Improving the Ecological Character of Moulting Lagoon and Apsley Marshes:

Long Point and The Grange Hydrological Restoration Plan

Report to NRM South

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23rd February 2022

This report may be referenced as follows:

Sheldon, R., Bachmann, M., Taylor, B. and Farrington, L. (2022) Improving the Ecological Character of Moulting Lagoon and Apsley Marshes: Long Point and The Grange Hydrological Restoration Plan. A report to NRM South. Nature Glenelg Trust, Hobart, Tasmania.

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Cover photo

Long Point, Mark Bachmann.

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1. Introduction

Nature Glenelg Trust (NGT) have been engaged by NRM South to undertake an independent eco-hydrological assessment of the Moulting Lagoon and Apsley Marshes Ramsar sites (**Figure 1**). The eco-hydrological assessment is part of the Regional Land Partnerships (RLP) project *Improving the ecological character of Moulting Lagoon and Apsley Marshes Ramsar sites*, which also involves weed control, livestock exclusion and revegetation within and adjacent to the Ramsar sites.

Ecology and hydrology are often assessed separately or at a single point in time, which can be detrimental for making sound, informed decisions about wetland restoration and management. Eco-hydrological assessment involves reviewing the ecology and hydrology of a site, the interrelationships between them and how they have changed through time to arrive at their present status. Eco-hydrological assessment can involve the collation and review of existing information, the collection of new data or both.

Key questions to be progressively investigated during the three-year project (July 2020 – June 2023) include:

- *Using historic sources of information, what can we say about how these wetland complexes have changed over the past 220 years – i.e., can we more accurately define their original condition, water regime and biodiversity values?*
- *Based on more recent information sources, and by documenting the modifications made to the sites and/or their catchments, what is the current "baseline" condition and values of the Ramsar sites?*
- *What additional information do we need to collect today (both biological / hydrological), to help improve our confidence in our understanding of trends in site condition / values?*
- *By analysing past modifications and any trends, are there positive improvements to water regime, site drainage and/or management that could be made in the future, within or surrounding both Ramsar sites, to improve condition and biodiversity values of the wetland complex?*
- *If future positive changes are technically feasible, can they be progressed in a way that is acceptable and/or mutually beneficial to landowners and the environment?*

1.1. Project Scope

An independent eco-hydrological assessment led by NGT is underway at both the Apsley Marshes Ramsar site and at properties adjacent the Moulting Lagoon Ramsar site, where changes to hydrology have occurred. To this end, two properties which have been extensively modified by drainage works, and are significantly involved in the broader RLP project, are Long Point and The Grange (**Figure 2**). The RLP project includes funds to undertake recommended hydrological restoration works at these two sites, whereas the project provides only for the initial eco-hydrological assessment of, and restoration planning for, the Apsley Marshes. If recommended and appropriate, restoration works funding for that site will be sourced via another means in the future.

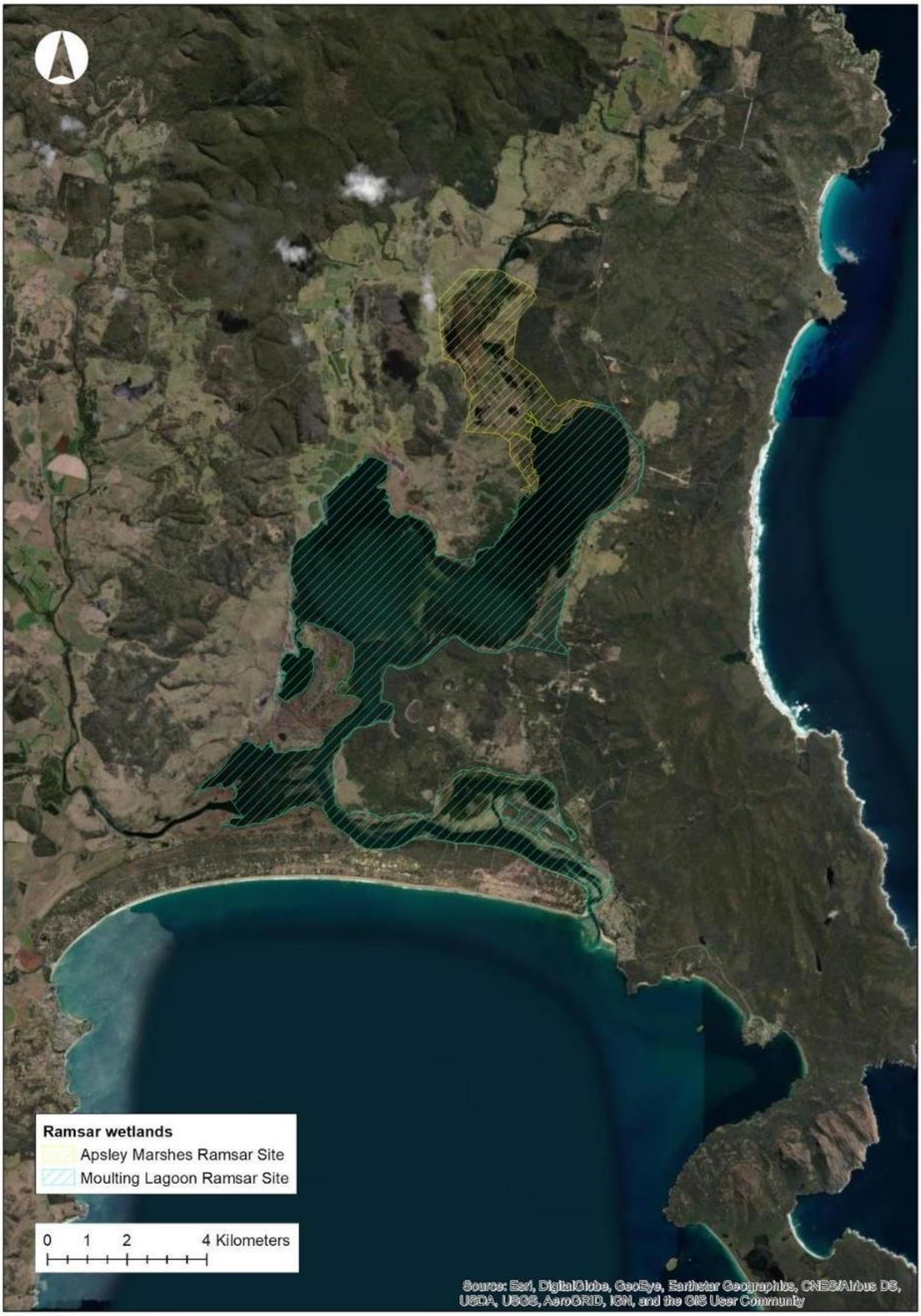


Figure 1: Overview of Moulting Lagoon and Apsley Marshes Ramsar sites.

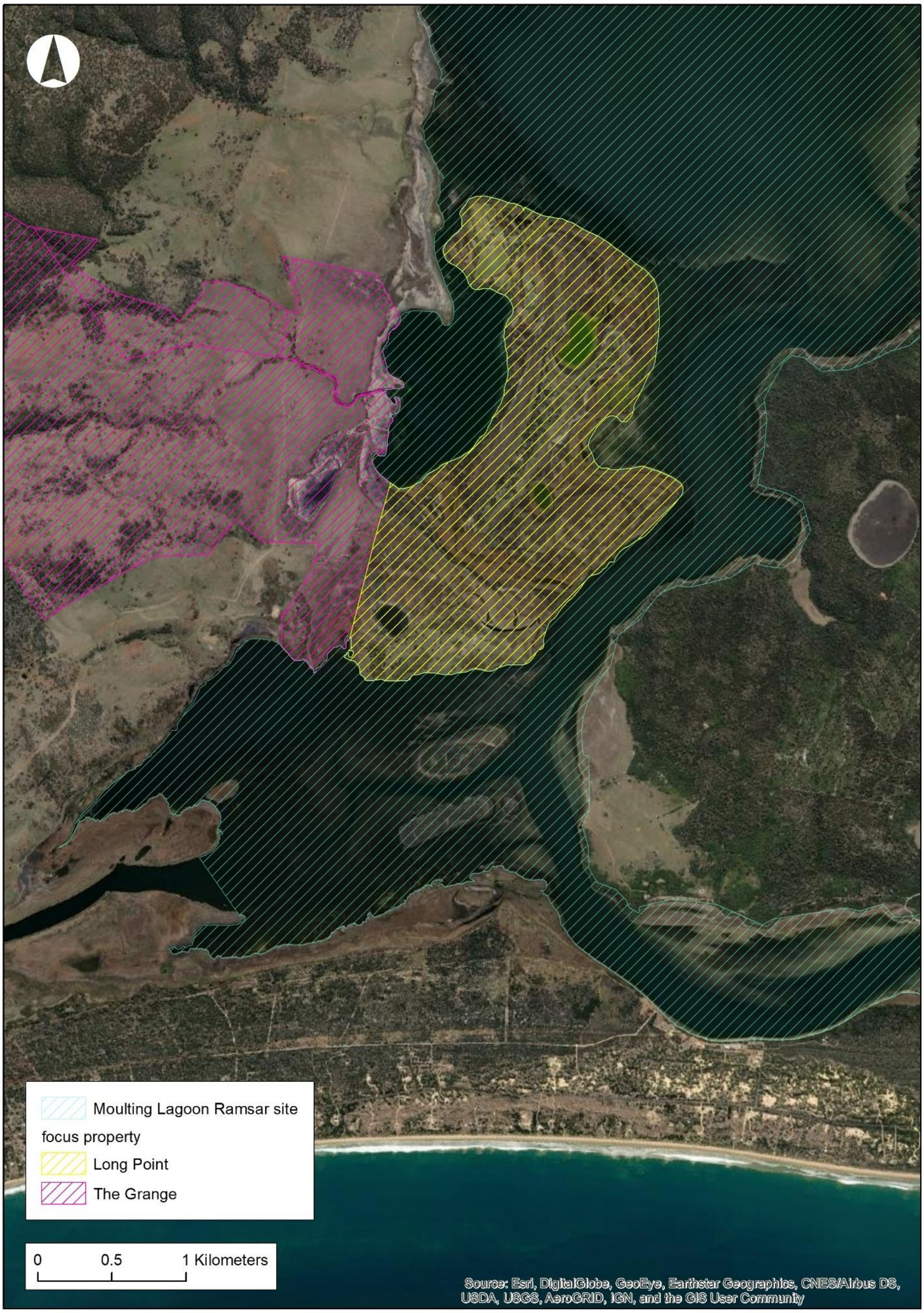


Figure 2: Location of The Grange and Long Point properties adjoining Moulting Lagoon Ramsar site.

1.2. Project Objectives

In relation to the hydrological restoration of wetlands and saline vegetation communities on The Grange and Long Point properties, the Monitoring, Evaluation, Reporting and Improvement (MERI) Plan for the RLP project includes the following project outcome:

- By 30 June 2023, the conditions to support saltmarsh and wetland vegetation extent and cover on five major landholdings adjacent to the Moulting Lagoon Ramsar Site (4 landholdings) and Apsley Marshes Ramsar Site (1 landholding), are demonstrably improved against baseline levels. This will be evidenced by the reinstatement of natural hydrology across 64 ha (of 554 ha) affected by altered drainage at Long Point Reserve and The Grange, within the Moulting Lagoon Ramsar Site (representing a 11.5 % improvement from pre-project levels).

More specifically, project service and output targets include to:

- **Improve hydrological regimes** - four earthwork treatments, covering approximately 64 ha of saltmarsh (infilling of human-made channels and ponds and removing levees) to restore natural drainage to existing and potential saltmarsh areas (38 ha Long Point, 26 ha The Grange).
- **Establish and maintain monitoring regimes** - 16 days in total to fill data gaps and provide baseline information ahead of future works.

This Restoration Plan describes the eco-hydrological assessment and how the above project outcomes and outputs were/will be achieved at The Grange and Long Point properties.

2. Site History Assessment

2.1. Site Description and Land Use History

The locations of The Grange and Long Point properties are shown in **Figure 2**. The Grange property is bordered by Cranbrook Estate in the north, The Bend property in the south and Little Bay and Long Point in the east. Land use on The Grange is primary production, mostly sheep grazing, with some areas set aside for conservation. An area in the far east of The Grange, including the waterbody known as Yards Hole, has recently been fenced to exclude grazing and to be managed for conservation henceforth, as part of the broader RLP project.

Long Point Reserve is a 386.5 ha low-lying peninsula located east of The Grange at the south-western corner of Moulting Lagoon, approximately 9km north-east of Swansea. Long Point has been owned and managed as a protected area for nature conservation under a covenant and Nature Conservation Plan (NCP) by the Tasmanian Land Conservancy (TLC) since 2005 (TLC 2008). Prior to that date, Long Point was part of the neighbouring pastoral property The Grange, then owned by the Cotton family. Long Point was grazed by sheep from the early-mid 1800s until purchase by the TLC. The site has been destocked for approximately 15 years to allow recovery of saltmarsh vegetation and associated environmental values.

The Grange (including TLC's Long Point property) has a long pastoral grazing history, dating back to the early 1800s, as well as an extensive phase when black wattle bark was harvested for the Swansea bark mill in the late 1800s, through until the 1930s.

A map dated July 1854, indicates that The Grange was initially claimed by, and later granted by the Colonial Government to, Walter Bethune and Thomas Gellibrand, as shown in Figure 3.

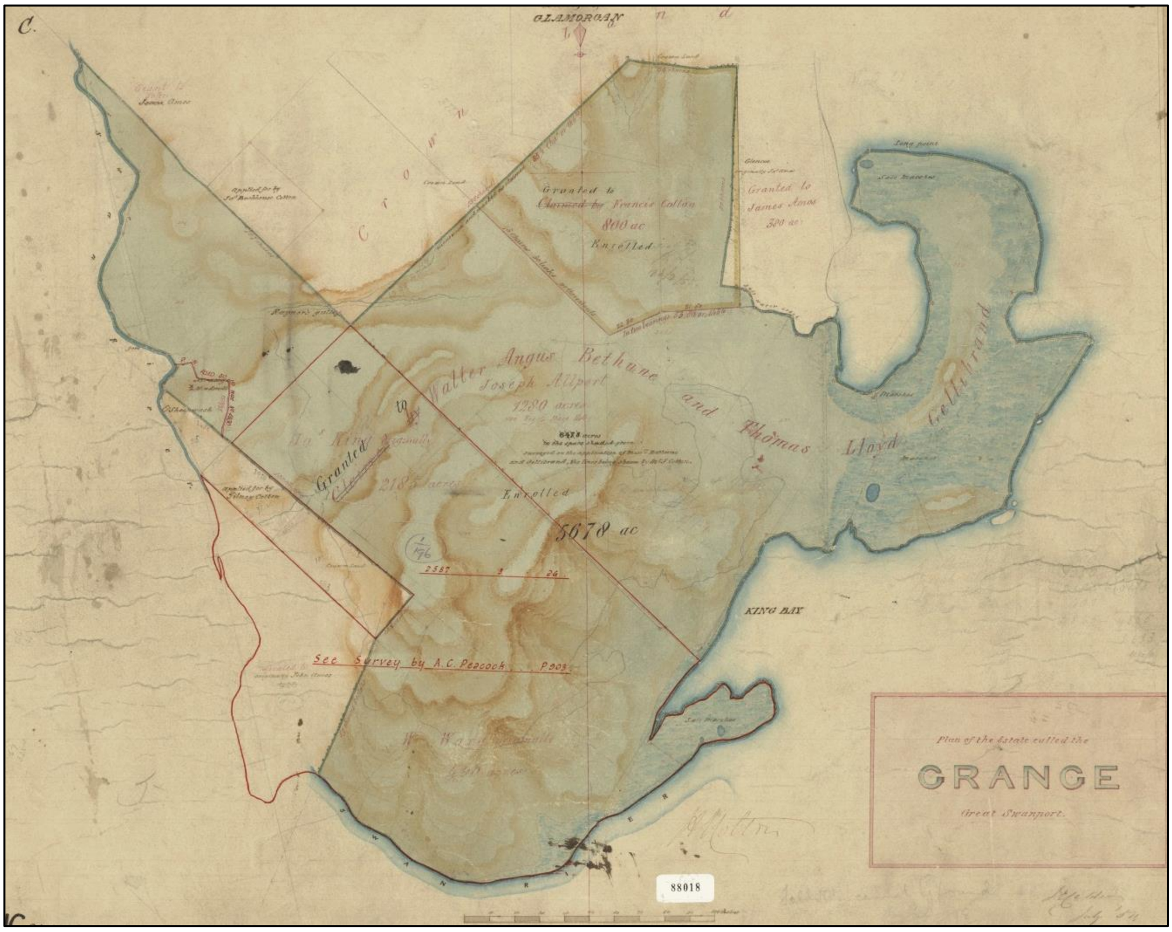


Figure 3: Original survey plan of The Grange, dated 1854, showing the large saltmarsh area on what is now the TLC Long Point Reserve.

From our research and all indications so far, it is most probable that this is the broad era (i.e. the mid-1800s) when the first phase of earthworks occurred on the property utilising convict labour, with a levee bank system constructed around the margins of Long Point. These works are clearly apparent on the first aerial imagery from 1948, as shown in **Figure 4**.

Figure 4: Long Point in 1948 (right), with the 1800s era system of levee banks highlighted.

The second era of major earthworks on and around Long Point occurred much later, during the 1990s, when The Grange was owned by the Cotton family. It was at this time that new earthworks in the saltmarsh areas were undertaken by 'Zootech Research', a company founded by Mr Ben Quin to try to develop techniques for industrial production of zooplankton as a replacement for wild harvested fishmeal in aquaculture feeds (pers. comm. Jim Mulcahy, 4th Feb 2022). In a related endeavour during the same period, Zootech Research were also involved in the design and development of new technology, a watercraft called the Baleen Zooplankton Harvester (**Figure 5**), which sought to mimic the plankton-feeding action of baleen whales, mechanically harvesting plankton from sheltered waters like Moulting Lagoon (Anderson 1992).

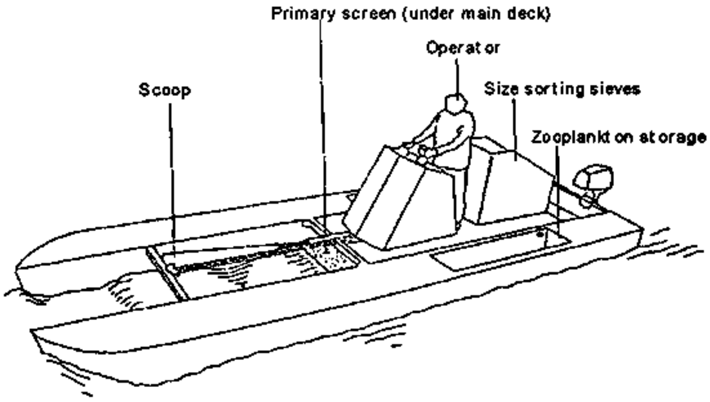


Figure 5: Sketch of a vessel similar to a Baleen Zooplankton Harvester (sourced from: https://www.fao.org/3/w3732e/w3732e0s.htm)

As a means of generating an income stream for research and to demonstrate techniques, Zootech Research was trying to culture Tasmanian whitebait in a series of artificially constructed or enhanced 'ponds' adjacent to Moulting Lagoon. The interest in whitebait was that the species consumes plankton throughout its life and is commercially valuable, but the wild fishery is considered unsustainable. During this trial phase for the experimental development of methods for zooplankton and whitebait growth and/or harvesting, Zootech Research had partnerships with several farmers on the east coast, including John Cotton at The Grange and Crispin Cotton at Lisdillon (pers. comm. Jim Mulcahy, 4th Feb 2022).

Jim Mulcahy, who worked for Zootech Research from 1991-1997, shared his understanding of the conceptual design for the works on The Grange and Long Point (in correspondence on 4th Feb 2022). Jim noted that construction activities at Yards Hole (The Grange) occurred a short time before he started with the organisation, but he was aware of the broad objectives of these c.1991 earthworks, as per **Figure 6**, which were to:

- construct a moat around the perimeter of the hole,
- use the spoil to create a wall and increase the capacity of the hole,
- introduce whitebait larvae to the hole,
- manage the moat for zooplankton production,
- regularly pump food directly over the wall to the fish, and
- also provide food with plankton harvested from Moulting Lagoon using the Baleen Zooplankton Harvester.

Figure 6: Yards Hole at The Grange, right, in its present modified condition as a result of the works undertaken in c.1991.

Jim also recalled that the later nearby works conducted to the north of Barkstand Point (**Figure 7**) had similar objectives, which were to:

- create a channel incorporating a larger 'pond', providing tidal water flow from east to west and linking several existing 'holes' in the saltmarsh,
- introduce fish larvae to the holes and ponds,
- manage parts of the system for plankton production,
- regularly pump food directly from the plankton ponds to the fish ponds, and
- also provide feed with plankton harvested from Moulting Lagoon using the Baleen Zooplankton Harvester.

Figure 7: Opening Hole, Barkstand channel and associated artificial drainage features at Long Point, in present modified condition as a result of the works undertaken in c.1991.

The works were completed using a large excavator and were perilous during wet conditions - at one point the excavator sank halfway up the cab and another machine had to be brought in to recover it. Large PVC pipes were used to connect the different parts of the system and Jim recalled some form of one-way valve was used along the main drain to prevent west-east flow. Hydraulically, the system performed as designed, but as for Yards Hole, to the best of his knowledge no fish larvae were ever introduced to the system (pers. comm. Jim Mulcahy, 4th Feb 2022).

