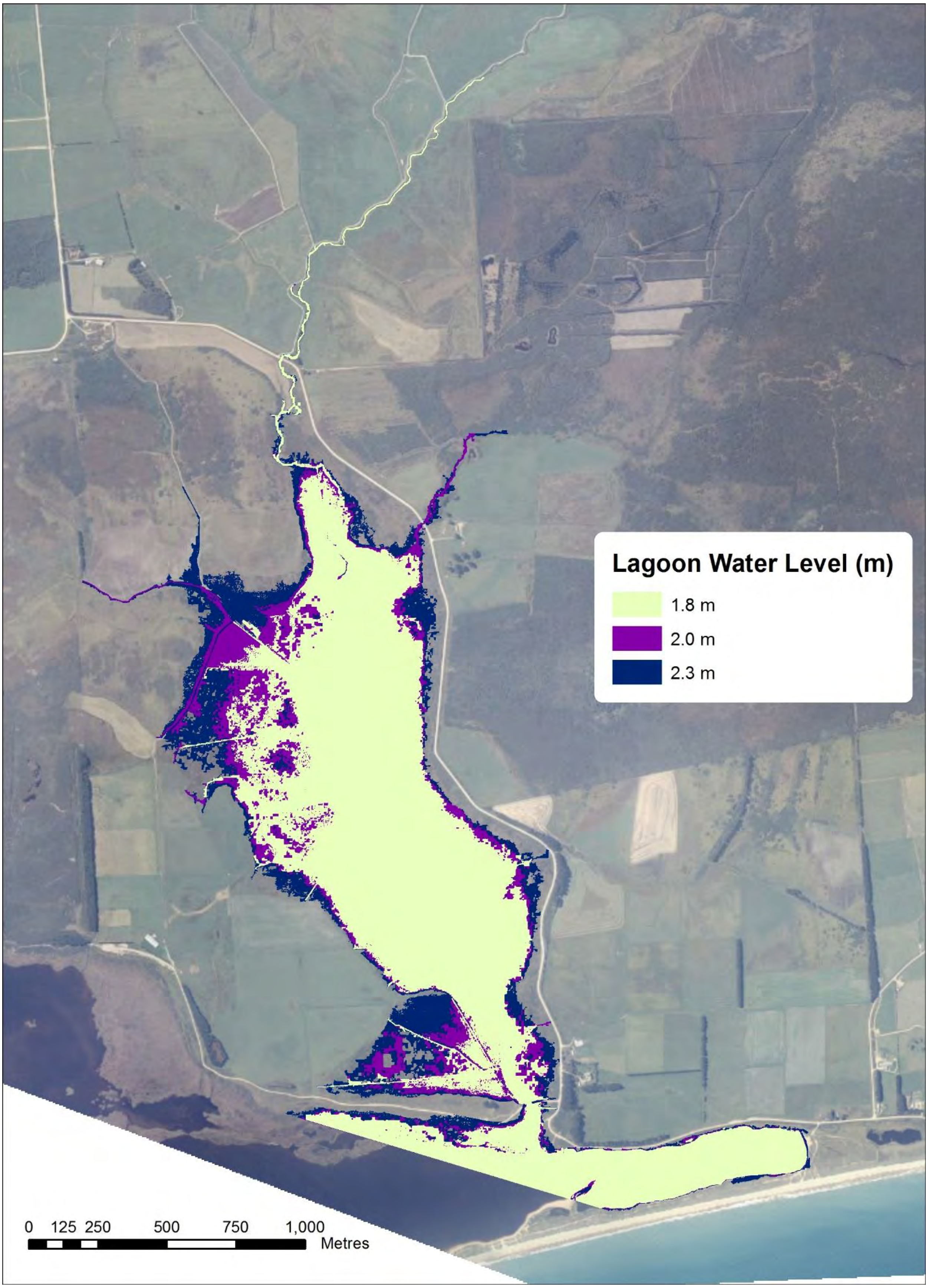


Figure D-6: Extent of Inundated land from Carran Creek for scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

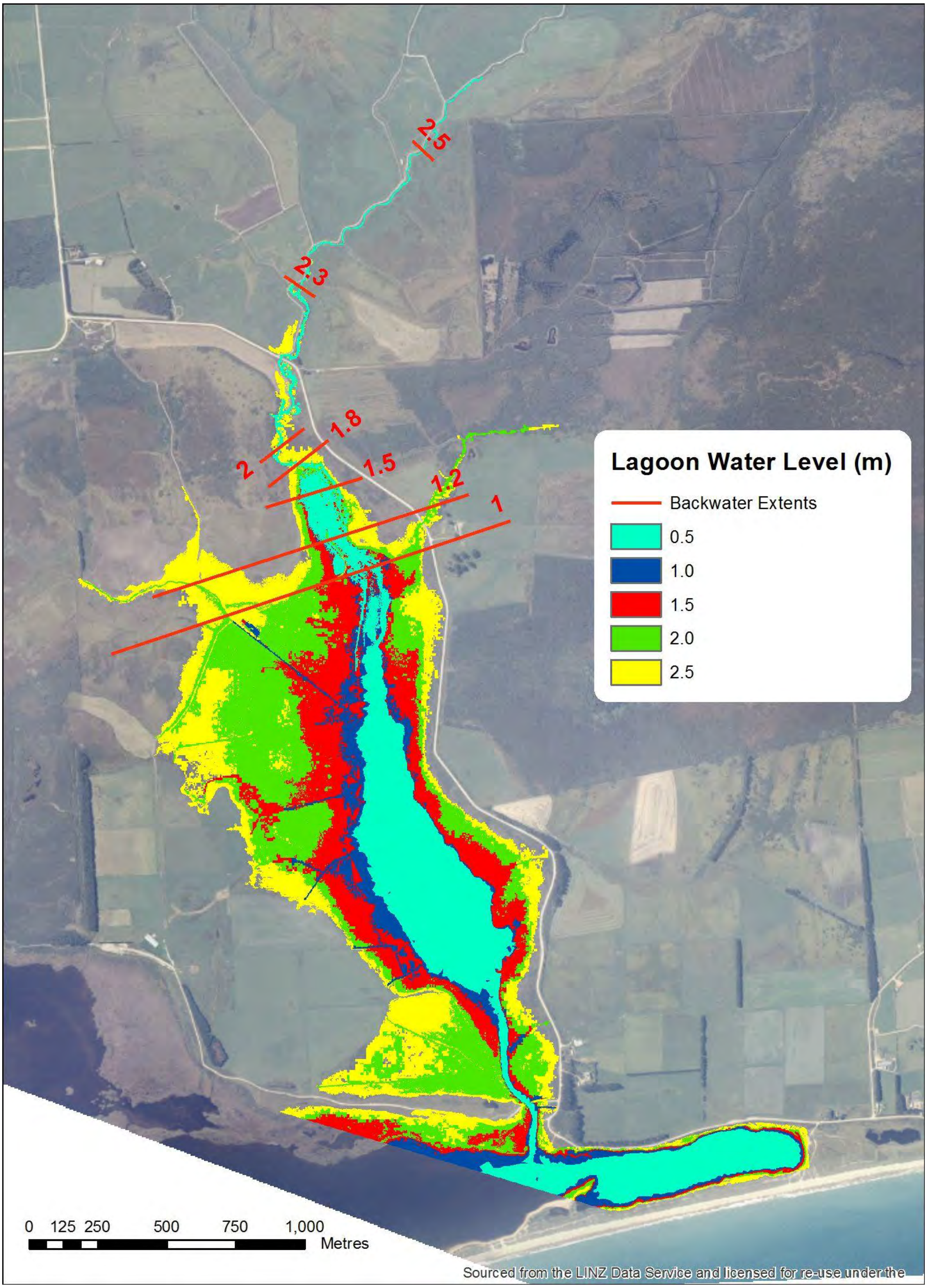


Figure D-7: Extent of Inundated land from Carran Creek and of the backwater effect from Waituna Lagoon for scenario "Q_{90}-Channel Vegetated". Inundated land is mapped for lagoon water levels of 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m. The red lines plot the maximum extent of the backwater effect at lagoon water levels as annotated on the line Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

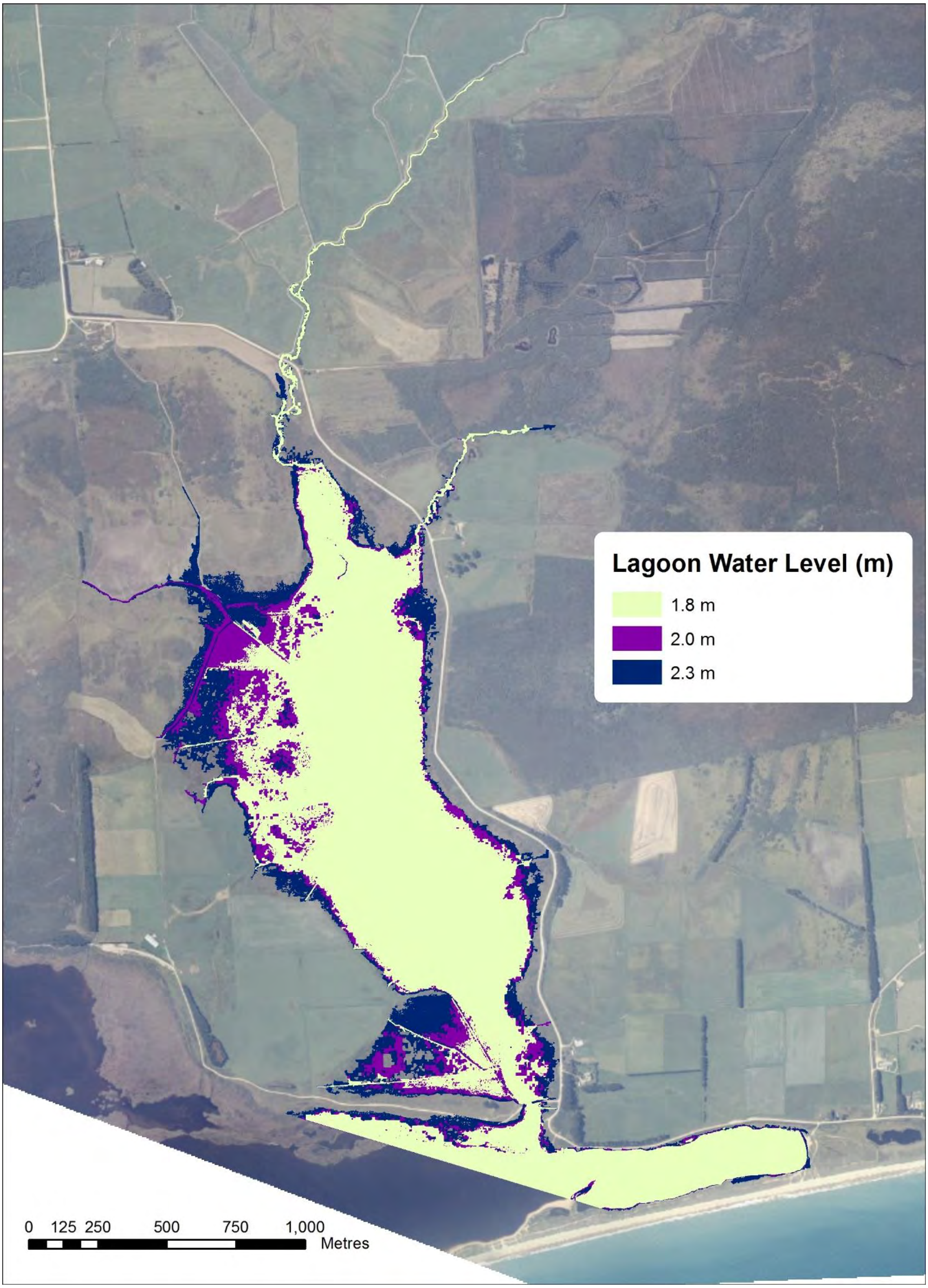


Figure D-8: Extent of Inundated land from Carran Creek for scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Inundated land is mapped for lagoon water levels of 1.8 m, 2.0 m and 2.3 m. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

Appendix E Waituna Creek potentially drainage affected land (1m threshold)