In summary, these works have had the effect of increasing the regularity of flows and connectivity between Opening Hole, Barkstand channel and Moulting Lagoon, wetland features which were formerly more isolated from each other across a wider range of potential hydrological conditions. Prior to the 1990s, the natural surface level of the intervening areas (which consists of slightly higher elevation saltmarsh) was originally responsible for regulating the degree of connectivity of the natural waterbodies under different conditions; i.e. filling and flows would depend on water levels achieved either during high tidal events or floods that are driven by catchment inflows, or indeed the combination of both.

Beyond the major earthworks of the early 1990s in the saltmarsh, one final and further modification to drainage has been detected north of Round Hole, between a small open saline wetland (surrounded by saltmarsh) and Moulting Lagoon. This is described in the following section, and is shown in **Figure 10**.

2.2. Timeline and Summary of Hydrological Modifications

As previously described, there have been three distinct periods of physical works impacting the hydrology of The Grange and Long Point properties, as shown in **Figure 11**.

In summary, they are:

- Pre-1948 (**Figure 11**, yellow lines):
    - Levee banks on Long Point were likely constructed in the mid-1800s with the use of convict labour, having a primary intent of restricting tidal ingress into 80 hectares of low-lying land situated behind the banks.
    - The intention appears to have been to encourage changes to the saltmarsh vegetation (via drying and freshening) that would improve its pastoral value for grazing livestock (**Figure 8**).
    - In places, these levees have now been breached, deliberately or otherwise (e.g. as a result of floods), and they are likely less effectively influencing hydrology than was originally the case.
    - Section 4 describes monitoring undertaken to determine the hydrological effects of the levees in their current state.

Figure 8: Looking south-east along the northern branch of the eastern levee bank c.1800s. The area to the right is the zone that it appears was intended to benefit from reduced tidal or flood ingress.

- Between 1970 and 1993 (**Figure 11**, orange lines):
    - A series of channels, banks, and ponds were constructed by the previous owner on both properties in an unsuccessful attempt to establish a whitebait aquaculture enterprise by linking those works with pre-exiting natural features (such as channels and lagoons).
    - At Long Point, this sought to create artificial tidal flows between Barkstand Point and King Bay, via constructed channels (**Figure 9**).
    - The Barkstand channel is expected to flow both ways dependent on tidal flows and lag times (equalisation of tides from both ends), however it can be regulated at the eastern end.
    - Natural drainage areas were deepened, impounded and linked to the channel via pipes, including Opening Hole.
    - Similar, associated works of the same general intent (i.e. for aquaculture) also occurred at Yards Hole nearby on The Grange.
    - Subsequent investigation of Landsat satellite imagery confirms that these works were completed around 1990.

Figure 9: Some of the drainage and whitebait pond works completed c. 1990.

- Between 1993 and 2010 (**Figure 11**, purple line):
    - A minor cutting was made in the small bay south-east of Long Point proper, to connect a small wetland within the saltmarsh to the main Moulting Lagoon waterbody, possibly by duck hunters to improve watercraft access.
    - This feature likely dates from the mid to late 1990s, does not have an obvious spoil bank adjacent to the cutting, and is not thought to significantly influence site hydrology (**Figure 10**).

Figure 10: The small channel on the edge of Moulting Lagoon into a wetland on Long Point c. mid-1990s. Note that this image is looking south-west, with a portion of the main eastern (L-shaped) levee in the background.

Figure 11: Modern aerial image of Long Point, showing the date when artificial drains first appeared in the aerial photographic record.

3. Eco-hydrology Assessment

3.1. Climate

The climate at Cranbrook, nearby to Long Point and The Grange, is temperate maritime. Temperatures range from an average 22 °C in summer to 14 °C in winter. Average annual rainfall is approximately 630 mm; however annual rainfall can range widely from 300 mm to 1100 mm, with episodic larger rainfall events playing a role in this variability. There is no apparent seasonality to rainfall, with slight peaks in autumn and spring, when changeable weather patterns bring easterly winds (**Figure 12**).

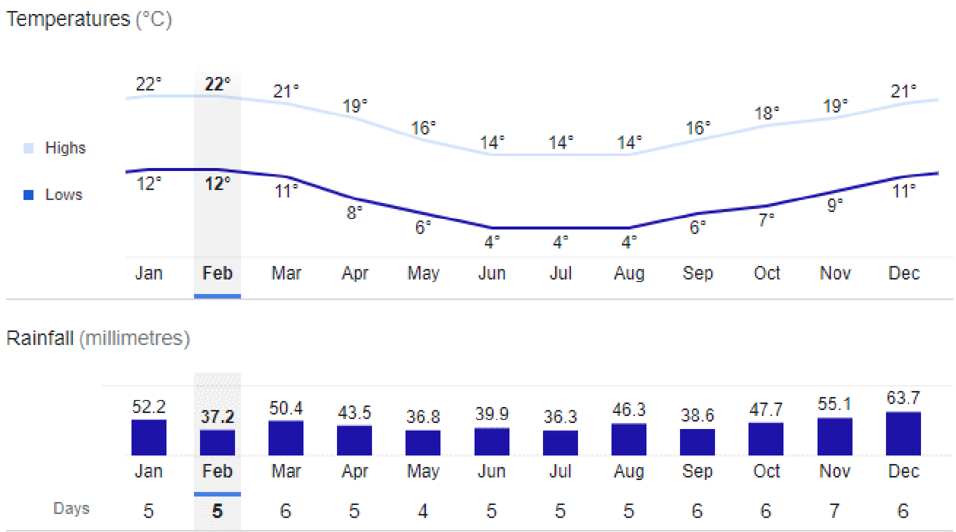


Figure 12: Average monthly rainfall and temperature for Cranbrook, Tasmania. Source: National Centers for Environmental Information (NCEI) (noaa.gov).

Annual rainfall is highly variable and the residual mass curve (i.e., deviation from mean annual rainfall over time) indicates a consistent period of below average rainfall experienced since the 1990s, following a wet period experienced in the 1970-80s. An especially dry period was recorded between 1997 and 2010 (**Figure 13**).

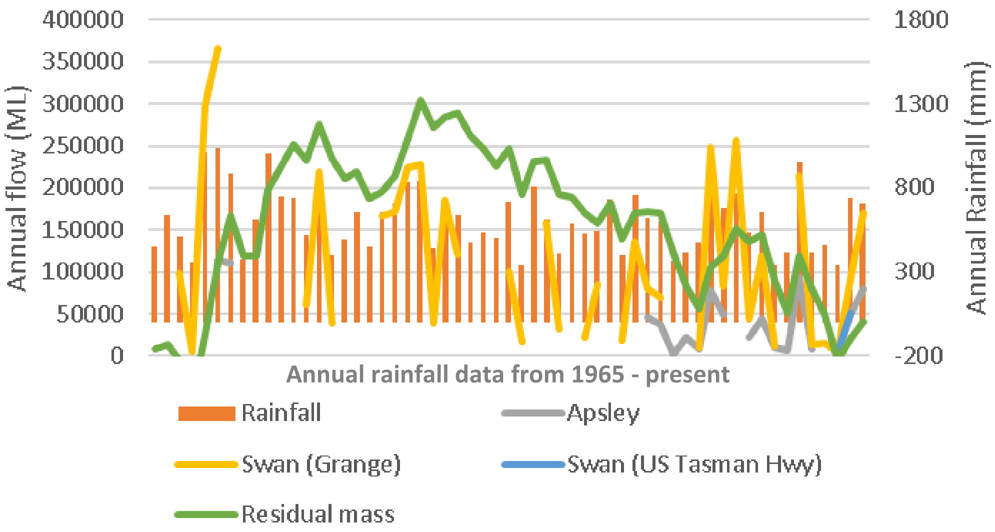


Figure 13: Annual rainfall and residual mass curve. Episodic inflows from the Swan and Apsley Rivers are also shown.

3.1.1. Climate change

There is evidence of an increase in average temperature for Swansea and a pattern of shifting wind direction generating more westerlies that erode the shoreline and increase evaporation. The area has suffered declining annual rainfall in recent decades (**Figure 13**), causing lower flows in the rivers, while demand for water access for irrigation and town water supply have increased. Despite this recent trend, an increase in annual rainfall is projected in coastal areas until 2100, but will vary seasonally. Average rainfall is projected to increase in autumn and summer (up to 10%) and decrease in spring and winter (up to 5%). Changes in rainfall are linked to an increase in projected mean annual runoff, with a substantial increase in summer (up to 30%) and autumn (>60%) linked to an increase in extreme, episodic rainfall events. According to the climate models, overall river flows may increase 10-15 % on the east coast (Grose *et al*. 2012).

Tasmania is projected to experience a rise in average temperatures of 2.6 to 3.3°C by 2100. Swansea is likely to experience an increase in summer days (>25 °C) from 17 to 44 per year and a decline in frost-risk days from a current 9 days per year to less than 1 day per year (Grose *et al*. 2012).

Sea level has been rising at a rate of 3.3 ±0.4 mm/year in the recent period and is expected to continue. A rise of 0.82 m global average sea level by 2100 is expected under a high emissions scenario (**Figure 14**).

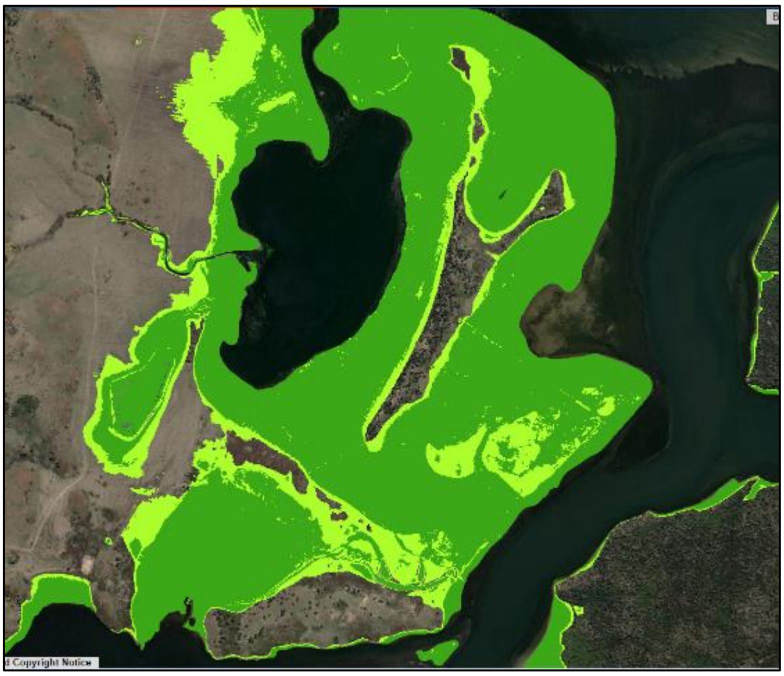


Figure 14: Projected sea level rise (dark green to 2050, light green to 2100. Source: [LISTmap - Land Information System Tasmania (thelist.tas.gov.au)](https://www.thelist.tas.gov.au).

Projections indicate that effects from changes to storm surges are likely to be negligible compared to that of underlying sea level rise. The sum of all effects means that a present 100-year event is projected to be a 2 to 6 year event in many places (Grose *et al*. 2012).

Sea level rise poses a potential threat to the listed ecological character of the Ramsar site, which is based on conditions at the time of assessment. Long Point's Tertiary sediment shorelines and low-lying saltmarsh make it one of the more sensitive coastal landforms in Tasmania (DTAE 2007). Sea level rise will cause salt water to penetrate further into, and more regularly inundate, Long Point, which will have significant impacts on saltmarsh communities and their distribution. The retreat (i.e. upslope movement) of lower marsh vegetation into areas previously occupied by upper marsh vegetation is already evident in some locations (Prahalad *et al* 2012).

3.2. Hydrology

Whilst Moulting Lagoon has a catchment of over 1,000 km^2 and has substantial freshwater inflows from the likes of the Swan and Apsley Rivers among others, there are no significant natural waterways discharging directly into the areas of interest on The Grange or Long Point properties. Thus, the following sections focus on the underlying wetland hydrology and tidal regime influencing the site as a result of its connection with Moulting Lagoon.

3.2.1. Wetland Water Regime

What is the water regime of the target wetlands?

The Water Observations from Space (WOfS) summary image of the entire LandSat satellite imagery record from 1986 to present is presented in **Figure 15**.

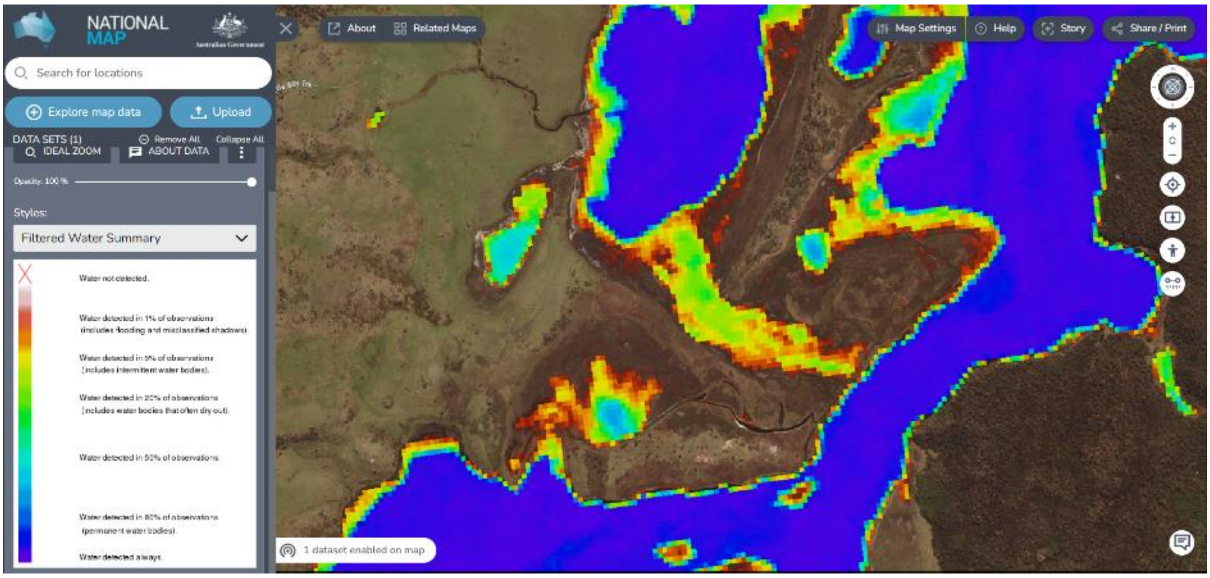


Figure 15: Water observations for Long Point and Yards Hole, based on LandSat satellite observations from 1986 – present. Source: Water Observation from Space (WOfS) national map (https://nationalmap.gov.au/).

This image indicates that Yards Hole, Opening Hole and Round Hole are ephemeral and occasionally dry in warm periods and dry years. The floodway across Long Point between the southern end of Little Bay and Moulting Lagoon is frequently inundated, but seasonal in nature. Gum Tree Hole to the north is more permanently inundated. The hydrological connection of Round Hole and Opening Hole to adjacent tidal areas is evident and would likely occur in flood and high tide events. The connection of Yards Hole to Little Bay is less evident but has likely increased since the aquaculture works were undertaken in the 1990s.

Has inundation or the water regime changed over time?

Figure 16 examines any significant change in water occurrence since 1984. This indicates that the water regime has been stable between the periods 1984-1999 as compared with 2000-2020 for the three wetlands of interest. Although the resolution of data is coarse, the margins of Yards Hole and Gum Tree Hole have possibly increased in inundation frequency (higher water levels), a trend that does not appear to have been detected at Round Hole and Opening Hole.

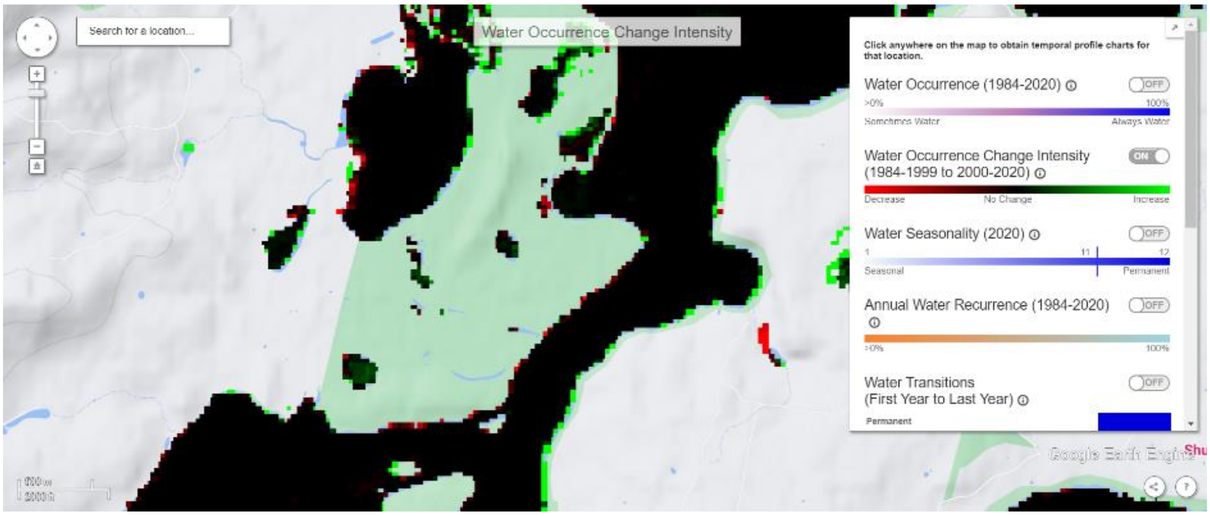


Figure 16: Water occurrence change intensity for Long Pint and Yards Hole. Source: Global Surface Water Mapper (https://global-surface-water.appspot.com/map).

Figure 17 indicates transitions in water regime observed between 1984 and 2020. This image suggests that in contrast to **Figure 16**, Round Hole and Opening Hole have become slightly more seasonal and less permanent over the past 3-4 decades (reduced frequency of inundation). The northern end of Yards Hole follows this trend, but the southern end has become more permanent. The shallow areas of adjacent Moulting Lagoon, including the bay northeast of Round Hole, indicate that more of the lagoon bed has become permanently inundated since 1986.

Although the aerial imagery does not explicitly show a change in shoreline, an increase in inundation of low-lying areas connected to the lagoon is observable over time, with evidence in erosion and vegetation change in many areas around the margin of the lagoon.

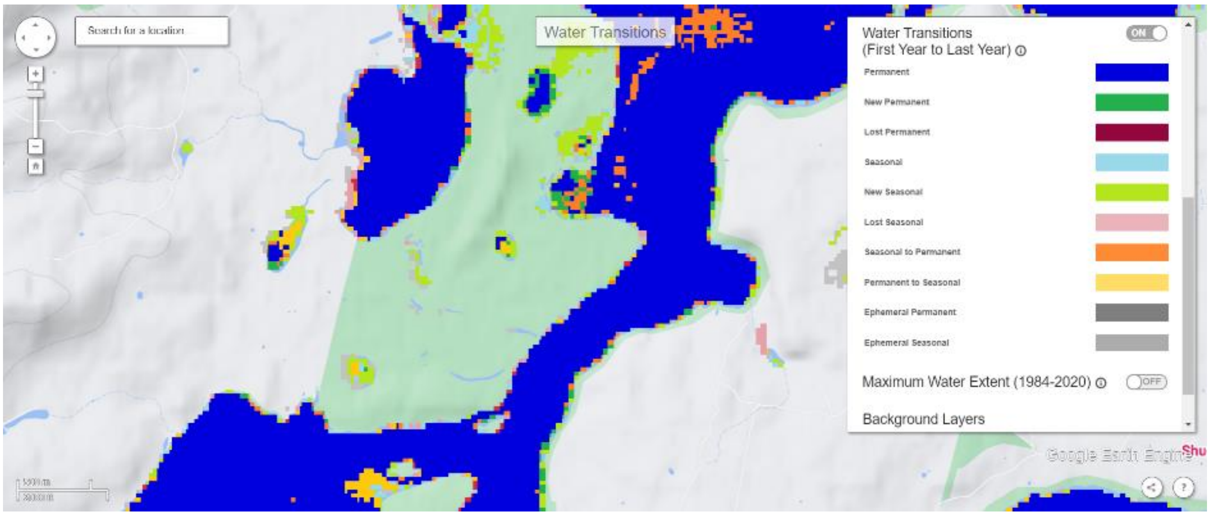


Figure 17: Water transitions 1984 – 2020 for Long Point and Yards Hole. Source: Global Surface Water Mapper (https://global-surface-water.appspot.com/map).

3.2.2. Tidal Regime

The tidal range experienced within the lagoon varies from 0.8 m at the mouth to 0.3 m in its upper reaches but can also be heavily influenced by wind strength, wind direction and barometric pressure. The tidal peak in the lagoon takes several hours to reach (is delayed), is short-lived and recedes quickly. Salinity varies considerably with climatic conditions and flow of the rivers, being generally higher in dry seasons and lower during wet phases which drive catchment inflows of fresher water. During hot and dry weather, evaporation can create salinity levels more than twice that of seawater in some areas (PWS 2007). The lagoon's hydrology is usually dominated by its estuarine nature, however during peak river inflows these are overridden by large quantities of fresh water.

The geomorphology of the lagoon including its entrance is also highly dynamic (**Figure 18**), and the estuarine dynamics of the lagoon, its relationship to Great Oyster Bay and the Tasman Sea is generally poorly understood.