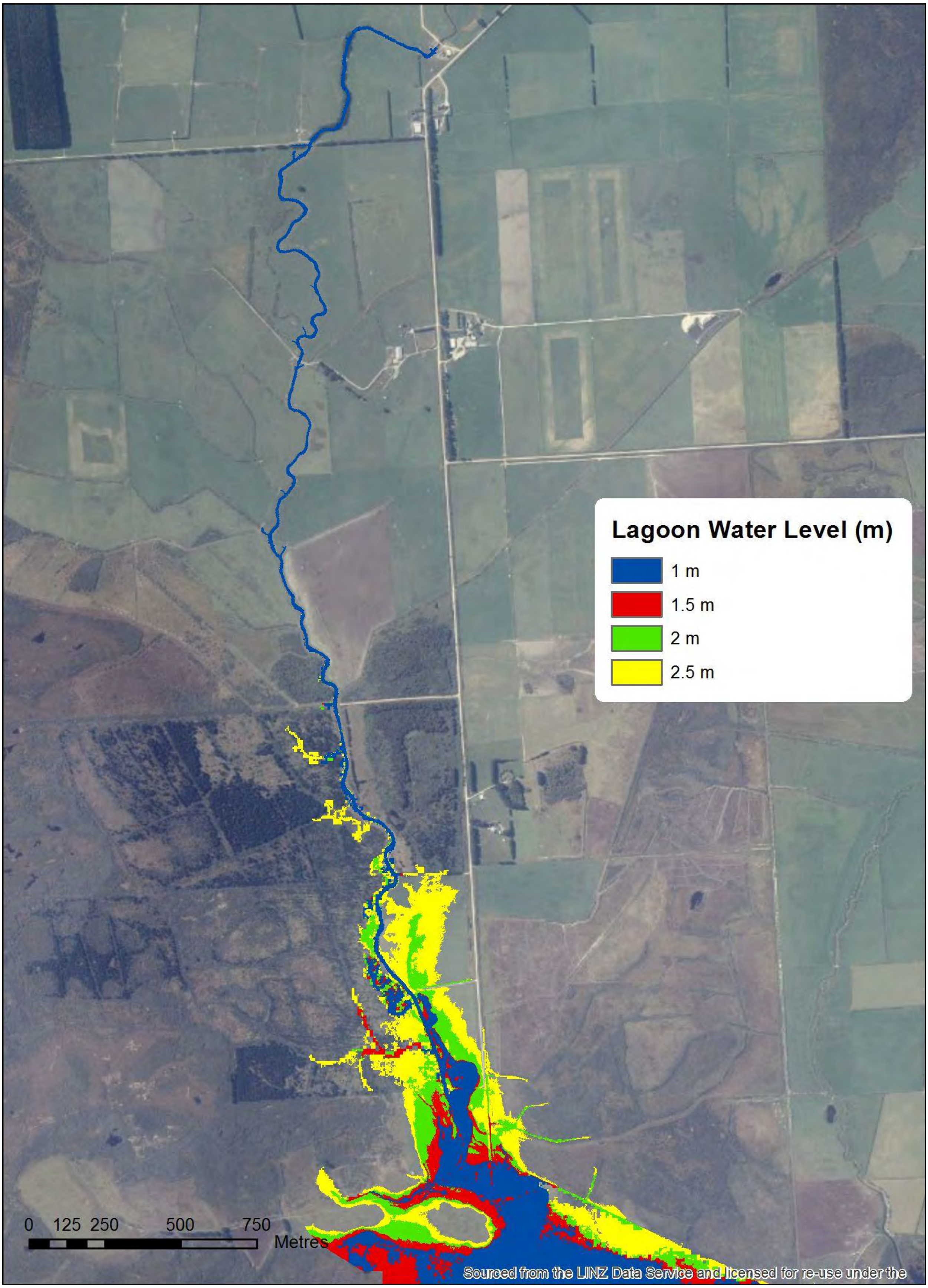


Figure E-1: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

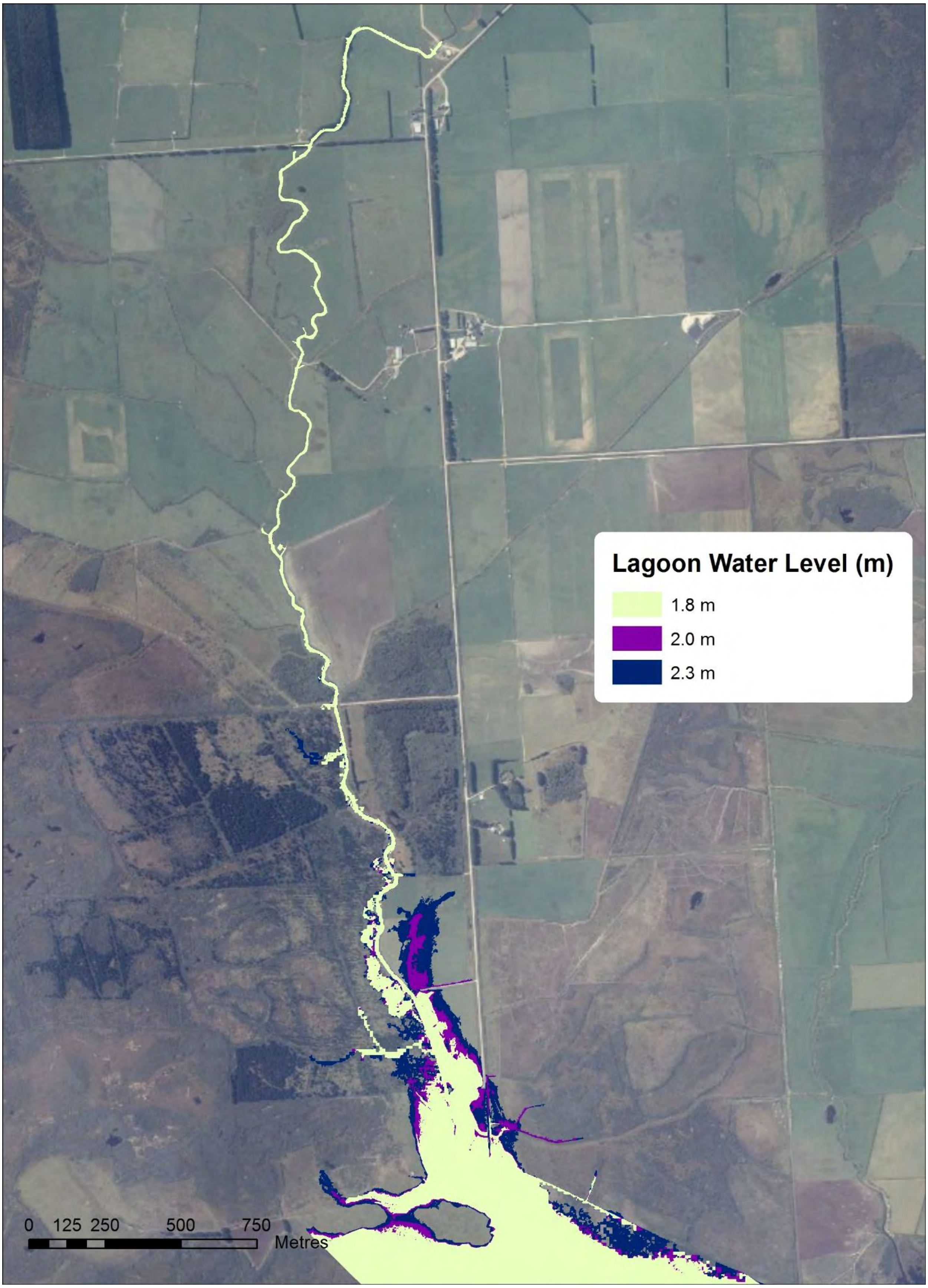


Figure E-2: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

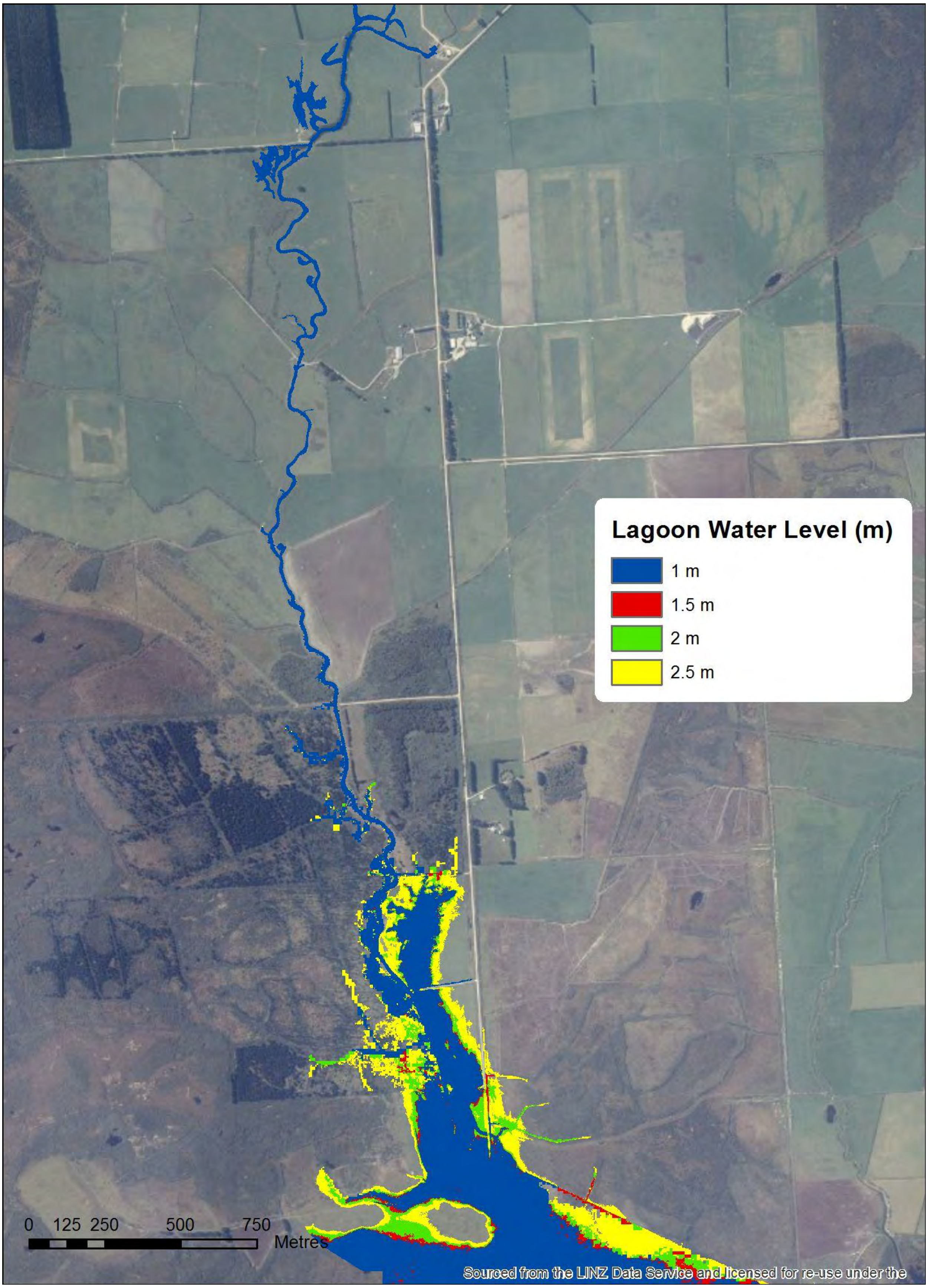


Figure E-3: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

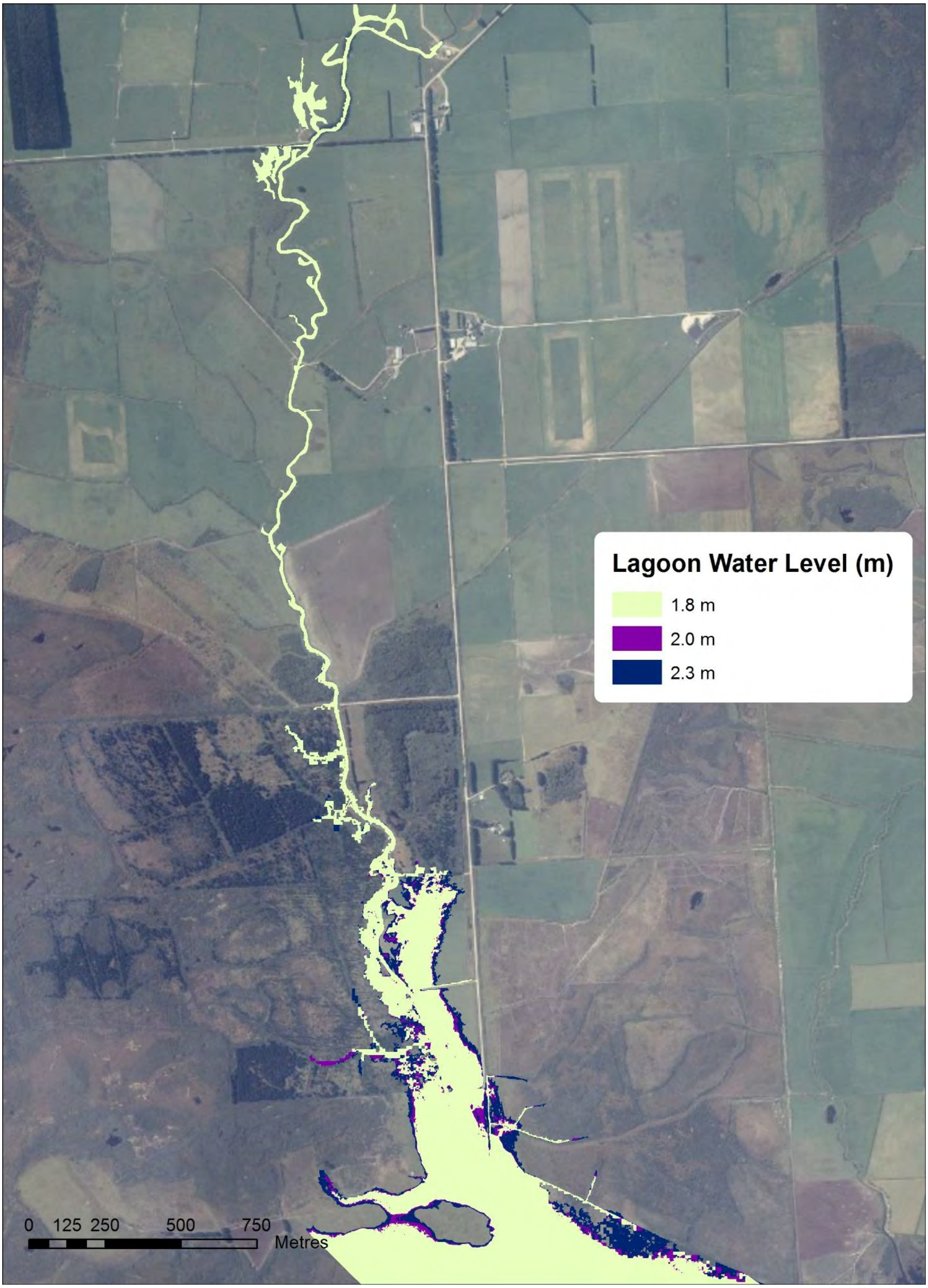


Figure E-4: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

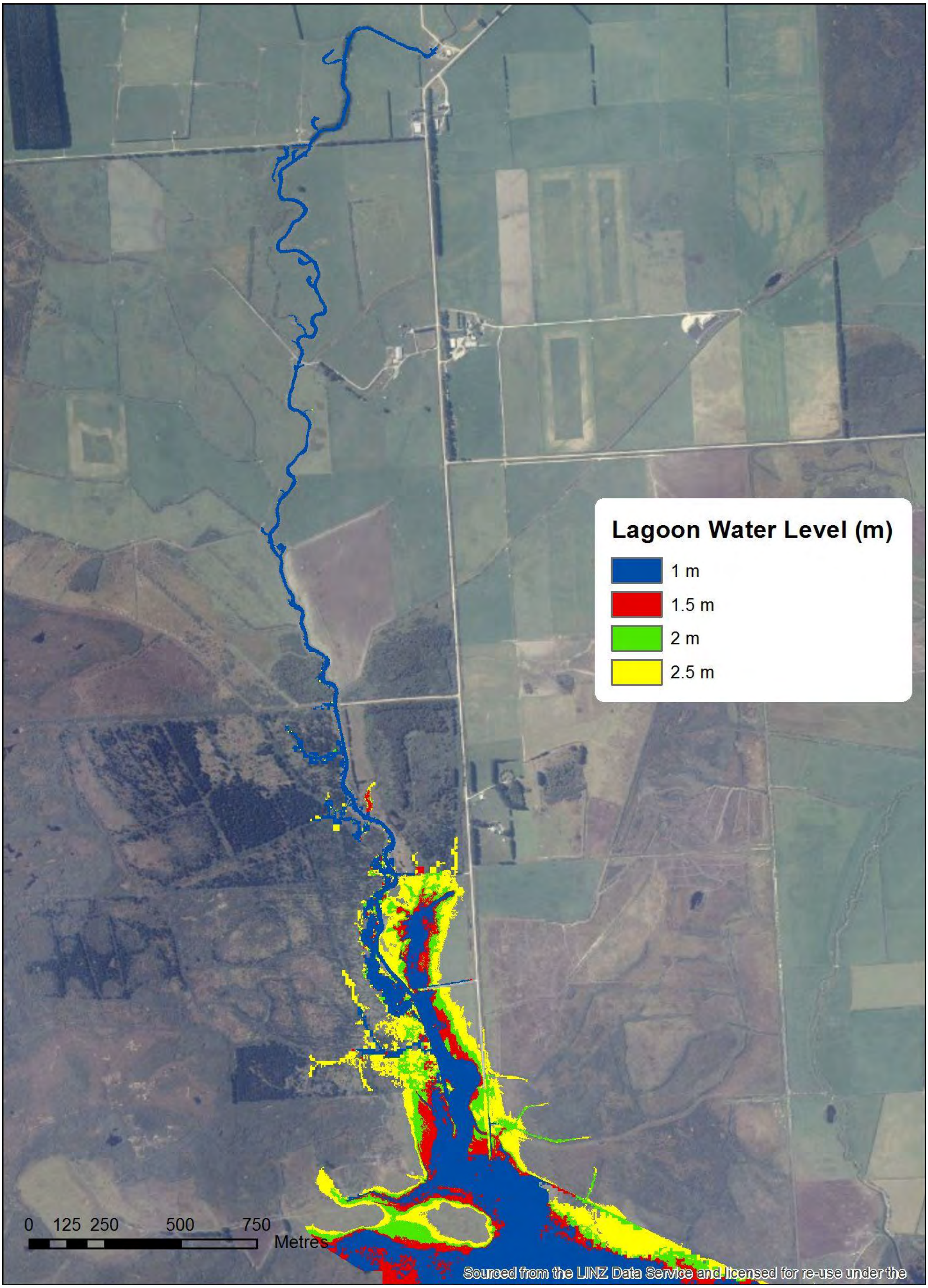


Figure E-5: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

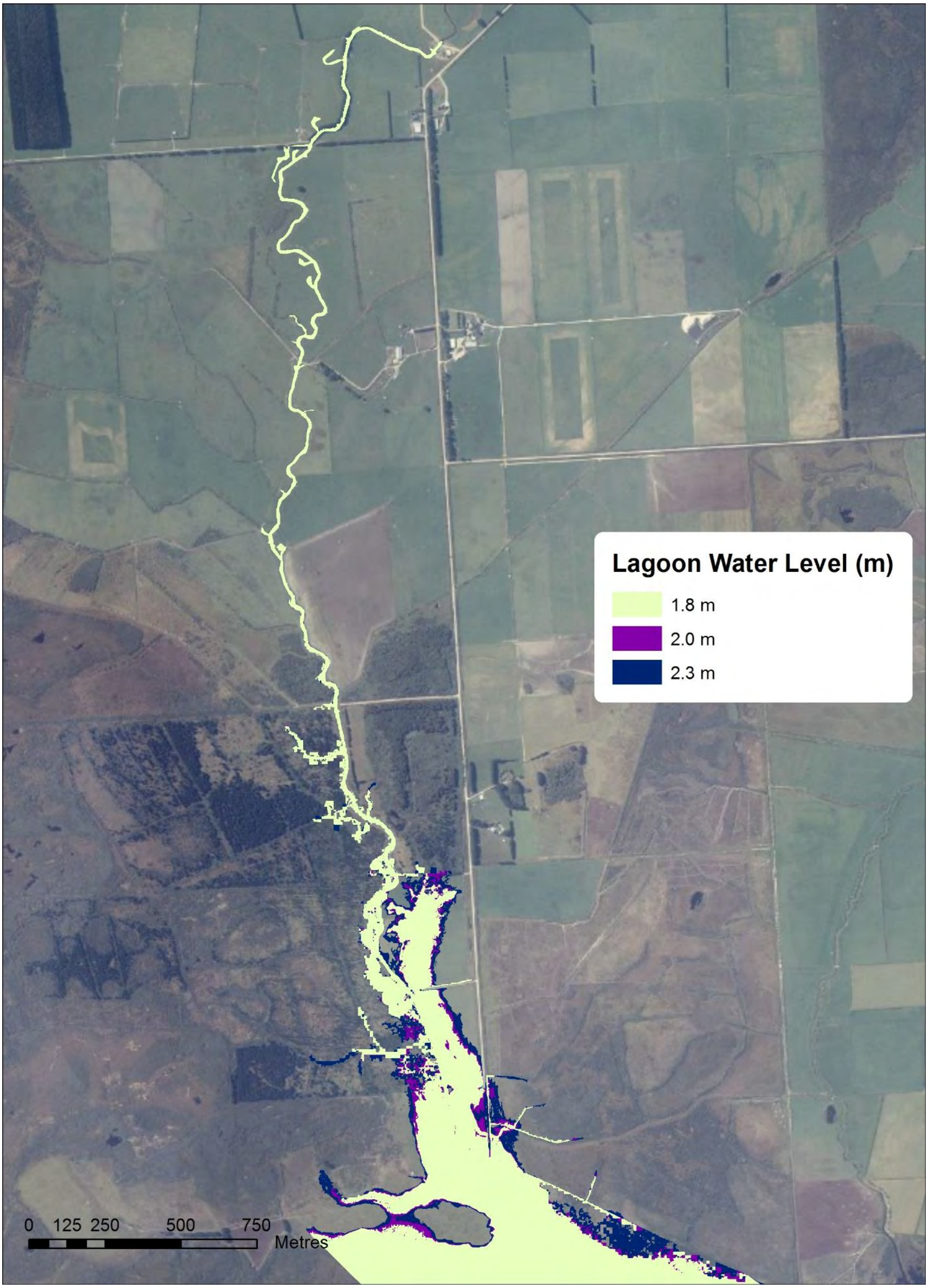


Figure E-6: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

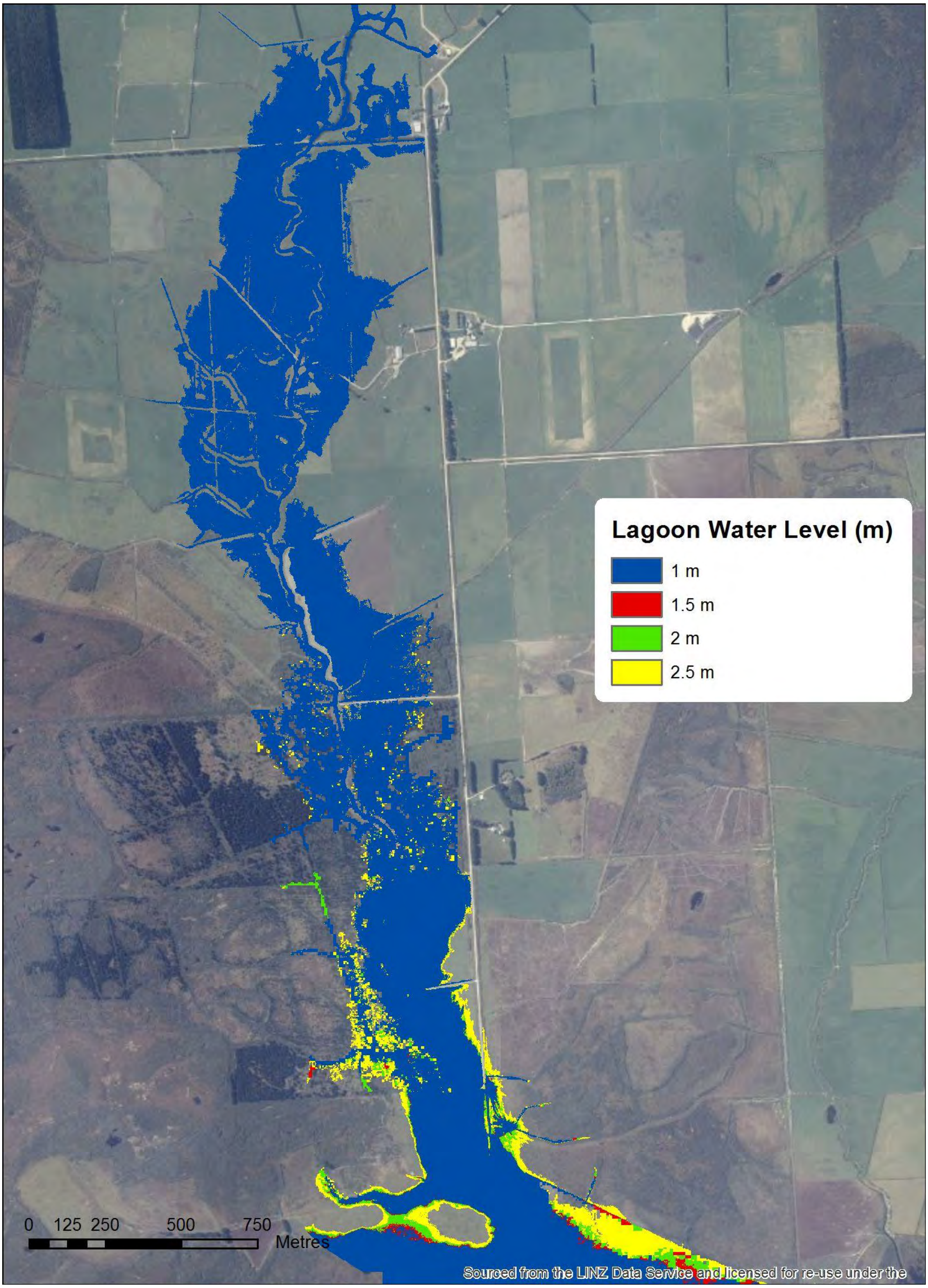


Figure E-7: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

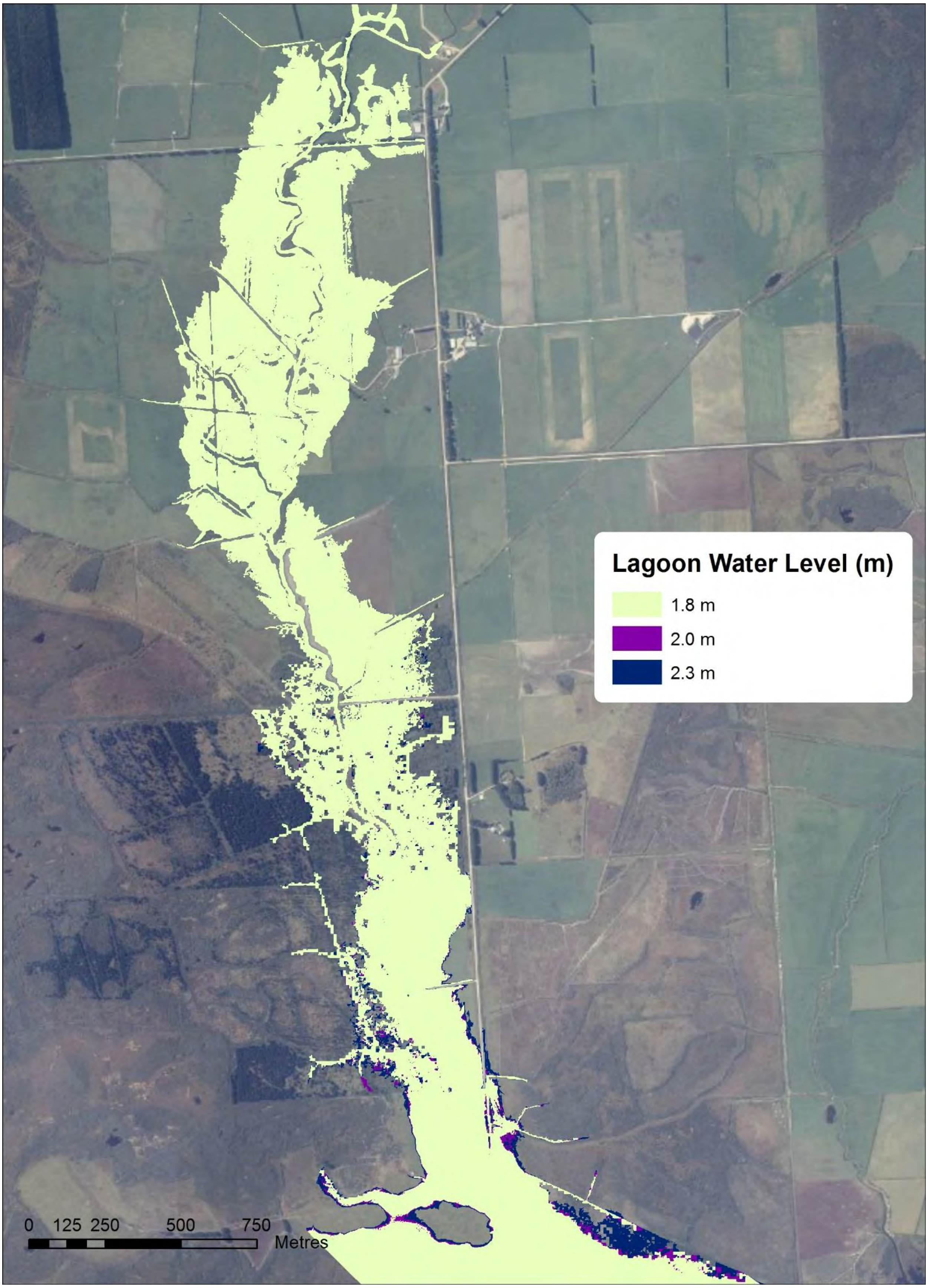


Figure E-8: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile flow with a vegetated main channel.

Appendix F Moffat Creek potentially drainage affected land (1m threshold)