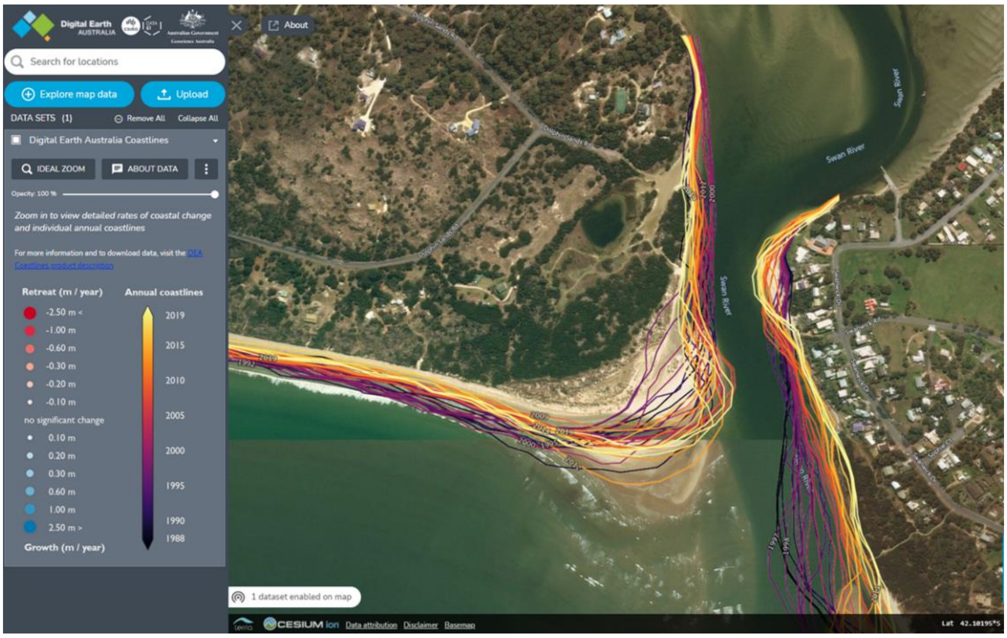


Figure 18: Change in coastline over time from 1988-2020 at the mouth to Moulting Lagoon. Source: Digital Earth Australia Map (ga.gov.au).

3.2.3. Hydrogeology

The Long Point peninsula and eastern part of The Grange, lie mostly near sea level (< 1 m above sea level (ASL)), except for two narrow sand dunes: one from Yards Hole in the west to Barkstand Point in the east with a maximum elevation of 4 m ASL; the second runs 2 km north-south along the spine of Long Point and has a maximum elevation of 19 m ASL. Jurassic dolerite forms the southern part of Long Point at Barkstand and comprises the oldest geology in the area (Corbett 2015). The remainder of both sites comprises a more recent Quaternary coastal complex (i.e. salt marsh, sedgeland, sand flat, lagoon deposits, tidal deposits, etc). Little Bay is likely a flooded deflation basin - strongly supported by the presence of the large lunette-like sand dune just to its east.

Lagoon/swamp deposits around Moulting Lagoon contain shallow saline aquifers with zones where salinity is in excess of 7000 mg/L (Matthews and Latinovic 2006). Similar water quality in lagoonal sediments is expected in the remainder of the Swansea Tertiary-Quaternary basin. In combination with perched shallow Tertiary aquifers, lagoon and alluvial quaternary aquifers between Cranbrook, Swansea and Apsley Marshes have the highest potential for the development of dryland salinity in the Swan-

Apsley catchment (DPIPWE 2015). Recorded water level elevations within these aquifers are usually higher than the surrounding surface water elevations. These sediments are important as they maintain baseflow in major creeks and contribute towards the overall water budget of surrounding wetlands and swamps.

There is a rapid groundwater response to rainfall in the area especially during East Coast Low driven events (DPIPWE 2015). Groundwater levels area typically 1-5 m below ground level and at, or up to, 2m ASL. Shallow standing water levels close to the ground surface are commonly recorded in the low-lying areas of the catchment, including saltmarsh areas of Long Point. All of the wetlands of interest are highly groundwater dependent. Regional groundwater flow is towards the lagoon and the coast. Water levels in monitoring bores at Dolphin Sands fluctuate minimally on a seasonal basis (0.2 - 0.4 m).

3.3. Vegetation Communities

Most of Long Point is made up of saltmarsh, sedgeland and grassland vegetation communities, with a sparse open forest along the sand dune spine.

Saltmarsh (AUS) occupies the majority of the site, Saline grassland (ARS) occurs in the inland area impacted by the L-shaped levee, Coastal grassland (GHC) occurs at the base of the sand dune and along the flow path between Little Bay and Moulting Lagoon, and Saline aquatic herbland (AHS) occurs in each of the wetlands (**Figure 19**).

The immediate edge of the lagoon supports an almost continuous belt of *Sarcocornia quinqueflora* often mixed with *Tecticornia arbuscula*. Behind the *Sarcocornia* where the bank begins to rise, there is an almost continuous fringe of coastal/saline grassland tussocks (*Juncus, Poa, Austrostipa* and *Gahnia*). These two bands range in width from 1-2 m each to 30 m or more depending on elevation. Behind this zone the vegetation cover is highly variable depending on the terrain (PWS 2007).

Large quantities of algae are produced in seasonal blooms throughout the drainage areas of the site and *Ruppia* is present in less saline locations such as King Bay where freshwater inflows occur (e.g., Swan River). This species has also been recorded in each of the wetlands of interest (December 2021 – see Section 3.4 below).

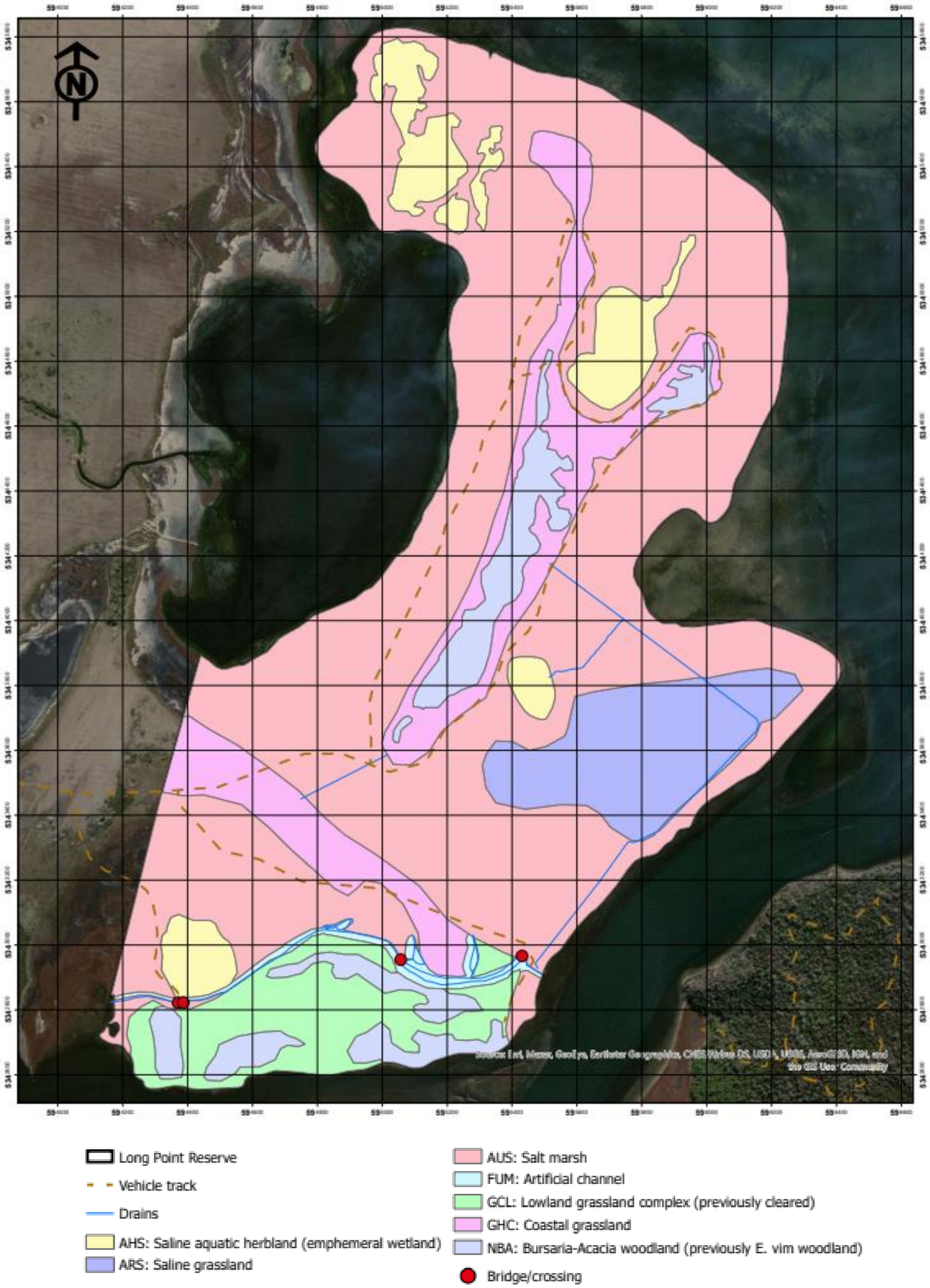


Figure 19: Vegetation communities mapped for Long Point. Source: TLC.

3.4. Conservation Values

Long Point represents one of the most extensive areas of the nationally vulnerable areas of temperate coastal saltmarsh in Tasmania and is the single largest saltmarsh in Tasmania (at 359 ha in area).

Long Point supports 25 ha of the threatened Saline aquatic herbland vegetation community (vulnerable). This community exists within the wetlands on Long Point and Yards Hole on The Grange. Four threatened plant species (all rare TSPA 1995) have been recorded: Narrow-leaf blown-grass (*Lachnagrostis punicea* ssp. *filifolia*), Silky Wilsonia (*Wilsonia humilis*), Roundleaf Wilsonia (*Wilsonia rotundifolia*) and Tuberous seatassel (*Ruppia tuberosa*). *W. rotundifolia*, has also been recorded from the western shore of Yards Hole. Records of the blown grass are from the northern areas of Long Point.

Ruppia tuberosa (rare)*, W. rotundifolia and W. humilis* have been recorded in the floodway connecting Little Bay to Moulting Lagoon. *W. humilis* and *R. tuberosa* have also been recorded in tidal areas northeast of Round Hole. During a field inspection in December 2021, *Ruppia* was also evident in all wetlands of interest, as well as adjacent tidal areas. The threatened flora records are outside the footprint of restoration works and all species are expected to benefit from the restoration activities.

Long Point and The Grange provide drought refuge and also support Moulting Lagoon as an important area for waterbirds by providing nesting and foraging habitat for a wide range of species and large numbers of birds including up to 80% of Tasmania's Black swan (*Cygnus atratus*) population and numerous migratory birds such as the Eastern curlew (*Numenius madagascariensis*) and Fairy tern (*Sterna nereis* subsp. *nereis*).

Over 30 species of fish have been recorded from the lagoon, and several species including Hardyhead (*Atherinosoma microstoma*) spawn in the middle reaches, however none of the recorded fish species are considered threatened, apart from Australian Grayling (*Prototroctes maraena*) which has been recorded from the Apsley catchment and would be unlikely to use any of the aquatic habitats on Long Point or The Grange (Moulting Lagoon Ramsar Site Ecological Character Description (awe.gov.au)).

Significant terrestrial fauna species such as Wedge-tailed eagles (*Aquila audax*), White-bellied sea-eagles (*Haliaeetus leucogaster*), Spotted-tail quolls (*Dasyurus maculatus*), and Tasmanian devils (*Sarcophilus harrisii*) have also been recorded extensively across Long Point (LISTmap - Land Information System Tasmania (thelist.tas.gov.au).

4. Ecohydrological Monitoring and Baseline Conditions

The eco-hydrological assessment is focused on understanding the links between hydrology and ecology and identifying potential improvements that can be achieved from hydrological restoration works, which usually remediate the physical landform and how it interacts with, conveys or retains flows. To identify hydrological restoration opportunities and measure the outcomes of hydrological restoration works, an eco-hydrological monitoring plan was developed.

4.1. Monitoring objectives

The objectives of the monitoring plan are to undertake monitoring at sites where the potential exists for hydrological restoration activities to:

- Collect baseline (pre-restoration) information on the vegetation, water quality and water regime to characterise the site before and after future restoration works and better understand the impact of previous hydrological manipulations.

- Determine opportunities for positive improvements in water regime to improve the condition of vegetation and conservation values of the Ramsar sites.

Key eco-hydrological questions guiding the monitoring at The Grange and Long Point include:

- Is the system of levees and associated drains in the southeast of the site affecting the water level and salinity regimes (and therefore saltmarsh community condition and extent) of the inland block and Round Hole?
- What is the water level and salinity regime of Opening Hole and is it affected by the Barkstand channel?
- What is the water level and salinity regime of Yards Hole and is it affected by recent drainage works?
- Is sea level rise impacting on the saltmarsh community (e.g. is it the potential driver of observed change in *Gahnia* community health and distribution over the last 15-20 years?)
- How has the high-water mark and shoreline changed over time?
- What is the tidal regime of Moulting Lagoon and how does water attenuate throughout in response to tidal and catchment inflows?

4.2. Monitoring locations and parameters

The monitoring program includes quantitative monitoring:

- In-situ, continuous monitoring of water level and electrical conductivity (EC) at Yards Hole, Round Hole, Opening Hole and adjacent Moulting Lagoon tidal areas to assess relationships between wetlands and Moulting Lagoon and establish baseline water regimes. Loggers have also been installed either side of the eastern and northern main levees to determine variation in water regime either side. Locations were selected based on proximity to any breaches (as far as possible from a breach) and similarity of topography on either side (areas where topography is similar and thus cannot explain variations in vegetation).
- Vegetation transects were established perpendicular to both the main northern and eastern levees to determine baseline vegetation cover and condition, as well as assess impact of drains and levees. Methods commensurate with Aalders *et al*. (2019) were implemented to ensure compatibility with other saltmarsh monitoring occurring at Long Point and The Grange. Plots were 2 x 1 m in area and were arranged central to the plot location (southern side for north-south transects and western side for east-west transects).

The program also includes qualitative monitoring:

- Photo-points established perpendicular to each of the wetland monitoring sites to record changes in water regime and vegetation in associated water bodies.
- Observational accounts.
- Aerial photography and satellite imagery were also used to investigate any observable change in water regime, shoreline and vegetation over time.

Monitoring locations across The Grange and Long Point properties are summarised in **Figure 20** and **Table 1**.

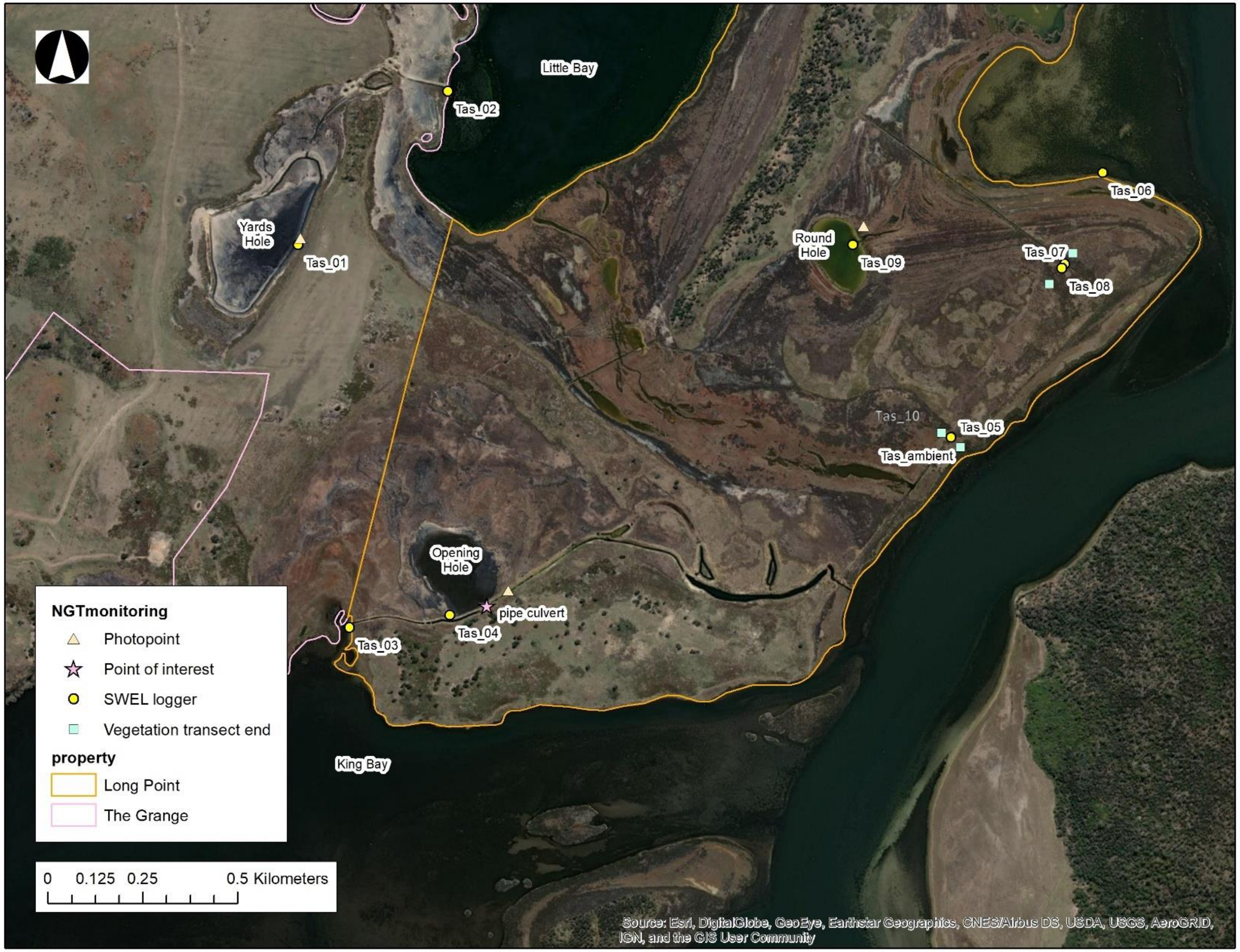


Figure 20: Monitoring locations, The Grange and Long Point.

Table 1: Summary of monitoring sites, The Grange and Long Point.

Logger ID	Site	Property	Easting	Northing	Objective
Surface water level and electrical conductivity loggers					
Tas_01	Yards Hole	The Grange	594029	5343830	Determine the water level and salinity regimes of Yards Hole and how they align with those in adjacent Little Bay
Tas_02	Little Bay	The Grange	594426	5344231	
Tas_03	King Bay	Long Point	594163	5342821	Determine the water level and salinity regimes of Opening Hole and how it aligns with those in the adjacent channel and King Bay
Tas_04	Opening Hole	Long Point	594433	5342843	
Tas_10	Eastern levee - lagoon	Long Point	595756	5343317	Determine if the levees are affecting the water levels and salinity regime of (i.e. hydrological connectivity across and within) the inland saltmarsh.
Tas_05	Eastern levee - land	Long Point	595751	5343319	
Tas_07	Northern levee - lagoon	Long Point	596052	5343774	
Tas_08	Northern levee - land	Long Point	596042	5343766	
Tas_06	Moulting Lagoon (Bay north of Round Hole)	Long Point	596160	5344015	Determine if the levees are affecting the water levels and salinity regime of Round Hole.
Tas_09	Round Hole	Long Point	595495	5343826	Determine the water level and salinity regimes of Round Hole and how it aligns with those in the adjacent bay.
Photo points					
	Round Hole	Long Point	595524	5343875	Link water level to water and vegetation extents. Collect baseline data to support pre and post restoration works.
	Opening Hole – north and south	Long Point	594588	5342914	
	Yards Hole – north and south	The Grange	594040	5343843	
	Northern transect – north and south	Long Point	596047	5343770	
	Eastern transect – west and east	Long Point	595753	5343318	

Vegetation transects					
	Northern levee – land end	Long Point	596007	5343712	Collect baseline data to support evaluation of saltmarsh habitat recovery and/or change pre and post restoration works.
	Northern levee – lagoon end	Long Point	596087	5343822	
	Eastern levee – lagoon end	Long Point	595787	5343306	
	Eastern levee – land end	Long Point	595629	5343351	

4.2.1. Complementary monitoring

Previous vegetation transect monitoring has been undertaken at Long Point by Aalders *et al* (2019) and TLC. In November 2021 we collaborated with the Tasmanian Land Conservancy (TLC) and John Aalders of the University of Tasmania, to undertake baseline vegetation monitoring across the Long Point property. John and TLC have previously monitored vegetation across the site. We resampled John's Yellow (Y), Red (R) and Green (G) transects previously sampled in 2013 and TLCs transects (previously sampled in 2014, 2016, 2019). TLC also regularly monitor a range of photo points across Long Point (**Figure 21**). Whilst the bulk of this information was not analysed for this project (see some data analysis on John Aalders' data below), the data provides a particularly useful baseline for assessing changes in vegetation, be it from restoration works, or other, future drivers.

The historic datasets, combined with NGTs recently acquired one (see section 4.3.2 below), will serve as a baseline prior to undertaking any wetland restoration works. It is expected that these surveys will be repeated post works and into the future, to track eco-hydrological change and recovery at the site over time.

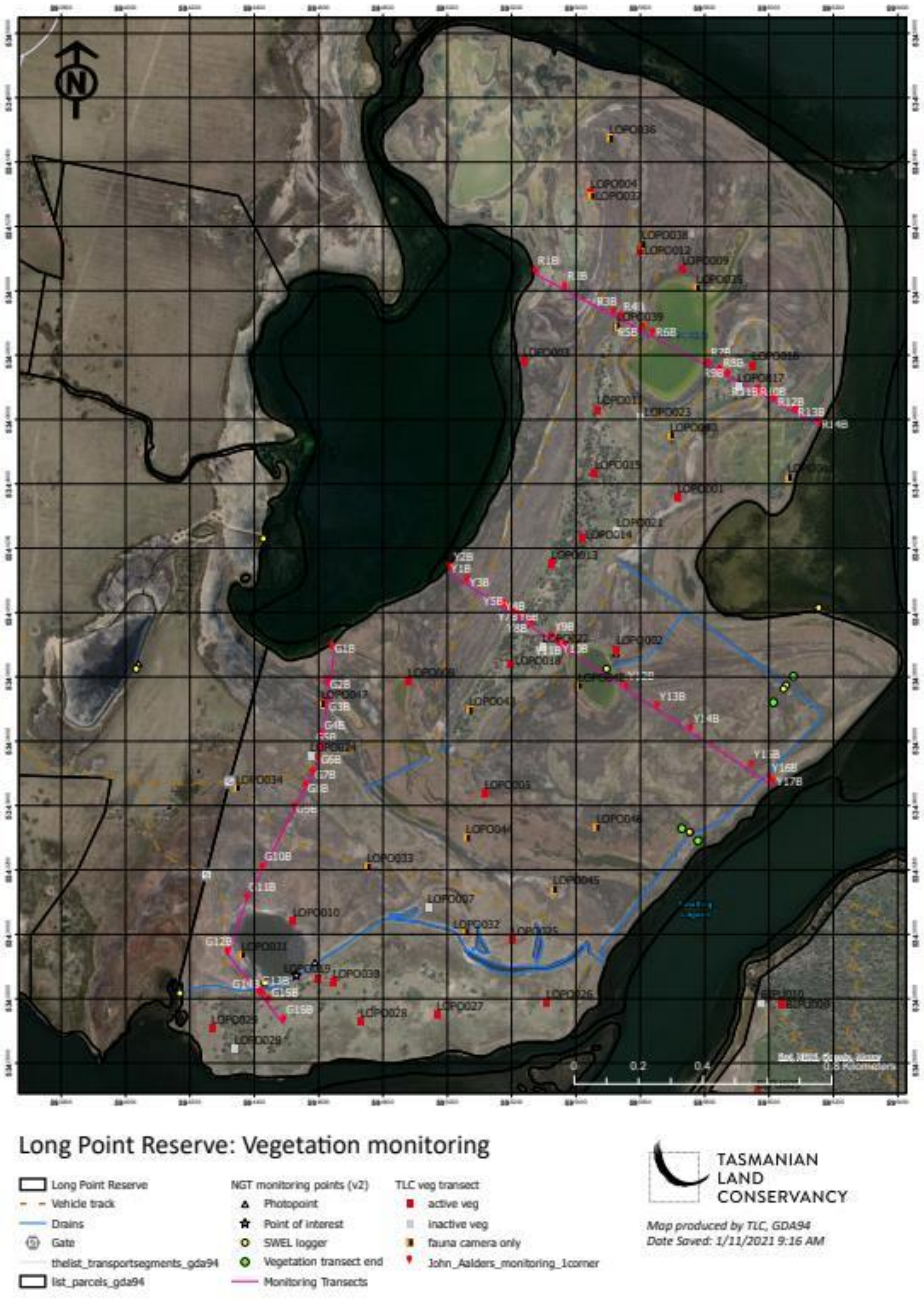


Figure 21: TLC, John Aalders' and NGT vegetation monitoring locations, The Grange and Long Point.

4.3. Monitoring analysis and results

4.3.1. Hydrology and water quality

Preliminary data from the loggers has provided some early insights into how different areas of the saltmarsh complex are responding to both rainfall patterns and tidal variations in sea level.

Yards Hole

At **Yards Hole**, water level data collection commenced in July 2021. Preliminary data shows that water levels in the wetland are driven by both local rainfall and adjacent tidal levels in Little Bay. Some key observations, as indicated in **Figure 22**, include:

A. Tidal level increases in Little Bay have little to no influence on Yards Hole water levels at heights below 0.4m AHD.
B. Filling of Yards hole (red line) is largely independent of Little Bay (blue line) tidal levels, however both responded to significant early October rainfall (suggesting water levels in Yards Hole may be more reliant on local rainfall).
C. Filling of Yards hole is associated with a tidal level in Little Bay above 0.25 m AHD, underpinned by a large rainfall event and associated catchment inflows (e.g. Swan and Apsley Rivers). Water level peaks in Little Bay are higher than in Yards Hole which suggests the inlet to Yards Hole is constricted.
D. Additional filling and emptying of Yards Hole in association with Little Bay tidal levels occurs to approximately 0.36 m AHD, after which point water levels decrease more slowly.
E. Early salinity data was compromised by some initial infrastructure malfunctions, but beyond November 2021 shows salinity levels equivalent between Yard Hole and Little Bay.

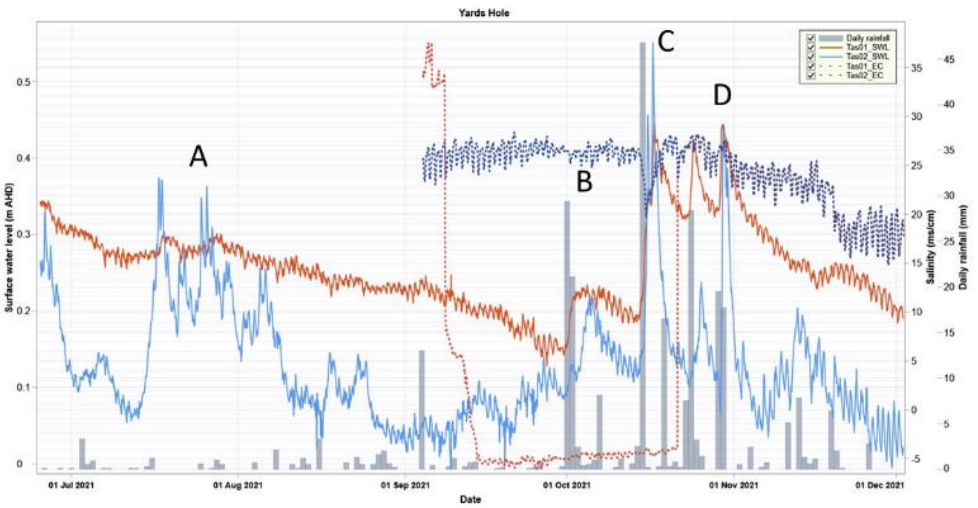


Figure 22: Surface water level (SWL) (solid lines) and salinity (EC) (dotted lines) at Yards Hole – **red** lines (Tas01) and Little Bay – **blue** lines (Tas02), in relation to daily rainfall – **grey** bars.
(SILO point data: -42.05;148.15) for the winter/spring period of 2021.

Round Hole

Water and salinity data collection commenced at **Round Hole** in September 2021. Like Yards Hole, water levels in Round Hole appear to be influenced by adjacent tidal water levels which, in turn, also respond to large rainfall events and nearby stream pulses.

Key observations, as indicated in **Figure 23**, include:

A. Filling of Round Hole (red line), is driven by water levels in Moulting Lagoon (blue line). Water level peaks are equivalent in the wetland and the lagoon, although retention occurs in Round Hole below 0.38m AHD. Water level increases correspond with rainfall events.
B. Filling of Round Hole is similar to that observed under point A, although after initial decline, water levels again increase, independent of adjacent sea levels or rainfall. Salinity also declines which may indicate a residual sub-surface response.
C. Salinity is lower in Round Hole than the adjacent Moulting Lagoon and it declines in the wetland with corresponding filling. This suggests that filling may be associated with fresher water sources additional to Moulting Lagoon (i.e., local rainfall runoff, groundwater).

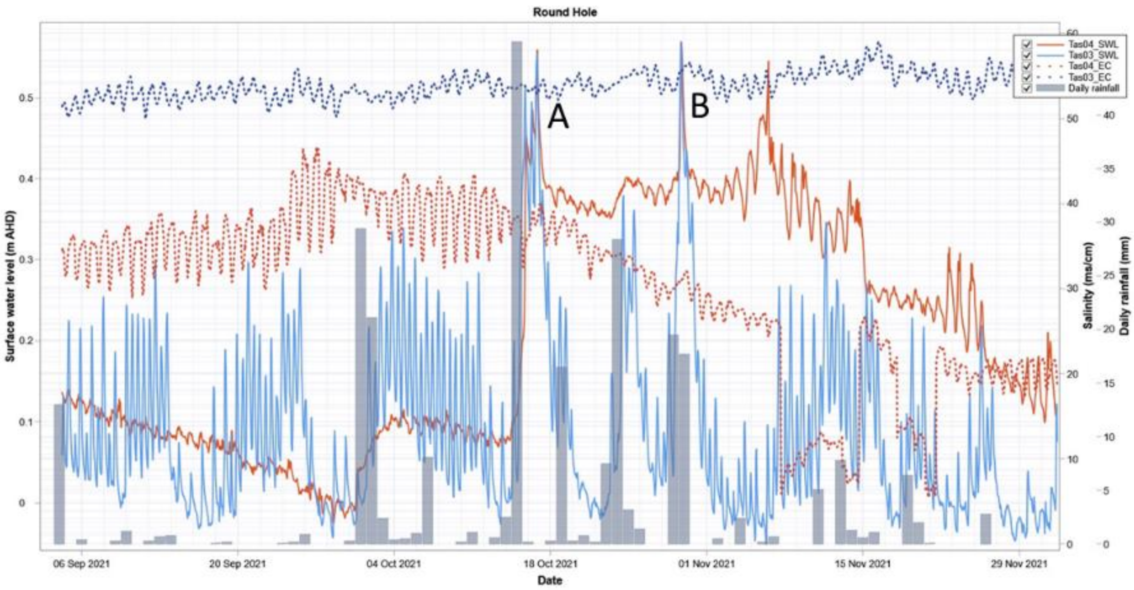


Figure 23: Surface water level (SWL) (solid lines) and salinity (EC) (dotted lines) at Round Hole – **red** lines (Tas04) and Moulting Lagoon – **blue** lines (Tas03), in relation to daily rainfall – **grey** bars.
(SILO point data: -42.05;148.15) for the winter/spring period of 2021.

Opening Hole

Water and salinity data collection commenced at **Opening Hole** in September 2021. Like Yards Hole and Round Hole, water levels are influenced by adjacent tidal levels and rainfall/streamflow events.

Key observations, as indicated in **Figure 24**, include:

A. Salinity increasing as water level drops in Opening Hole (red lines) prior to rainfall induced freshening and partial filling.
B. More complete filling occurs during peak sea levels following a large rainfall event in mid-October. Peaks in water levels in Opening Hole and King Bay are similar. Salinity decreases in response to wetland filling. Opening Hole water level recedes back to 0.4m AHD after fill event.
C. Filling occurs to the same level as adjacent King Bay in response to rainfall and runoff event, again receding to 0.4m AHD after fill event. Salinity decreases in response to filling. As water levels decline, presumably through evaporation and seepage, salinity slowly increases again.

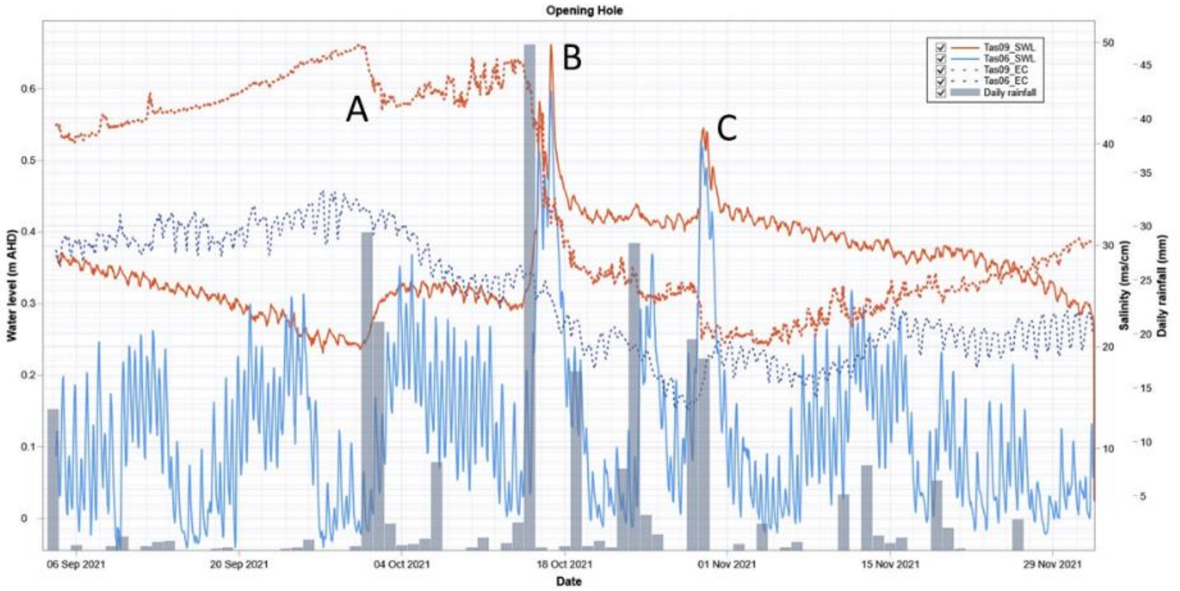


Figure 24: Surface water level (SWL) (solid lines) and salinity (EC) (dotted lines) at Opening Hole – **red** lines (Tas09) and King Bay – **blue** lines (Tas06), in relation to daily rainfall – **grey** bars.
(SILO point data: -42.05;148.15) for the winter/spring period of 2021.

What is the tidal variation at Moulting Lagoon tidal monitoring sites and the nearest state tidal gauge at Spring Bay?

Comparison of the three Moulting Lagoon tidal monitoring sites with the state monitoring site at Spring Bay, indicates that tidal variations are more conservative within the lagoon (**Figure 25**) – which is to be expected given the constriction of tidal flows at the lagoon entrance.

Elevation reference details between the state monitoring site and Moulting Lagoon requires further exploration, however the emphasis of this comparison is to demonstrate overall fluctuations in the open ocean, versus Moulting Lagoon. Again, given the constriction at its mouth, Moulting Lagoon water levels are also influenced by local catchment runoff events (e.g., 1,000 m^2 catchment including the Swan and Apsley Rivers) causing additional peaks in water level that are not linked to tides. Tidal variation in Little Bay is much lower than in King Bay and Moulting Lagoon proper, due to its distance from the lagoon mouth.

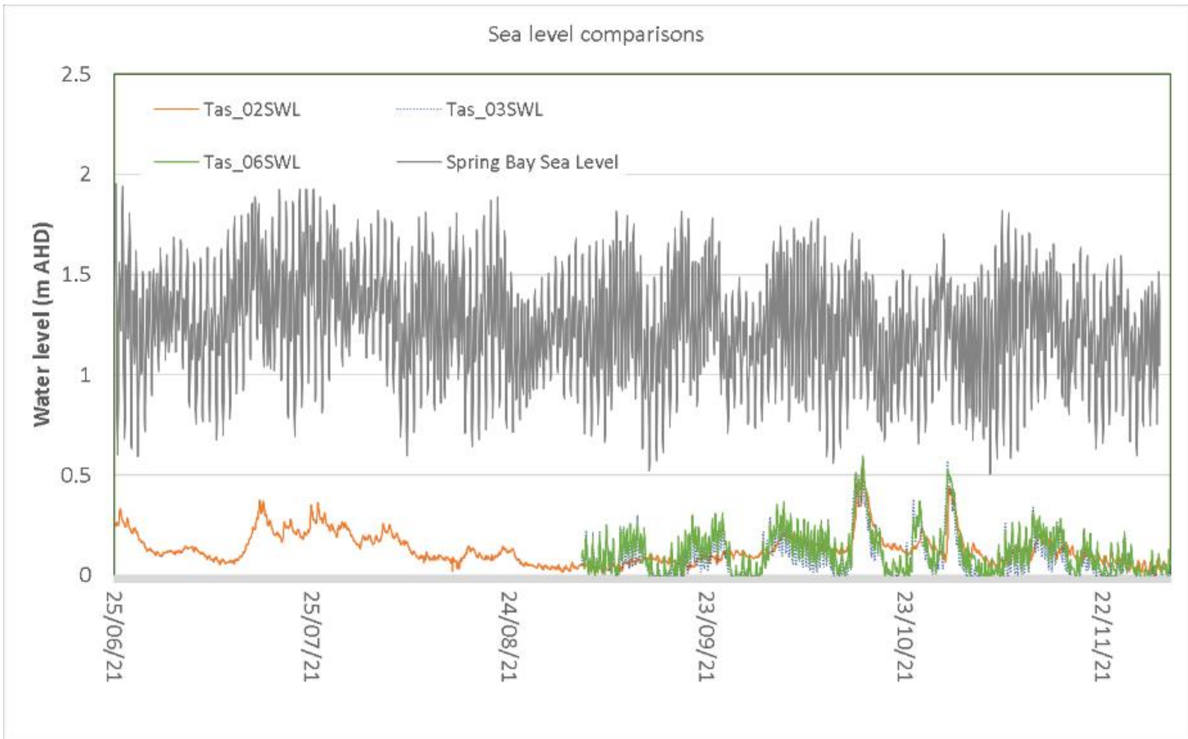


Figure 25: Comparison of tidal levels for Little Bay – orange line (Tas_02), Moulting Lagoon east of the eastern main drain – green line (Tas_06), King Bay – pale blue line (Tas_03) and the state tidal gauge at Spring Bay (grey line).

What impact on water level and EC are the main levees/drains having?

Northern levee/drain

Water level and salinity data also shows some interesting patterns in relation to the influence of the main L-shaped levees. The northern levee appears to be acting to retain water on the inland side (**Figure 26**) – impeding the movement of flows through the saltmarsh in this location.

The following observations can also be shared:

A. Water levels increase more on the inland side of the levee (blue line) following rainfall events.
B. High water levels on the lagoon side of the levee appear to correspond with levels on the inland side of the levee, but water does not recede from the inland side after the event. This indicates that these flows breach the levee and equalise above a certain level, but that these flows cannot readily escape to equalise as lagoon levels recede.
C. Following larger rainfall events, water levels inland decrease, although salinity doesn't increase notably.

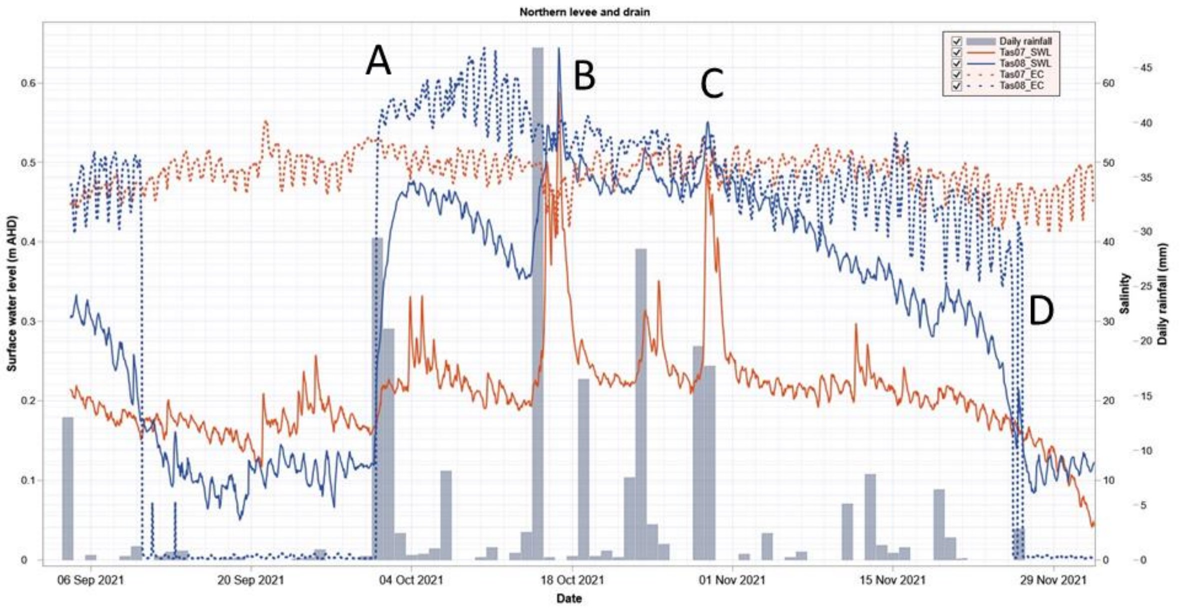


Figure 26: Surface water level (SWL) (solid lines) and salinity (EC) (dotted lines) on the inland (Tas08, **blue** line) and lagoon side (Tas07, **red** line) in relation to daily rainfall (**grey** bars) (SILO point data: -42.05;148.15) for the winter/spring period of 2021.

Eastern levee/drain

The impact of the eastern levee on water movement and retention appears to be less than for the northern levee but is still observable (**Figure 27**).