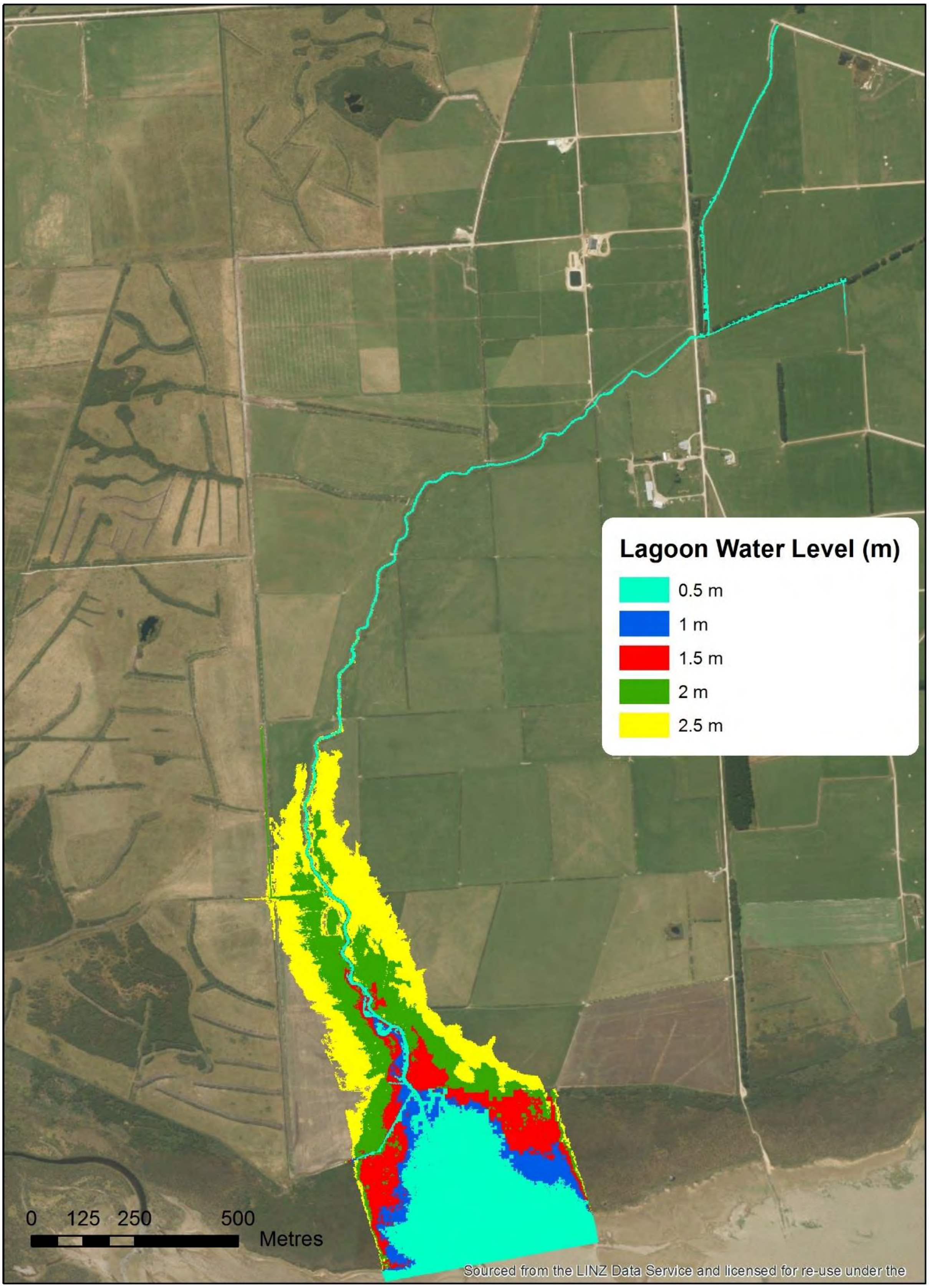


Figure F-1: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

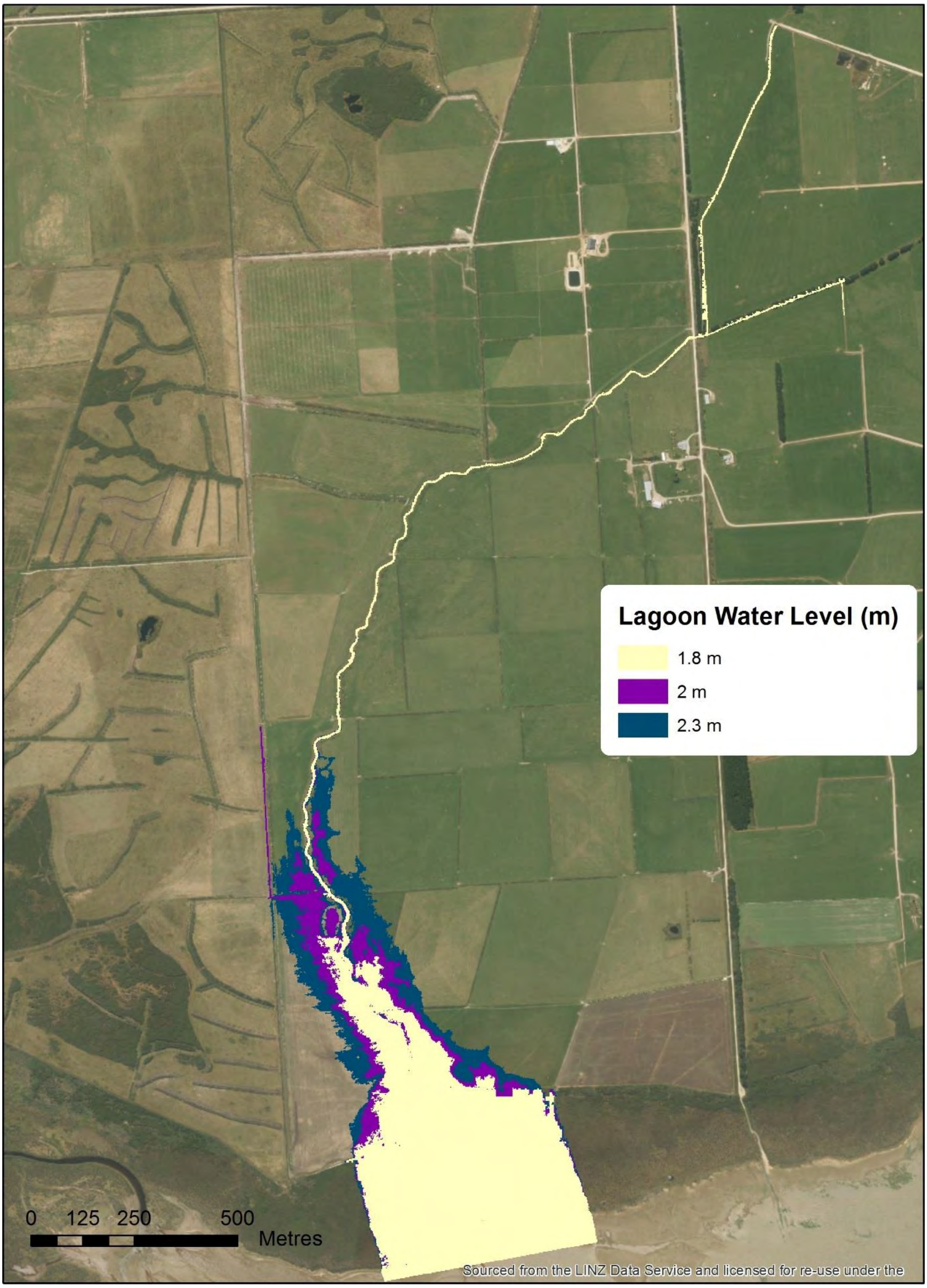


Figure F-2: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

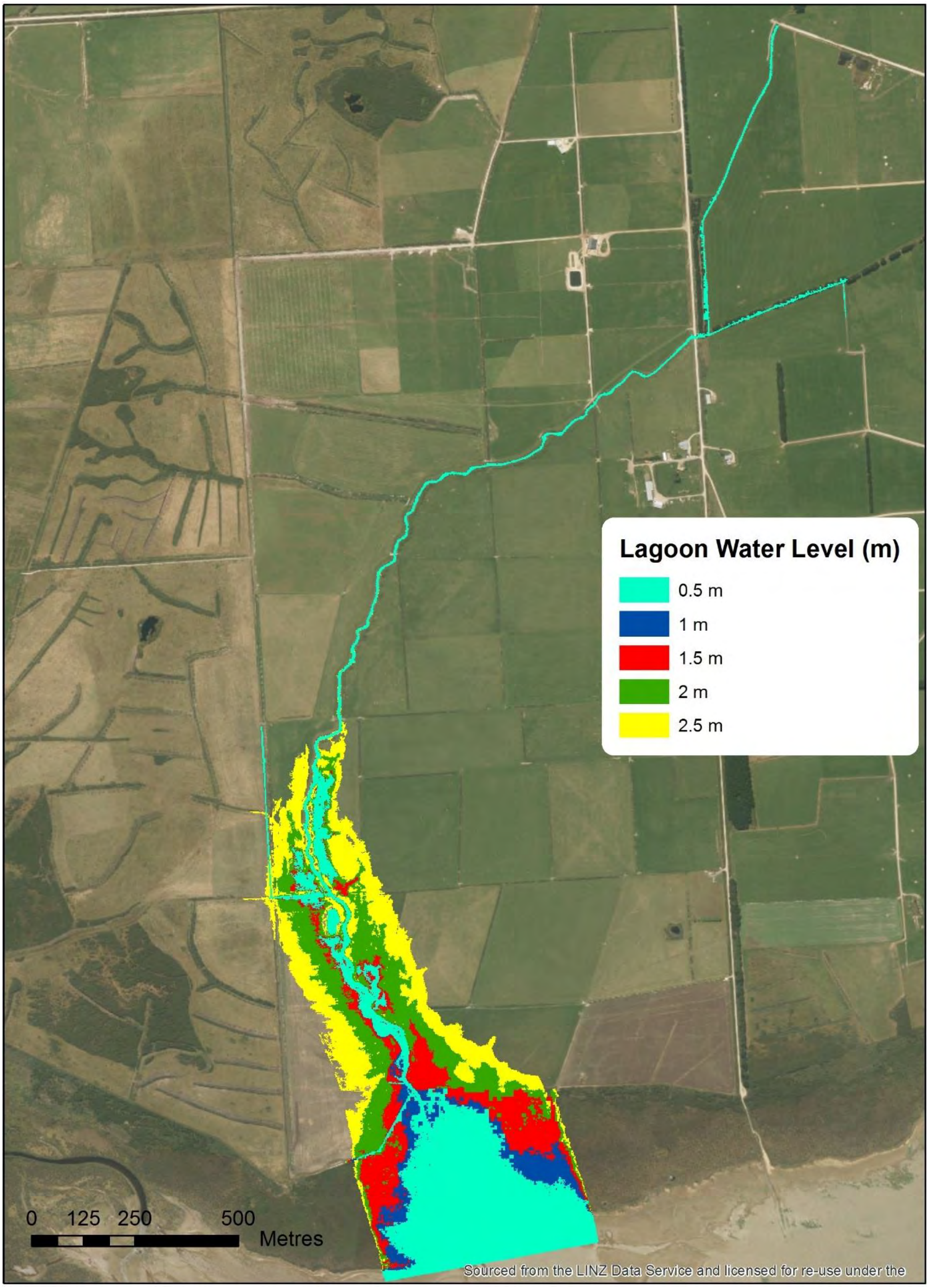


Figure F-3: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

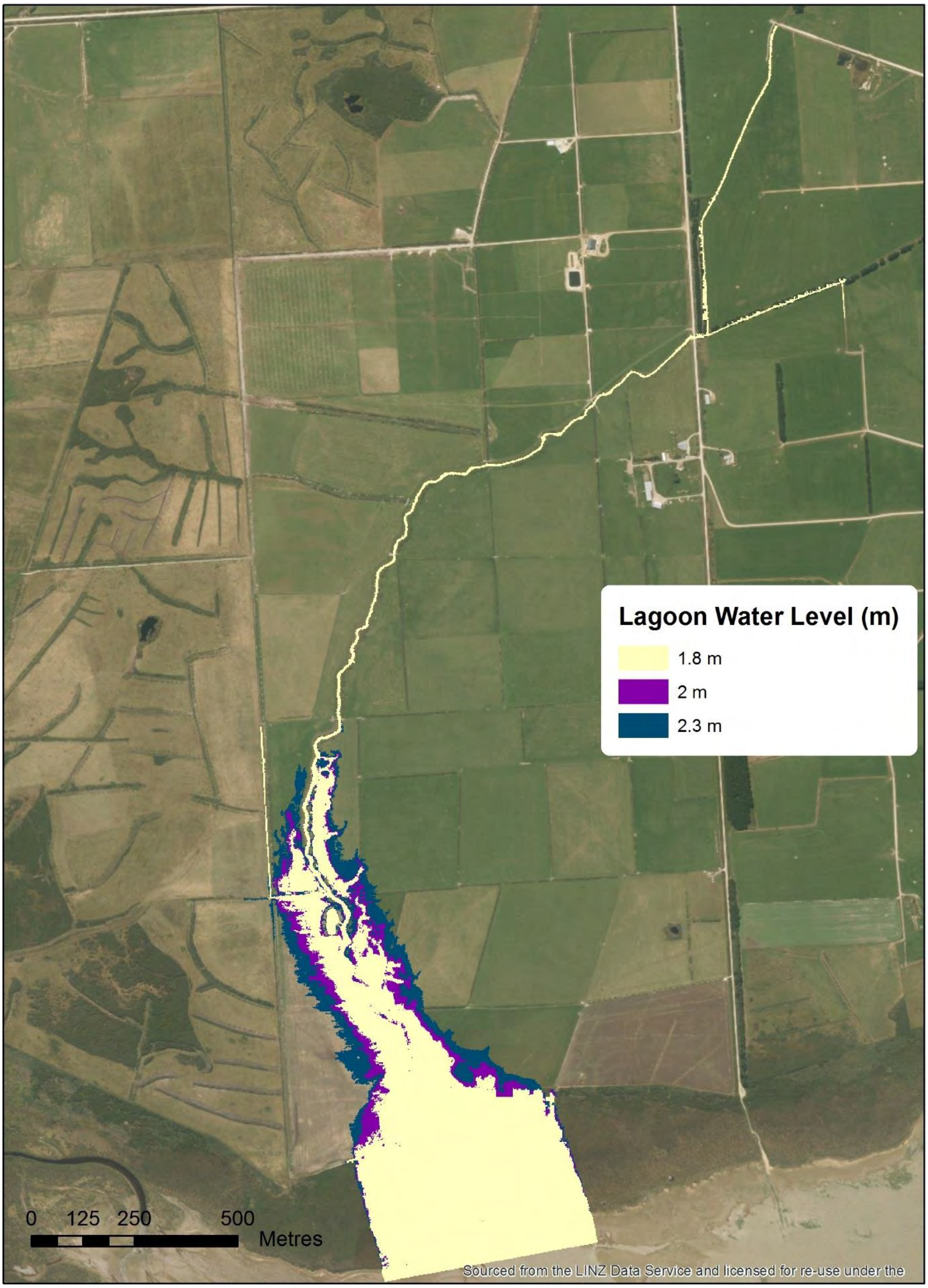


Figure F-4: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

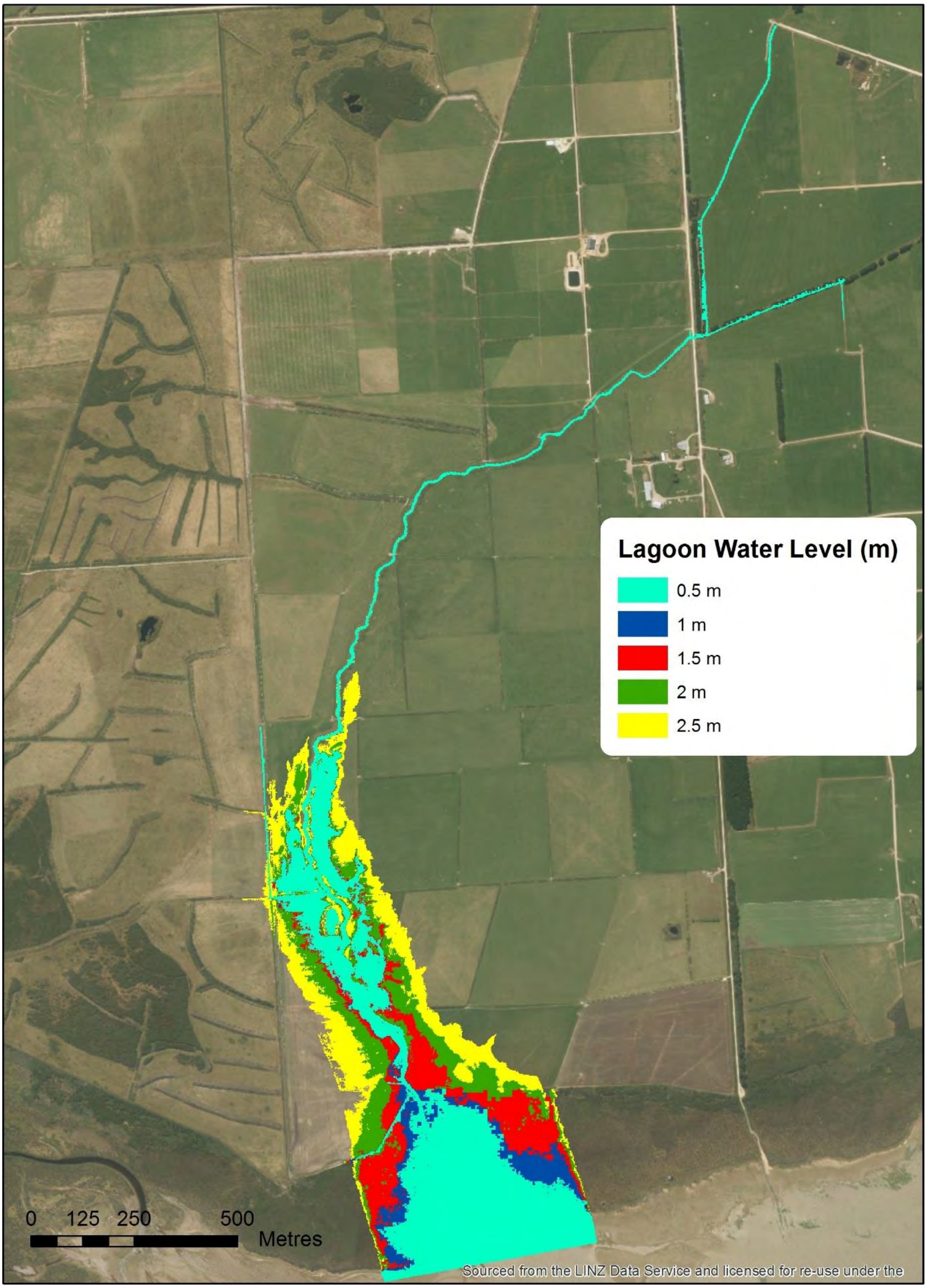


Figure F-5: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

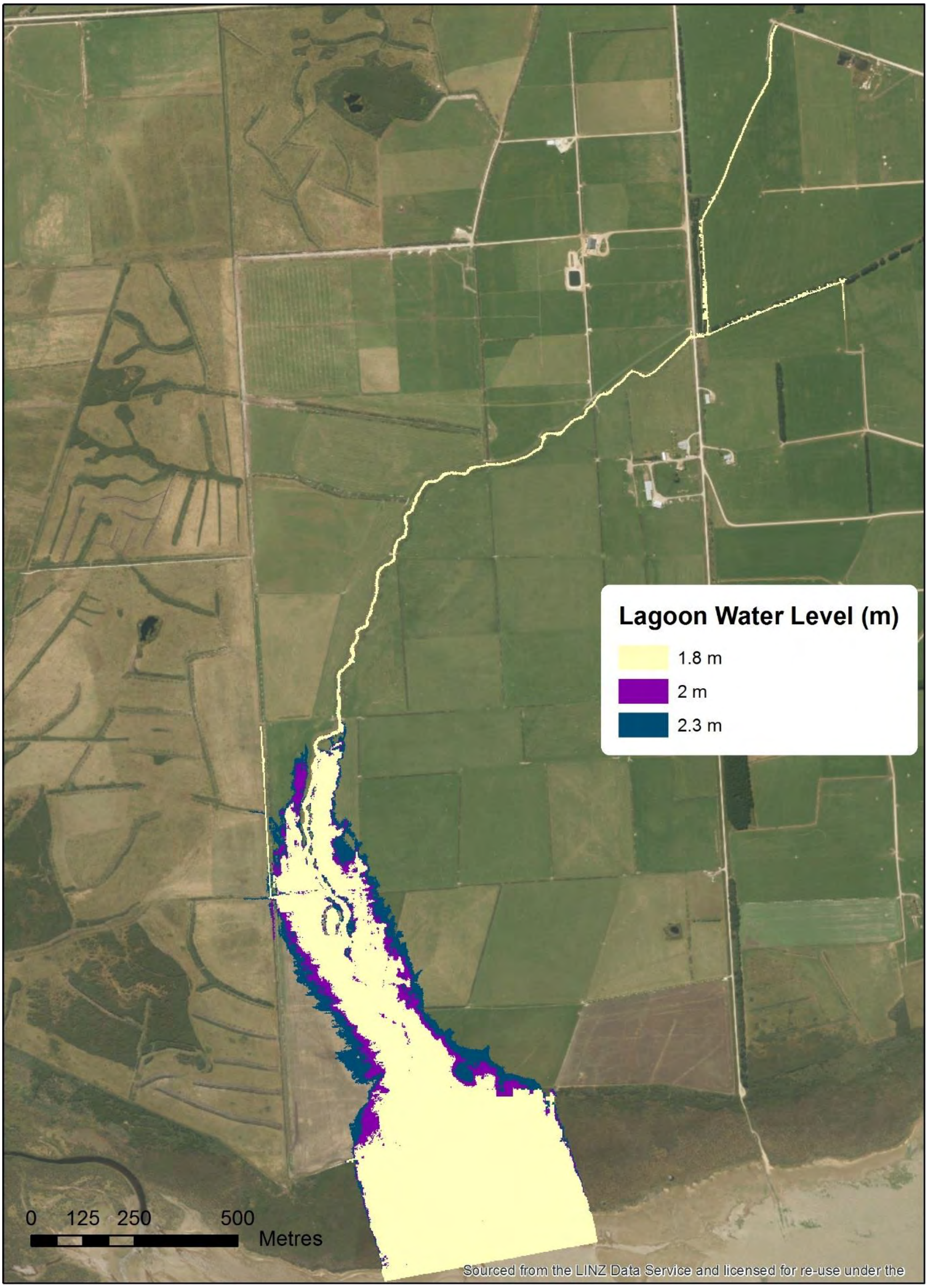


Figure F-6: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

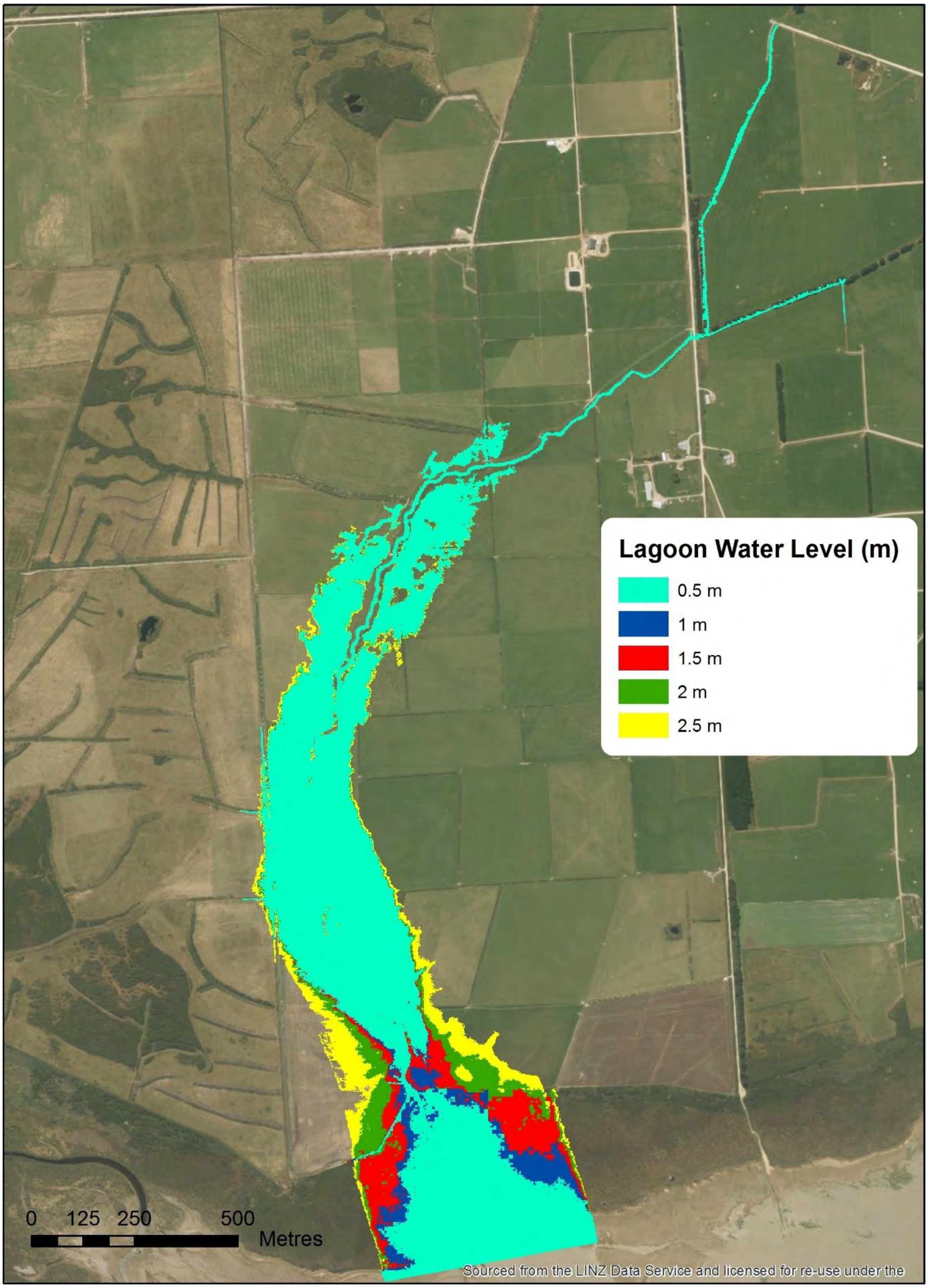


Figure F-7: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

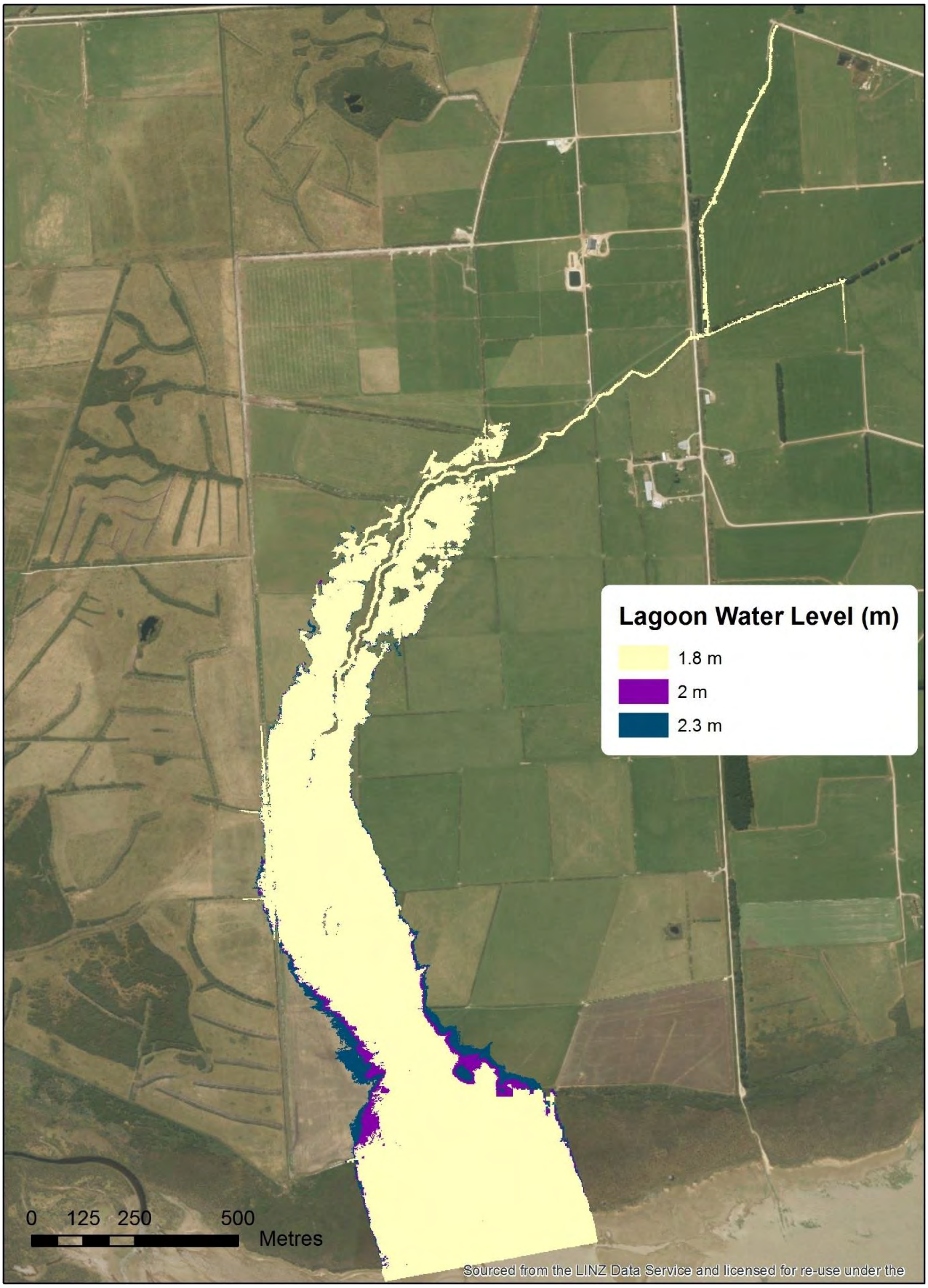


Figure F-8: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile flow with a vegetated main channel.

Appendix G Carran Creek potentially drainage affected land (1m threshold)

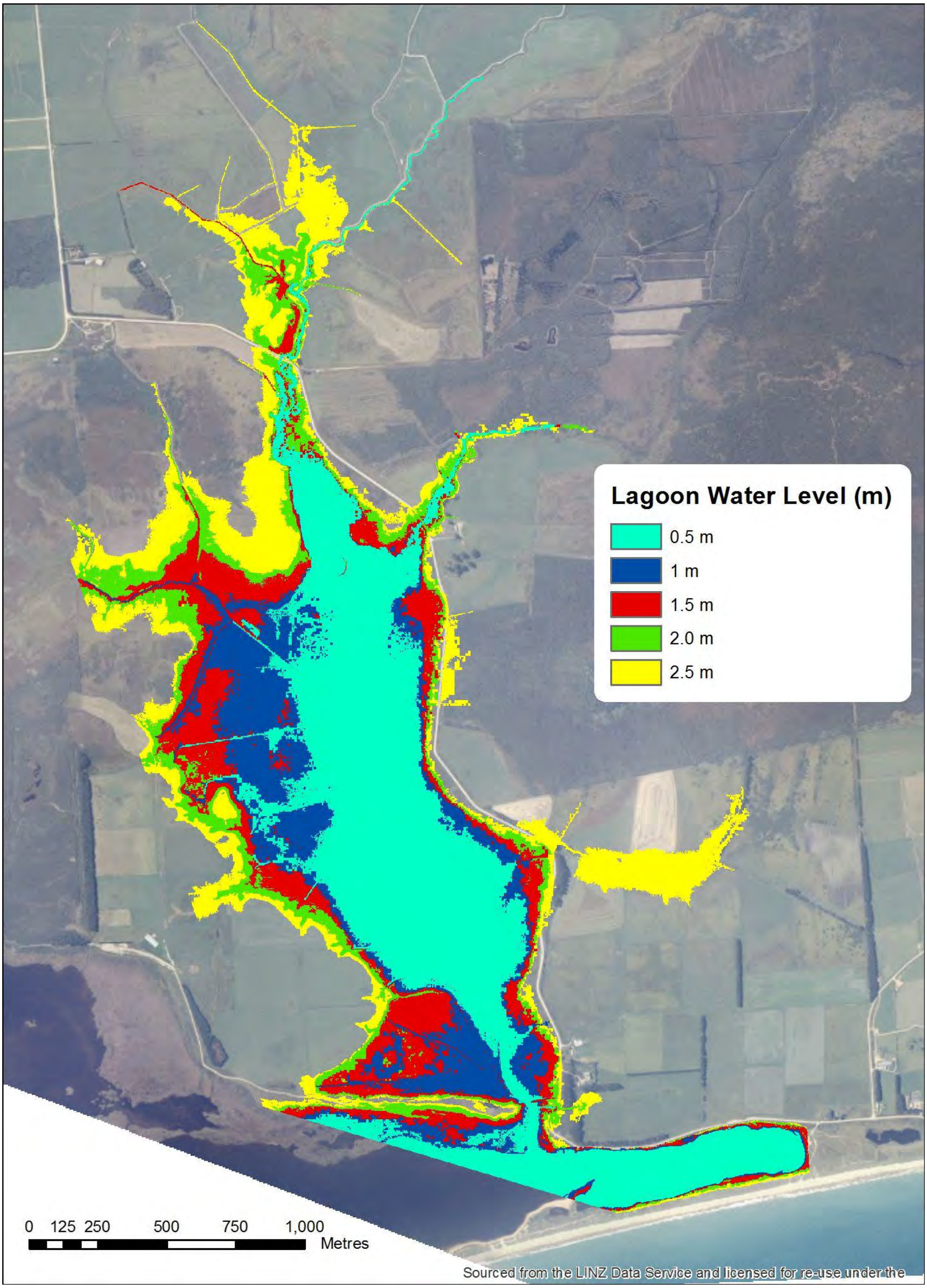


Figure G-1: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

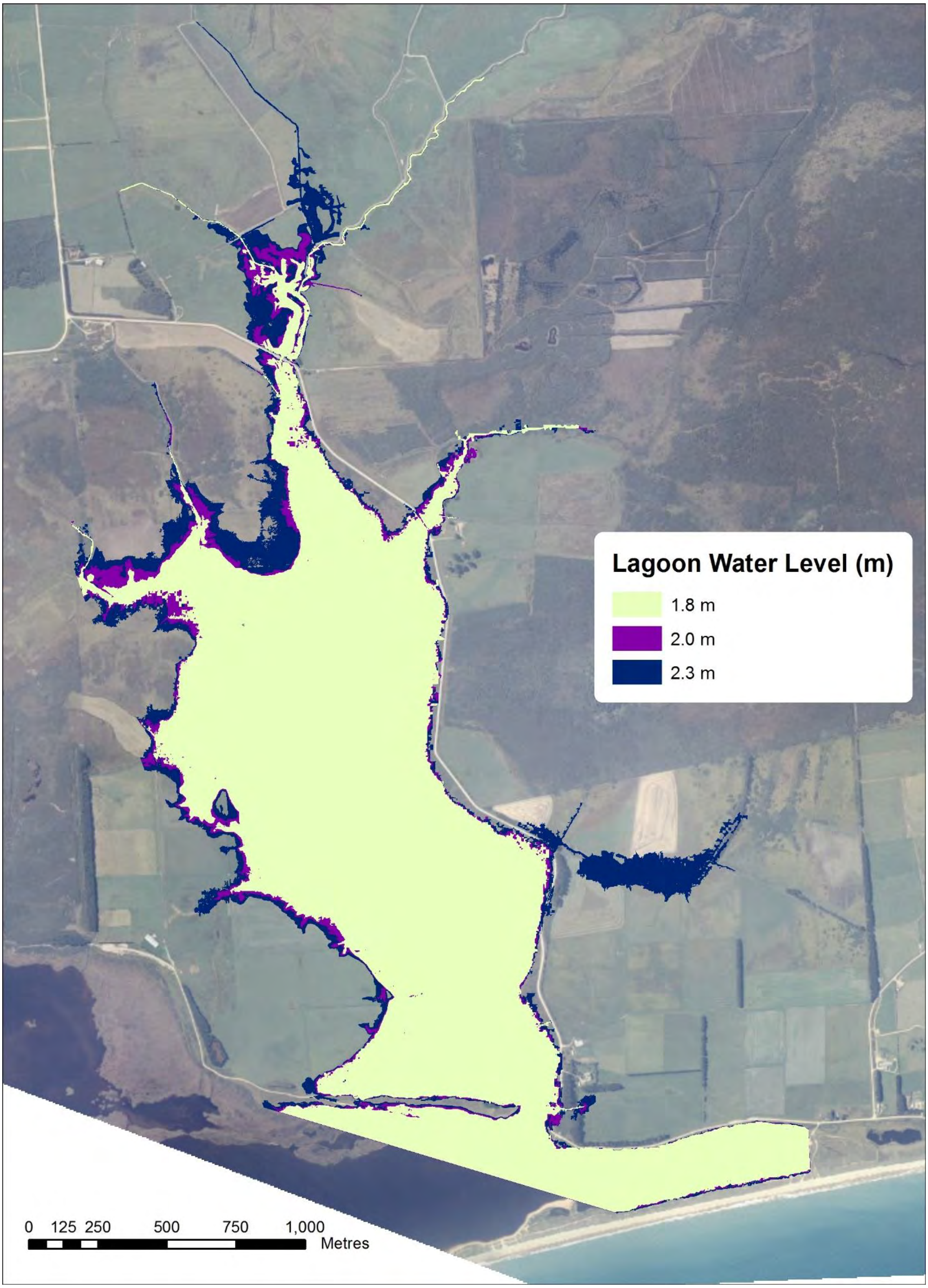


Figure G-2: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

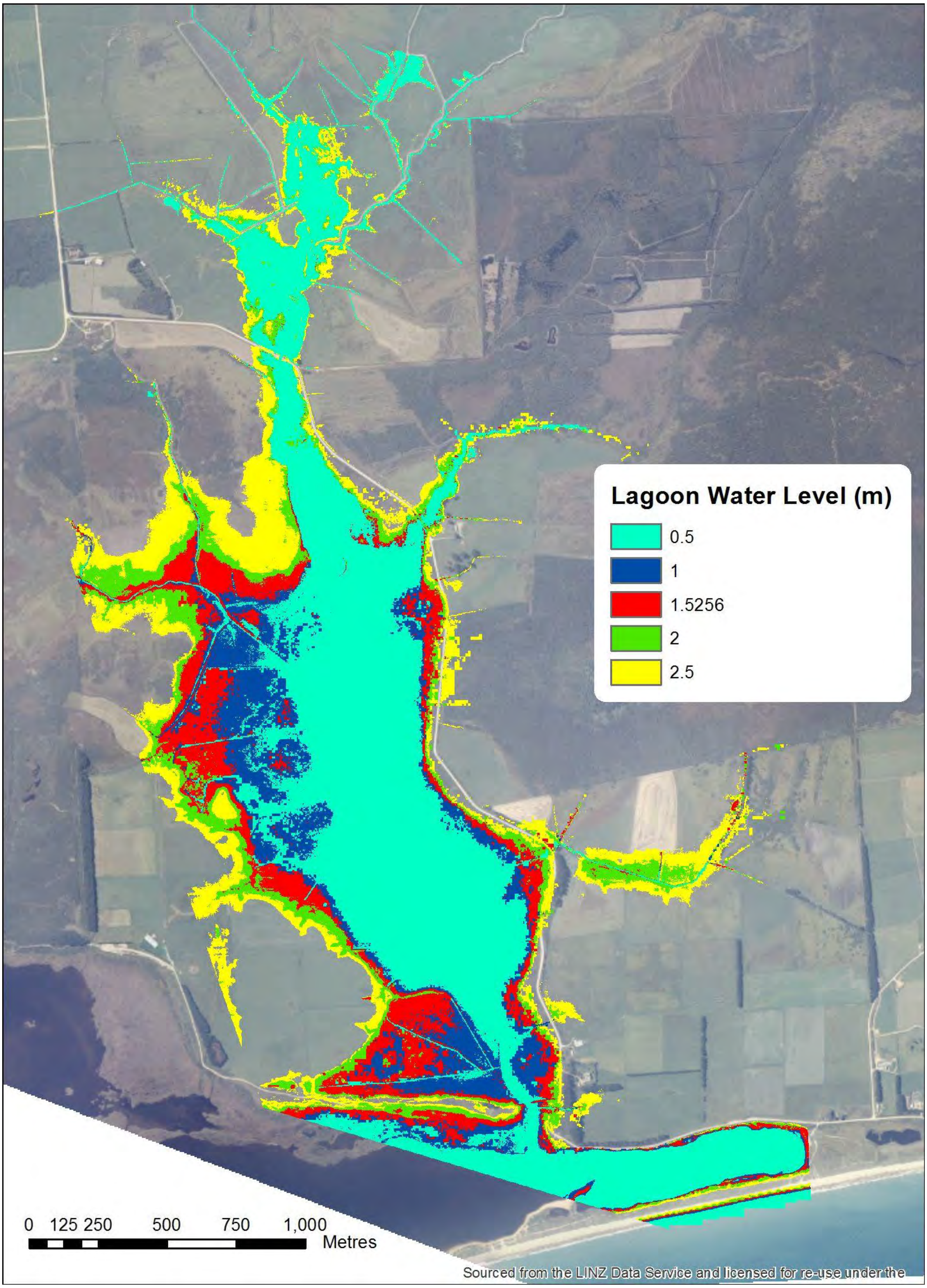


Figure G-3: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

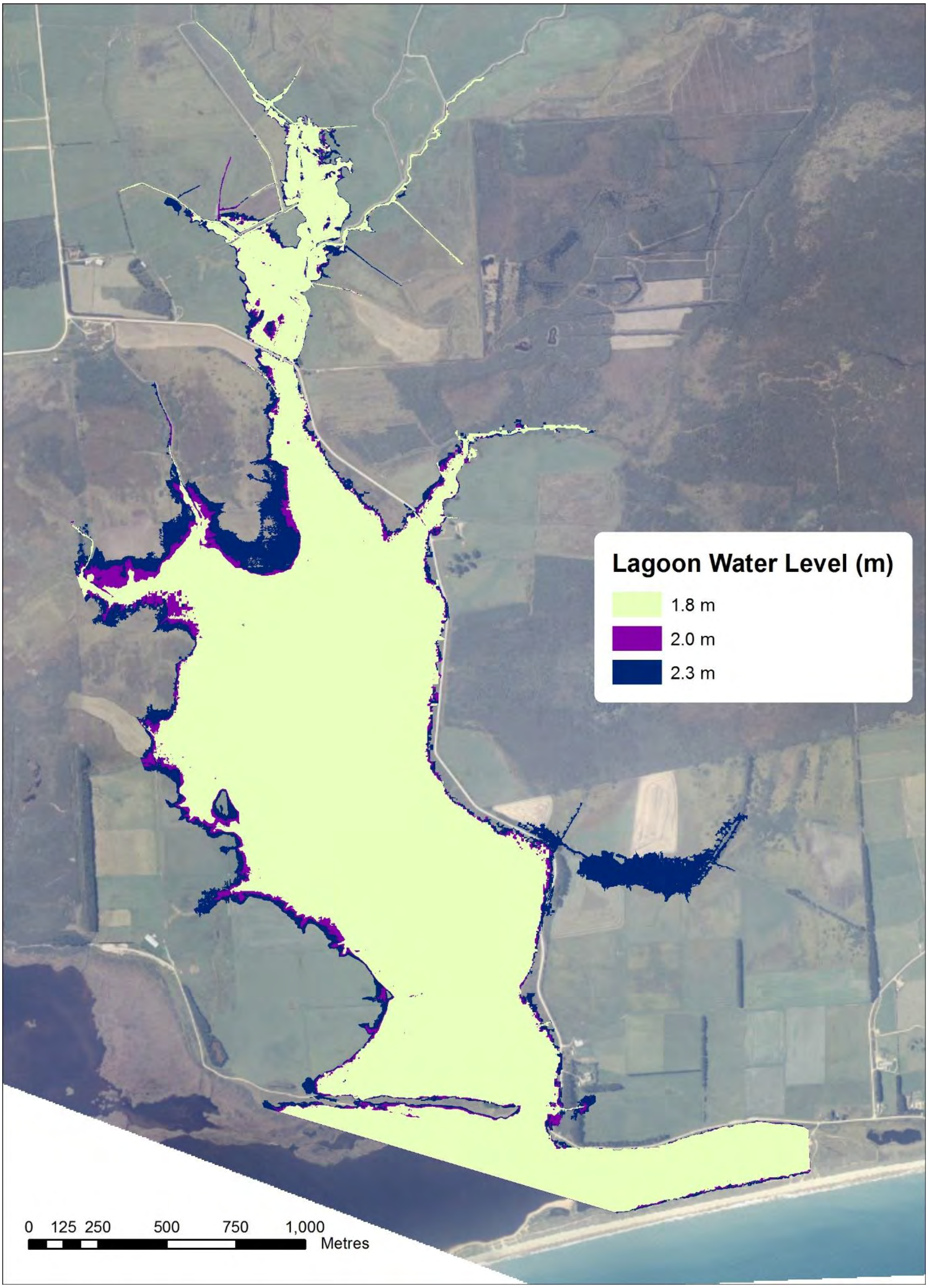


Figure G-4: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models 90 percentile high flow with a recently cleared main channel.

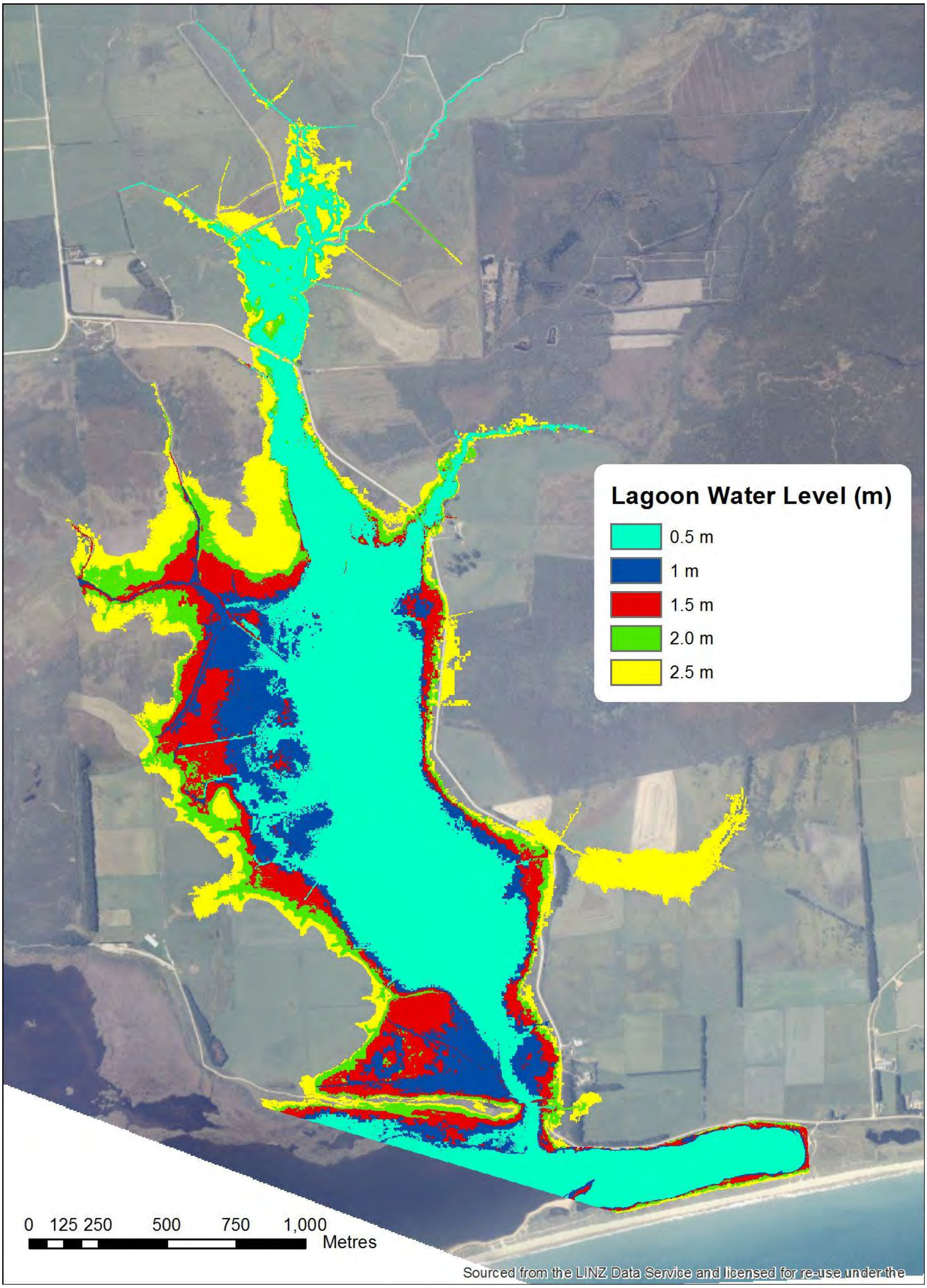


Figure G-5: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

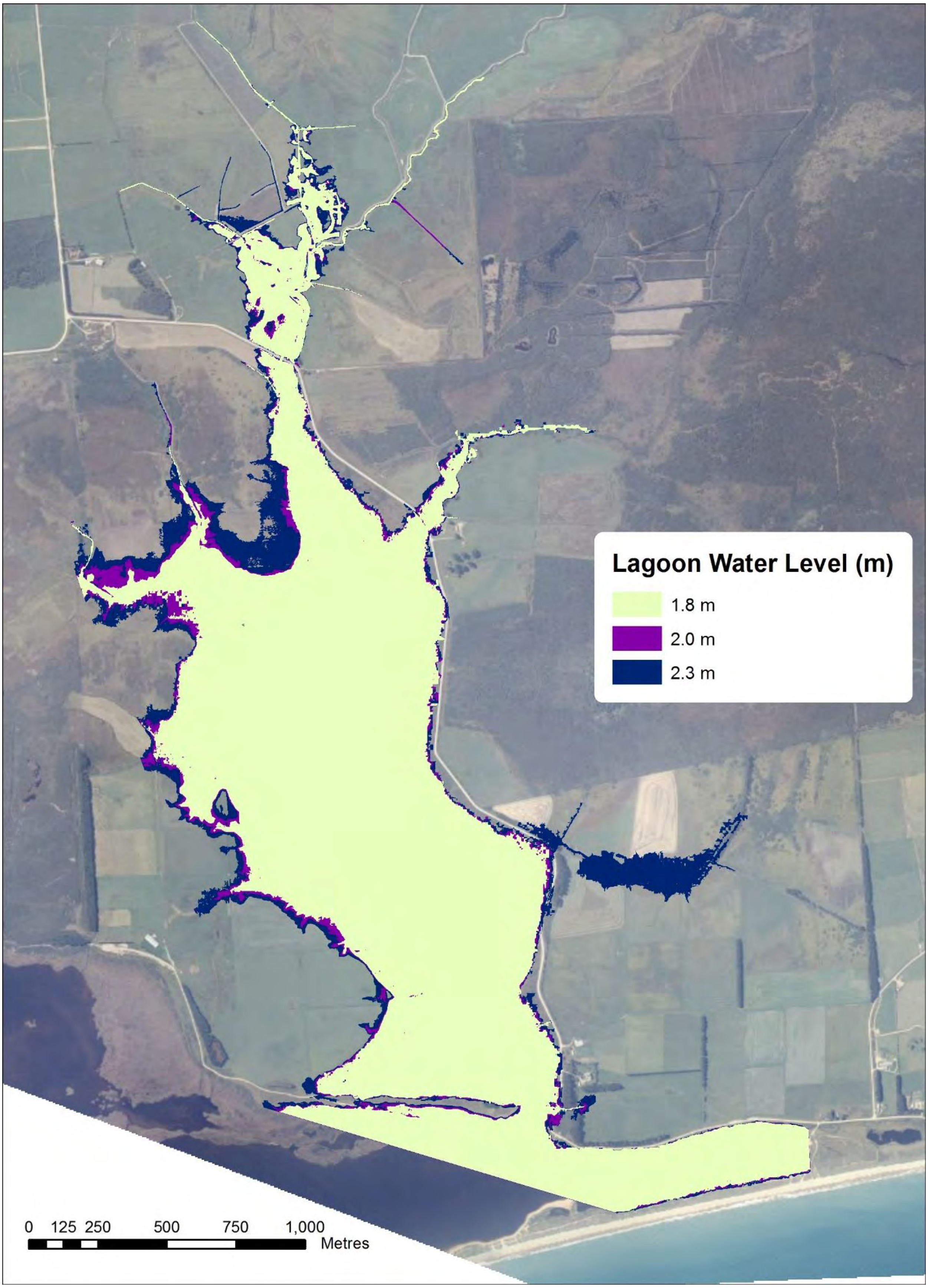


Figure G-6: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q$_{mean}$-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q$_{mean}$-Channel Vegetated" models mean flow with a vegetated main channel.

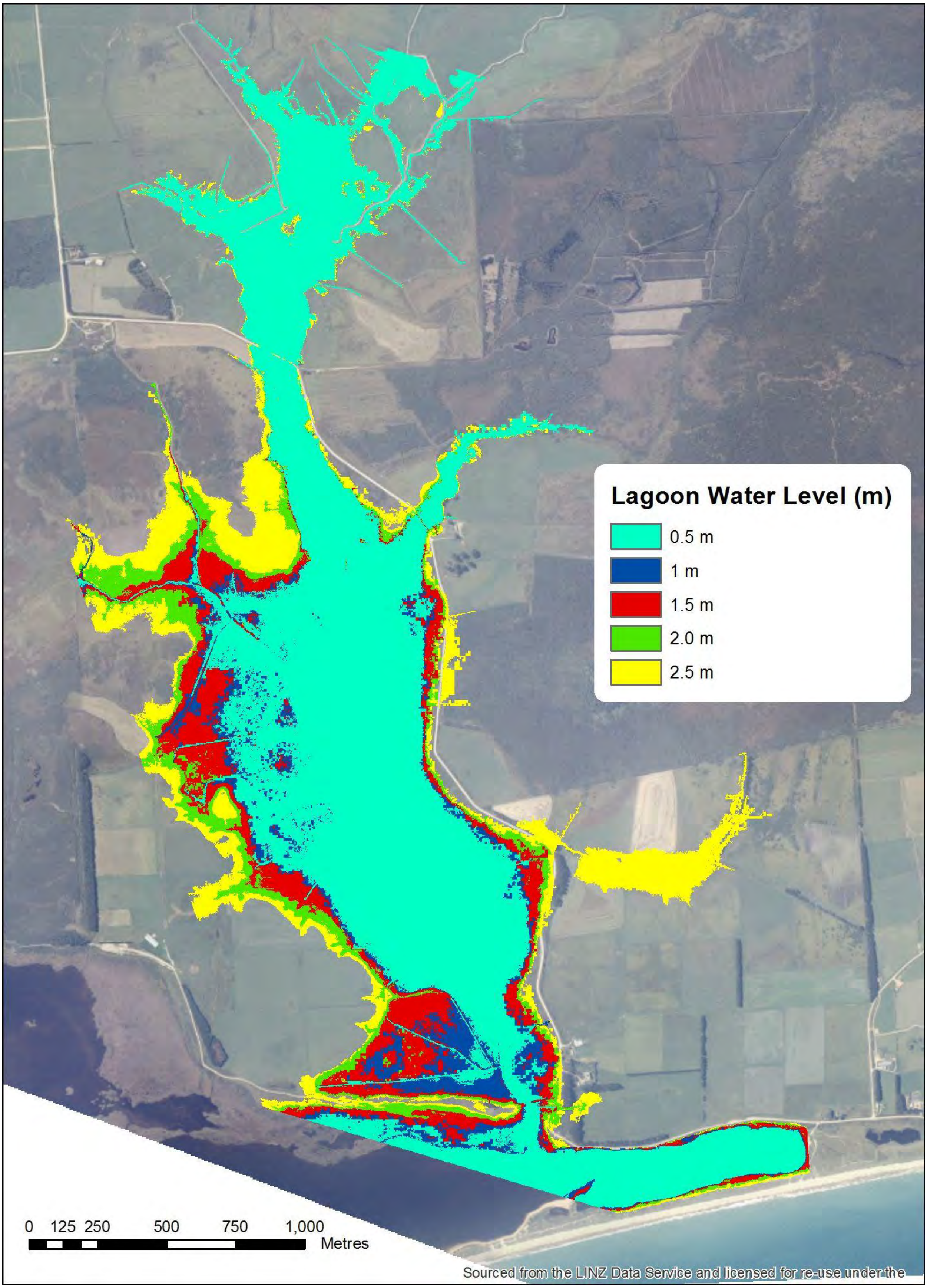


Figure G-7: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

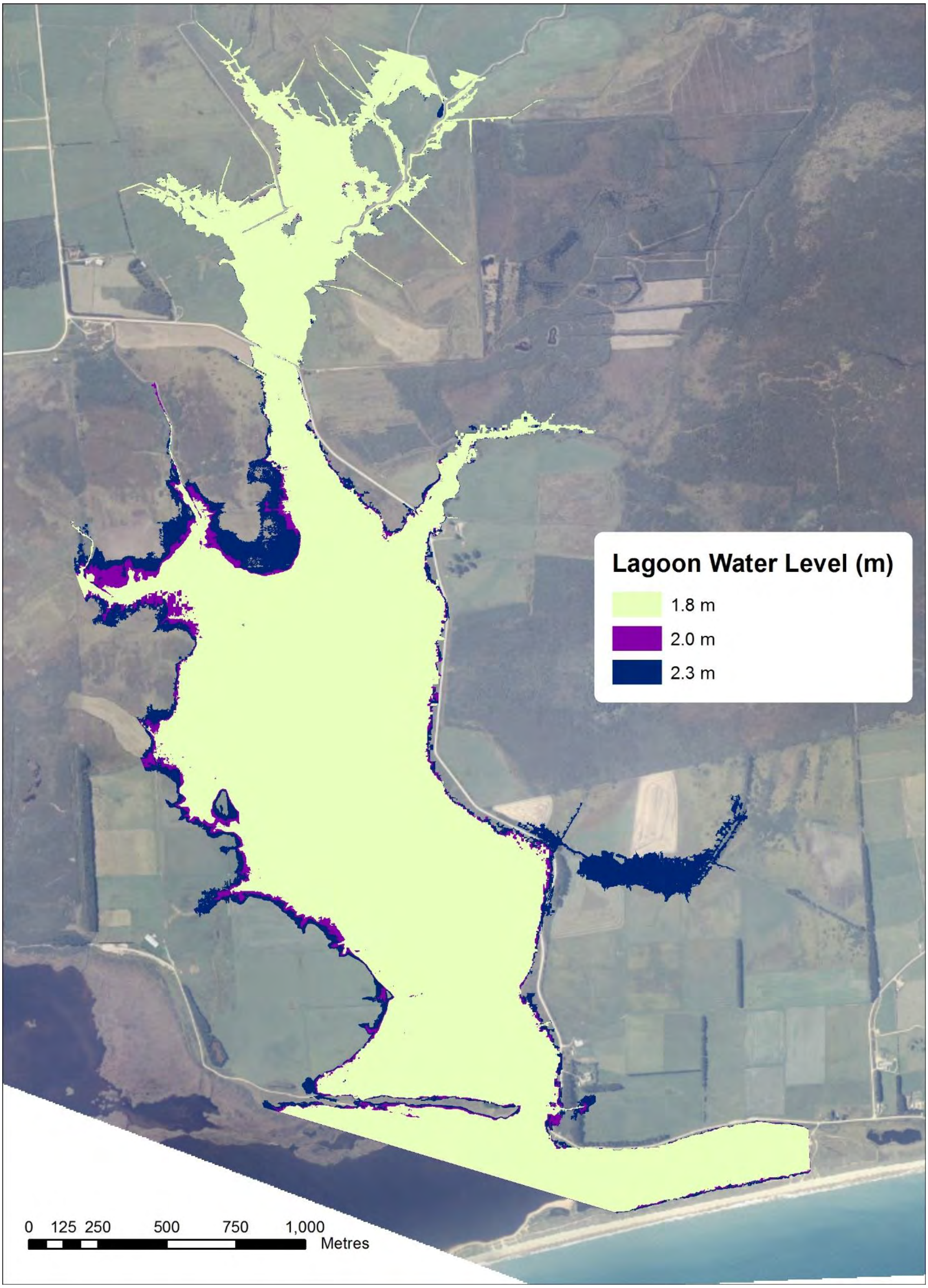


Figure G-8: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 1.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

Appendix H Waituna Creek potentially drainage affected land (2m threshold)

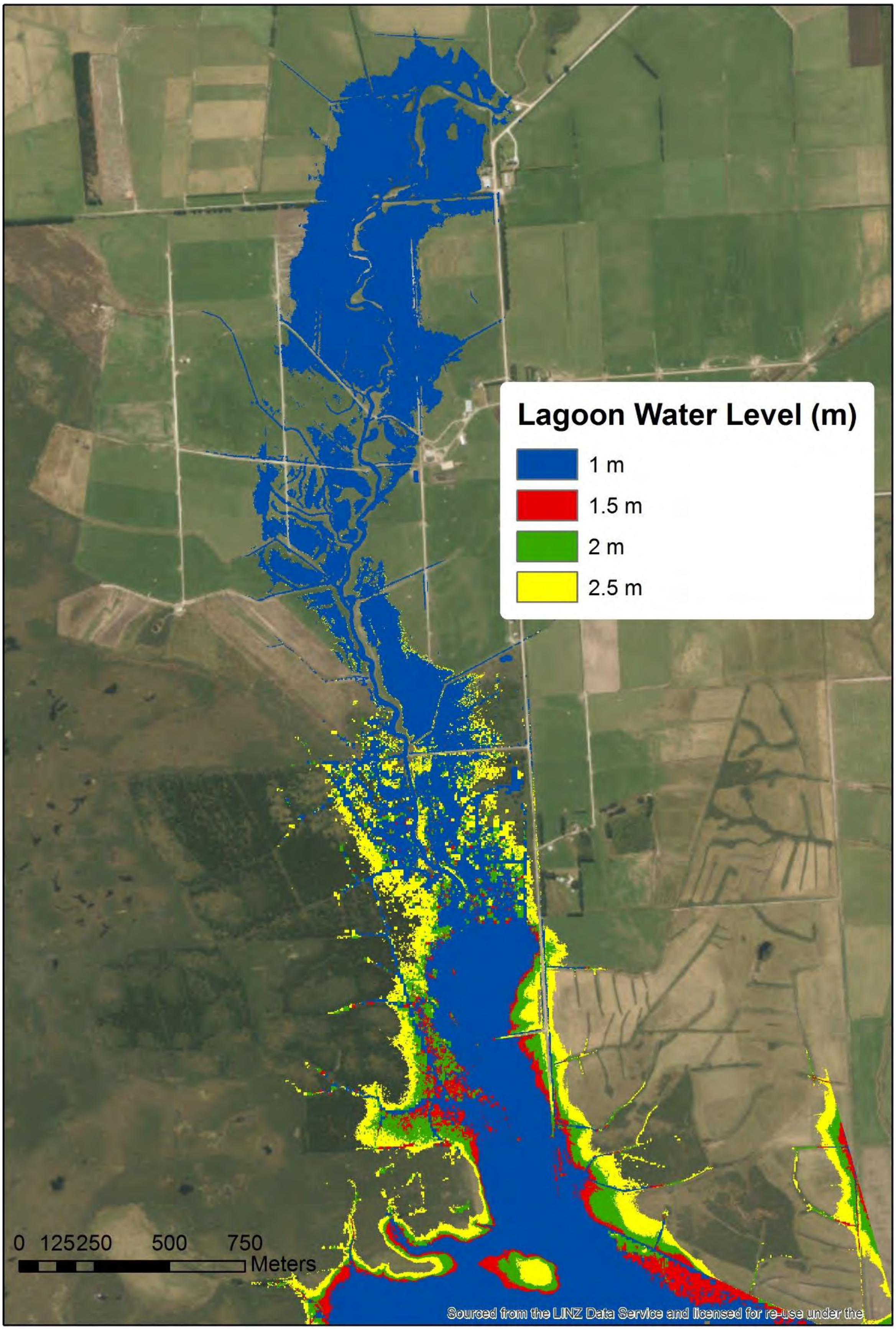


Figure H-1: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

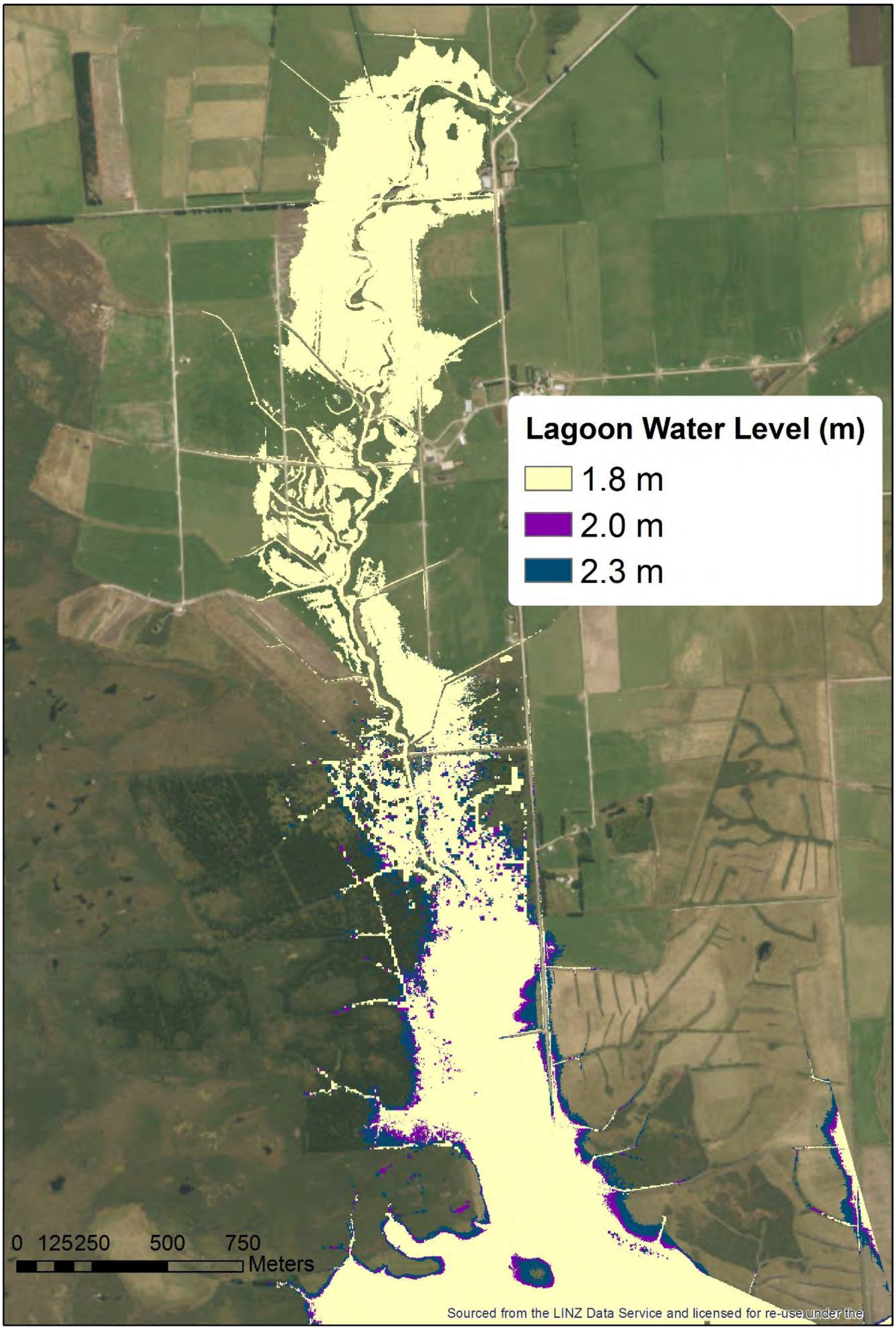


Figure H-2: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

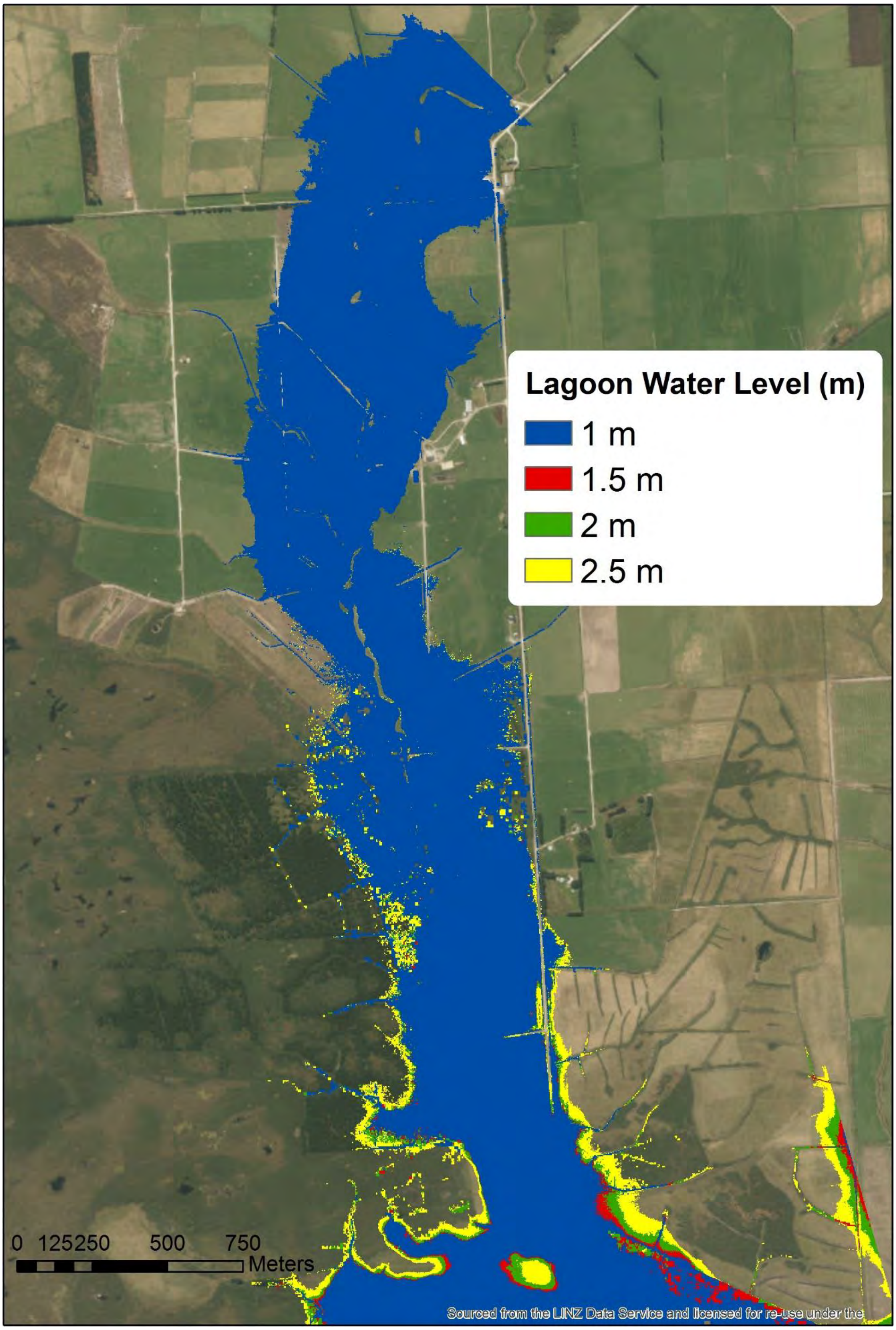


Figure H-3: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q90-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q90-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