- Water levels remain almost entirely equivalent on the inland (Tas05, red line) and lagoon (Tas10, blue line) sides of the levee.
- However, salinity on the inland side declines more with rainfall events, relative to those on the lagoon side, indicating the degree of water mixing occurring in the saltmarsh habitat either side of the levee is being influenced.

Whilst we attempted to avoid levee breaches in the selection of these logger locations, the eastern levee is breached in more places than the northern levee and these preliminary results would appear to be affected by this.

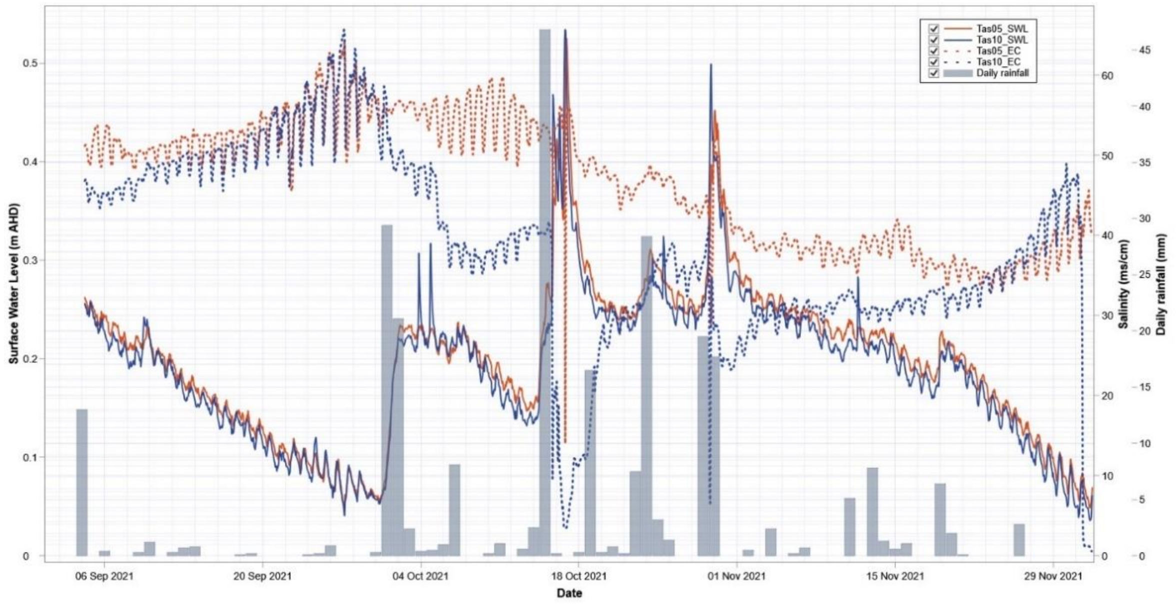


Figure 27: Surface water level (SWL) (solid lines) and salinity (EC) (dotted lines) on the inland (Tas08, **blue** line) and lagoon side (Tas07, **red** line) in relation to daily rainfall (**grey** bars) (SILO point data: -42.05;148.15) for the winter/spring period of 2021.

Although we are at an early stage in collection of hydrological information at these sites, the likely impacts of the artificial drainage and levee works are already apparent at some sites in the data shared above. Hence, in terms of our understanding of hydrological conditions, this information is providing us with an invaluable 'baseline' of current, modified conditions. From that baseline, we will be able to accurately detect, measure and describe any impacts of restoration works on site hydrology as the project progresses. This data will be able to be cross-referenced with the results of the vegetation monitoring described in section 4.3.2 below.

4.3.2. Vegetation

What impact on vegetation species and cover are the main levees/drains having?

The vegetation was similar between transects and for each transect, either side of the levee and drain system (**Table 2** and **Figure 28**). *Hemichroa pentandra* was only found in the inland plots. *Tecticornia arbuscula* was also present mostly in inland plots (despite high cover recorded in plot 'c', transect 1). *Sarcocornia blackiana* was only recorded in plot e of transect 2 and *Gahnia filum* was only recorded on the lagoon side of transect 1 at an elevation at or above 0.4 m AHD. *Austrostipa stipoides* was only recorded at the end plots (i.e. 'a' and 'g') of transect 1 (> 0.4 m AHD). Overall, the cover of species present was similar along transects between inland and lagoon plots. This dataset will provide a robust, easily resampled dataset with which to measure any future change in vegetation in proximity to the levees, once restoration works have been completed.

Table 2: Summary of vegetation species and cover at NGT transects. NGT transect 1 is perpendicular to the northern levee and NGT transect 2, the eastern levee. In the former the levee and drains occur between plots c and d, in the latter between b and c. Plot a on both transects commences the lagoon side off the levee. The numbers in each plot refer to the Braun-Blanquet cover scale: 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = >75%. Note >100% cover per plot was possible due to vegetation layering.

Scientific name	**Common name**	**Transect NGT 1**							**Transect NGT 2**				
	Plot	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**a**	**b**	**c**	**d**	**e**
Bare ground	Bare ground	3	4	4	2	4	3	4	3	2	1	3	2
Austrostipa stipoides	coast speargrass	3						4					
Disphyma crassifolium	roundleaf pigface	4	3	2	3	2	2		2	3	5	2	3
Gahnia filum	chaffy sawsedge	3		2									
Hemichroa pentandra	trailing saltstar				4						1		
Sarcocornia blackiana	thickhead glasswort		4	2		2	4						3
Sarcocornia quinqueflora quinqueflora	beaded glasswort	4	3	3	5	3	4	3	6	5	5	5	4
Tecticornia arbuscula	shrubby glasswort			5	2	3	3						3

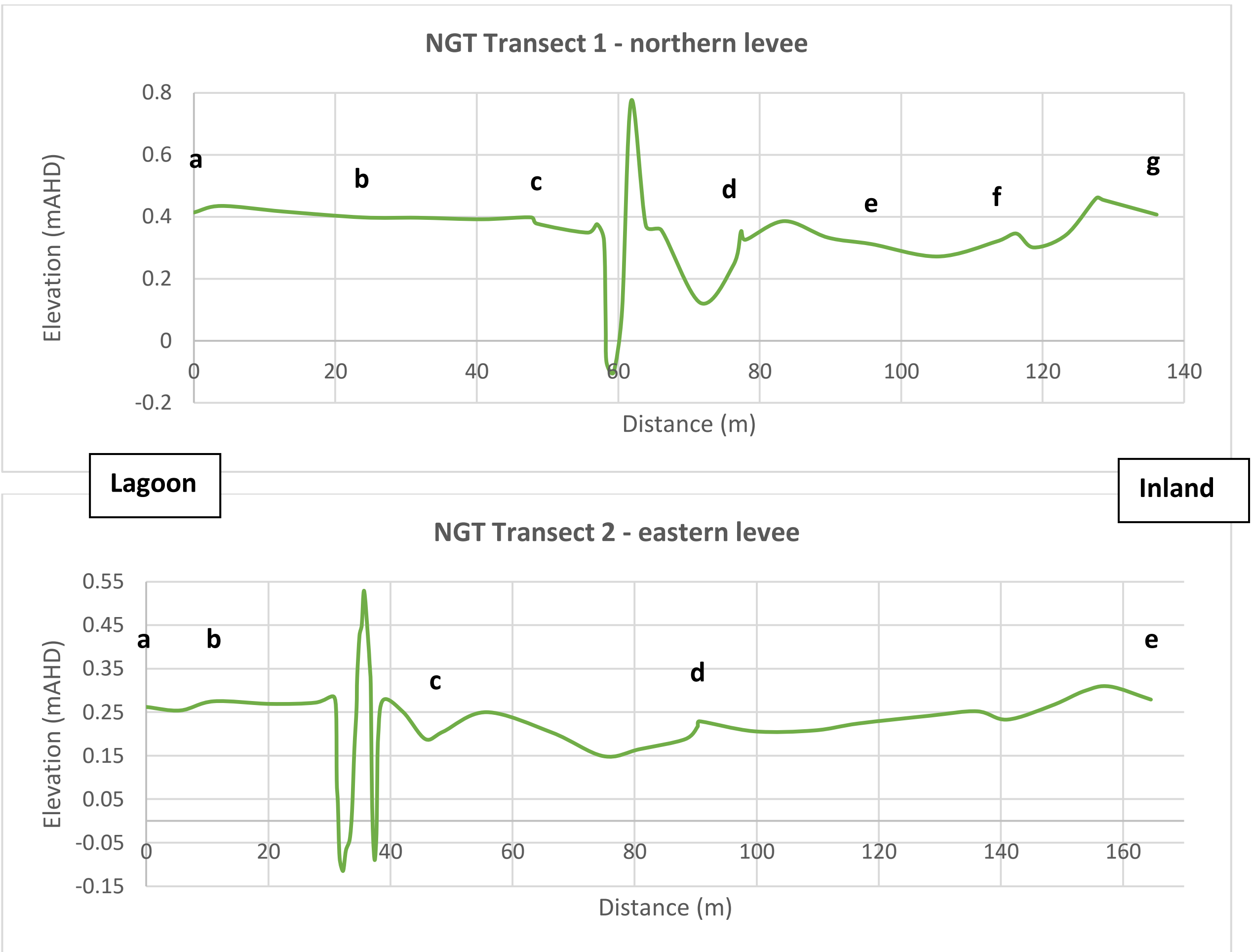
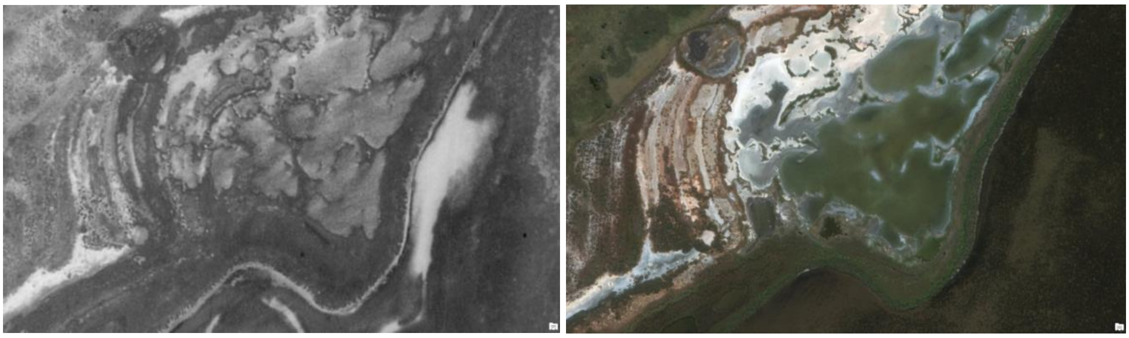


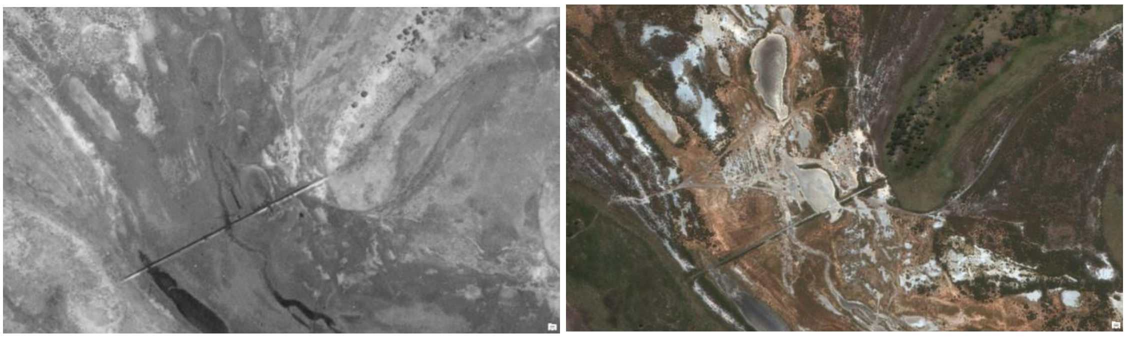
Figure 28: Cross sections of NGT transects; transect 1 which traverses the main northern levee (top), and transect 2 which traverses the main eastern levee (bottom). Corresponding plot locations and letters are shown. Drains and levees are evident in sudden increase and decreases in elevation.

How has vegetation at Long Point and The Grange changed over time?

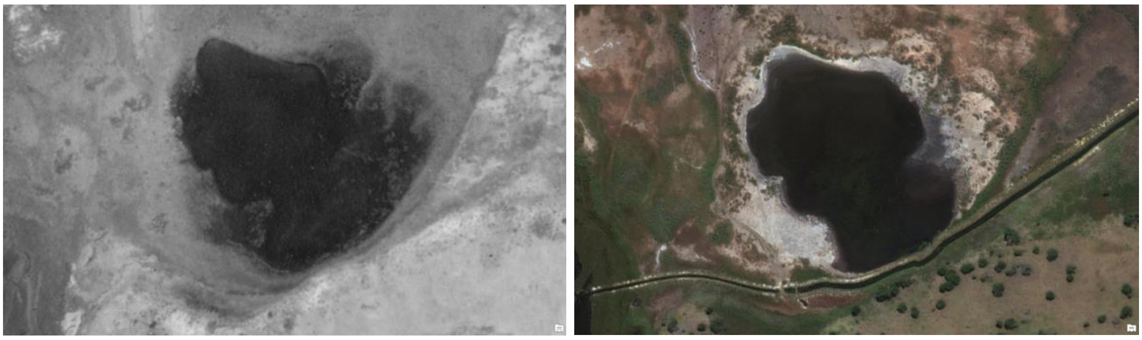
Comparison of aerial imagery shows displacement of saltmarsh by mudflat/open water in some areas (**Figure 29**). This trend is only observable in a few, low-lying locations across Long Point. Note the shoreline has remained consistent over time, despite the observed recent increase in coastal inundation.



a) *low-lying area northeast of Round Hole and southeast of Gum Tree Hole, Long Point*



b) *floodway connecting Little Bay to Moulting Lagoon, Long Point*



c) *Opening Hole, Long Point*

Figure 29: Aerial image from 1949 (left) and 2021 (right) showing decline in extent of saltmarsh and increased extent of open water/mudflat.

These long-term changes are consistent with observations of TLC and John Aalders. In a comparison of data from 2013 and 2021 for John's three long transects which traverse Long Point, vegetation in several plots, notably those in low-lying areas, have significantly changed over time (see Appendix 1).

Most noticeable was an increase in bare ground and a loss of saline vegetation species (plots R2, Y17 and G12, G13 are of particular concern). Plot R2 is in the low-lying area between the northern end of the sand ridge and Little Bay. This area appears to have been inundated more frequently or for greater duration in recent times. Plot Y17 is on the lagoon side of the eastern levee and may be a result of increased inundation and ongoing influence of the levee/drainage system. Plots G12 and 13 are proximal to Opening Hole. The western shore of Opening Hole had significantly increased in bare ground since 2013 and is likely a result of increased inundation in recent times. *Tecticornia arbuscula* mostly remained constant in cover and extent across Long Point transects.

In summary (see **Figure 21** on **Page 29** for plot and transect locations and Appendix 1 for detailed data):

- Red transect:
    - Plots 1, 2, 3, 5, 6, 7 and 11, 12, 13 showed the most change, particularly an increase in bare ground and loss of *Disphyma crassifolium* and *Sacocornia* sp.
- Yellow transect:
    - Plots 1, 2, 3 and 16, 17 showed a significant increase in bare ground, and typically a decrease in *Sarcocornia* sp. *Gahnia filum* disappeared from plot 1.
- Green transect:
    - Plots 3, 11, 12 and 13 showed increase in bare ground and loss of saline vegetation (typically *Sarcocornia* sp. and *Dysphema* sp.). *Gahnia filum* disappeared from plot 12.

This shift in *Gahnia filum* health and extent has also been observed by TLC photo-point and vegetation transect monitoring over the past seven years, especially in the lowest lying samphire flats in the western part of the TLC Reserve, but also scattered elsewhere (**Figure 30** and **Figure 31**).

Figure 30: Variability in health of Thatching Grass (*Gahnia filum*) at Long Point, corresponding with elevation. Here, the Thatching Grass growing on a slight rise is persisting while the species is dying out of the adjacent lower areas.

While a few factors could be driving this change (e.g. flooding frequency, the intensity and duration of recent East Coast droughts, etc.), given the general hardiness of Thatching Grass, the most likely and obvious conclusion is that we are witnessing the commencement of vegetation transitions that are now occurring as a result of upslope migration caused by sea level rise. Thatching Grass is a species typical of brackish or mildly saline, rather than hyper-saline, conditions, which is why it tends to grow at the upper margins of saltmarsh, above the influence of tidal flows.

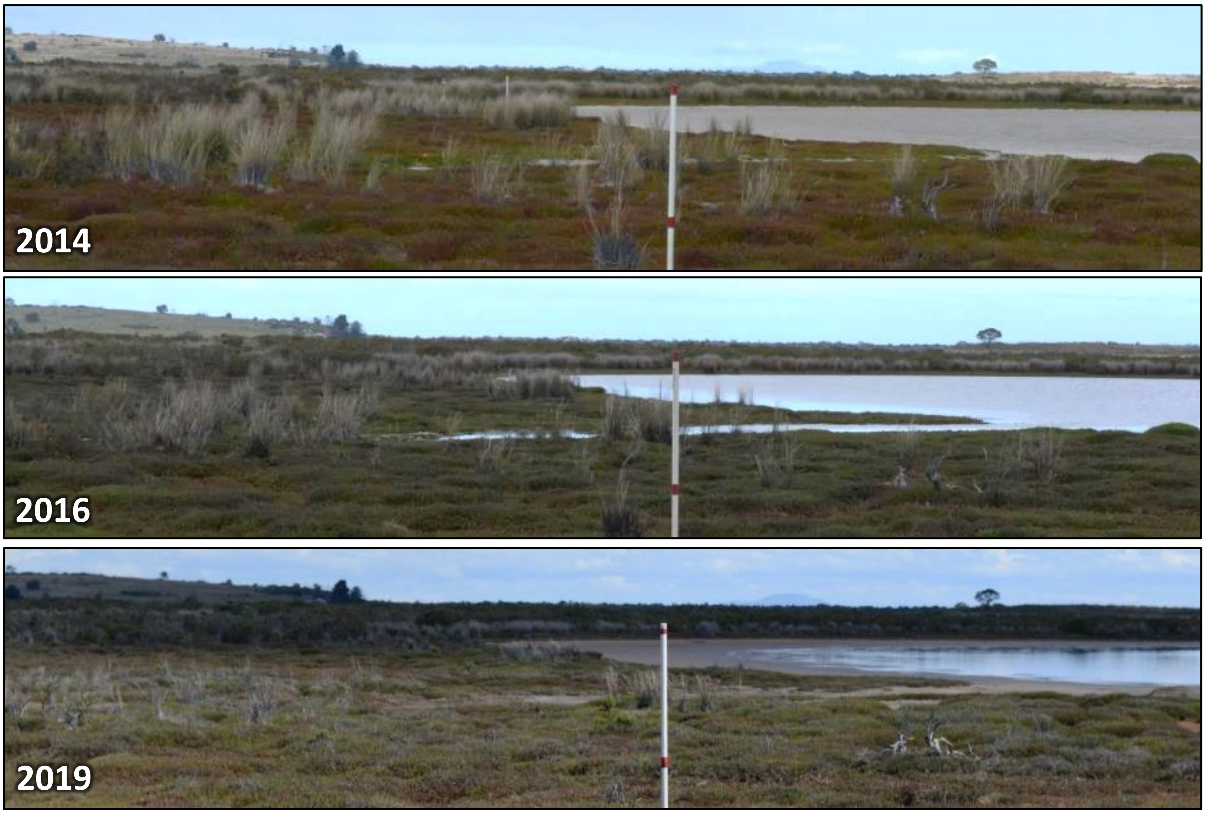


Figure 31: Thatching Grass (*Gahnia filum*) dieback between 2014 and 2019 at Long Point.
Photos: Tasmanian Land Conservancy

4.3.3. Photo points

Photo points were established at Round Hole, Opening Hole and Yards Hole, as well as along the two vegetation transects (**Figure 20** – note photo point records to date are presented in Appendix 2).

To date photos have been taken in June, September and December 2021.

A few initial observations include:

- Opening Hole has exhibited a drying trend since June 2021 and *Gahnia filum* dieback in this area is obvious in the photo collection.
- The water level in Yards Hole has remained stable over time.
- *Ruppia* beds were observed in all wetlands in December 2021 and are evident in some photos.
- Round Hole has also exhibited a drying trend since June.
- Drying algal mats were observed on the shoreline in December 2021.
- Saltmarsh at all sites was flowering and in full show in December 2021.

5. Impact of Drains and Levees

Despite the majority of the drainage network at Long Point being in place for over 150 years, as described in previous sections, there is evidence that it is still impacting on hydrology, water quality and vegetation.

The following provides an overall summary of the impacts identified at Long Point and The Grange through investigations and the eco-hydrological assessment to date:

- **Yards Hole** – the aquaculture development in the 1990s effectively sought to impound the wetland and increase water permanency. There is some evidence that the water regime at this site has become more permanent since this time by excavating a moat around the outer rim and channelising the connection of the wetland to Little Bay at its northern end.
- **Opening Hole** - The water regime of Opening Hole may now align more closely with the tidal regime within the greater Moulting Lagoon than was previously the case due to connection via a pipe to the Barkstand channel (an artificial channel also developed as part of the aquaculture development in the 1990s). It seems from our preliminary hydrological analysis that this wetland is now regulated at 0.4 m AHD until it dries internally from seepage and/or evaporation.
- **Barkstand channel and associated drainage features** - This channel has extended and deepened a natural drainage feature and several other smaller features have been connected to it as part of aquaculture works. The water regime of all of these features has now been artificially altered. It is likely that the channel is also intercepting shallow groundwater flow from the higher Barkstand Point onto the lower saltmarsh areas, further impacting local flushing dynamics.
- **Northern and eastern levees and drains (including Round Hole)** - Round Hole is situated within an area that appears to be affected by the surrounding levee banks and drains. The levee mound itself and adjacent void have not only compromised the saltmarsh habitat along its length by creating a disturbance footprint with an altered elevation profile, but the levee system appears to be having an ongoing impact on contemporary hydrology and saltmarsh condition, including flood flows, attenuation and natural drainage across the saltmarsh.