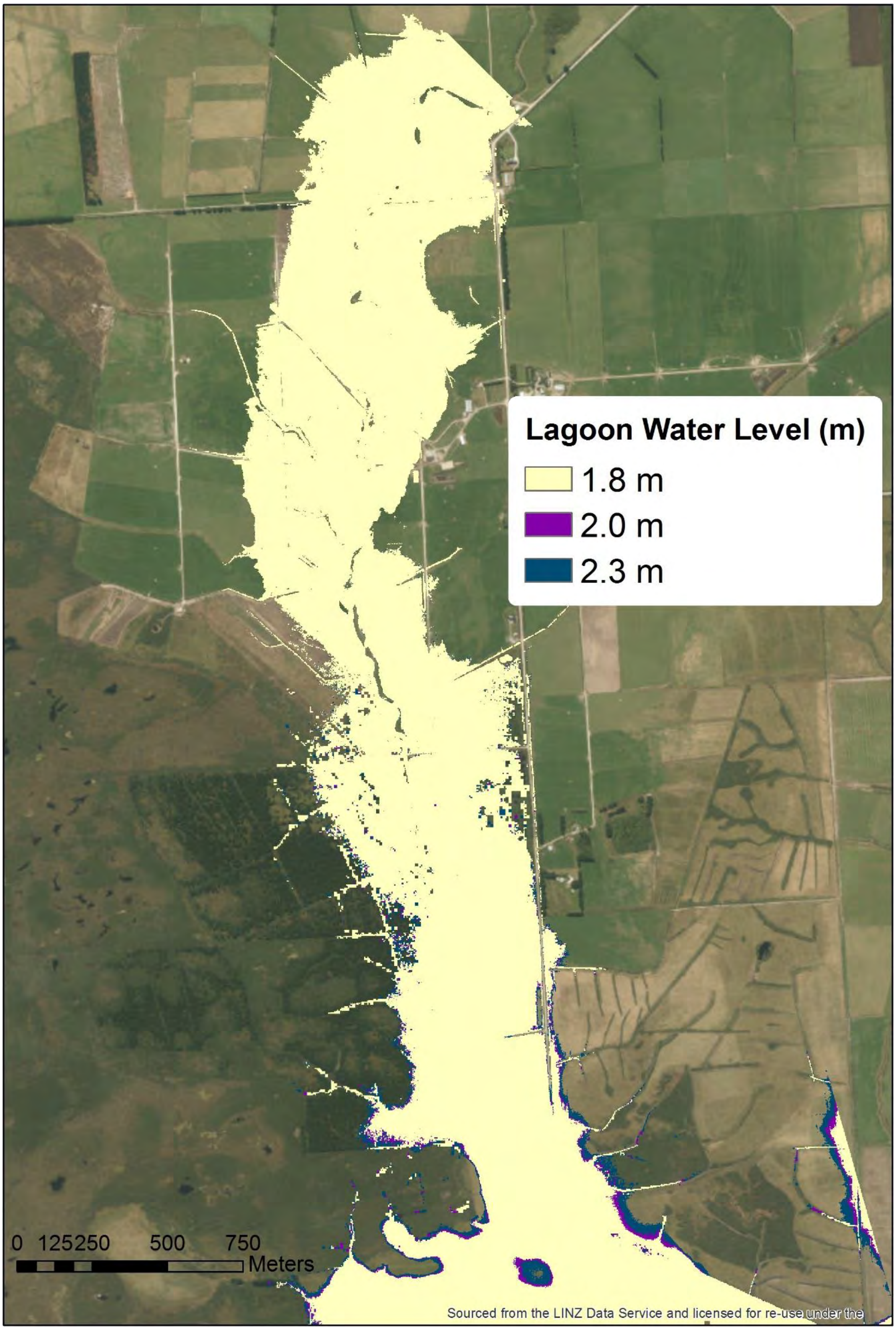


Figure H-4: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

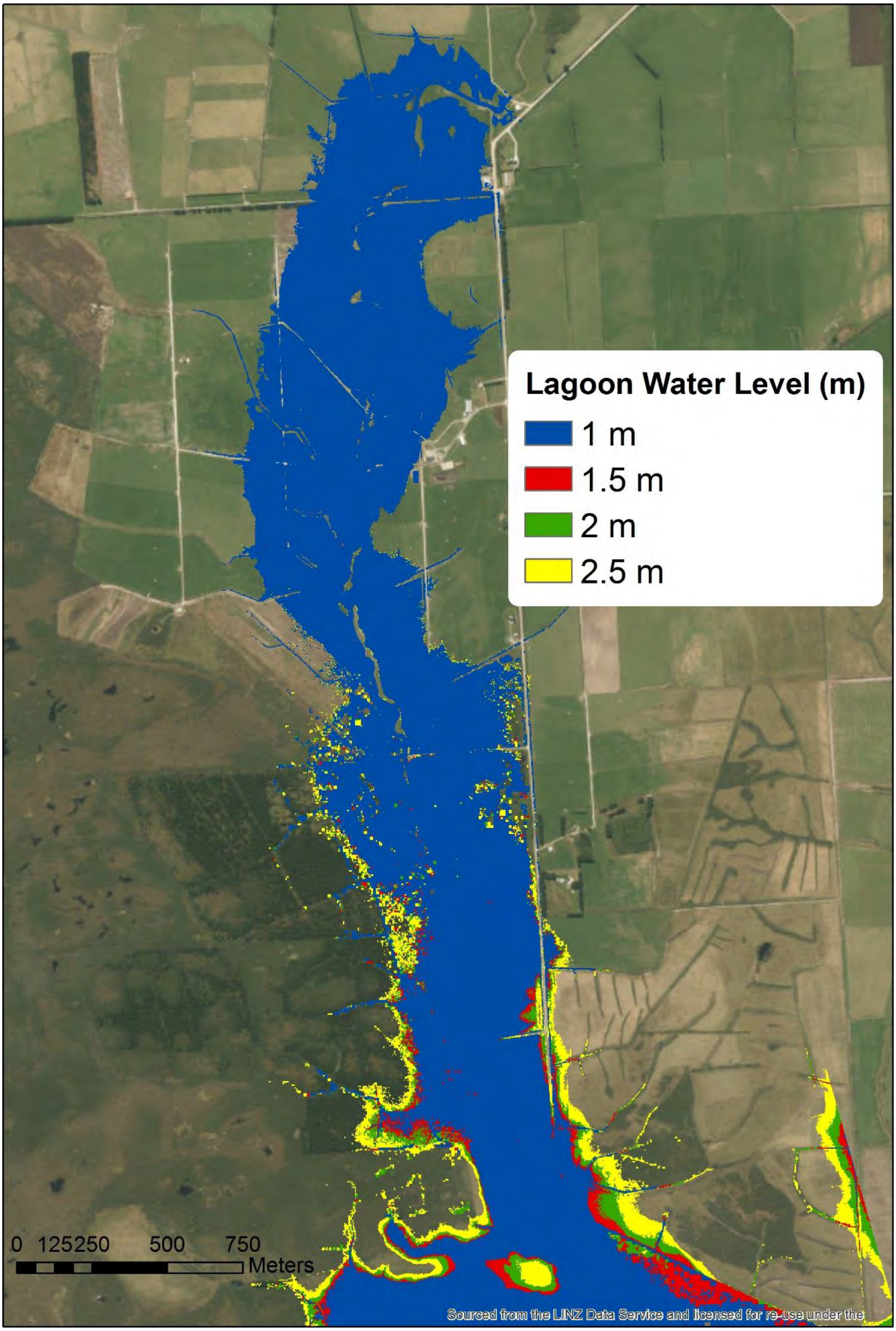


Figure H-5: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

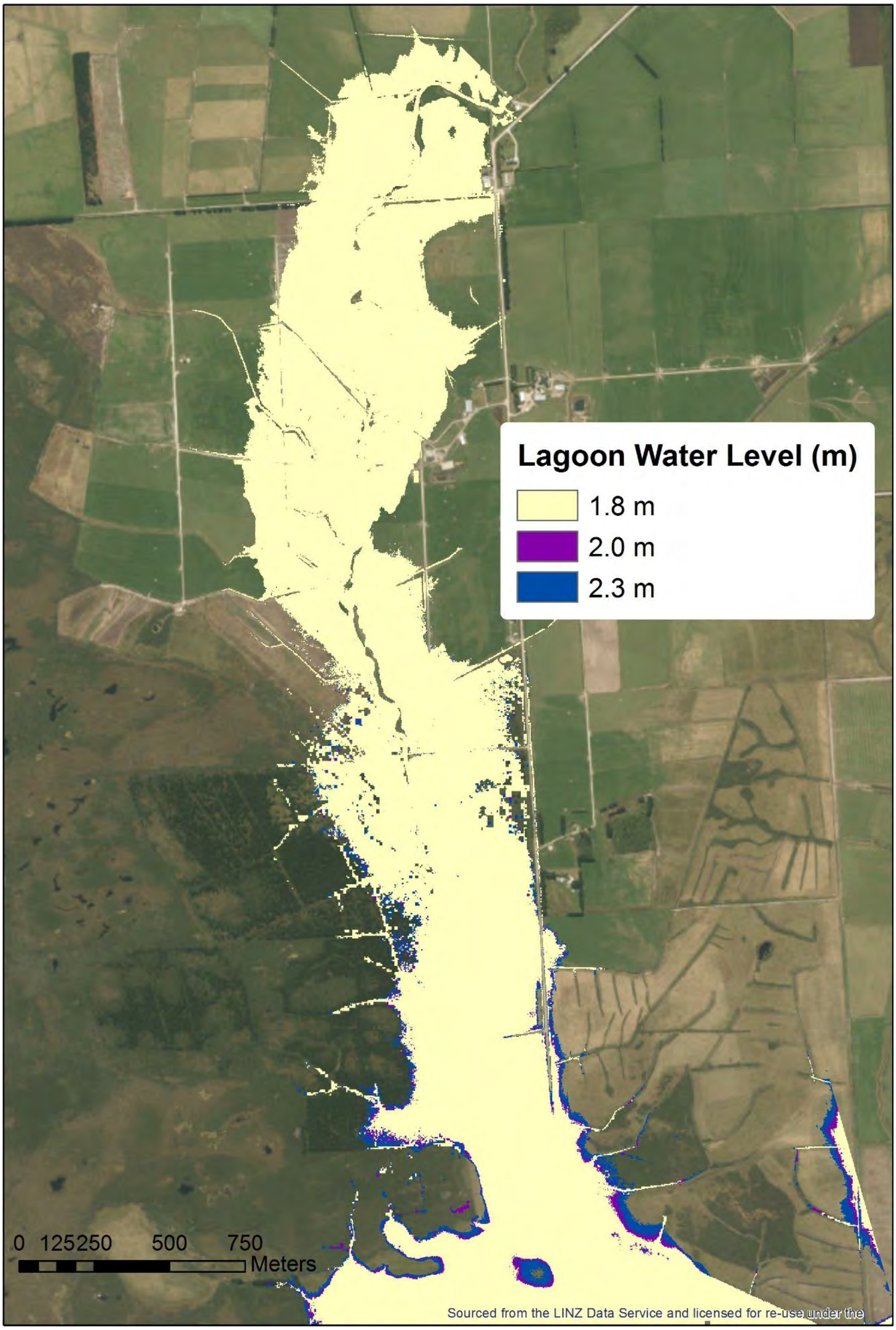


Figure H-6: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

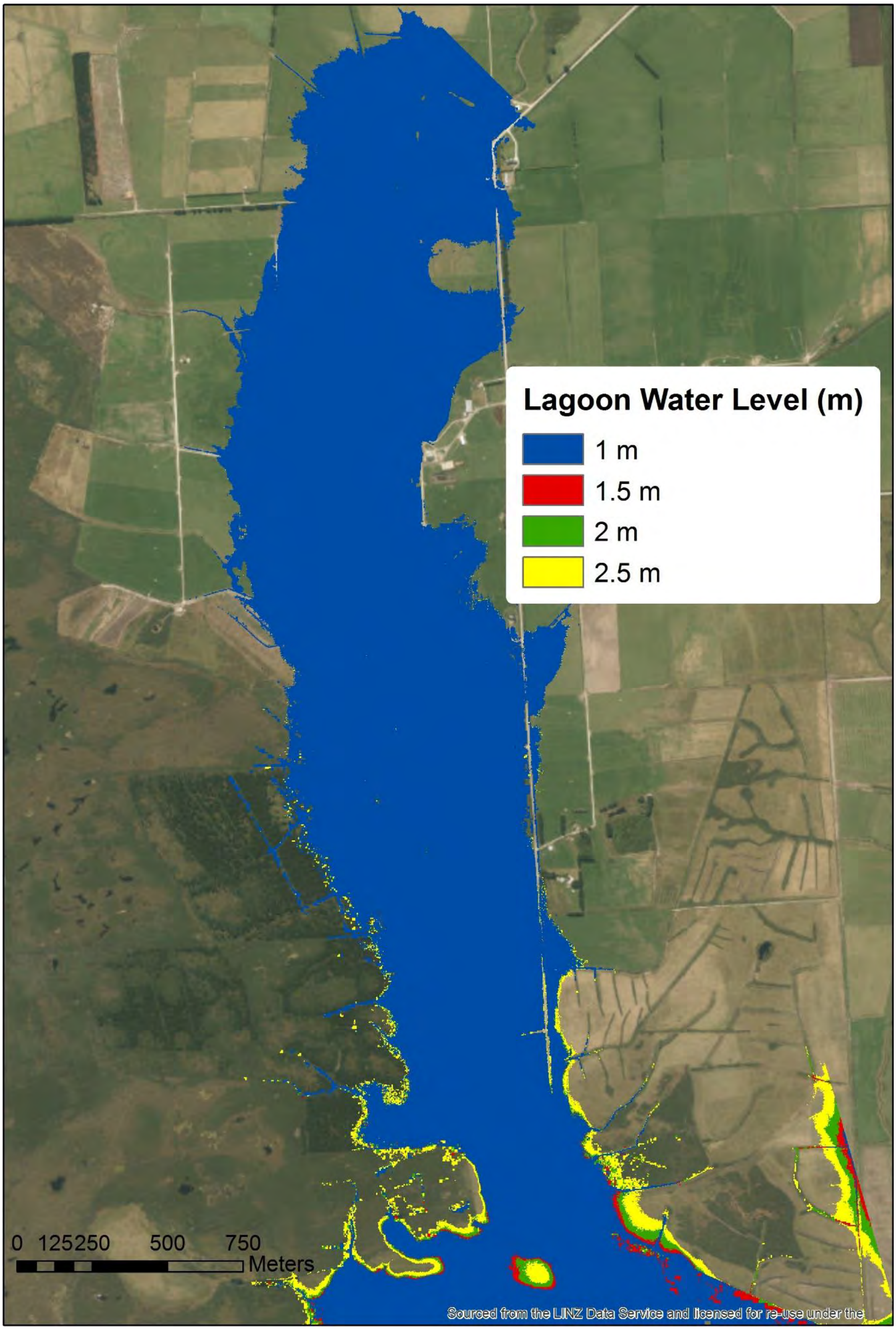


Figure H-7: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

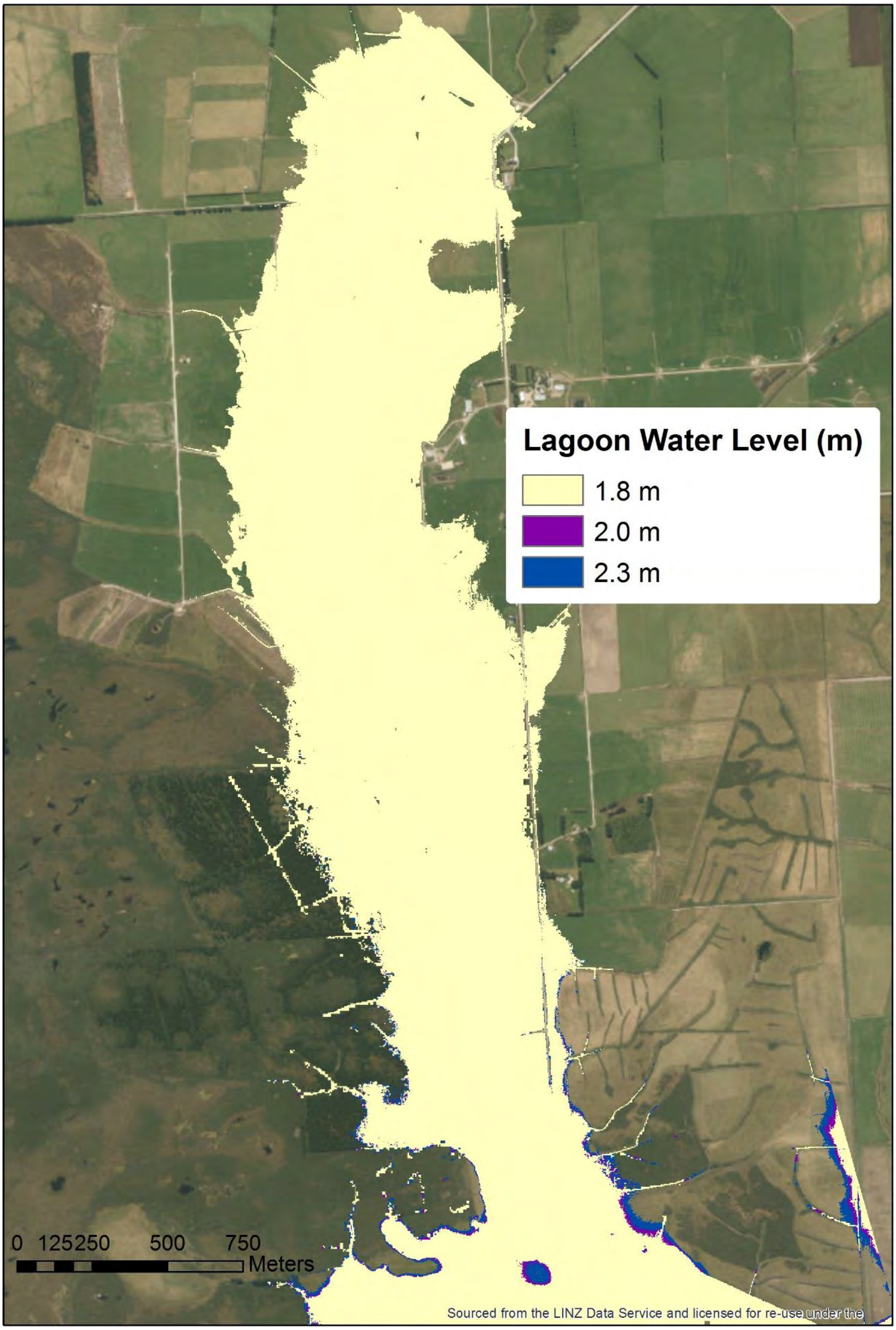


Figure H-8: Extent of land bordering Waituna Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile flow with a vegetated main channel.

Appendix I Moffat Creek potentially drainage affected land (2m threshold)

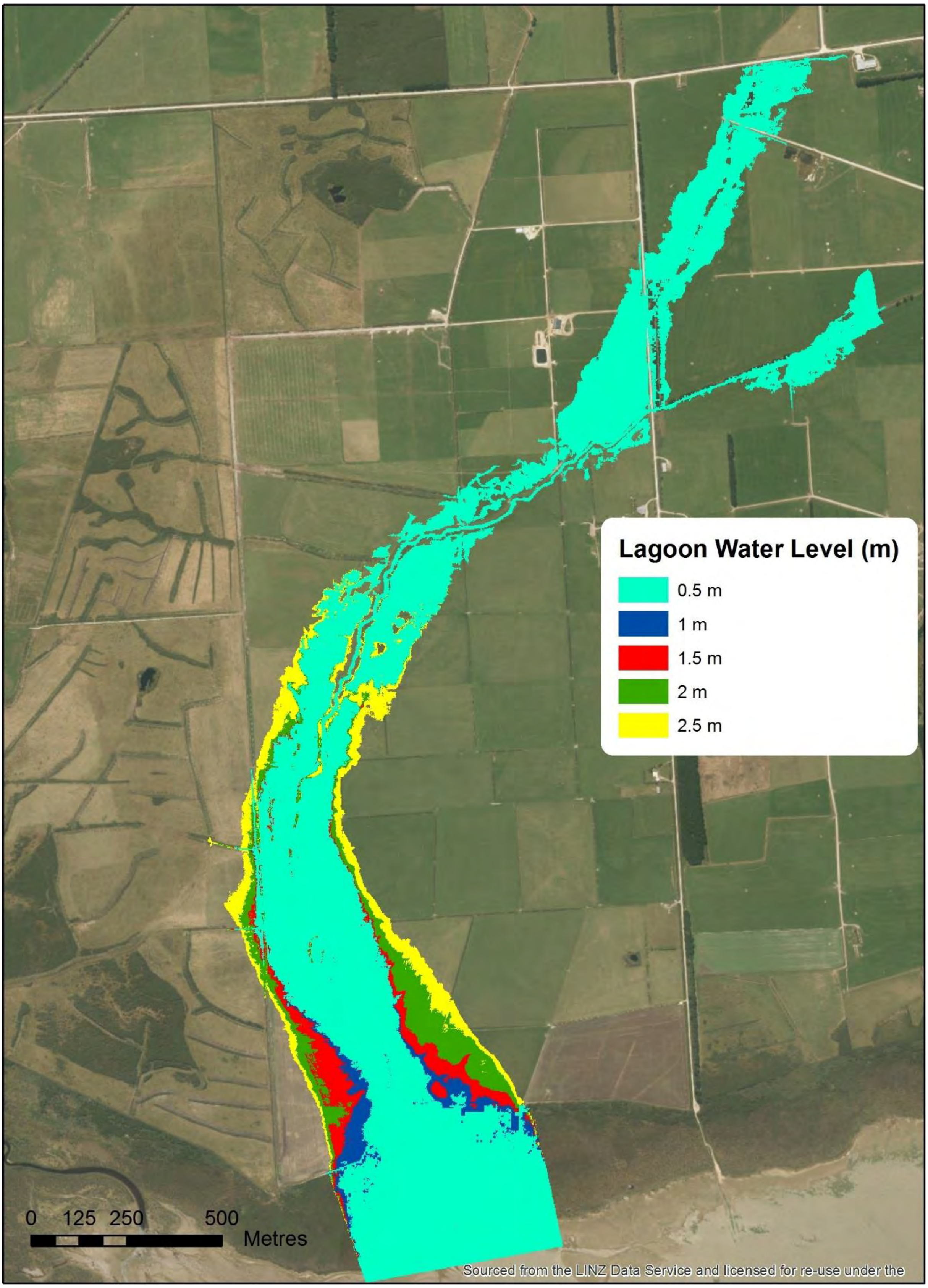


Figure I-1: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

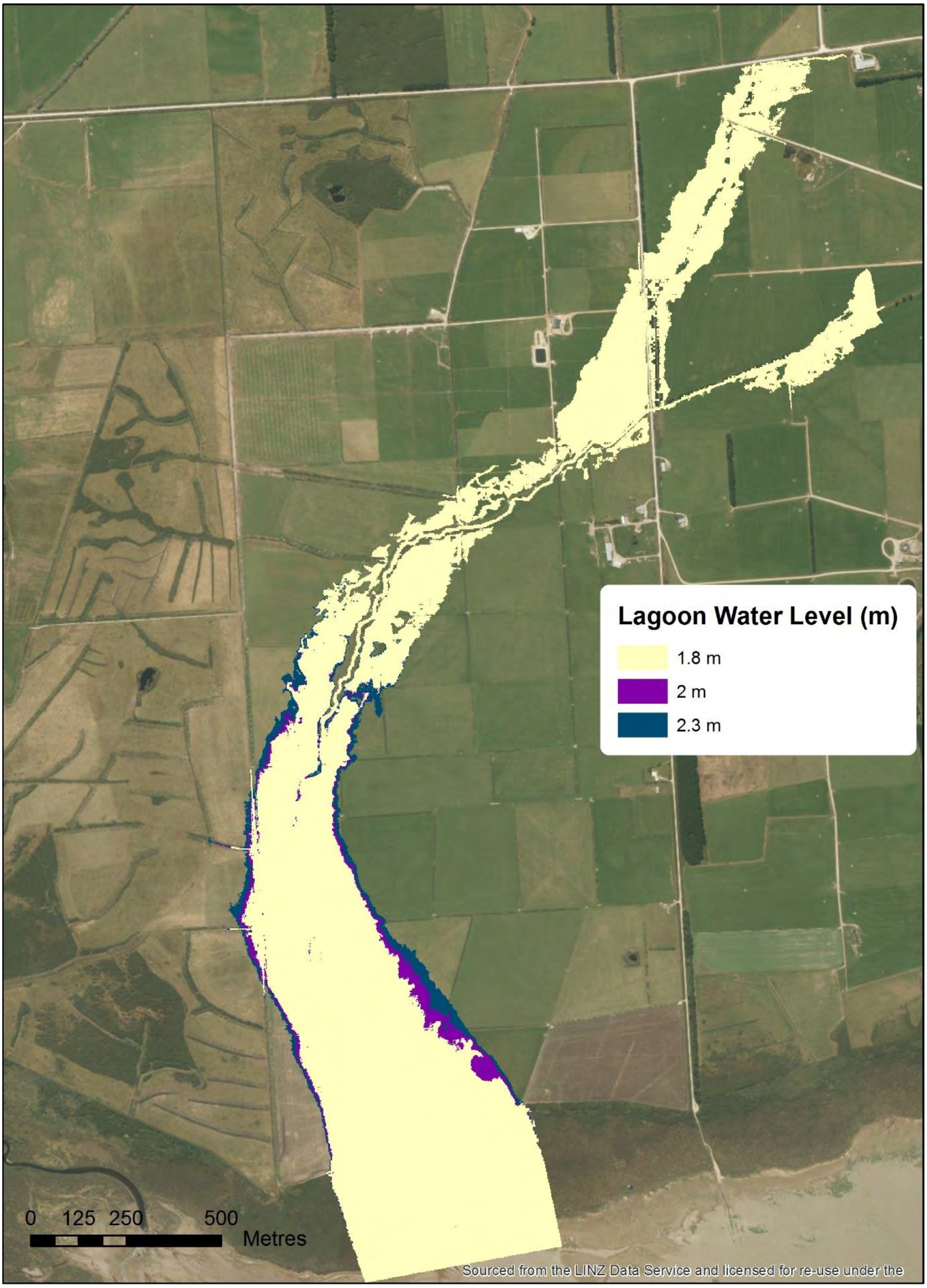


Figure I-2: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.

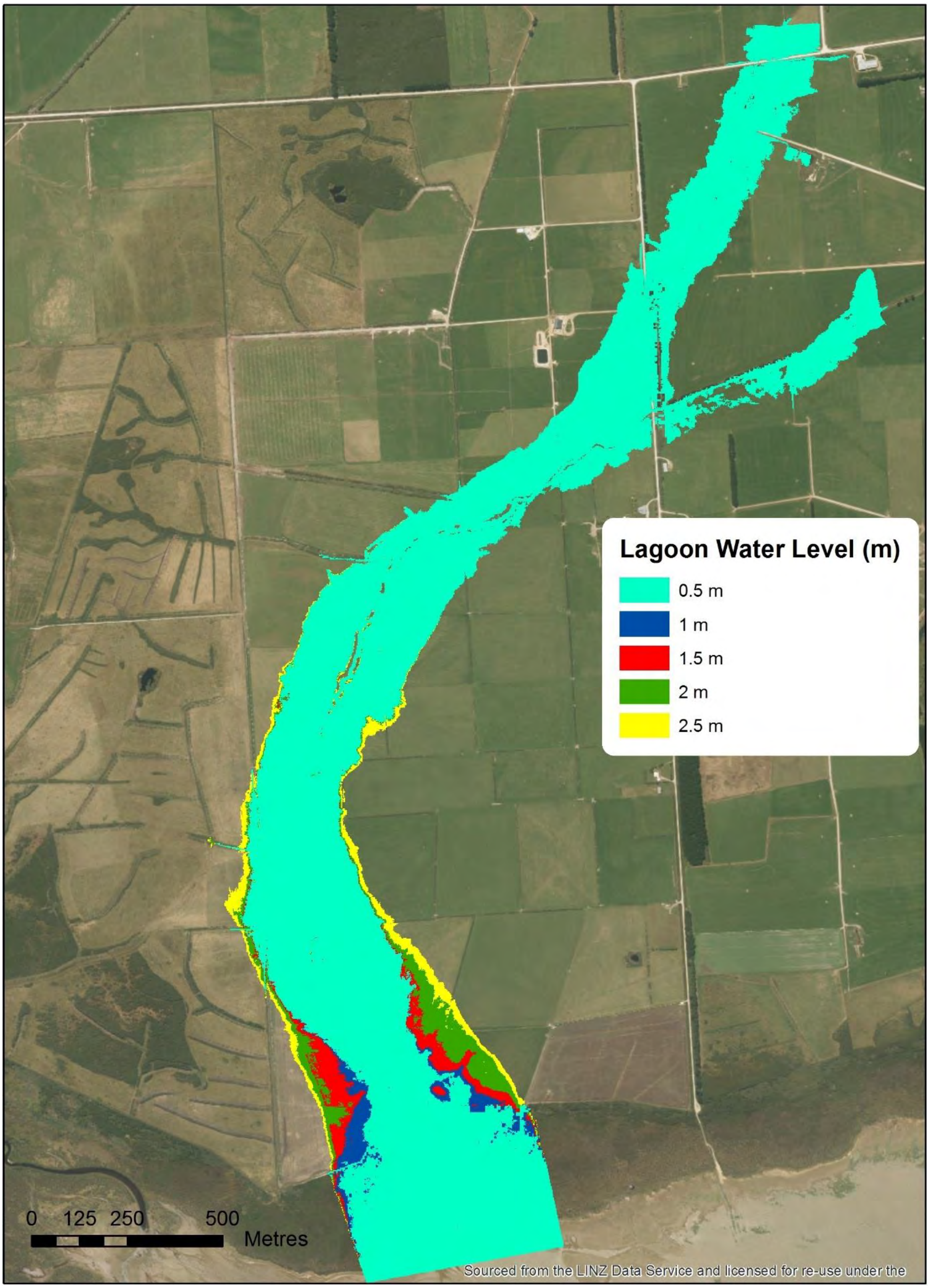


Figure I-3: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

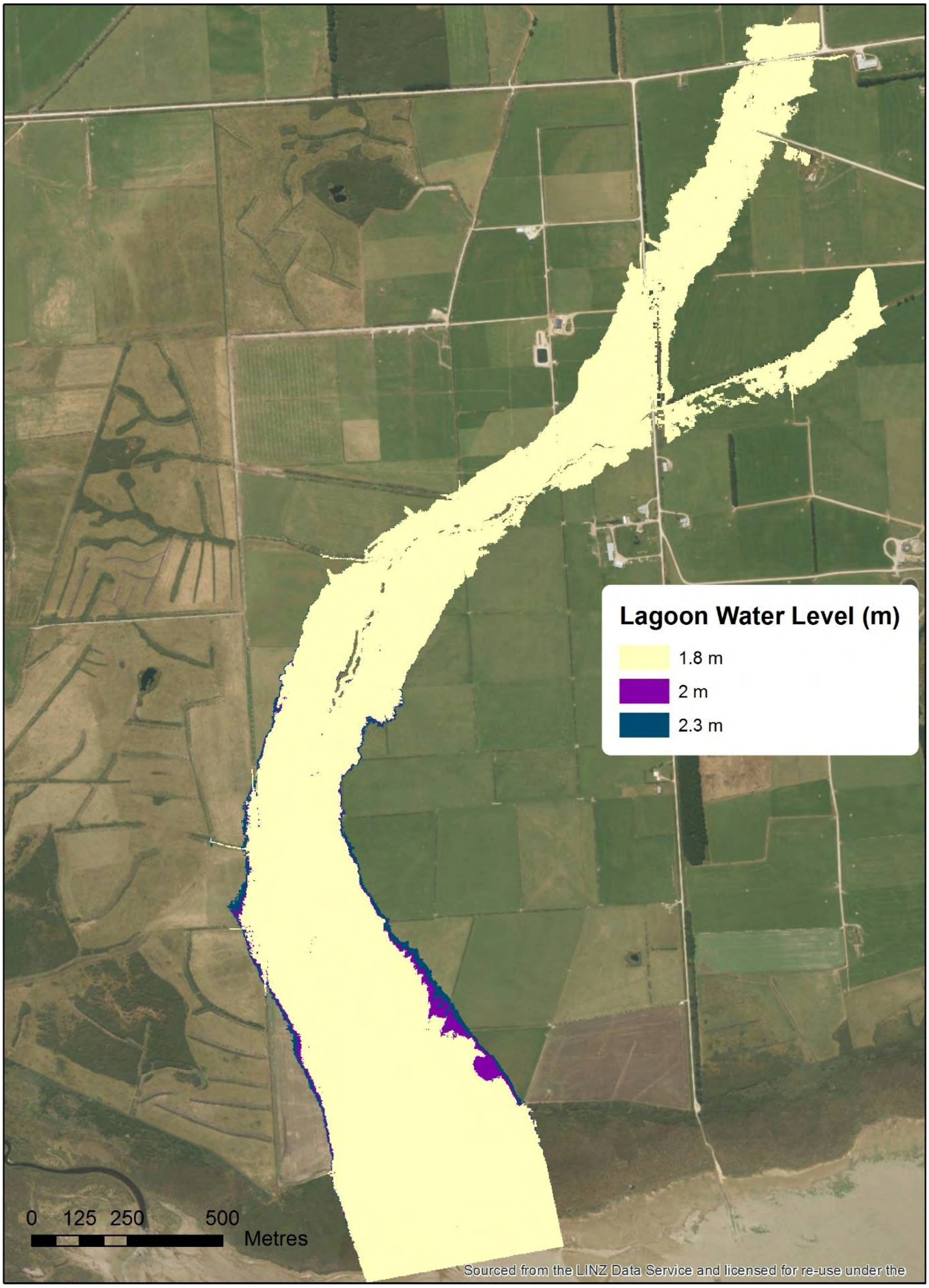


Figure I-4: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Cleared" models the 90 percentile high flow with a recently cleared main channel.

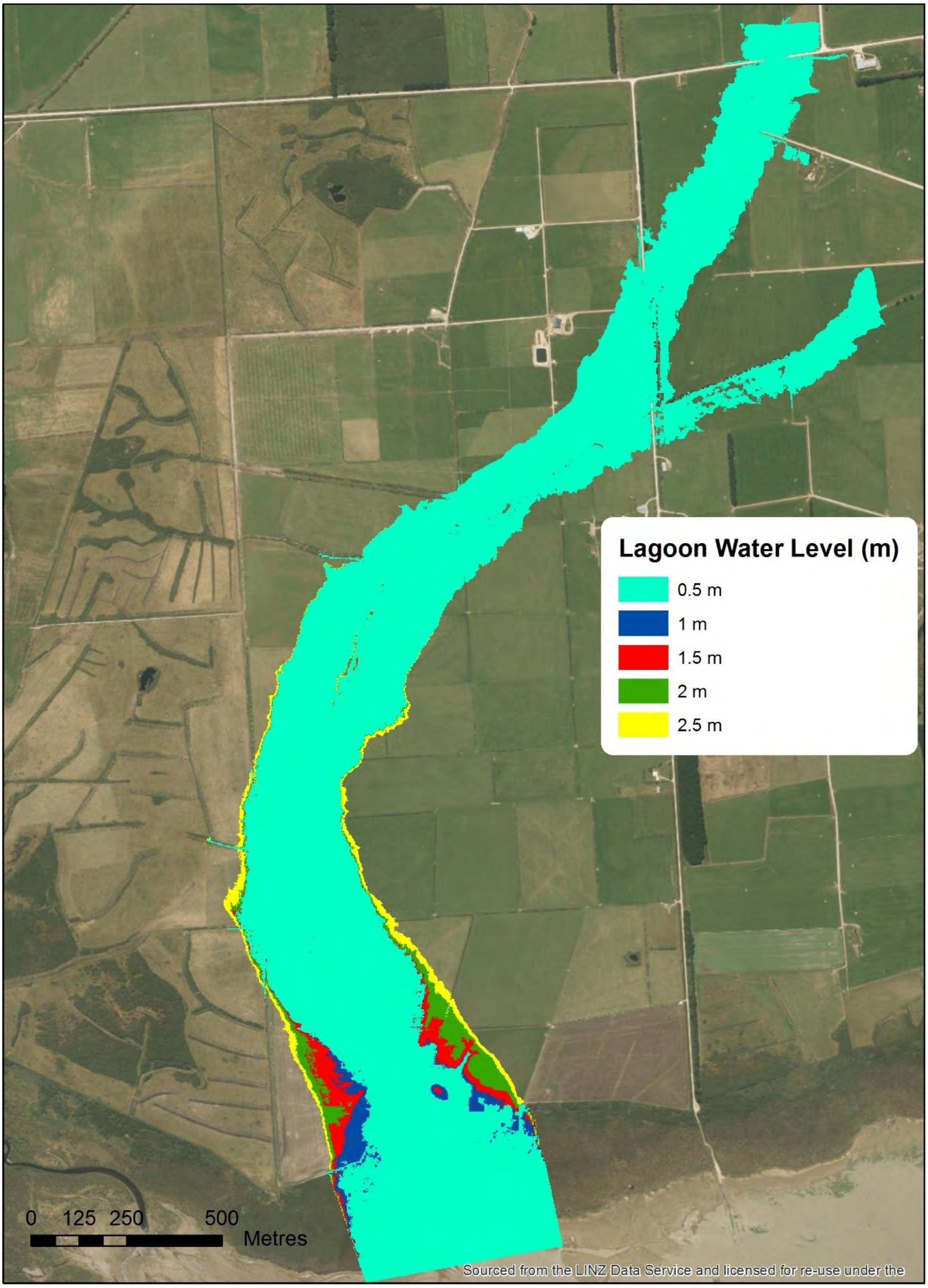


Figure I-5: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

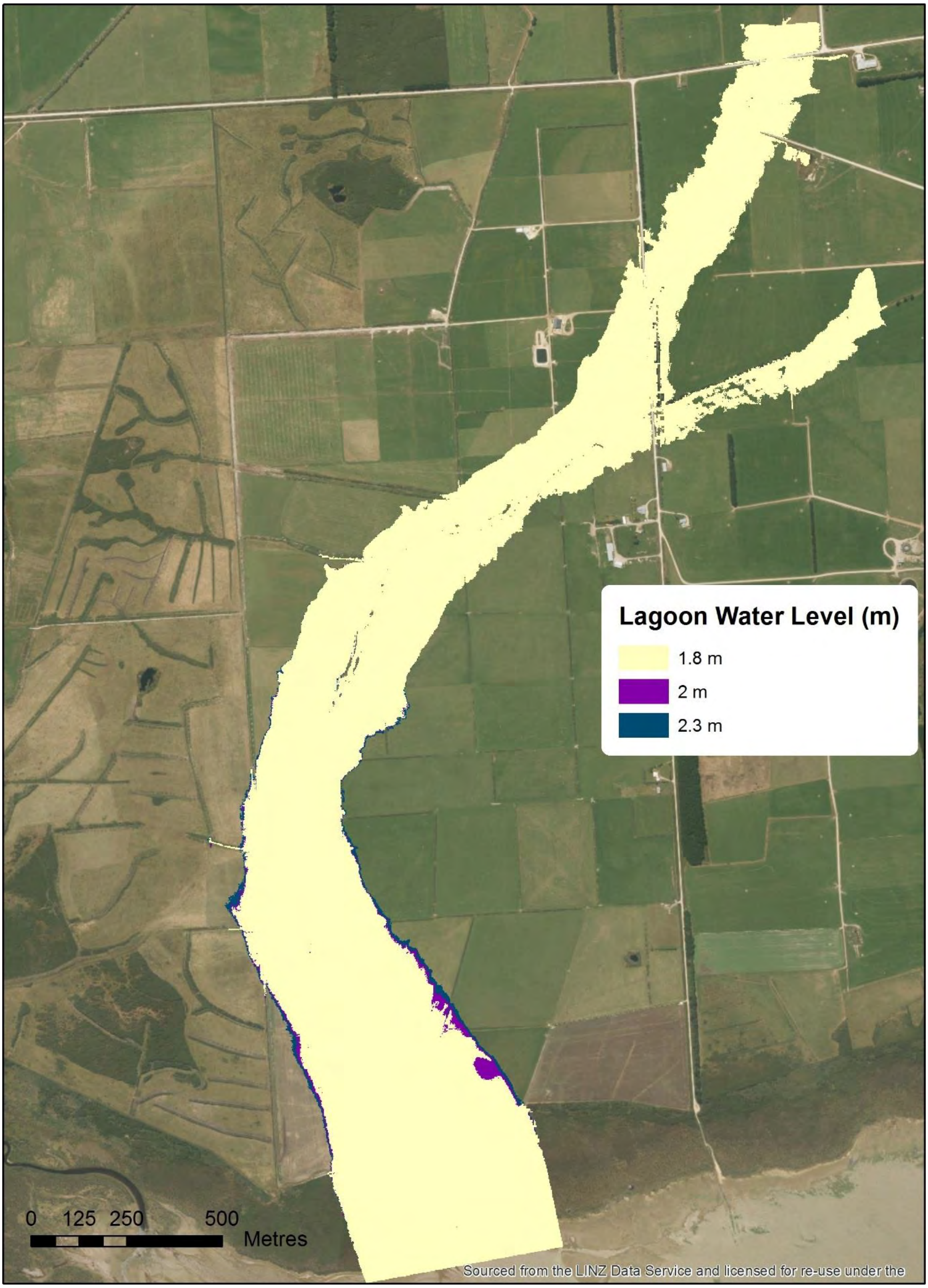


Figure I-6: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Vegetated" models mean flow with a vegetated main channel.

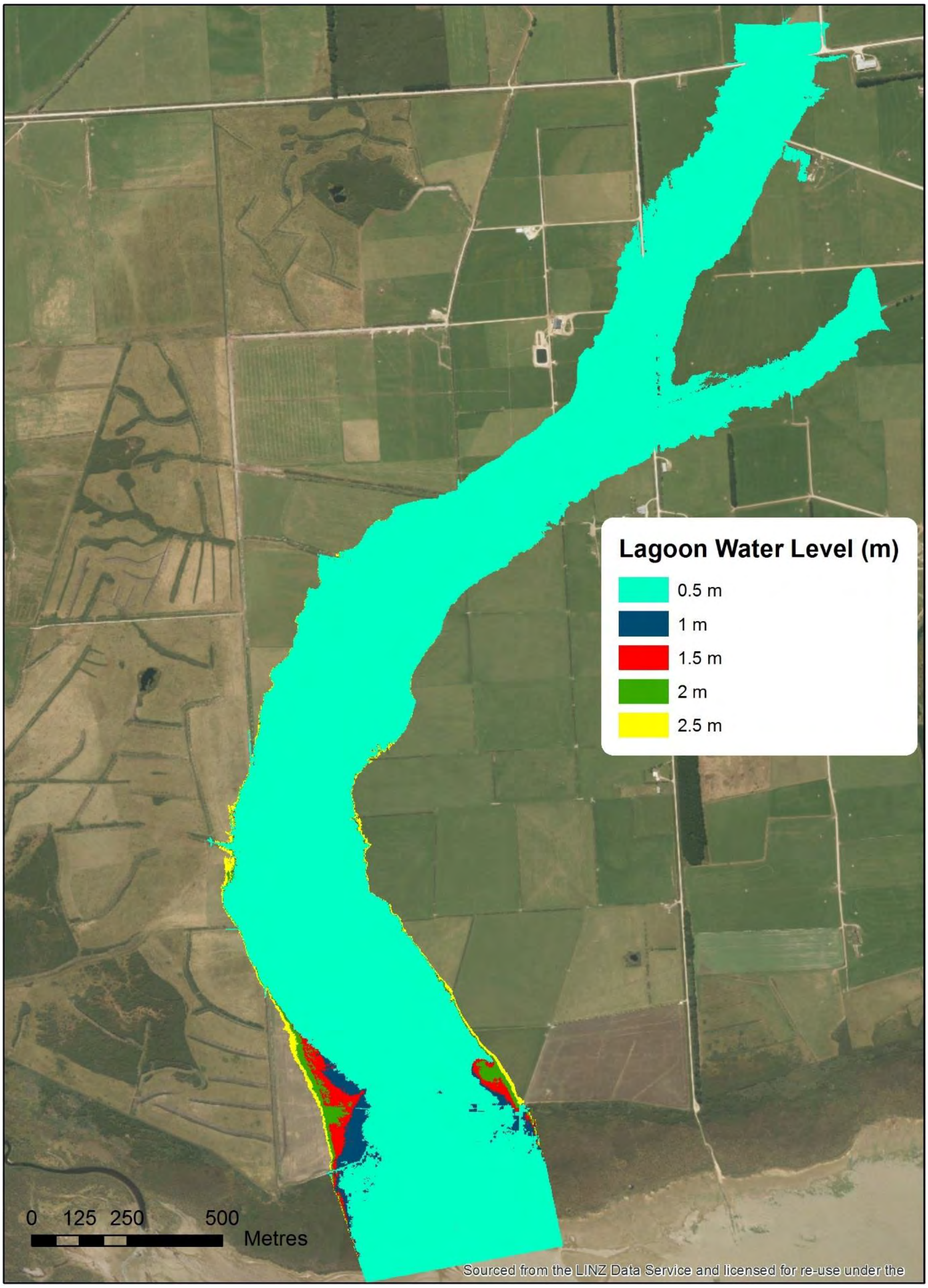


Figure I-7: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated". Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile high flow with a vegetated main channel.

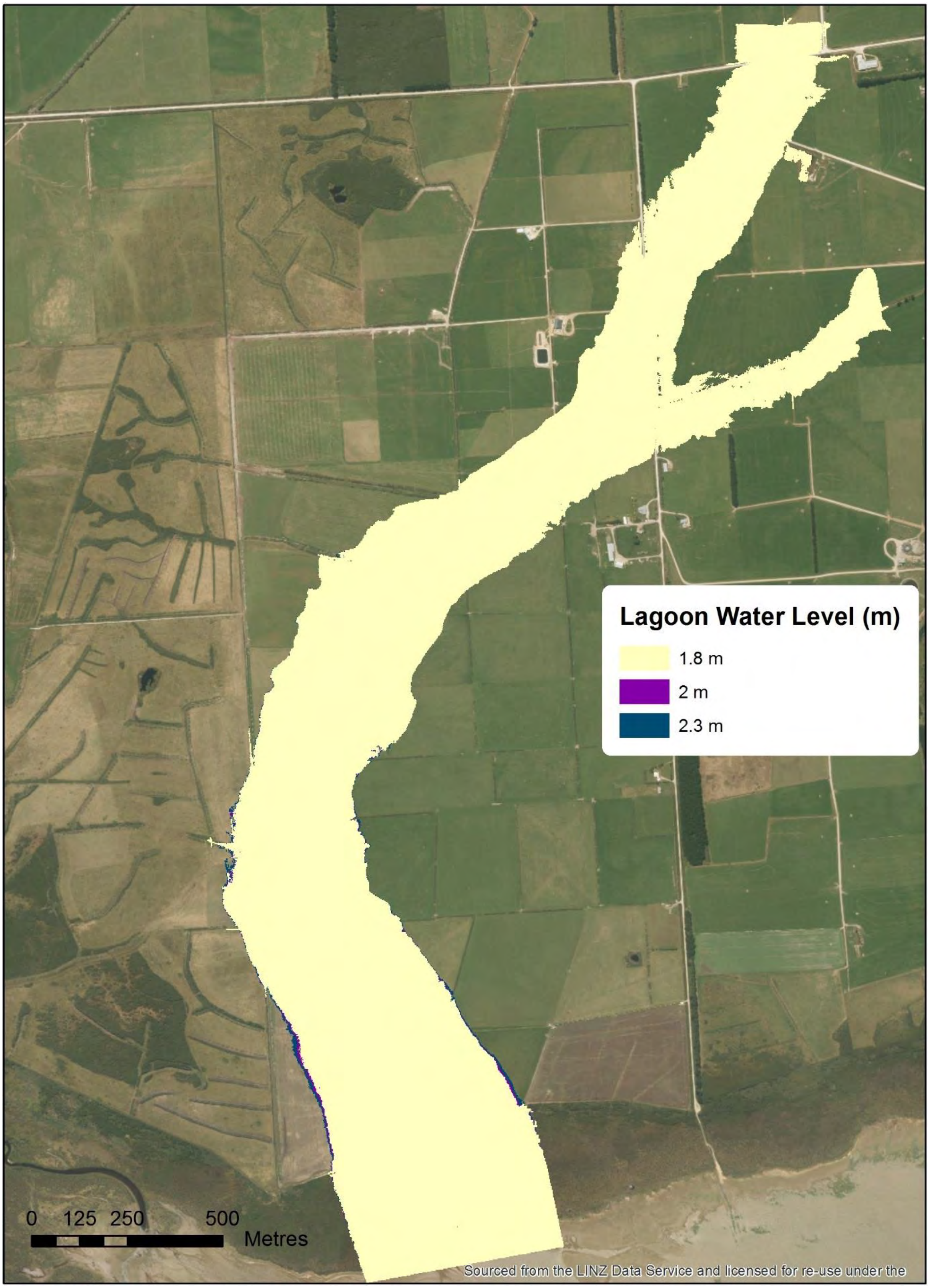
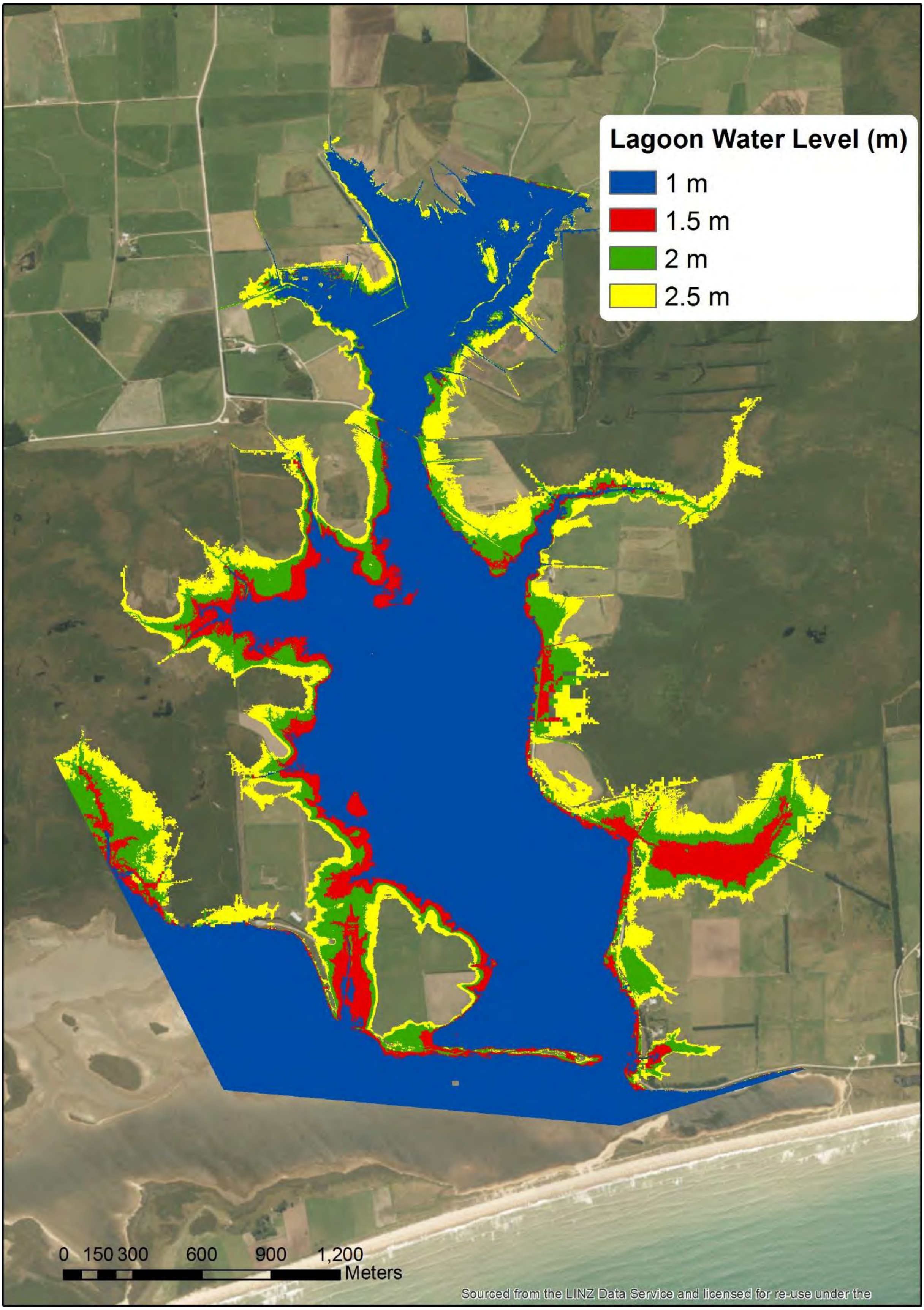


Figure I-8: Extent of land bordering Moffat Creek that is potentially drainage affected under scenario "Q_{90}-Channel Vegetated" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{90}-Channel Vegetated" models the 90 percentile flow with a vegetated main channel.

Appendix J Carran Creek potentially drainage affected land (2m threshold)



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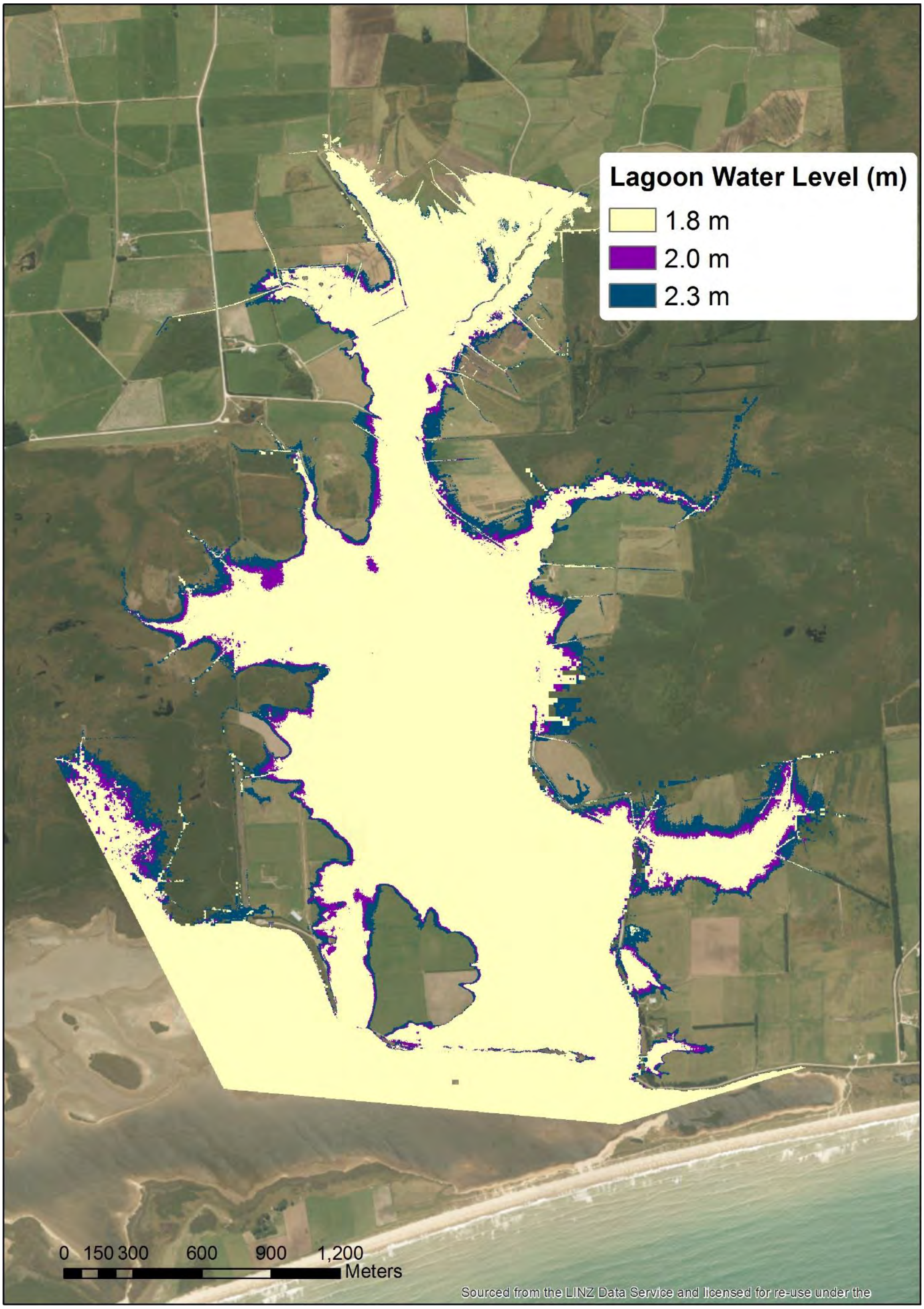
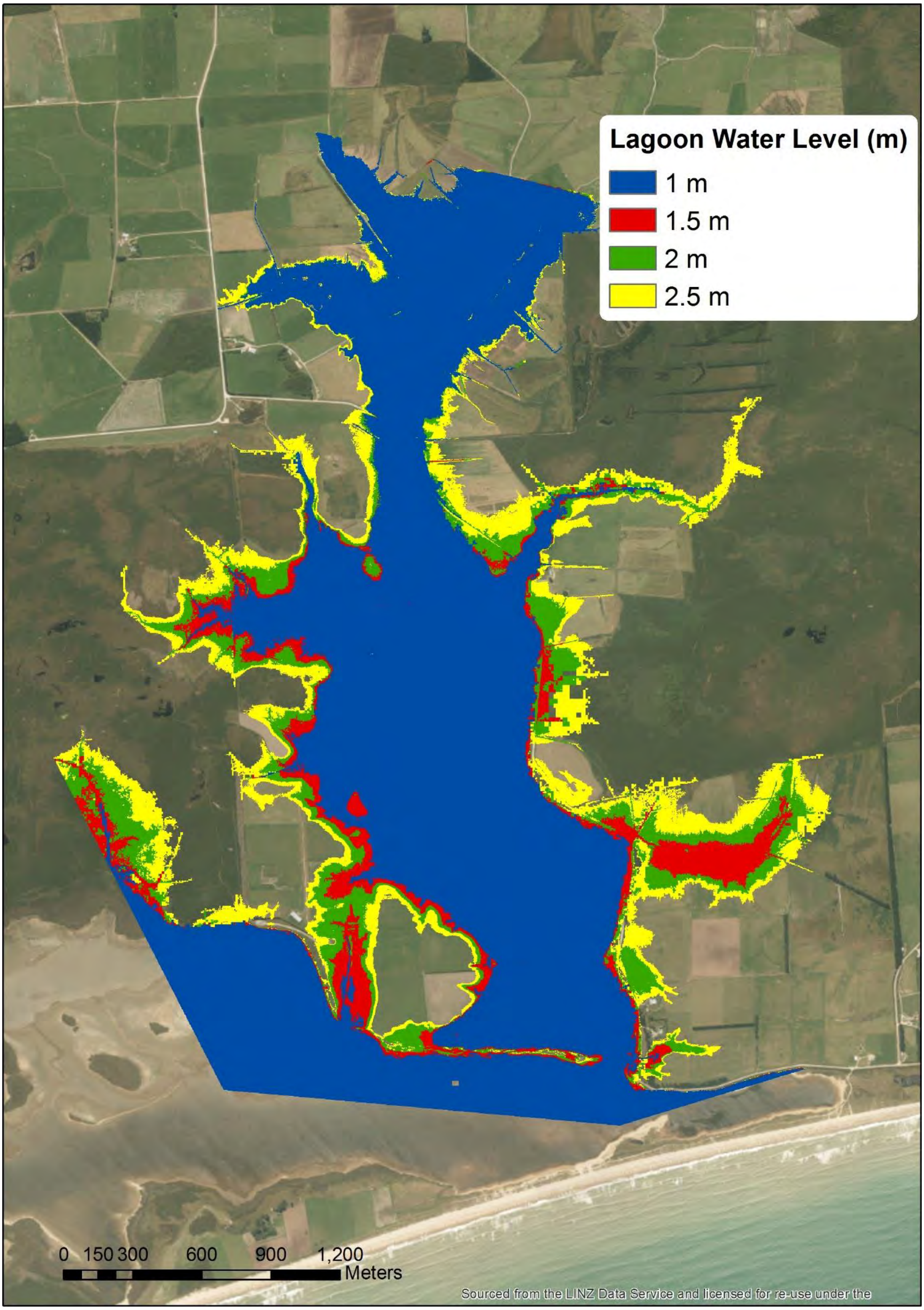


Figure J-2: Extent of land bordering Carran Creek that is potentially drainage affected under scenario "Q_{mean}-Channel Cleared" (specific lagoon levels of interest). Potentially drainage affected land is taken to be land adjacent to the channel with ground elevation less than 2.0 m above the channel water level. Scenario "Q_{mean}-Channel Cleared" models mean flow with a recently cleared main channel.