  There is evidence that the levees are impeding the movement of water (northern levee) and altering the mixing of fresh and saline water (eastern levee) across the eastern area of Long Point. The levee banks have deteriorated and are breached in many places, clearly reducing their efficacy in preventing tidal incursion (**Figure 32**).

Figure 32: Looking south-west over the shorter, western levee bank – also showing multiple locations where it has been breached in the approximately 150 years since it was constructed. Photo: Mark Bachmann

However, there are still ongoing impacts evidenced by the fact that the saltmarsh vegetation itself in many locations either side of these embankments experiences sudden changes in character and composition (along the eastern levee in particular) – disturbing the natural gradient and vegetation ecotones that should be present as you move upslope from the water's edge through the saltmarsh (**Figure 33** and **Figure 34**).

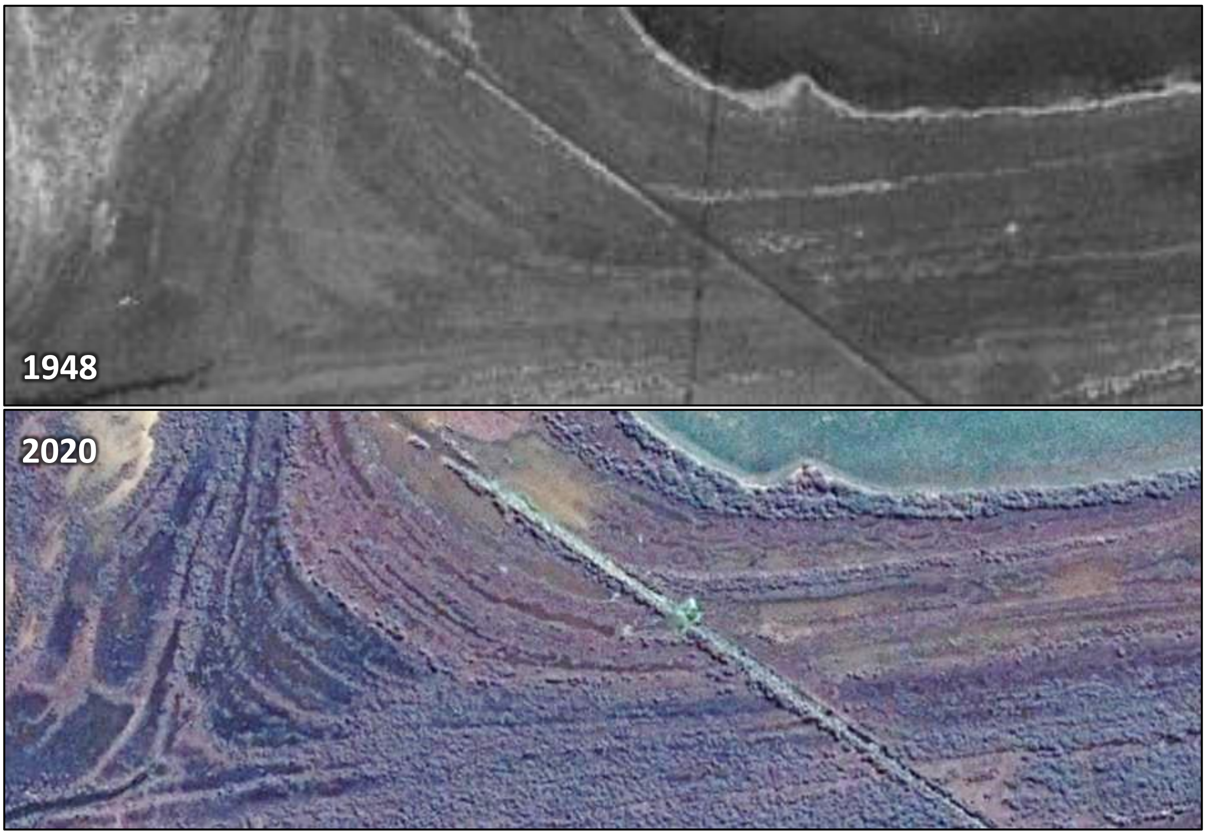


Figure 33: The northern end of the eastern levee bank at Long Point. This is where natural patterns visible in the bands of saltmarsh vegetation, growing under high tidal influence, have been interrupted by the levee bank altering water regime. These changes in vegetation were already apparent in the 1948 image, indicating the levee bank was long established by that time.

Figure 34: Looking north along the eastern levee bank at Long Point. Cath Dickon from the TLC is standing in the channel that was created when the levee was built, to indicate its depth. Note the significant difference in vegetation either side of the bank, where the natural gradient of the saltmarsh and vegetation ecotones have been disrupted. Photo: Mark Bachmann

Given the generally low-energy nature of tidal flows and the very flat character of saltmarsh areas like those found at Long Point, only minor changes in elevation and topography can have a significant impact on flow patterns and inundation regime. As we factor in current and future predicted sea-level rise, the contours and micro-topography of this land becomes especially important for how seamlessly the coastal vegetation communities will adjust and shift as part of the inevitable upslope migration process which is already underway. Adjacent saltmarshes are going to be some of the first communities to experience changes as a result.

Key issues associated with the physical changes to landform

The Grange

Previous earthworks around Yards Hole have physically disrupted the natural bank gradient and also altered both connectivity and the nature of flows/tidal exchange with Little Bay.

Long Point

There are two key issues at Long Point that are linked to the presence of the levees, drains and their development footprint – and these operate at different scales.

As shown below in **Figure 35**, they are:

1. the total footprint of drains/levees, which equates to 5.23 hectares, and
2. the broader ~80 hectare saltmarsh area originally intended to be protected by (and still impacted by) the levees.

Figure 35: Artificial drainage footprint at Long Point. Direct impact areas are marked pink, with hectares shown. The 80 hectare area potentially impacted by broader hydrological changes is hatched.

These are explained in more detail as follows:

1. *Displacement of saltmarsh habitat by drain and levee disturbance footprint, and the alteration of site landscape character*

It is now recognised and understood that when Long Point was covenanted, existing physical threatening processes were already in place and operating at the site and that these are yet to be addressed.

The most overt of these is the physical development footprint associated with extensive network of drains and levees which are having ongoing impacts to saltmarsh extent and condition, as well as ongoing implications for how the process of sea level rise is - and will be - expressed at the site.

The Nature Conservation Plan for Long Point identified 4.4 hectares of land directly impacted by the presence of artificial drains on site (revised to 5.23 hectares) and that the major disturbance to wetlands (including Opening Hole) on Long Point is the canal system linking a series of wetlands at the southern end of the property (NCP 2005). The NCP acknowledges that the artificial linkage of these once ephemeral wetlands to Moulting Lagoon has impacted their eco-hydrology and clearly assumed that the canals would be closed off in future:

> *"Once the canals have been closed off to tidal flow and ephemeral conditions are re-established, the biota of the lagoons will once again become largely restricted to the typical range of very specialised species capable of dealing with the highly variable environment in the wetlands"* (NCP 2005, p.13).

The historic purpose of the wider system of levee banks was not as well understood at the time that the NCP was prepared.

The embankments and voids/drains have not only caused direct displacement of saltmarsh habitat, but are also etched into the landscape in a way, and are of such scale, that they physically alter the natural landform and remain an omnipresent feature at the site – as shown in **Figure 36** and **Figure 37**.

Figure 36: The northern arm of the eastern levee at Long Point, showing the change to natural landform. Photo: Mark Bachmann

Figure 37: Looking south-east along the highly visible disturbance footprint of the levee shown in **Figure 36**.

2. *Potential ongoing impact of levees and drainage on broader site eco-hydrology*

Beyond the physical changes to the immediately disturbed ground, the levee bank system was intended to reduce inundation frequency across a much larger 'reclaimed' 80-hectare area located between the embankments, as also shown in **Figure 35**. Visible vegetation differences in the saltmarsh at different locations either side of the embankments (evident on the ground in in the aerial photographic record) indicate an ongoing impact despite breaches to the embankments at various locations.

Further, the Long Point property title extends to the high-water mark which means that sympathetic management of the land is also critically important to current and future protection of the Moulting Lagoon Ramsar site (as stated in the NCP). Hydrological barriers and changes can have large ecological impacts in the tidal zone where micro-topography is a key driver of vegetation characertistics. DPIPWE (2016) states that Moulting Lagoon has at-risk vegetation values requiring management for sea level rise, including succulent saline herbland which was identified as having critical ecological function. Areas on the Long Point property have been identified as retreat or refuge sites for accommodating inland migration of saltmarsh induced by sea level rise.

6. Restoration Plan

The restoration plan outlines restoration objectives, permit and planning processes and details the recommended restoration works for Long Point and The Grange properties. Due to the nature of the works and the need to complete works within a fixed budget, prioritisation of the plan for works is also documented in the event that the entire plan cannot be completed (weather, access, time or budget dependent).

6.1. Restoration objective

The current restoration vision for the site proposed by NGT is to:

> *''remediate all existing development footprints and restore the physical landform as closely as possible to its predevelopment state.''*

The primary objective of the works is to reinstate the natural geomorphology of the site – i.e. to 'knit' the modified natural surface back together.

This will, in time, ameliorate the physical disturbance footprints of the former drains and adjacent spoil/levee banks, as well as reverse the associated impacts on hydrology (i.e. flows, connectivity, depth of inundation) across the site in areas previously affected by drainage. Restoration activities will immediately make a total of 5 hectares of presently modified (disturbed and degraded) land available for saltmarsh expansion / regeneration, but also permanently remove any ongoing eco-hydrological impacts of drains / levees to Opening Hole and the broader adjacent 80 ha area of saline grassland and saltmarsh (including Round Hole).

This will also provide the site (especially the significant salt-marsh vegetation communities present) the best opportunity to gradually shift and adapt to sea level rise as tide levels in Moulting Lagoon are expected to continue to increase over time. Reinstatement of natural geomorphology will provide retreat pathway (areas where habitats would be impacted by SLR, but that sufficient area existed landward to allow for habitat migration – DPIPWE 2016). Saline vegetation communities will have the opportunity and capacity to retreat landward (**Figure 38**).

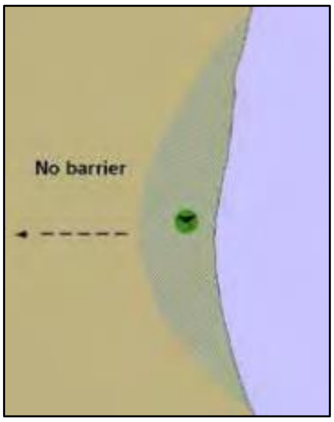


Figure 38: Retreat pathway response for natural values to sea level rise at Long Point (Source: DPIPWE 2016).

Hydrological restoration of Long Point involves the use of a short-term positive disturbance event (drain/void backfilling) to remediate an already disturbed footprint, and in doing so, setting the site on a new trajectory of long-term recovery.

6.2. Permits and approvals

6.2.1. Aboriginal and historic heritage

TLC had Rocky Sainty (Aboriginal Heritage Officer, AHO) undertake a heritage assessment for Long Point in 2007 (Sainty 2007). No sites had previously been recorded on the Tasmanian Aboriginal Site Index nor were any sites located during field investigations.

Despite this, before European settlement this area had a large Aboriginal occupation. Given this, the close proximity to the coast, and the abundance of cultural resources in the area, once the top surface is removed the chances of unearthing Aboriginal sites (e.g. shell material) are high.

As no Aboriginal sites were found within the survey area there is no objection to the works proceeding. However, it is recommended that whoever carries out land management works are fully briefed before commencement. If any Aboriginal sites (i.e. shell material, artefacts) are unearthed once works begin, then works are to cease immediately, and the Tasmanian Aboriginal Land and Sea Council and the Aboriginal Heritage Tasmania will be contacted immediately.

NGT will ensure that contractors are briefed on this issue and will supervise all works onsite to comply with heritage requirements.

NRM South had an Aboriginal Heritage Desktop Review undertaken by Aboriginal Heritage Tasmania for The Grange project site. These indicted that there are no Aboriginal heritage sites recorded within or close to the project site and it is believed that there is a low likelihood of Aboriginal heritage being present (pers. comm. Laurel McGinnity, NRM South, 20 August, 2021).

6.2.2. Native vegetation

The disturbance footprint of embankments and drains at Long Point are novel communities, and in many cases weed infested, that are inconsistent with the surrounding saltmarsh vegetation. These novel communities have established in response to the changes in elevation created by these works (e.g. the embankments are drier than the surrounding saltmarsh habitat). Hence, as long as the works are completed carefully to stay within the former disturbance footprint, no remnant native vegetation clearance will be required to complete site remediation.

Further, the remedial works will allow for recolonisation and seamless expansion of the threatened saltmarsh community across its former full extent. This is supported by the NCP (2005), which states that the relatively high degree of specialisation required to live in the saltmarsh environment means that once remediated, degraded areas will almost certainly regenerate to typical saltmarsh vegetation given enough time.

The capacity of saltmarsh vegetation to re-establish in degraded areas is directly correlated to the frequency of inundation (Laegdsgaard, 2002). Sites close to the low water mark (which typifies most of the proposed works areas) and subject to regular inundation may regenerate relatively quickly, while those close to the high water mark and subject to irregular inundation may take several years to regenerate. Hence, no permit for native vegetation clearance was sought.

6.2.3. Water

NGT has consulted with the water regulator, NRE Tasmania and there are no issues of concern with the proposed works under the *Water Management Act 1999* (as per email correspondence with Bill Shackcloth, NRE Tas, 23rd August 2021). As the margin of Moulting Lagoon is deemed a tidal area and there is no true watercourse, back-filling non-natural drains/voids does not trigger any permit requirements, as long as works are done sensitively, with minimal footprint, and if no soil is introduced to the site.

In summary, no permit was required to be sought under the Water Act.

6.2.4. Planning

Glamorgan Spring Bay Council

Exemptions for restoration works under the Glamorgan Spring Bay Council planning code (planning permit and Waterway and Coastal Protection Code) were discussed and then requested formally via Alex Woodward, Director Planning and Development, GSBC (December 2021). Given authorisation for the works had already been provided by NRE Tas, exemption under Council's planning code was accepted and formal correspondence on the matter was provided as a matter of due diligence (email from James Bonner, Senior Planner, 10th January 2022).

The works are exempt from a planning permit as we determined the works meet the provisions under clause 5.4.4 (d) of the Interim Planning Scheme: the implementation of a vegetation management agreement or a natural resource, catchment, coastal, reserve or property management plan or the like, provided the agreement or plan has been endorsed or approved by the relevant State authority or a council.

An exemption under the Waterway and Coastal Protection Code applied based on the logic that:

1. The state government (NRE Tas) have already scrutinised (to an especially rigorous and high standard, given the existence of the covenant) and approved the proposed works on private land adjacent to Moulting Lagoon, which confirms that the works are "considered necessary by an agency" "to mitigate or prevent environmental harm";
2. NGT has been engaged to manage the project and works by NRM South, the responsible, state government endorsed, regional land management agency for the area proposed for works, with funding provided by the Australian Government; and
3. Given Item 1, the following exemptions under the local government development code apply:

   (i) works considered necessary by an agency or council to remedy an unacceptable risk to public or private safety or to mitigate or prevent environmental harm;

   (j) works considered necessary by an agency or council for the protection of a water supply, watercourse, lake, wetland or tidal waters or coastal values as part of a management plan.

Authorisation under Covenant, Natural Resources and Environment, Tasmania

TLC in conjunction with NGT, submitted an application and supporting information to seek the Minister's authorisation to undertake restorative, remedial works at Long Point Reserve under the existing Conservation Covenant C625722 (August 2021).

NRE acknowledged that at the time of covenant drafting, there was an intention to allow for future restorative works within the covenanted land and that the covenant provides for the owner to undertake activities to protect and enhance the natural values. The NCP clearly stated that the land had been subjected to degradation by a range of processes including major disturbance to the wetlands and saltmarsh from drains, canals and levees established by previous owners.

NRE Tas provided authorisation for the works in October 2021 (letter, Iona Mitchell, Team Leader (Covenants, Communications & Monitoring), Private Land and Conservation Program, NRE Tas, 27 October 2021) subject to the following:

- Restoration works will be limited to voids and drains being backfilled with material from existing levee embankments and spoil heaps in the most sensitive manner possible.
- Ground disturbance is limited to the footprint area of drains and levees presently modified.
- Appropriately qualified contractors will operate under NGT supervision.
- Vehicles and machinery must use formed tracks and traverse over dry, high ground.
- Earthworks will be limited to restoration of the natural landform to facilitate natural regeneration of native saltmarsh vegetation.
- Personal and equipment hygiene must be implemented.
- TLC must undertake ongoing surveys of the disturbed area and weed control actions as necessary.
- TLC must provide a copy of NGT's eco-hydrological assessment and restoration plan (this document) to the Private Land Conservation Program, NRE.

6.3. Works philosophy and methodology

Where possible, all existing drainage and levee footprints across Long Point and Yards Hole will be targeted to reinstate natural geomorphology and surface elevations. Voids and drains will be back-filled with material from existing levee embankments and spoil heaps in the most sensitive manner possible, with appropriately qualified contractors operating under NGT supervision, to limit the area of restoration disturbance and avoid the need to bring fill in from off site.

One previous NGT example that highlights the general method proposed and potential hydrological and ecological response is at Glenshera Swamp, Stipiturus Conservation Park (Swamps of the Fleurieu Peninsula, critically endangered under the EPBC Act). Despite being in a different landform and vegetation type, this is a useful visual example.

Figure 39 shows the method of sensitive drain backfilling and its impact on hydrology, which will now trigger an ecological response in the flora of the disturbance footprint.

Figure 39: The process of drain back-filling and its impact on site hydrology at Glenshera Swamp, Stipiturus Conservation Park. Photos: Mark Bachmann

Figure 40 is an area of earlier works showing how spontaneous native vegetation recovery can be expected in areas that support intact surrounding vegetation.

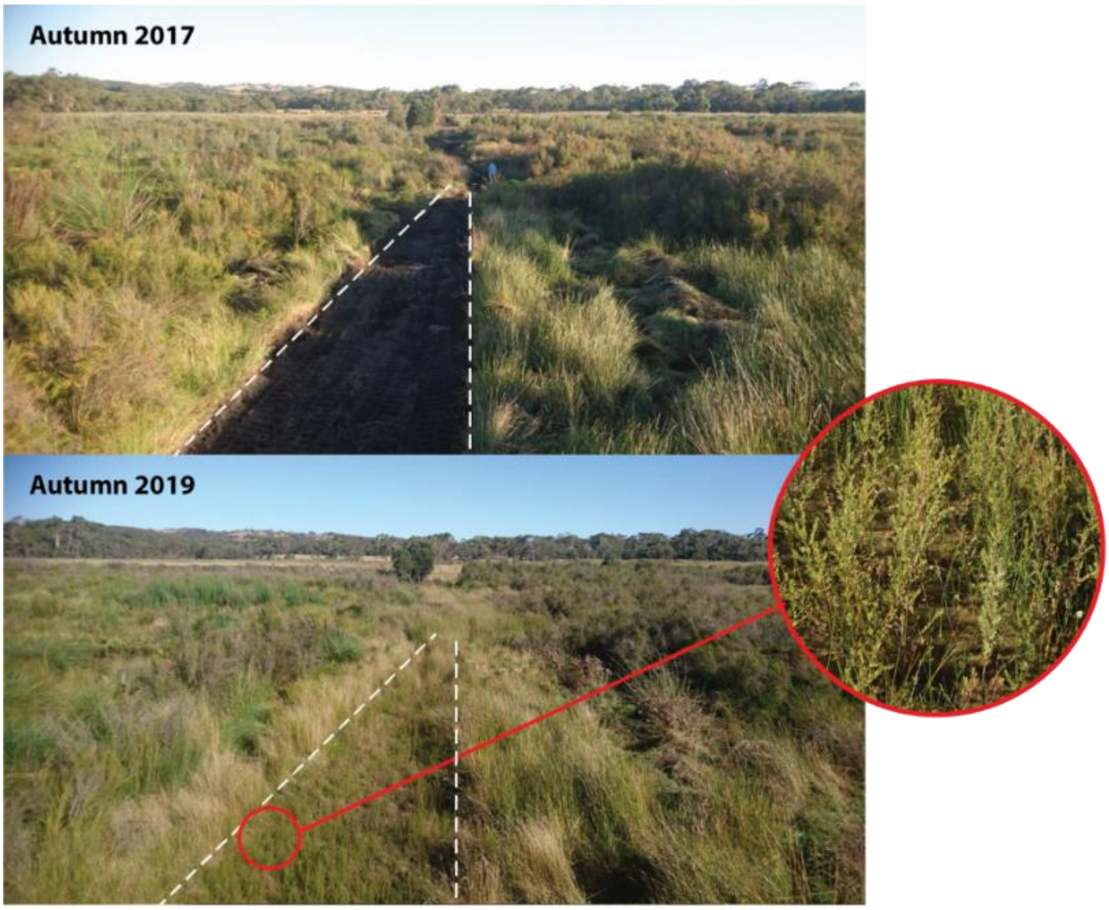


Figure 40: Drain back-filling (above) resulting in spontaneous native vegetation recovery (below) at Glenshera Swamp, Stipiturus Conservation Park. Photos: Mark Bachmann

6.3.1. Selection of appropriate plant and equipment

Liaison with the preferred earthworks contractor has involved the preliminary selection of the most appropriate plant and equipment for the job, including different sizes of excavator and the option to access additional, specific, fit-for-purpose machinery if required. This is in consideration of factors like: ground wetness, accessibility, width and type of machine tracks, as well as the weight and reach of the machine.

Lower-impact rubber tracked excavators will be used when machines are accessing the lower saltmarsh areas, and the option of using a small barge mounted excavator is available, if required, to improve access the margin of the site when artificial channels require remediation where they discharge into Moulting Lagoon.

6.4. Specific site restoration plans

More specific restoration plans for individual areas with a legacy of past physical disturbance are detailed in the sections below, noting that:

- for artificial drainage earthworks works completed since the 1950s with heavy machinery, we will use the earliest aerial imagery as a remediation template,
- for earlier levee bank works completed prior to the 1950s, which used convict labour, we will reference the topography of the adjacent undisturbed land to guide works and undertake works according to the agreed, low impact method.

Works will also be informed by the modern LiDAR imagery which clearly displays the location of artificial spoil banks, drains, mounds, levees and voids created by past physical works.

Remediating sites disturbed since the 1950s

Northern saltmarsh and inlet to Yards Hole (The Grange)

To the north of Yards Hole, we have the benefit of being able to refer to the 1948 image, to guide the works and provide a remediation template, as shown in **Figure 41**.

Remediation template:

Figure 41: Northern saltmarsh and inlet to Yards Hole, The Grange – pre-disturbance conditions in 1948, providing a site remediation template for the northern end of the wetland.

Remediating the northern portion of Yards Hole involves a series of actions to reverse past damage to the natural channel that connects Yards Hole with Moulting Lagoon, as well as the reinstating the natural topography of the surrounding saltmarsh zone, as shown in **Figure 42**.

Current condition:

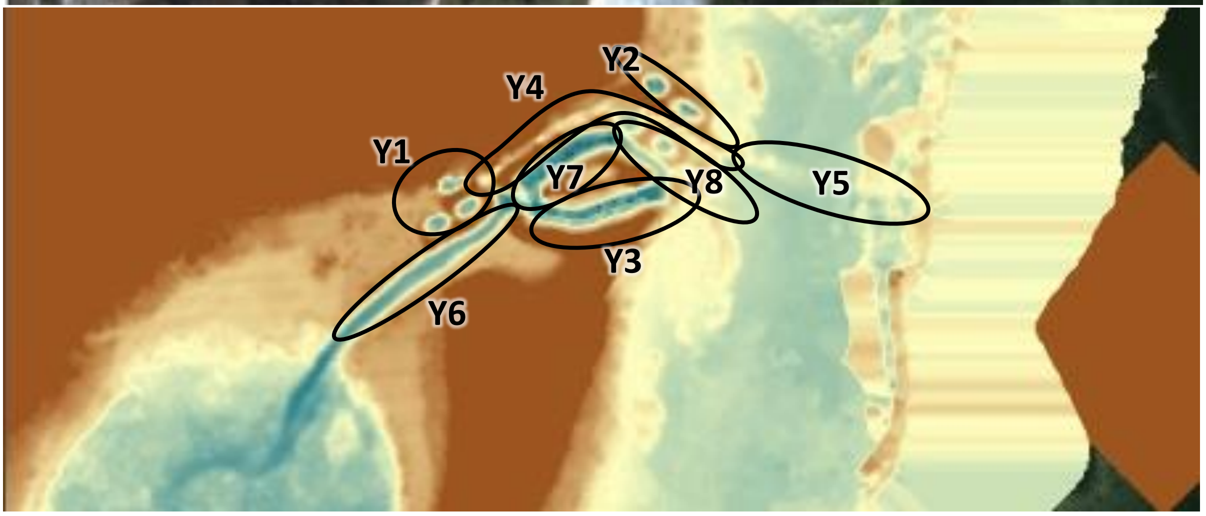


Figure 42: Northern saltmarsh and inlet to Yards Hole, The Grange – current conditions (above) and annotated LiDAR (below) outlining restoration activities. See text for explanation of codes.

As highlighted in **Figure 42**, the remediation of the northern saltmarsh and inlet to Yards Hole will involve:

- **Task Y1:** Backfilling upper ponds, using spoil to reinstate saltmarsh surface.
- **Task Y2:** Backfilling lower ponds, using spoil to reinstate saltmarsh surface.
- **Task Y3:** Backfilling this larger artificial channel branch / pond and using spoil to reinstate natural surface profile in the saltmarsh.
- **Task Y4:** Backfilling the landward portion of the narrow artificial channel to Little Bay and using spoil to reinstate natural surface profile in the saltmarsh.
- **Task Y5:** Backfilling the Little Bay inlet to the narrow artificial northern channel branch, if enough material is available in the available spoil to reinstate the bed natural surface. This task is especially dependent on site conditions enabling access.
- **Task Y6 and Y7:** Re-instating the natural bank contours and alignment of the original waterway and adjacent natural saltmarsh surface.
- **Task Y8:** Backfilling remaining lower ponds, using spoil to reinstate saltmarsh surface and re-instate the natural bank contours and alignment of the original waterway that occurred in this location. This includes reforming the shallow inlet with a depth profile that peters out to natural surface at the edge of Little Bay.

Yards Hole (The Grange)

At Yards Hole, we also have the benefit of being able to refer to the 1948 image, to guide the works and provide a remediation template, as shown in **Figure 43**.

Site remediation template:

Figure 43: Yards Hole, The Grange – pre-disturbance conditions in 1948, providing a site remediation template.

Remediating Yards Hole involves a series of actions to reverse past damage to a narrow band around the outer bank, and a small portion of bed, of this wetland feature, as shown in **Figure 44**.

Current condition:

Figure 44: Yards Hole, The Grange – current conditions (left) and annotated LiDAR (right) outlining restoration activities. See text for explanation of codes.

As highlighted in **Figure 44**, the remediation of Yards Hole will involve:

- **Task Y9:** Backfilling the outer channel around the eastern edge of Yards Hole, re-instating the natural bank contour and its gradient with the adjacent natural saltmarsh surface**.**
- **Task Y10:**
    - **Step 1:** undertake a pre-works survey of the works disturbance footprint (i.e. along the spoil bank and excavated channel) to check for the presence of the rare species Roundleaf Wilsonia (*Wilsonia rotundifolia*), which has previously been detected on the western side of Yards Hole.
    - **Step 2:** if the species is present in the works disturbance footprint, mark out any zones where this is the case and delay works in those areas until 2023, to allow for a mitigation plan to be developed. The goal of the mitigation plan would be to ensure that species is able to recover and recolonise more of Yards Hole in response to hydrological restoration works and grazing exclusion, and/or to provide for the physical relocation of any plants that may be impacted by the future works footprint, to facilitate its post-works recovery.
    - **Step 3:** if and where the species is not present in the works disturbance footprint, backfilling of the outer channel around the western edge of Yards Hole will occur. The objective will be to achieve the re-instatement of the natural bank and bed contour and its gradient with the adjacent natural saltmarsh surface.
- **Task Y11:** Backfilling the channel by removing the spoil bank through the northern end of Yards Hole, reinstating the bathymetry of the bed of the wetland, with timing subject to site conditions.

Opening Hole and associated artificial drainage features (Long Point)

The 1948 image shows the original topography surrounding Opening Hole, which will guide on-ground works and provide a remediation template, as shown in **Figure 45**.

Site remediation template:

Figure 45: Opening Hole, Long Point – pre-disturbance conditions in 1948, providing a site remediation template.

Remediating Opening Hole involves disconnecting it from the influence of artificial drainage channel which runs between King Bay and Moulting Lagoon. This primary action required is to reverse the artificial channel works south of Opening Hole, as shown in **Figure 46**.

Current condition:

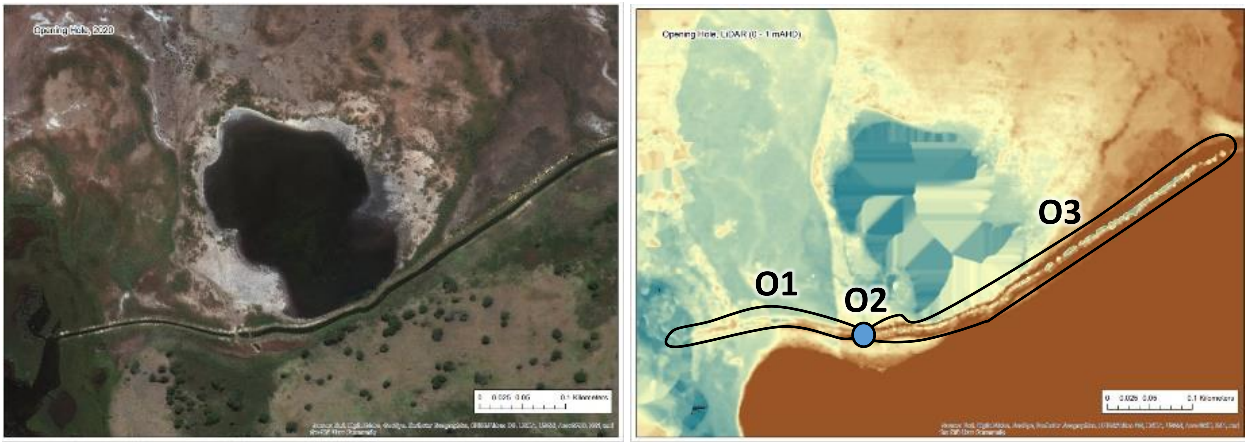


Figure 46: Opening Hole, Long Point – current conditions (left) and annotated LiDAR (right) outlining restoration activities. See text for explanation of codes.

As highlighted in **Figure 46**, the remediation of Opening Hole will involve:

- **Task O1:** Backfilling the outer channel between Opening hole and King Bay, with timing subject to site conditions, reinstating to match the adjacent natural saltmarsh surface.
- **Task O2:** Removing the culvert and backfilling to match the adjacent natural saltmarsh surface.
- **Task O3:** Backfilling the inner channel between Opening hole and the natural section of the Barkstand channel. In this zone, in places the channel is situated on the slope between Barkstand Point and the saltmarsh, so care will be taken to ensure the bank slope/gradient is correctly reinstated to allow the future natural regeneration of habitat along this ecotone.

Barkstand channel and associated drainage features (Long Point)

The 1948 image also shows the original topography to the east of Opening Hole, around the Barkstand channel, which will guide on-ground works and provide a remediation template, as shown in **Figure 47**.

Site remediation template:

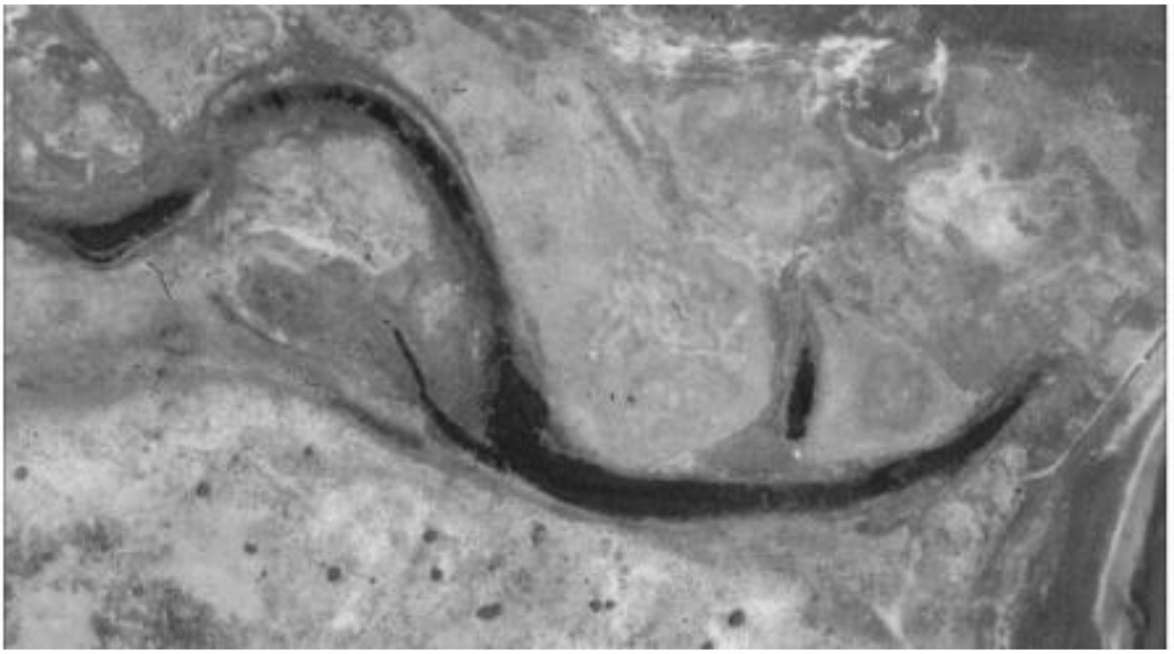


Figure 47: Barkstand channel, Long Point – pre-disturbance conditions in 1948, providing a site remediation template.

Remediating the Barkstand channel area involves disconnecting it from having permanent connection with Moulting Lagoon and remediating the adjacent saltmarsh surface, as shown in **Figure 48**.

Current condition:

Figure 48: Barkstand channel, Long Point – current conditions (above) and annotated LiDAR (below) outlining restoration activities. See text for explanation of codes.

As highlighted in **Figure 48**, the remediation of Barkstand channel will involve:

- **Task B1:** Backfilling the entire artificial channel situated between works location O3 and Barkstand channel, reinstating to match the adjacent natural saltmarsh surface.
- **Task B2:** Backfilling the spoil material excavated from bed of the Barkstand channel, re-instating the natural bank contour and its gradient with the adjacent natural surface– which is a mixture of saltmarsh and higher ground on Barkstand Point**.** Care will be taken to ensure the bank slope/gradient is correctly reinstated to allow the future natural regeneration of habitat along this ecotone.
- **Task B3:** Backfilling the connection point between Barkstand channel and Moulting Lagoon, using spoil to reinstate saltmarsh surface and re-instate the natural bank contours and alignment of the original waterway that occurred in this location. This includes reforming the shallow inlet with a depth profile that peters out to natural surface.
- **Task B4:** Backfilling to recreate the small series of saline lagoons, to match their natural bank profiles, original connectivity with adjacent features and the adjacent saltmarsh surface.

Inlet cutting to small saltmarsh wetland (north of main levee) (Long Point)

All aerial imagery up until the early 1990s shows a small saltmarsh wetland north-east of Round Hole being disconnected from Moulting Lagoon (**Figure 50**), but more recent imagery shows a small cutting was made at this location in the mid-late 1990s (**Figure 49** and **Figure 50**).

Current condition:

Figure 49: Inlet cutting to small saltmarsh wetland, Long Point – oblique image looking east. Photo: Mark Bachmann

Current condition: **Site remediation template:**

Figure 50: Inlet cutting to small saltmarsh wetland, Long Point – current conditions (left) and pre-disturbance conditions in 1948 (right).

As shown in **Figure 50**, at **Location I1** the site will be assessed with the contractors while on-site (undertaking the other work in autumn 2022) to determine the best method for access and availability of spoil. This is because unlike all other works locations, this site appears to have been accessed by those who completed the work (possibly duck hunters) from the water's edge and has not resulted in the formation of a spoil bank, which implies that heavy machinery was not used to make the cutting. Works at this location are a lower priority than other sites and will be an option for completion, subject to budget availability, in 2023.

Remediating sites disturbed before the 1950s

The levee embankment works that date to the mid-1800s are not as physically large or deep as, and the disturbance footprint is typically narrower than, those created later with heavy machinery; however, they are nevertheless extensive (in length) across the property. While these disturbance sites do not have the benefit of being able to now reference aerial imagery that pre-dates construction, the narrow footprint of disturbance does provide the advantage that the topography of the typically flat natural (undisturbed) ground either side of the levee can simply be used as an accurate visual guide for works.

Hence the method to be adopted at these sites is very much consistent with the examples provided earlier in **Figure 39** and **Figure 40**, but noting that access is to be gained during the driest time of year (autumn) when there is minimal or no surface water in the saltmarsh.

A cross-section showing the process for levee bank remediation, how this reinstates the natural topography of the surrounding saltmarsh, and what drives recovery of the remediation works footprint, is shown in **Figure 51**.

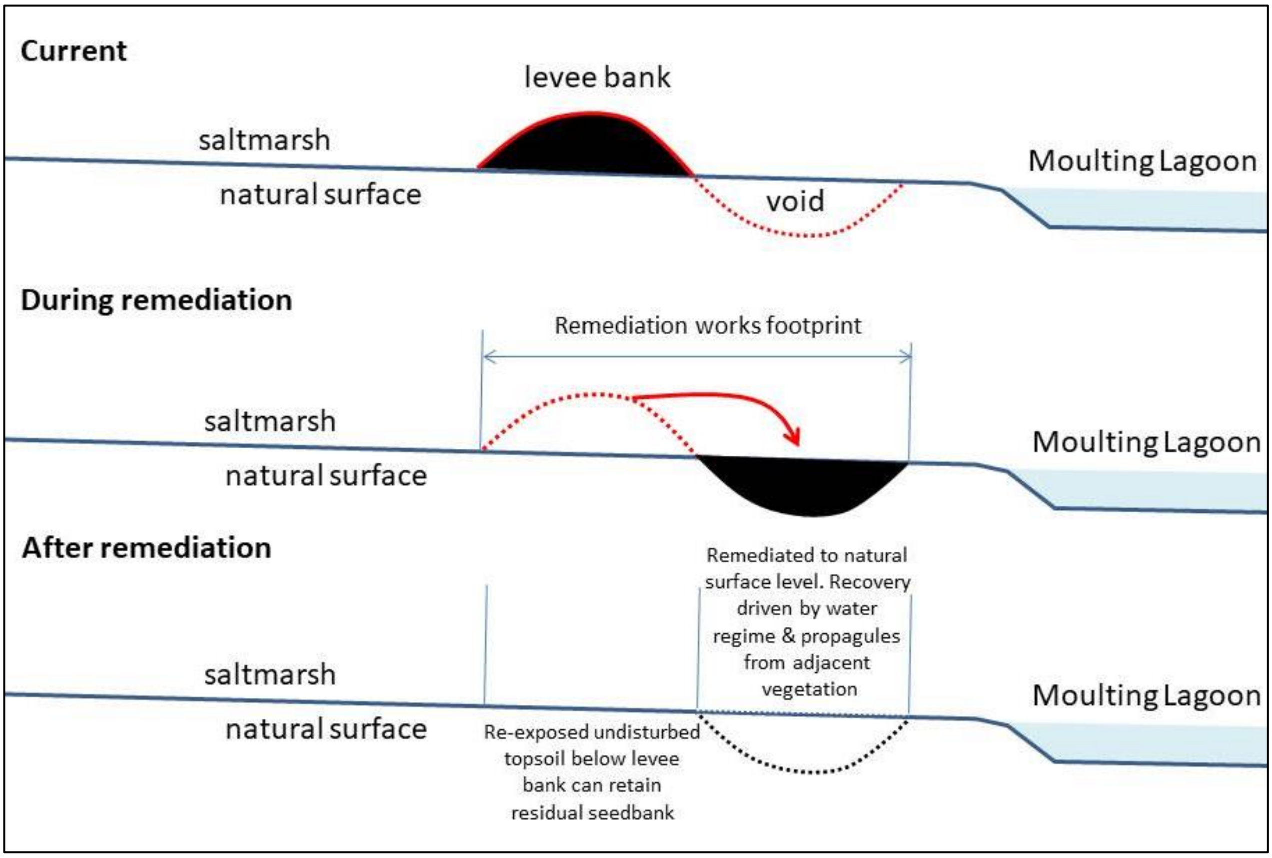


Figure 51: Cross-section, illustrating the restoration process being used by NGT to remediate the 1800s-era network of levees on Long Point, to knit the natural surface back together as close as possible to its original gradient and elevation, allowing for the reinstatement of natural tidal movements and floods across the project area.

The sites relevant to this remediation method are outlined over the subsequent pages, as shown in the images from **Figure 52** to **Figure 54**.

Eastern (main L-shaped) levee – northern arm

Current condition:

Figure 52: The northern arm of the eastern (main L-shaped) levee, Long Point – current conditions (oblique [Photo: Mark Bachmann] and aerial images) showing works area and disturbance footprint.

Eastern (main L-shaped) levee – eastern arm

Current condition:

Figure 53: The eastern arm of the eastern (main L-shaped) levee, Long Point – current conditions (oblique [Photo: Mark Bachmann] and aerial images) showing works area and disturbance footprint.

Western (minor) levee

Current condition:

Figure 54: Western (minor) levee, Long Point – current conditions (oblique [Photo: Mark Bachmann] and aerial images) showing works area and disturbance footprint.

6.4.1. Works prioritisation and timing

All works will be completed in an order and manner that minimises traffic movements across the site, and with equipment (i.e. rubber tracked excavators where applicable) that minimises impact. The specific order of works at each location will be dictated by site conditions, access and other requirements, after site induction and consultation with the contractor. Works will commence in March 2022 according to the over-arching priority order outlined below. This is based on the need to successfully commence, and if possible complete, works on both properties, as well as achieve an appropriate level of supervision at different sites (i.e. to facilitate adequate supervision at those locations with more complex requirements).