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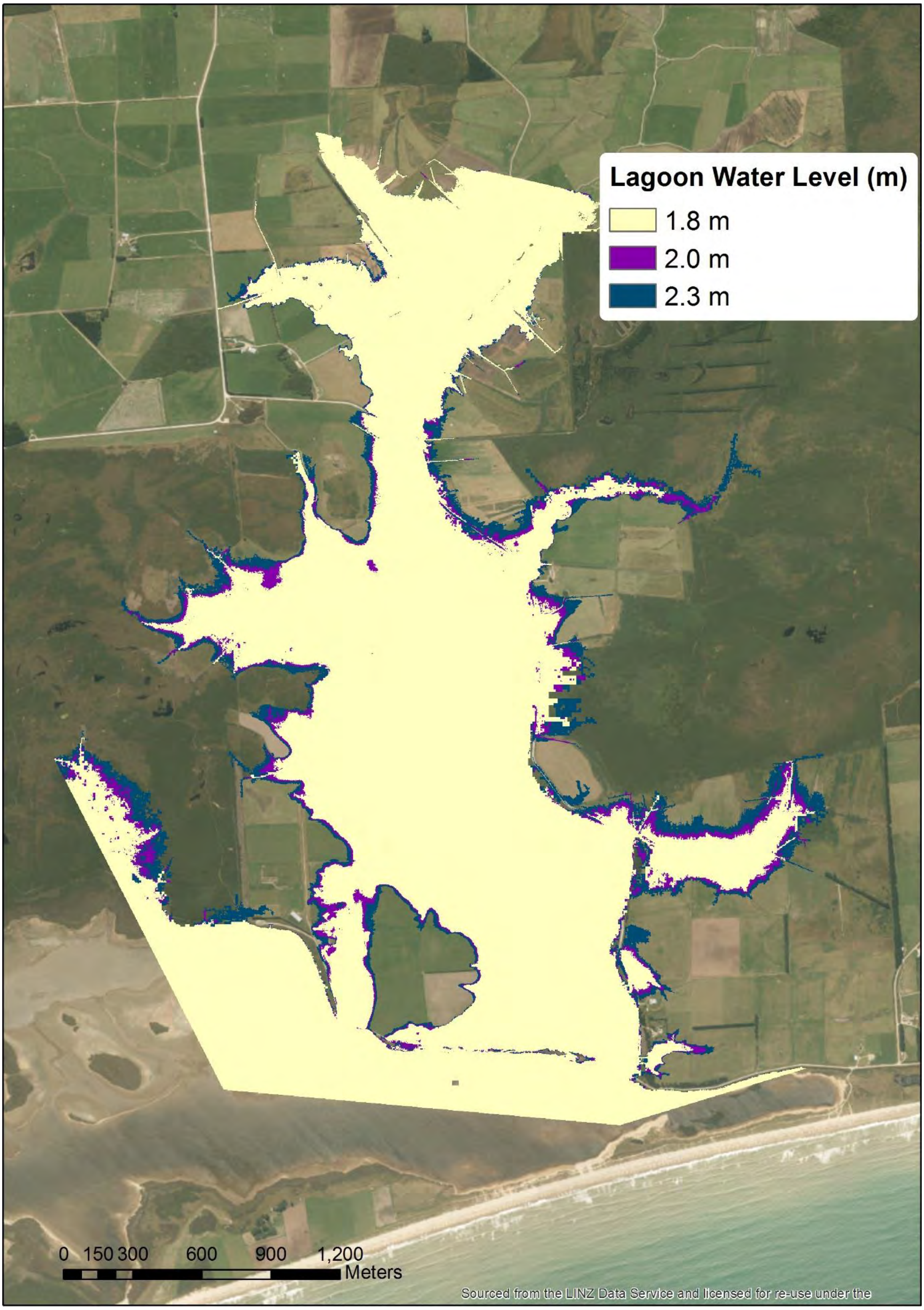

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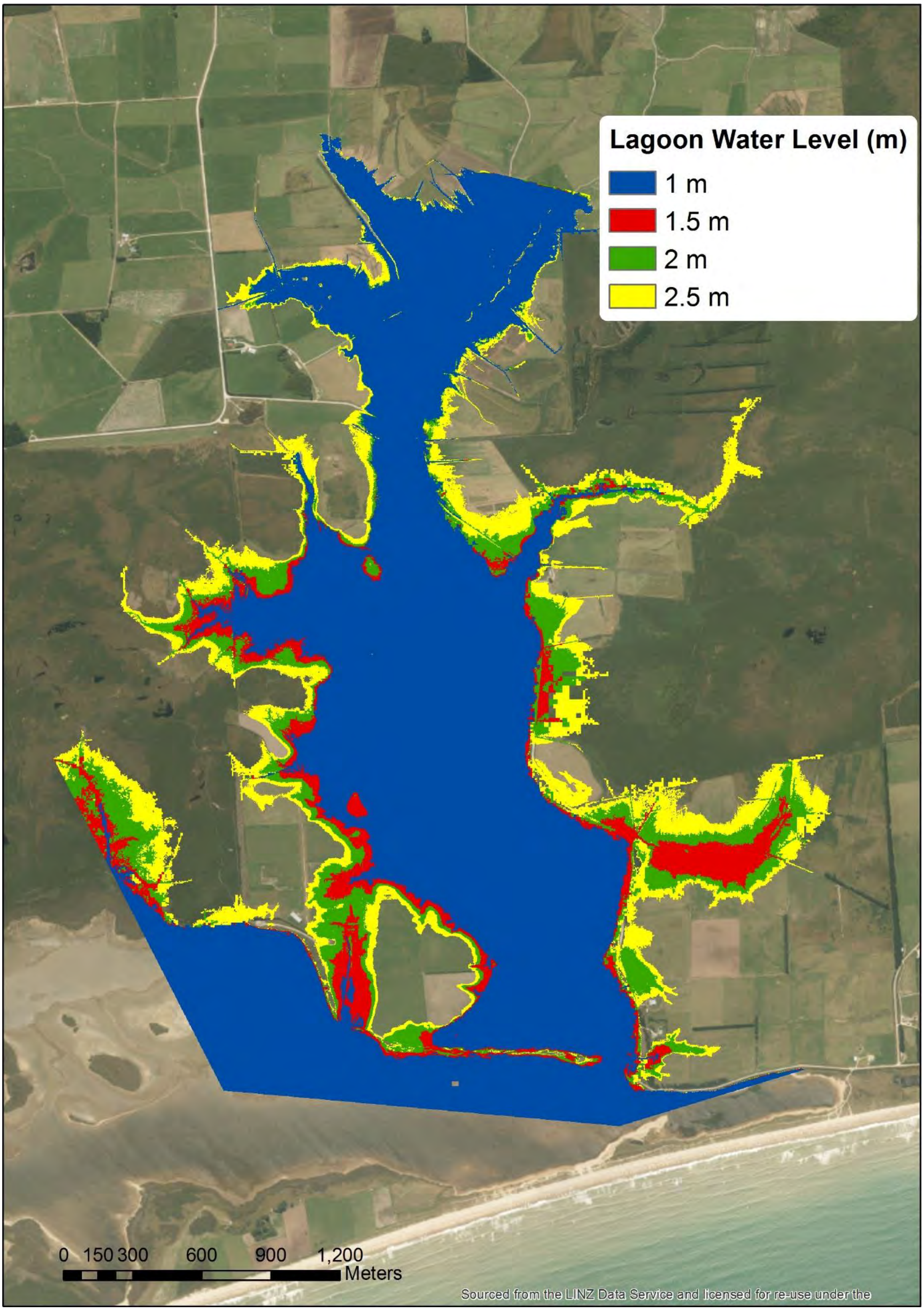

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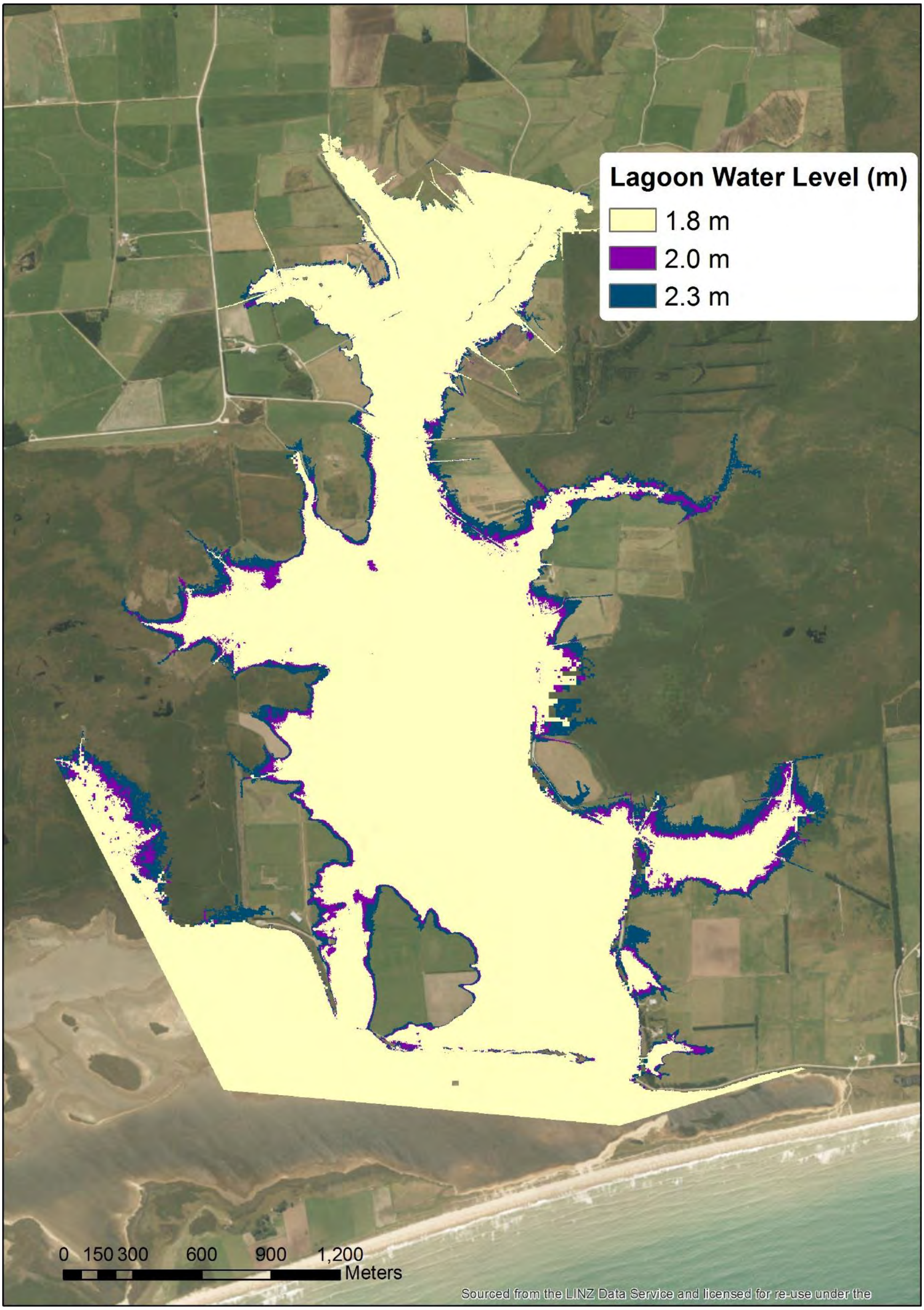

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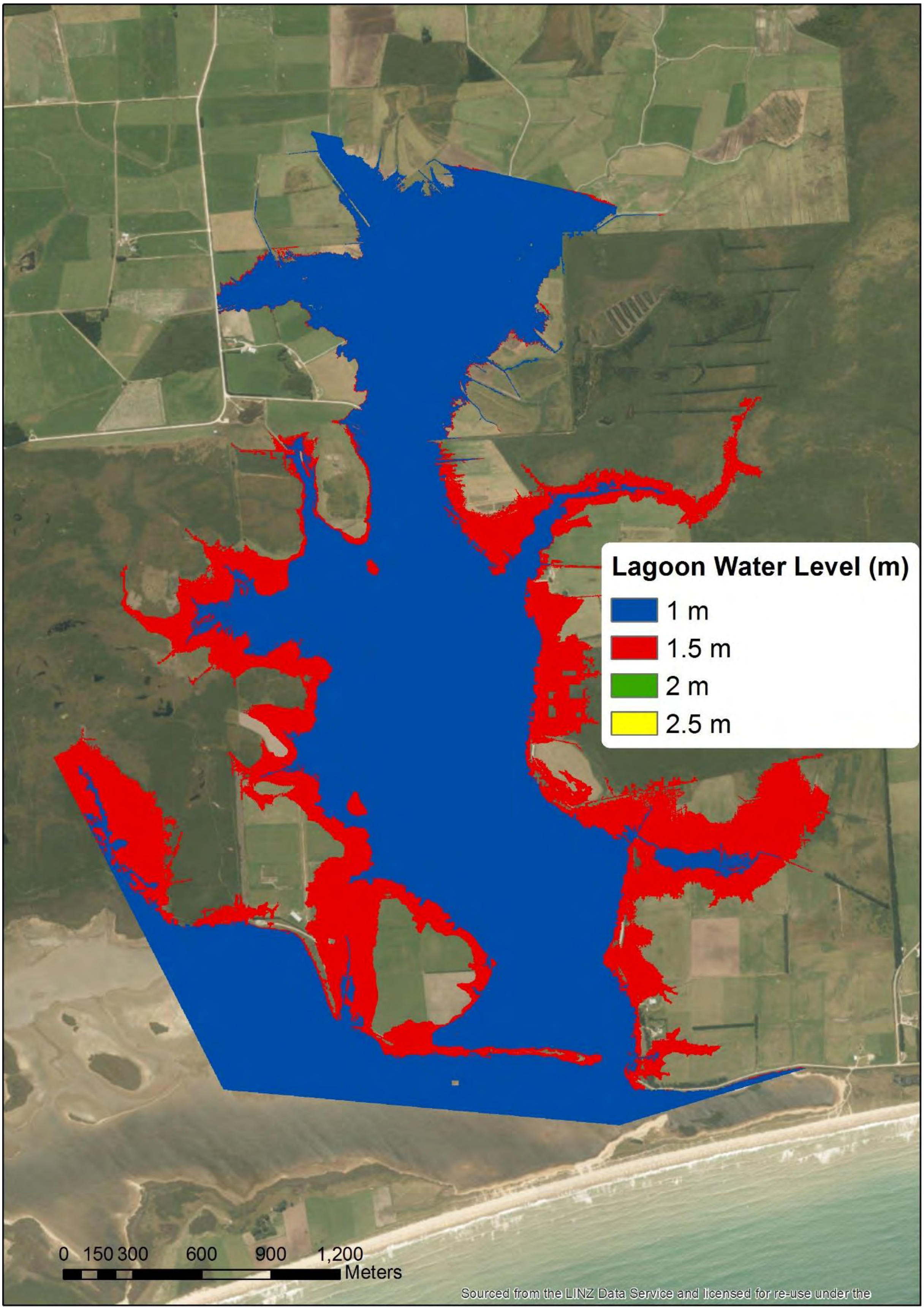

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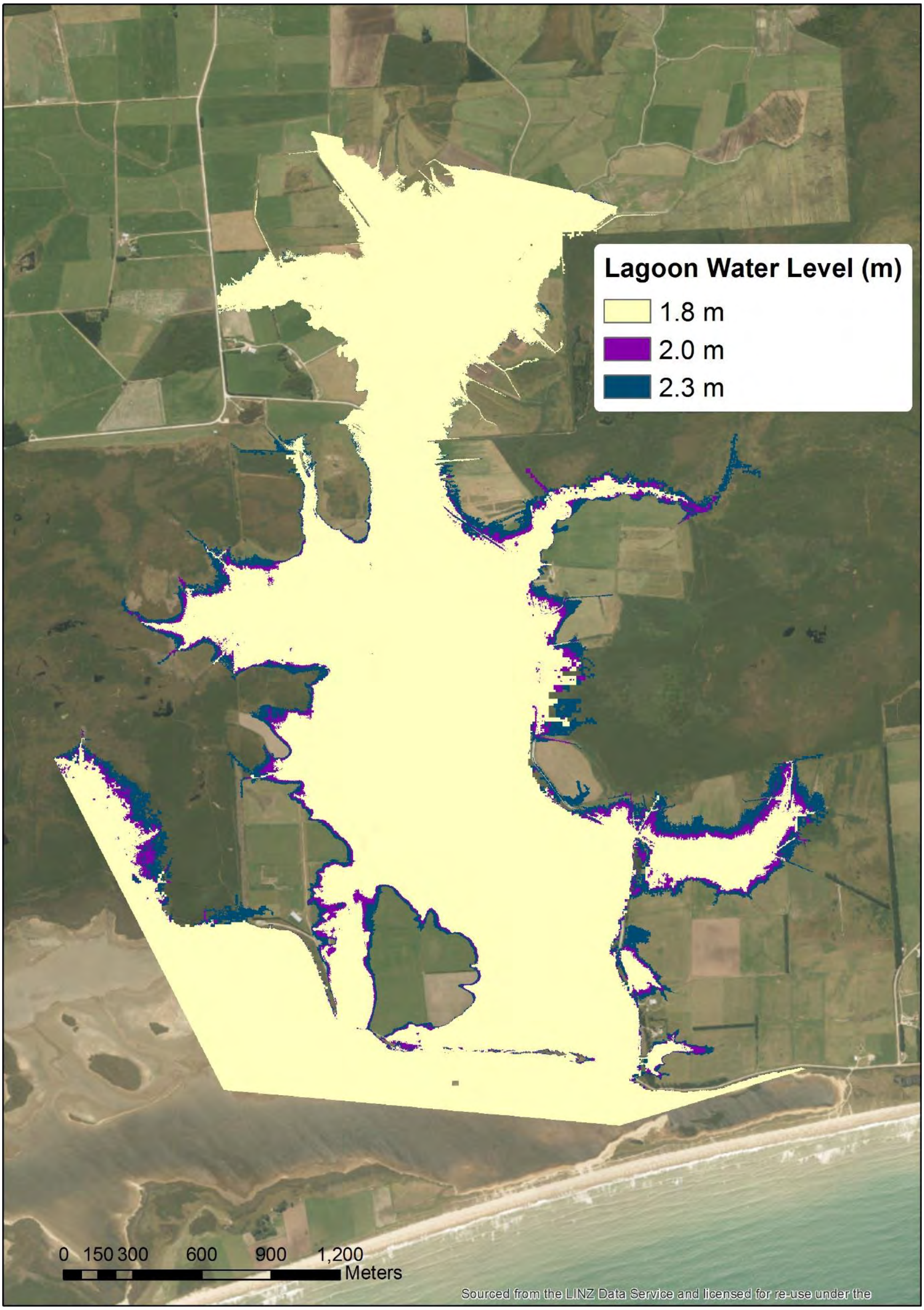

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Appendix N: Consultation Strategy and Material

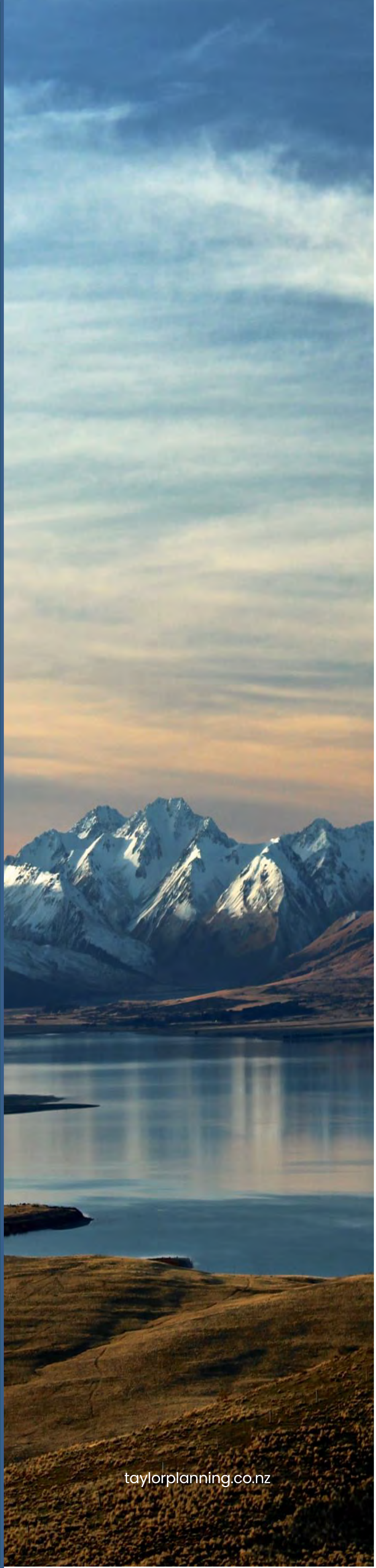
Taylor. Planning

Consultation Strategy

Waituna Lagoon
Resource Consent
Application

14 November 2023

Supporting clients to solve their resource management challenges.



Introduction

Te Rūnaka o Awarua (‘**Awarua Rūnaka’**), the Department of Conservation Te Papa Atawhai (‘**DOC’**), and Environment Southland (‘**ES**’) are partners with a shared interest in restoring the mana and ecological and cultural health of the Waituna Lagoon, and these parties are co-applicants to a resource consent application being prepared to periodically open the lagoon for these purposes. This consultation strategy guides how consultation will be undertaken with parties that have an interest in the resource consent.

The Resource Consent Application

The resource consent application seeks a transition to a new opening regime:

- for the first five years of the consent (years 1-5):
  - summer openings (1 September to 30 April) may occur if water levels are at or above 2.5m for 24 hours; and
  - winter openings (1 May to 30 August) may occur if water levels are at or above 2.3m for seven days;
- for the next ten years of the consent (years 6-15), openings may occur if water levels are at or above 2.5m for three days; and
- for the final five years of the consent (years 16-20), openings may occur if water levels are at or above 2.5m for seven days.

In addition, openings will be enabled for ecological / water quality and fish passage reasons and on the recommendation of a Technical Advisory Group (‘**TAG**’). TAG members will be suitably qualified representatives of the Lake Waituna Control Association (‘**LWCA**’), DOC, Awarua Rūnaka and ES.

There will be a review condition, that can be exercised once five years of monitoring data is available. A condition will also enable anyone to raise an issue with the Technical Advisory Group, who can make recommendations to the consent holders to consider an ecological opening.

There will be conditions detailing how stakeholder engagement occurs. This could provide, for example, for the consent holders to update the community on water levels as they approach the opening thresholds and confirm when machinery will be mobilised etc. For the avoidance of doubt, the conditions of consent will set the trigger levels for opening – the stakeholder engagement conditions are for communication and providing assurance that an opening will occur when the trigger level is met.

A 20 year term will be sought.

Although the parties will apply for and pursue the conditions recorded above, the final conditions will be determined by an independent decision-maker. The final conditions may, therefore, be different to those sought if the consent is granted.

Consultation Principles

This strategy has been developed to follow current examples and guidance under the Resource Management Act 1991 and the Local Government Act 2002. From this guidance, the following key principles assist to set out what might be considered best practice when consulting:

Early – consultation should occur as soon as possible when the details of the proposal have more flexibility to change in response to issues raised by interested and affected parties.

Transparent – the proposal initiator needs to be open about what they want to achieve, what scope they have to change the proposal and what elements cannot be altered.

Open mind – the proposal initiator needs to keep its views open regarding people's responses and to the benefits that might arise from consultation.

Two-way process – consultation is intended as an exchange of information and requires both the proposal initiator and those consulted to put forward their points of view, and to listen to and consider other perspectives.

Not a means to an end – while consultation is not an open-ended, never-ending process, it should not be seen merely as an item on a list of things to do that should be crossed off as soon as possible.

Ongoing – it may be that consultation, or at least ongoing communication, will continue after a resource consent has been notified or even after a decision has been made.

Agreement not necessary – consultation does not mean that all parties have to agree to a proposal, although it is expected that all parties will make a genuine effort. While agreement may not be reached on all issues, points of difference will likely become clearer or more specific.

Consultation on the application should adhere to the principles set out above and focus on early and continued engagement with stakeholder groups as the resource consent application is developed.

Consultation Scope

LWCA

Consultation on a transition to higher lagoon levels to restore the cultural and environmental health of the lagoon has been ongoing with the LWCA and landowners (particularly in the lower catchment) for a number of years. Given the level of engagement that has already taken place with LWCA, and the differences between the parties views are well understood, further consultation with LWCA should now focus on updating them on progress towards lodgment, and providing an opportunity to comment on proposed conditions.

Other Parties

There are a number of other parties that will have an interest in the application who will need to be consulted, and the approach to consultation with different parties will differ depending on their interest in the application. Early and continued pre-application engagement with the ES processing planner will also be necessary to ensure that the application addresses all relevant resource management issues upfront.

Summary

The scope of consultation will be to:

- Build on the engagement process that has already been undertaken with Lake Waituna Control Association ('**LWCA**') on their previous consent application, by targeting consultation to feedback on the currently proposed consent conditions, and particularly related to the TAG and stakeholder consultation regarding lagoon opening. It will not be used to discuss the proposed transition regime and opening triggers, as those concerns are already well understood, but will provide the opportunity to better target the conditions to the concerns the LWCA have regarding how the consent will be exercised; and
- Engage with parties that have previously submitted on Waituna Opening consent applications. Consultation has not taken place with these parties since the three co-applicants have agreed a memorandum of understanding. Consultation with these parties will be broader – where the focus will be to introduce the application and its purpose, and seek feedback targeted to their interest in the catchment. This will assist in ensuring that parties who have an interest have the opportunity to have their say on the application before it is formally notified, and the application considers and responds to any concerns that may not yet be known.
- Engage early and continuously with the processing planner (ES has advised the processing planner will be an external planning consultant) to coordinate dates, and seek feedback so the application is accepted as complete when lodged and addresses the key matters identified by

the reporting planner.

Consultation Strategy

Notification and Submissions

Given the likely level of public and stakeholder interest in the application, it is the co-applicants request that the application be publicly notified.

Effort should be made to engage with known parties to narrow down and address key issues of contention through consultation and prior to lodgement. This will assist to narrow the scope of submissions in opposition to the remaining key issues of contention, and to encourage submissions in support of the application where issues in contention have been resolved between parties prior to lodgement.

Communications and Messaging

All communications and messaging will be in accordance with the Communications Strategy so that messaging about the application is transparent and consistent.

Website

It is recommended that key information about the application is available publicly as the application is prepared. Letters to stakeholders and general communications and messaging can then direct people to the website where the information is available. This means letters can be simple and targeted.

The website can include information about the proposed transitional regime, the long-term restoration purpose of the application, contact details, key dates, and key documents – e.g. draft conditions for feedback, cultural values assessment, the TAG state of health reports, and linking to the broader work of the Whakamana te Waituna Trust.

The website will be hosted by ES. This will be a separate web page to a general consent page often hosted by the processing council.

Consultation with Parties

Parties to be consulted, their likely interest in the application, and the proposed consultation approach are set out below:

Who	Their Interest	Consultation Approach / Timeframes
ES Resource Consent Team	Ensuring application is complete under the Act, timeframes are achievable, avoid notification over the Christmas period	Early and continued pre-application meetings with processing planner: • First to introduce the Action Plan – confirm technical inputs required and discuss approach to notification and key timeframes-13.10.23 • Last to introduce the draft application and conditions for feedback prior to lodgment – week of 11.12.23
LWCA	Proposed transition levels and timing, LWCA role in TAG, conditions of consent, effects on land use, environmental effects	Continuation of previous engagement. As the key elements of the application will be unchanged from position previously consulted on, engagement will be targeted to: • An update letter on progress – providing a high-level overview of the approach and key timeframes for application and notification and seeking feedback on draft conditions – week of 20.11.23 • Update letter commenting on feedback received and advising on next steps for lodgment and notification – week of 11.12.23
Submitters to LWCA application not otherwise captured Catchment Landowners	Proposed transition levels and timing, LWCA role in TAG, conditions of consent, effects on land use, environmental effects	Letter drop to landowners in the catchment in order to capture those who may not be represented by LWCA. • Advising the purpose of the application, how they can have their say, timeframes to notification, draft conditions – direct them to website to know more – week of- 20.11.23

		• Update letter commenting on feedback received and advising on next steps for lodgment and notification – week of 11.12.23
Federated Farmers	Proposed transition levels and timing, conditions of consent, effects on land use, environmental effects	Same approach to other submitters above, and in the first letter offer the opportunity to meet over teams
Whakamana te Waituna Trust	Proposed transition levels and timing, conditions of consent, environmental effects, alignment with Trust objectives	Engage with Whakamana te Waituna Trust throughout preparation of application (via Nicol Horrell and Gail Thompson) – along with letters at key stages as with other parties above
Ngāi Tahu	Full application, alignment with Ngāi Tahu objectives	Engage with Ngāi Tahu throughout preparation of application (via Sue Corby/Jessica Riddell) – along with letters at key stages as with other parties above
Te Wai Parera Trust	Full application, alignment with Trust objectives	Engage with Te Wai Parera Trust throughout preparation of application (via Gail Thompson) – along with letters at key stages as with other parties above
Southland Conservation Board	Proposed transition levels and timing, environmental effects, alignment with Conservation Board objectives	Same approach to other submitters above, and in the first letter offer the opportunity to meet over teams or in person
Southland Fish and Game Council	Proposed transition levels and timing, environmental effects, effects on fish and sports fish	Similar approach to other submitters above, but target the letter to recognize the recent Environment Court judicial review process regarding the status of the lagoon and application of the National Environmental Standards for Freshwater Management, and in the first letter offer the opportunity to meet over teams or in person.

Royal Forest and Bird	Proposed transition levels and timing, environmental effects	Similar approach to other submitters above, but target the letter to recognize the recent Environment Court judicial review process regarding the status of the lagoon and application of the National Environmental Standards for Freshwater Management, and in the first letter offer the opportunity to meet over teams or in person.
Southland District Council	Proposed transition levels and timing, effects on council infrastructure (e.g. Waghorn bridge)	Same approach to other submitters above, and in the first letter offer the opportunity to meet over teams or in person to discuss how the application relates to SDC plans to replace Waghorn Bridge e.g. (opportunity to time lagoon opening with SDC bridge works?)
Other recreational users or interest groups	Proposed transition levels and timing, effects on recreational values.	Same approach to other submitters above

27 June 2024

Te Rūnanga o Awarua, Department of Conservation Te Papa Awawhai and Environment Southland
C/-o Taylor Planning

Tēnā Koe,

Application for Resource Consent for: Periodic opening of Waituna Lagoon to maintain and restore ecological health and cultural values of the lagoon ecosystem.

Thank you for contacting us regarding an application for resource consent to undertake the above activities.

We understand that the application is seeking the views of Te Rūnanga o Awarua in accordance with obligations arising under s 62 of the Marine and Coastal Area (Takutai Moana) Act 2011 (MACA). Whilst an application for customary marine title across the Ngāi Tahu Takiwā has been made in the name of Te Rūnanga o Ngāi Tahu, it is made on behalf of Ngāi Tahu Whānui and Papatipu Rūnanga. In Murihiku/Southland we have four Papatipu Rūnanga, Awarua, Hokonui, Oraka Aparima and Waihōpai. Papatipu Rūnanga are the tangata whenua in their respective areas throughout the Ngāi Tahu Takiwā.