Highest initial priority for concurrent works:

- **The Grange – Yards Hole:**
  - Tasks Y1, Y2, Y3, Y4, Y6, Y7, Y8 and Y9, with sequence to be discussed with the contractor.
  - Task Y10 is subject to the additional steps put in place for significant native flora.
- **Long Point – Eastern (main L-shaped) levee:**
  - Tracking along the levee embankment, to the farthest points from the two likely access locations (at either end of the levee) and working backwards, avoiding later having to track back over remediated ground (which is also likely to be wetter and more difficult for repeat access).

Followed by concurrent works at:

- **Long Point – Western (minor) levee**:
  - Work can occur in either direction, using the adjacent vehicle track for access, and avoiding later having to track back over remediated ground (which is also likely to be wetter and more difficult for repeat access).
- **Long Point – Opening Hole and Barkstand channel:**
  - Tasks O2, O3, B1, B2 B3 and B4, with specific sequence to be discussed and agreed with the contractor to minimise movements and access beyond the works footprint.

Then finally:

- **Long Point – Inlet cutting** to small saltmarsh wetland (north of main levee):
  - Location I1 - subject to site conditions and discussion with the contractor.
- **The Grange and Long Point –** Any other locations at either property that may only be accessible by barge from the water or in the driest seasonal conditions:
  - Potentially relevant to Tasks Y5, Y11 and O1, subject to site conditions.

The works will be fully supervised, guided and directed by NGT in March and/or April 2022, and be completed by two operators experienced in undertaking sensitive environmental works, with access to multiple machines provided by the contractor. Contractor input and knowledge of the capabilities of their machines will be incorporated into adaptive decision making while the works are underway, remaining at all times consistent with the remediation philosophy and other guidance outlined in this plan.

6.4.2. Contingency plans

Subject to weather and site conditions, as well as additional factors outlined in this plan (e.g. flora at Yards Hole), a provision has been made in project agreements to allow for works to be carried over into summer/autumn 2023, if necessary. Should the works not be able to be completed in their entirety during the current project, NGT will ensure that the maximum amount of remedial work possible is completed for the budget made available by NRM South. Under such a scenario, this restoration plan will remain a live document in the event that further funding becomes available to complete any outstanding works.

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APPENDIX 1: Vegetation Transect Data

Transect data for 2013 and 2021 for John Aalders transects, Long Point (see transect locations in Figure x, section x). Green plots are those <0.5m elevation and deemed saltmarsh. Those in yellow are deemed saline grassland/fringing woodland. Plots highlighted red are those which have had a significant observable change in either vegetation extent and or composition.

RED TRANSECT

Scientific name	Common name	R1		R2		R3		R4		R5		R6		R7		R8		R9		R10		R11		R12		R13		R14	
	Eastings	0595274		0595364		0595516		0595540		0595604		0595637		0595812		0595846		0595871		0595963		0595979		0596015		0596082		0596154	
	Northings	5345047		5344998		5344920		5344908		5344872		5344854		5344762		5344742		5344728		5344684		5344672		5344652		5344617		5344577	
	Plot elevation	0.304		0.169		0.509		1.153		0.243		0.214		0.293		0.611		2.157		2.873		0.472		0.238		0.257		0.227	
	Survey year	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021
Bare ground	**Bare ground**	0	4	4	6	0	3			0	5	0	2	2	6	4	3					0	4	3	4	0	3		
Acetosella vulgaris	sheep sorrel																			2	?								
Aira caryophyllea	silvery hairgrass																												
Allocasuarina verticillata	drooping sheoak																												
Anagallis arvensis	scarlet pimpernel																												
Anthoxanthum odoratum	sweet vernalgrass																					3	?						
Astroloma humifusum	native cranberry							2	?									2	?										
Austrodanthonia setacea	bristly wallaby-grass																												
Austrostipa flavescens	yellow speargrass															2	?												
Austrostipa stipoides	coast speargrass					6	4	1	1							4	3	2	2										
Baumea juncea	bare twigrush							5	4							2	2												
Carex breviculmis	short stem sedge																	2	?										
Centaurium erythraea	common centaury																					2	?						
Danthonia (spicata)	poverty grass																	1	?										
Dichelachne crinita	longhair plumegrass																												
Dichondra repens	kidneyweed																	2	?	2	?								
Disphyma crassifolium	roundleaf pigface	2	1			2	3			3	0	2	0	2	0	2	1						3	2	0			3	5
Distichlis distichophylla	Australian saltgrass																												
Ehrharta stipoides?	weeping grass							3	?									2	?	4	?								
Festuca arundinacea	tall fescue																												
Gahnia filum	chaffy sawsedge																												
Gahnia trifida	coast sawsedge																												
Galium australe	tangled bedstraw																												
Hemochroa pentandra	trailing saltstar																												
Hibbertia procumbens	spreading guineaflower																	2	?										
Hibbertia prostrata	prostrate guineaflower																												
Hypochoeris radicata	rough catsear																	2	?										
Isolepis cernua	nodding clubsedge																2						4						
Isolepis nodosa	knobby clubsedge																2	2	?	3	3	2	1						
Jacobaea vulgaris	ragwort															1	?												
Juncus kraussii australiensis	sea rush					3	3									2	2					3	3						1
Juncus pallidus	pale rush																					2							
Leontodon taraxacoides	hairy hawkbit							2	?							1	?	1	?	1	?								
Lepidosperma concavum	sand swordsedge							3	?																				
Leptocarpus brownii	coarse twine rush							2	2																				
Lissanthe strigosa subulata	peachberry heath																												
Lobelia alata	angled lobelia																					2							

Lomandra longifolia	sagg							3	3									6	5	2	2								
Oxalis perennans	grassland woodsorrel							2	?									1	?	2	?								
Pimelea glauca	smooth riceflower																												
Pimelea humilis	dwarf riceflower																												
Plantago coronopus	buckshorn plantain																												
Poa labillardierei var. labillardierei	silver tussockgrass					2										2	?			2	2	6	3						
Poa rodwayi	velvet tussockgrass																	2	?										
Pteridium esculentum	bracken							4	4									4	4	5	5								
Sarcocornia blackiana	thickhead glasswort					2	3			4	2	2	0				2												
Sarcocornia quinqueflora quinqueflora	beaded glasswort	5	3	5	0	0	3			4	3	6	6	4	0									5	5	6	4	3	4
Schoenus nitens	shiney bog rush															1	?												
Scleranthus biflorus	twinflower knawel																												
Selliera radicans	shiny swampmat																						2						1
Spergularia tasmanica	greater seaspurrey																												
Spergularia marina	lesser seaspurrey																												3
Tecticornia arbuscula	shrubby glasswort	6	6							4	4			4	4									5	4			5	5
Themeda triandra	kangaroo grass																												
Ulex europaeus	gorse							2	-									3	0										
Vellereophyton dealbatum	white cudweed																			1	?								
Zoysia macrantha	prickly couch																						3						

YELLOW TRANSECT

Scientific name	Common name	Y1		Y2		Y3		Y4		Y5		Y6		Y7		Y8		Y9		Y10		Y11		Y12		Y13		Y14		Y15		Y16		Y17	
	Eastings	0595006		0595012		0595062		0595168		0595186		0595211		0595230		0595260		0595323		0595344		0595366		0595554		0595650		0595756		0595944		0596000		0596011	
	Northings	5344136		5344132		5344089		5344016		5344004		5343988		5343975		5343957		5343913		5343897		5343883		5343760		5343696		5343626		5343513		5343474		5343462	
	Plot elevation	0.270		0.221		0.233		0.527		0.491		0.608		2.180		9.069		3.633		0.660		0.467		0.330		0.479		0.849		0.516		0.225		0.247	
	Survey year	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021
Bare ground	**Bare ground**	0	1	0	2	2	5	2	3	3	4		2									4	5	2	2		3		2	4	6	0	3	0	4
Acetosella vulgaris	sheep sorrel																	2	2																
Aira caryophyllea	silvery hairgrass																																		
Allocasuarina verticillata	drooping sheoak													2	3																				
Anagallis arvensis	scarlet pimpernel											1								1															
Anthoxanthum odoratum	sweet vernalgrass															2	2			3															
Astroloma humifusum	native cranberry																																		
Austrodanthonia setacea	bristly wallaby-grass																																		
Austrostipa flavescens	yellow speargrass																																		
Austrostipa stipoides	coast speargrass							2	4	3				1		3		2								5		3		3					
Baumea juncea	bare twigrush											3		2						1															
Carex breviculmis	short stem sedge																																		
Centaurium erythraea	common centaury																																		
Danthonia (spicata)	poverty grass															2	2																		
Dichelachne crinita	longhair plumegrass																																		
Dichondra repens	kidneyweed																																		
Disphyma crassifolium	roundleaf pigface	4	4			1	0	1		1	2											2		0	3	3	2			2	2			4	0
Distichlis distichophylla	Australian saltgrass													2				2	2									2	3						
Ehrharta stipoides?	weeping grass													5		6	?	5	5																
Festuca arundinacea	tall fescue																			5															
Gahnia filum	chaffy sawsedge	2	0								1									2				2	2		2	2							

Gahnia trifida	coast sawsedge							2		2										3						4									
Galium australe	tangled bedstraw													1																					
Hemochroa pentandra	trailing saltstar																								1						1				
Hibbertia procumbens	spreading guineaflower																																		
Hibbertia prostrata	prostrate guineaflower																																		
Hypochoeris radicata	rough catsear																																		
Isolepis cernua	nodding clubsedge																																		
Isolepis nodosa	knobby clubsedge							1				2						3																	
Jacobaea vulgaris	ragwort																																		
Juncus kraussii australiensis	sea rush							2		1		2	2					1		1	1					1		2	3						
Juncus pallidus	pale rush															2																			
Leontodon taraxacoides	hairy hawkbit											1						2	2																
Lepidosperma concavum	sand swordsedge																																		
Leptocarpus brownii	coarse twine rush							1	2				2																						
Lissanthe strigosa subulata	peachberry heath													2																					
Lobelia alata	angled lobelia							1								1																			
Lomandra longifolia	sagg													5	4	1	2																		
Oxalis perennans	grassland woodsorrel													1	1	2	2	2	2																
Pimelea glauca	smooth riceflower																											2							
Pimelea humilis	dwarf riceflower													1																					
Plantago coronopus	buckshorn plantain							1				1				1	2																		
Poa labillardierei var. labillardierei	silver tussockgrass							3	1			4	3			2				2	2							3	5						
Poa rodwayi	velvet tussockgrass															2	3	2	2																
Pteridium esculentum	bracken																																		
Sarcocornia blackiana	thickhead glasswort							2	3	2	3											2				3	3			2					
Sarcocornia quinqueflora quinqueflora	beaded glasswort	5	4	6	6	5	2			3	4											3		5	6	3	6			3	2	6	6	4	2
Schoenus nitens	shiney bog rush																																		
Scleranthus biflorus	twinflower knawel																	1	1																
Selliera radicans	shiny swampmat												2																						
Spergularia tasmanica	greater seaspurrey																																		
Spergularia marina	lesser seaspurrey																																		
Tecticornia arbuscula	shrubby glasswort	5	5			5	5															3	4	4	3	1				4	4			6	6
Themeda triandra	kangaroo grass													1		2																			
Ulex europaeus	gorse																											3							
Vellereophyton dealbatum	white cudweed							1																											
Zoysia macrantha	prickly couch							4				6								3															
Introduced species & weeds												2								5								4							

GREEN TRANSECT

Scientific name	**Common name**	**G1**		**G2**		**G3**		**G4**		**G5**		**G6**		**G7**		**G8**		**G9**		**G10**		**G11**		**G12**		**G13**		**G14**		**G15**		**G16**	
	Eastings	0594642		0594627		0594619		0594605		0594604		0594598		0594584		0594557		0594524		054424		0594375		0594316		0594417		0594425		0594441		0594489	
	Northings	5343882		5343774		5343710		5343608		5343570		5343535		5343490		5343447		5343384		5343195		5343104		5342933		5342809		5342800		5342782		5342722	
	Plot elevation	0.273		0.227		0.234		0.427		0.529		2.061		2.298		0.778		0.528		0.460		0.290		0.264		0.363		0.532		4.338		10.323	
	Survey year	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021	2013	2021
Bare ground	**Bare ground**	0	2	3	2	4	6	5	5			3	3	2	2	3	3	3	3	5	5	0	3	3	6								
Acetosella vulgaris	sheep sorrel																																
Aira caryophyllea	silvery hairgrass																													3	?	3	?
Allocasuarina verticillata	drooping sheoak																																
Anagallis arvensis	scarlet pimpernel																																
Anthoxanthum odoratum	sweet vernalgrass																																
Astroloma humifusum	native cranberry																													1	?		
Austrodanthonia setacea	bristly wallaby-grass																													4	?	3	?
Austrostipa flavescens	yellow speargrass																													2	?		
Austrostipa stipoides	coast speargrass									3	3							3	2									3	3				
Baumea juncea	bare twigrush										2					4	3											3	4	4	3		
Carex breviculmis	short stem sedge																																
Centaurium erythraea	common centaury																																
Danthonia (spicata)	poverty grass																																
Dichelachne crinita	longhair plumegrass																															3	?
Dichondra repens	kidneyweed																																
Disphyma crassifolium	roundleaf pigface	4	4															2	2		3	0	3										
Distichlis distichophylla	Australian saltgrass																											4	3				
Ehrharta stipoides?	weeping grass																																
Festuca arundinacea	tall fescue																																
Gahnia filum	chaffy sawsedge																	4	3			4	4	3	0			3	3				
Gahnia trifida	coast sawsedge																																
Galium australe	tangled bedstraw																																
Hemochroa pentandra	trailing saltstar																																
Hibbertia procumbens	spreading guineaflower																																
Hibbertia prostrata	prostrate guineaflower													3	3																		
Hypochoeris radicata	rough catsear																																
Isolepis cernua	nodding clubsedge																										2						
Isolepis nodosa	knobby clubsedge											3																					
Jacobaea vulgaris	ragwort																																
Juncus kraussii australiensis	sea rush									3	3		3		3	3	3	3	2									3	2			1	2
Juncus pallidus	pale rush											3		3														2				3	
Leontodon taraxacoides	hairy hawkbit																																
Lepidosperma concavum	sand swordsedge																																
Leptocarpus brownii	coarse twine rush																																
Lissanthe strigosa subulata	peachberry heath																																
Lobelia alata	angled lobelia									2																							
Lomandra longifolia	sagg											1	2	3	3	3	4													3	3		
Oxalis perennans	grassland woodsorrel													1																		2	2
Pimelea glauca	smooth riceflower																																
Pimelea humilis	dwarf riceflower																																
Plantago coronopus	buckshorn plantain																																

Poa labillardierei var. labillardierei	silver tussockgrass									5	4			3	2	4	2											5	3	4	4	2	2
Poa rodwayi	velvet tussockgrass																															3	3
Pteridium esculentum	bracken											4	4	5	5																		
Sarcocornia blackiana	thickhead glasswort																		4		4												
Sarcocornia quinqueflora quinqueflora	beaded glasswort	5	6	4	5			3		1								4	2	5		5	3	5	0	6	0						
Schoenus nitens	shiney bog rush																																
Scleranthus biflorus	twinflower knawel																																
Selliera radicans	shiny swampmat										2																						
Spergularia tasmanica	greater seaspurrey																								2								
Spergularia marina	lesser seaspurrey																																
Tecticornia arbuscula	shrubby glasswort			4	4	4	4	3	5																								
Themeda triandra	kangaroo grass															2	?																
Ulex europaeus	gorse																																
Vellereophyton dealbatum	white cudweed																																
Zoysia macrantha	prickly couch																													4	4	5	4
Introduced species & weeds											3																						

APPENDIX 2: Photo Point Monitoring

All monitoring site photos below correspond to monitoring sites identified in Figure 20.

THE GRANGE

Yards Hole

North	
23 June 2021	
3 September 2021	

2 December 2021	
South	
23 June 2021	

3 September 2021	
2 December 2021	

LONG POINT

Opening Hole

North	
24 June 2021	
3 September 2021	

2 December 2021	
South	
24 June 2021	

3 September 2021	
2 December 2021	

Round Hole

North	
24 June 2021	
3 September 2021	

2 December 2021	

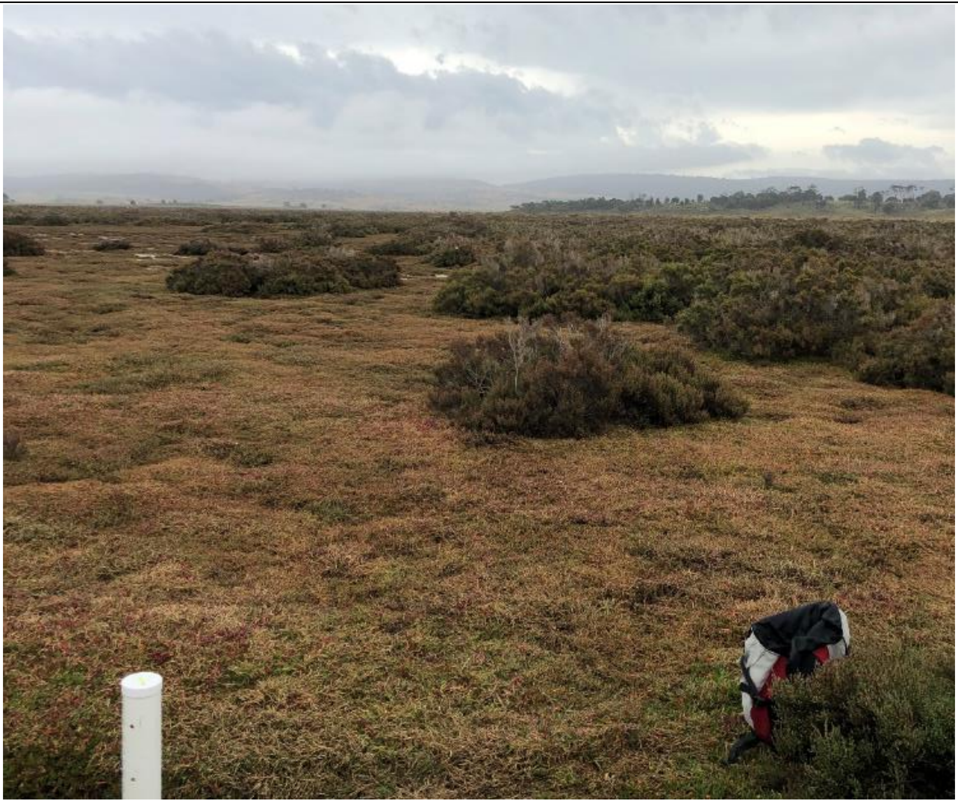
Transects

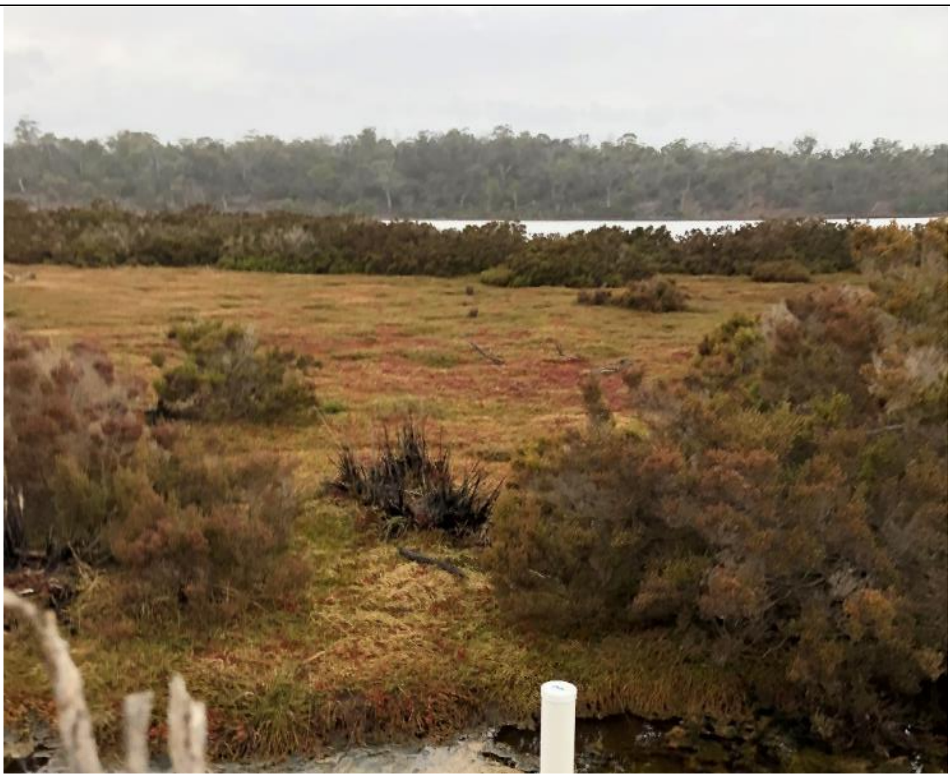
East-West Inland	
24 June 2021	

3 September 2021	
2 December 2021	
East-West lagoon	

24 June 2021	
3 September 2021	

2 December 2021	
North-South Inland	
23 June 2021	

3 September 2021	
2 December 2021	
North-South lagoon	

23 June 2021	
3 September 2021	

2 December 2021