I have prepared this letter for the kaitiaki Rūnanga whose takiwā includes the site the application is within.

Rūnanga representatives have been involved in the development of the proposal and associated conditions, and the views of the Rūnanga have been incorporated into the application. The Rūnanga accept the proposal outlined in the application received on 25 June 2024.

This reply is specific to the above application and any changes to the application will require further consultation. We trust the information contained within this letter is sufficient; however, should you wish to discuss any aspect further, please do not hesitate to contact me.

I have the authority to sign on behalf of the Rūnanga.

Nāhaku noa nā,

Barry Bragg
Kaiwhakahaere
Te Rūnanga o Awarua

Te Rūnanga o NGĀI TAHU

2 July 2024

Environment Southland
Private Bag 90116
INVERCARGILL 9840

Attention: Lacey Bragg
lacey.bragg@es.govt.nz

Tēnā koe,

Opening of Waituna Lagoon Resource Consent Application

Te Rūnanga o Ngāi Tahu (**Te Rūnanga**) has recently been informed that Te Rūnaka o Awarua, the Department of Conservation and Environment Southland are seeking a letter of support for a resource consent application to periodically open Waituna Lagoon to the sea.

Te Rūnanga is aware that the application is supported by Te Rūnaka o Awarua; one of the 18 Papatipu Rūnanga of Ngāi Tahu Whānui. Te Rūnanga is the statutorily recognised representative body for Ngāi Tahu Whānui "for all purposes"[1]. Notwithstanding this, Te Rūnanga recognises and supports the individual rangatiratanga and mana of Papatipu Rūnanga within their respective takiwā[2]. Therefore, Te Rūnanga supports the role of Te Rūnaka o Awarua as co-applicants and the applications intent to restore the customary relationship between mana whenua and taonga species.

The Ngāi Tahu Claims Settlement Act 1998 acknowledges the mauri of Waituna wetland and the importance of the spiritual relationship between Ngāi Tahu Whānui and the rohe. Te Rūnanga understands that the application falls within the Ngāi Tahu Takiwā and specifically within the recognised takiwā of Te Rūnaka o Awarua.

Accordingly, this letter records our support for Te Rūnanga o Awarua to exercise, as they see fit, their rangatiratanga and rights as mana whenua in the area where the activity is intended to occur.

Ngā mihi,

Jacqui Caine
Group Head, Strategy & Environment

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1 Te Runanga o Ngai Tahu Act 1996, section 15.

2 As set out in the Te Runanga o Ngai Tahu (Declaration of Membership) Order 2001.

Te Rūnanga o Ngāi Tahu
15 Show Place, Addington, Christchurch 8024
PO Box 13-046, Christchurch, New Zealand
Phone + 64 3 366 4344, 0800 KAI TAHU
Email: info@ngaitahu.iwi.nz
Website: www.ngaitahu.iwi.nz

27 June 2024

Te Rūnanga o Awarua, Department of Conservation Te Papa Awawhai and Environment Southland
C/-o Taylor Planning

Tēnā Koe,

Application for Resource Consent for: Periodic opening of Waituna Lagoon to maintain and restore ecological health and cultural values of the lagoon ecosystem.

Thank you for contacting us regarding an application for resource consent to undertake the above activities.

Te Wai Pārera Trust manage land on the edge of the Waituna Lagoon, actively transforming the property into a mahinga kai pā. This has involved the construction of mahinga kai ponds on the land, supported by active native tree planting.

Te Wai Pārera Trust representatives have been actively involved in the development of the proposal to create an opening regime that will maintain and restore ecological and cultural health to the Waituna Lagoon. The Trust considers the management regime proposed for Waituna Lagoon will have a positive contribution towards the goals for the mahinga kai pā. The Trust support the proposal and conditions as outlined in the Resource Consent Application received on 25 June 2024.

I have authority to sign on behalf of Te Wai Pārera Trust.

Nāhaku noa nā

D Whaanga

Dean Whaanga

On behalf of:

Te Wai Pārera Trust

SOUTHLAND CONSERVATION BOARD

TE ROOPU ATAWHAI O MURIHIKU

29 February 2024

Environment Southland, the Director-General of Conservation (D-G) and Te Rūnaka o Awarua (Awarua Rūnaka)

Via email to Jenna Sinclar: jsinclair@doc.govt.nz

Re: Resource Consent Application for the Periodic Opening of the Waituna Lagoon

Tena koe,

The Southland Conservation Board appreciates the opportunity to discuss the proposed consent application to periodically open Waituna Lagoon to the sea. We found our discussions with you on 21 February 2024 both positive and encouraging.

We note the intention of the application to manage and restore the ecological and cultural health of the lagoon, and to transition to a more natural regime by increasing the trigger levels over time. This aligns well with the Murihiku Conservation Management Strategy (Policy 2.8.2). We also note the strong alignment with two of the three SCB's Guiding Principles, specifically the Principle of Preservation and Protection and the Principle of Treaty Partnership.

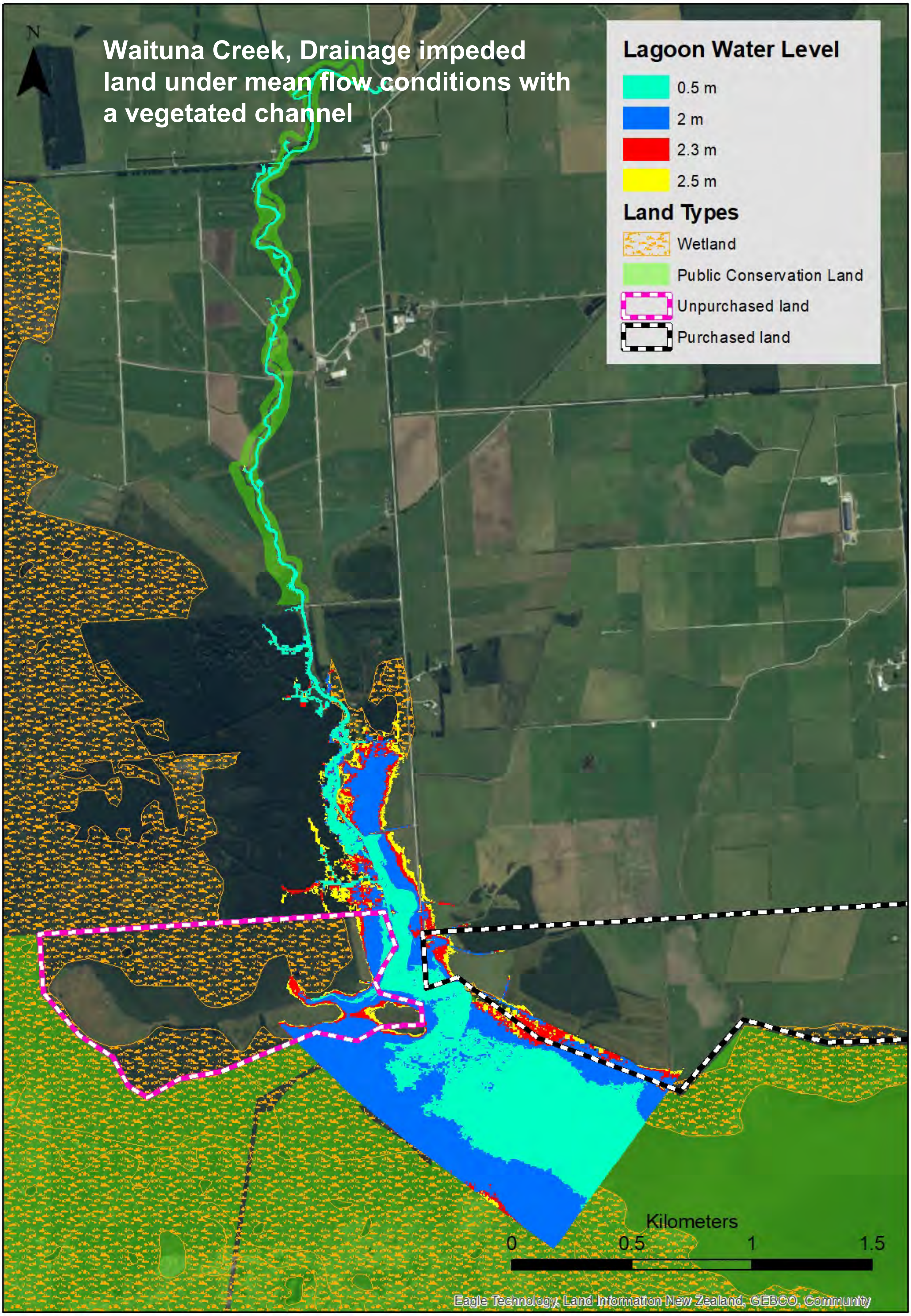
We look forward to engaging further in the next stages of this application.

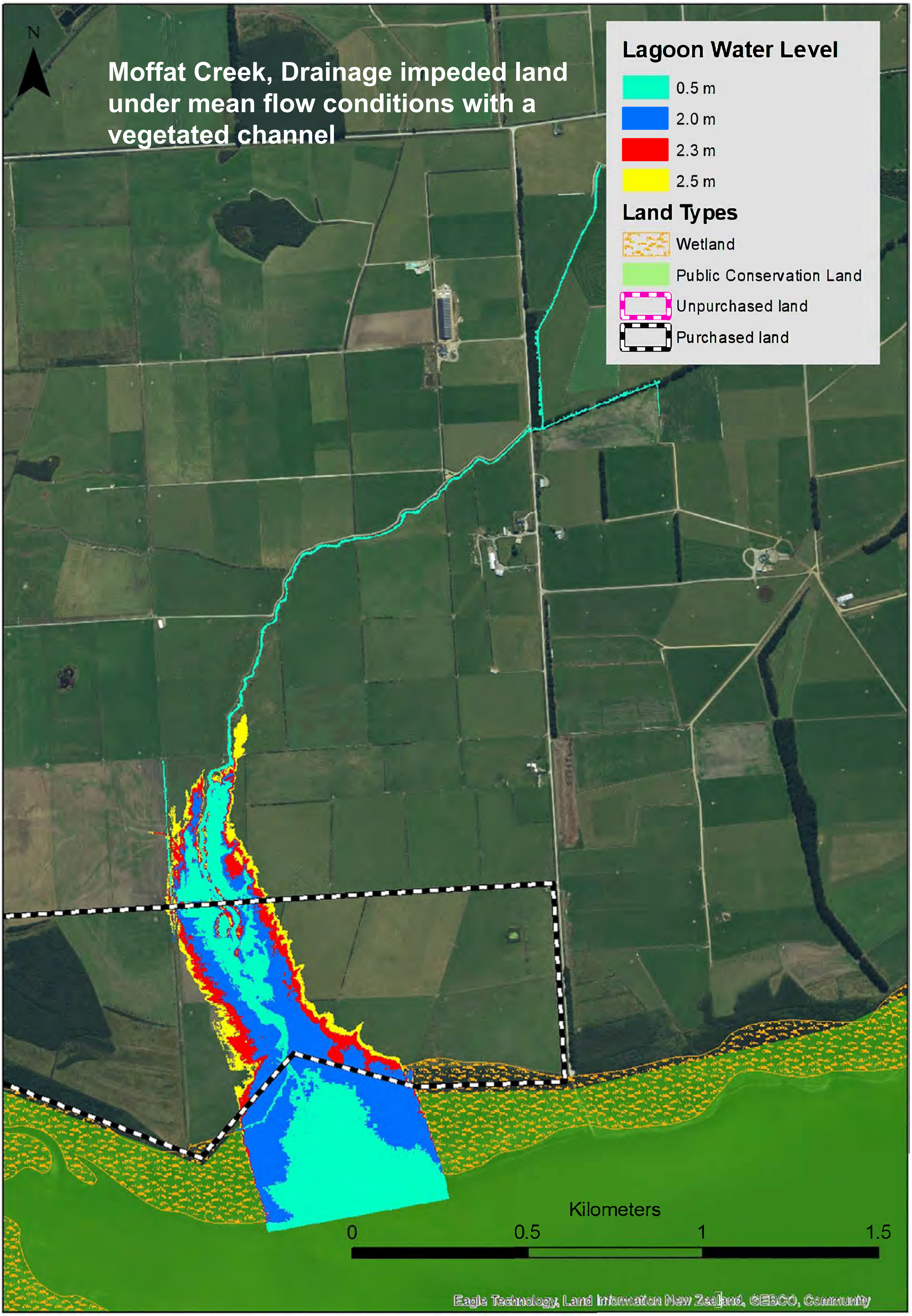
Yours sincerely,

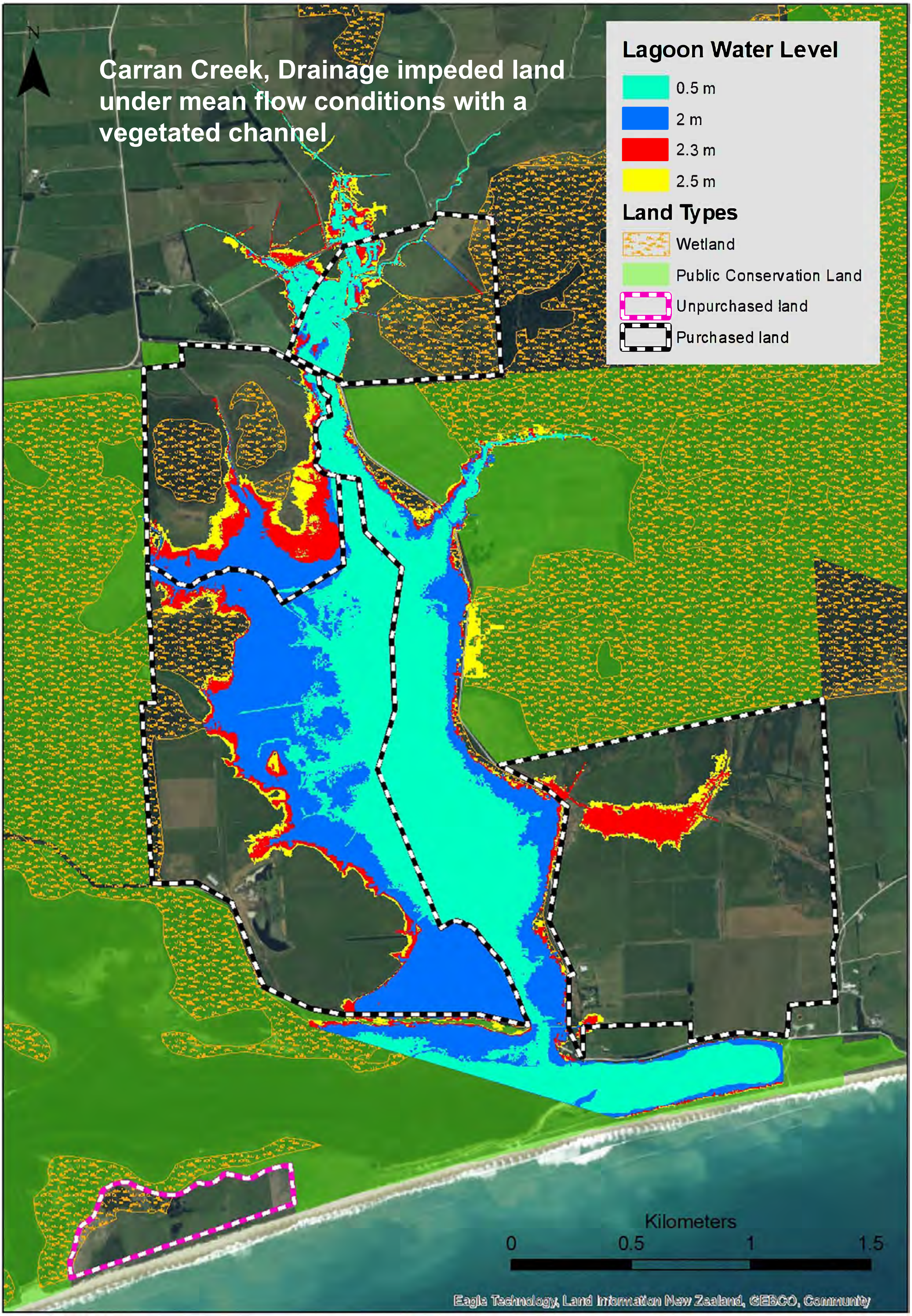
Shona Sangster
Board Chair

Serviced by the Department of Conservation
PO Box 743, Invercargill 9840
33 Don Street, Invercargill, New Zealand
Telephone (03) 211-2400, Email southlandconservationboard@doc.govt.nz

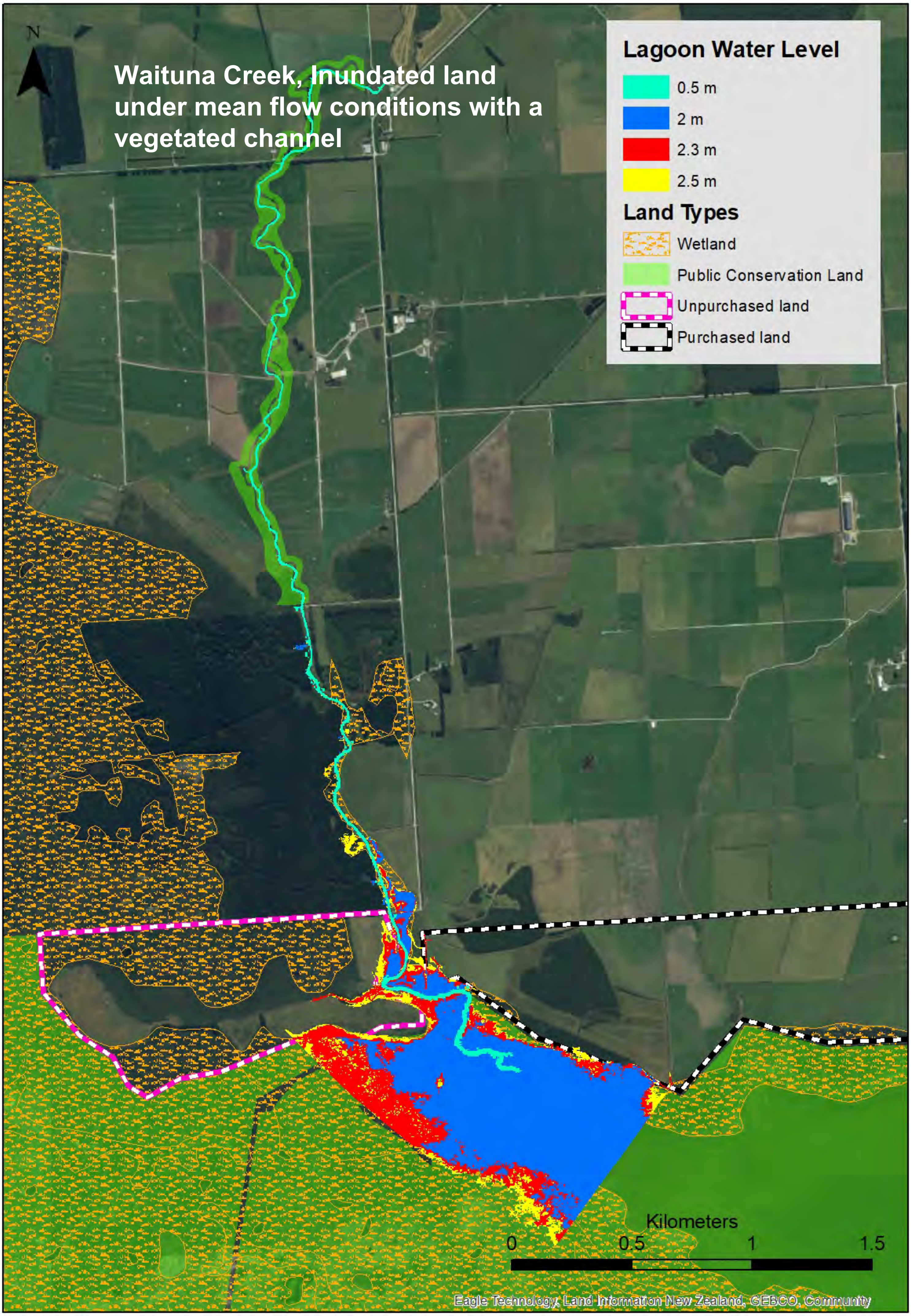
Appendix O: Inundation Maps

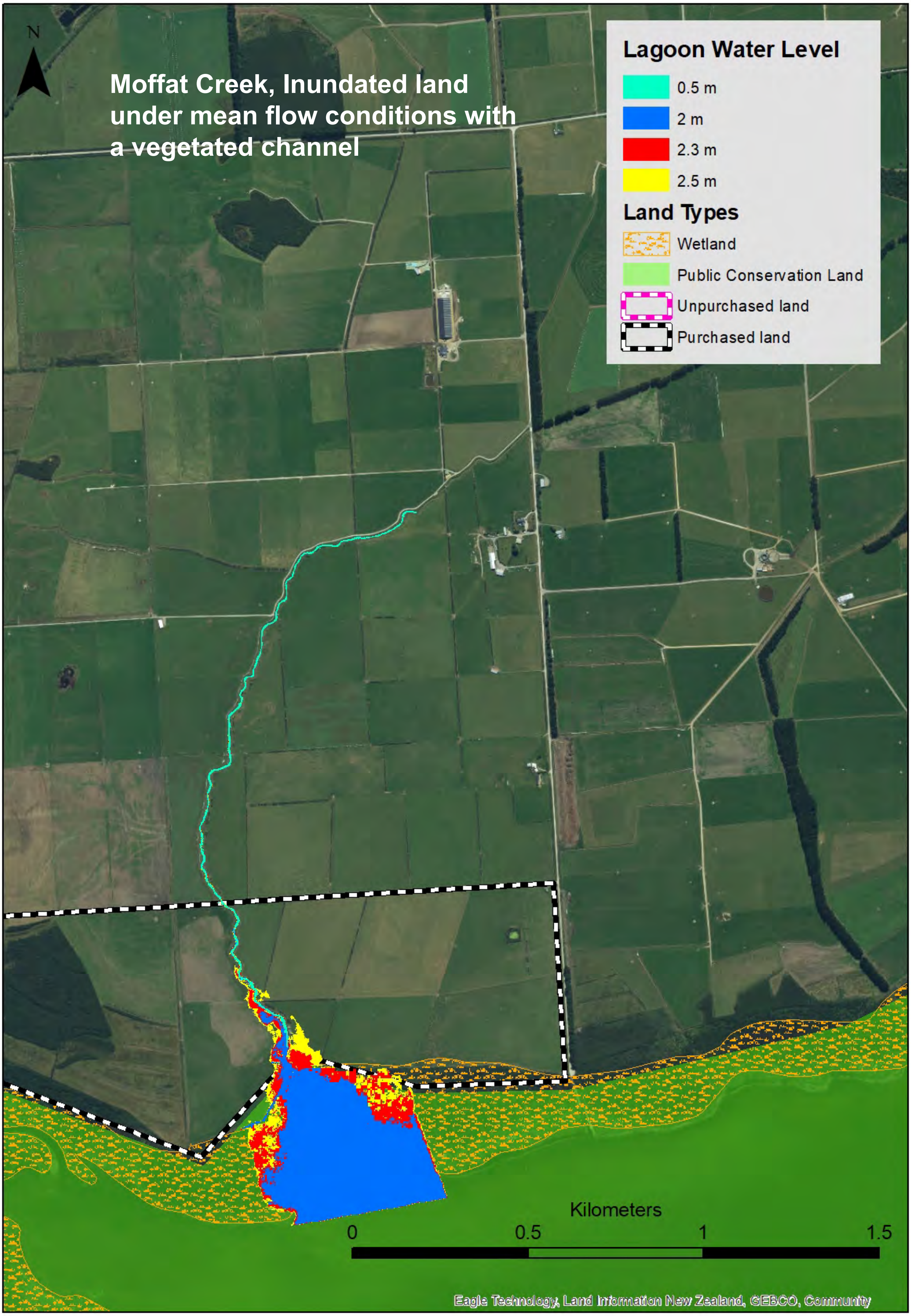

N
Waituna Creek, Drainage impeded land under mean flow conditions with a vegetated channel
Lagoon Water Level
0.5 m
2 m
2.3 m
2.5 m
Land Types
Wetland
Public Conservation Land
Unpurchased land
Purchased land
Kilometers
0
0.5
1
1.5
Eagle Technology, Land Information New Zealand, GEBCO, Community


N
Moffat Creek, Drainage impeded land under mean flow conditions with a vegetated channel
Lagoon Water Level
0.5 m
2.0 m
2.3 m
2.5 m
Land Types
Wetland
Public Conservation Land
Unpurchased land
Purchased land
Kilometers
0
0.5
1
1.5
Eagle Technology, Land Information New Zealand, GEBCO, Community



N
Carran Creek, Drainage impeded land under mean flow conditions with a vegetated channel
Lagoon Water Level
0.5 m
2 m
2.3 m
2.5 m
Land Types
Wetland
Public Conservation Land
Unpurchased land
Purchased land
Kilometers
0
0.5
1
1.5
Eagle Technology, Land Information New Zealand, GEBCO, Community


N
Waituna Creek, Inundated land under mean flow conditions with a vegetated channel
Lagoon Water Level
0.5 m
2 m
2.3 m
2.5 m
Land Types
Wetland
Public Conservation Land
Unpurchased land
Purchased land
Kilometers
0
0.5
1
1.5
Eagle Technology, Land Information New Zealand, GEBCO, Community



Moffat Creek, Inundated land under mean flow conditions with a vegetated channel
N
Lagoon Water Level
0.5 m
2 m
2.3 m
2.5 m
Land Types
Wetland
Public Conservation Land
Unpurchased land
Purchased land
Kilometers
0
0.5
1
1.5
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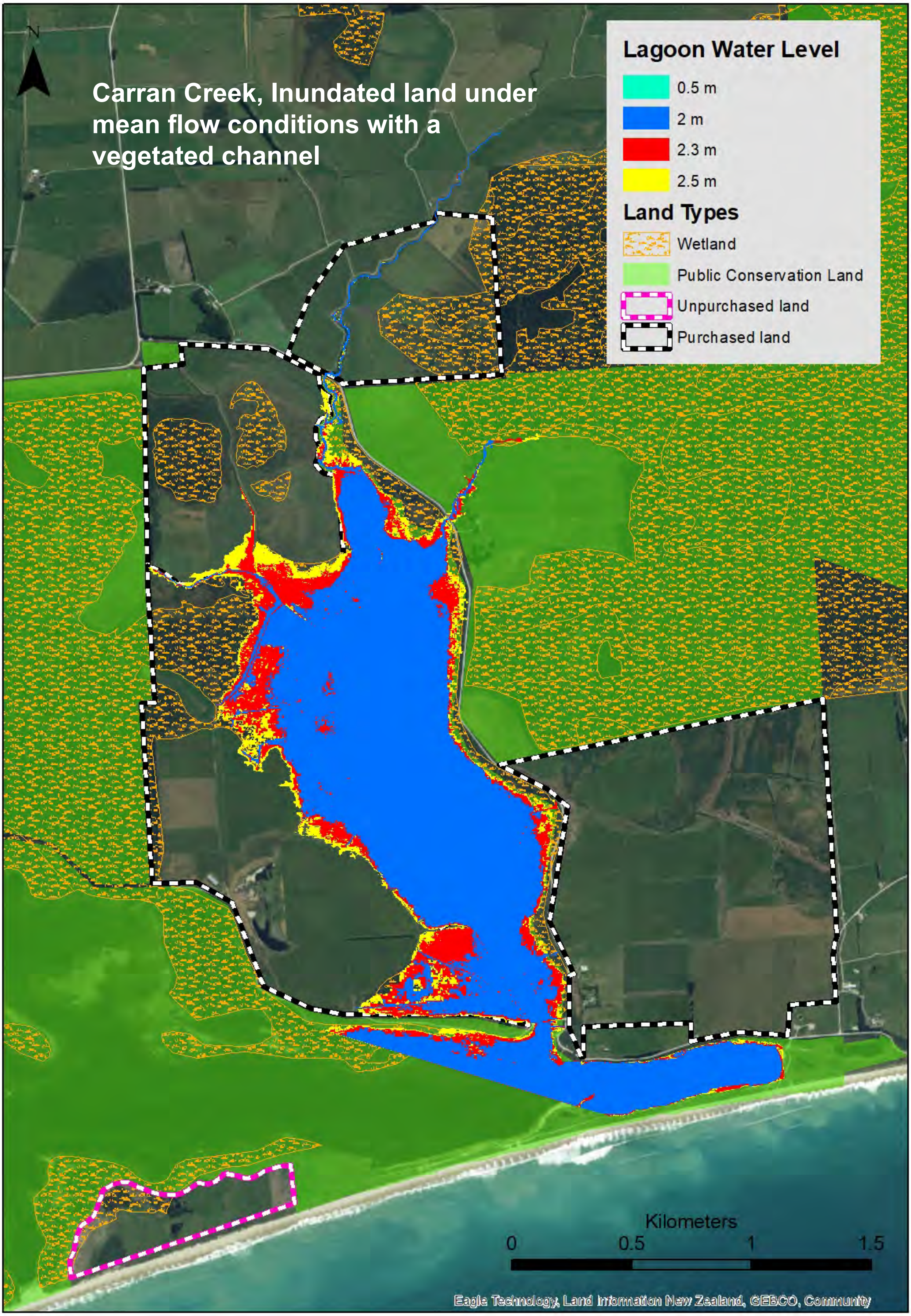

N
Carran Creek, Inundated land under mean flow conditions with a vegetated channel
Lagoon Water Level
0.5 m
2 m
2.3 m
2.5 m
Land Types
Wetland
Public Conservation Land
Unpurchased land
Purchased land
Kilometers
0
0.5
1
1.5
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