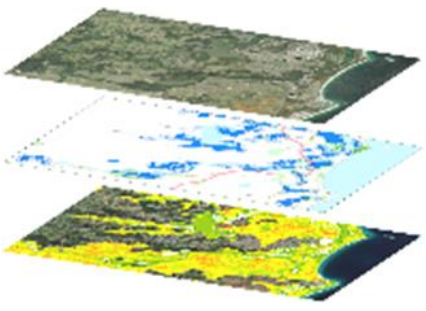
Intertidal Marine Vegetation Strategies:

Tweed River Estuary

MARINE ESTATE MANAGEMENT AUTHORITY



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Main cover image: Intertidal habitats at Ukerebagh Passage: Large-leafed Mangrove *Bruguiera gymnorhiza*, Saltwater Couch *Sporobolis virginicus* and Coastal Swamp Oak *Casuarina glauca*.

Image collage: Left, degraded freshwater wetland. Centre, concrete retaining wall landward of an urban intertidal habitat. Right, some GIS layers used in the IMVS methodology.

Images courtesy of: Patrick Dwyer, Kate Buckley and Emma Asbridge unless otherwise cited.

Executive summary

The *Intertidal Marine Vegetation Strategies: Tweed River Estuary*, provides detailed information on recommended responses to the key threats and risks to saltmarsh and mangrove communities in the Tweed River estuary study area.

In 2022, NSW Fisheries mapped 5.09 km^2 of intertidal marine vegetation in the study area, including 4.66 km^2 of mangroves and 0.42 km^2 of saltmarsh. Under SLR scenarios projected by Hughes et al. (2022) the extent of area potentially available for intertidal marine vegetation may increase significantly at 0.5 m SLR, but thereafter decline due to complete inundation of low-lying areas and coastal squeeze at 1.5 m SLR.

Using the methods described in the *Intertidal Marine Vegetation Strategies: Methodology Report*, the area incorporating both current and potential future intertidal habitats was assessed to identify areas where intertidal vegetation is likely to persist considering geophysical and anthropogenic constraints. In total, 4.09 km^2 of area was identified as having a high potential to support future intertidal marine vegetation. Within this area, 21 hotspots were identified where management actions could be undertaken to increase the resilience of saltmarsh and mangrove habitats by mitigating risk and supporting adaption.

Management actions categorised under Hydrology, Sediments, Vegetation and, People and Planning approaches are outlined for each hotspot. More detailed information on the objectives and suitability of these management approaches can be found in the *Intertidal Marine Vegetation Strategies: Key approaches to Mitigate Risk and Support Adaptation.*

Recommended management actions across the 21 hotspots were:

- Reinstate and maintain natural tidal hydrology and catchment connectivity
- Reduce flow velocities and raise groundwater levels
- Strategic limitation of accelerated mangrove expansion
- Protect intertidal vegetation from erosion
- Promote sediment accretion to restore intertidal habitats
- Prevent sediment smothering intertidal habitats
- Minimise disturbances to riparian or intertidal vegetation
- Create vegetation buffers around intertidal vegetation and waterways
- Manage feral or invasive species including weeds
- Provide migration pathways for saltmarsh and mangroves to adapt to SLR
- Manage foreshore access
- Manage urbanisation.

The recommended management actions address 21 Key Threatening Processes listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), NSW *Biodiversity Conservation Act 2016* (BC Act) and the NSW *Fisheries Management Act 1994* (FM Act). These are listed in Appendix 2.

Some management actions, such as reinstating natural tidal hydrology and catchment connectivity, could change areas where threatened species or communities occur in artificially drained landscapes. The IMVS is an important step toward considering, with an estuary-wide perspective, the benefits of undertaking incremental adaption actions informed by current and projected SLR. The alternative approaches (either not acting or attempting to isolate ecological communities from their changing environmental settings) reduce the time available for ecosystems to adapt or migrate, consequently increasing their vulnerability.

Judicious undertaking of the management actions in this *Intertidal Marine Vegetation Strategies: Tweed River Estuary* strategy may result in, at the estuary-wide scale, improved management or conservation outcomes for up to 15 threatened ecological communities and 71 threatened species listed under the EPBC Act, BC Act and FM Act. These communities and species may experience direct or indirect impacts from actions undertaken and these are listed in Appendix 3 and Appendix 4 respectively.

Snapshot: Tweed River estuary

Estuary type:	**Trained wave dominated barrier estuary**
Study area (<10 m AHD):	**179.43 km^2**
Land zoning patterns[1]:	**Rural 70.92 %; Residential 11.54 %; Employment 1.84 %; Mixed Use 0.03 %; Special Purpose 2.99 %; Recreation 5.07 %; Environment Protection 2.93 %; Waterways 0.36 %; Other 4.07 %.**
Mapped area of mangroves[2]:	**4.66 km^2**
Mangrove species (listed under the FM Act):	**Grey Mangrove (*Avicennia marina*), River Mangrove (*Aegiceras corniculatum*), Large Leaf Mangrove (*Bruguiera gymnorhiza*), Milky Mangrove (*Excoecaria agallocha*), Stilted Mangrove (*Rhizophora stylosa*) and Mangrove Fern (*Acrostichum speciosum*).**
Most upstream mangrove trees[3]:	**Distance from the ocean: 28.4 km (Tweed River, 2001); 32.5 km (Rous River, 2001).**
Mapped area of saltmarsh[2]:	**0.42 km^2**
Dominant saltmarsh species (listed under the FM Act):	**Saltwater Couch (*Sporobolus virginicus*), Seablite (*Suaeda australis*), Beaded Glasswort (*Sarcocornia quinqueflora*), Sea Rush (*Juncus kraussii*), Streaked Arrow-grass (*Triglochin striata*), Bare Twig-rush (*Baumea juncea*), Creeping Brookweed (*Samolus repens*) and Prickly Couch (*Zoysia macrantha*).**
Total mapped area of intertidal vegetation[2]:	**5.09 km^2**
Total projected area (excluding urban areas) available for intertidal vegetation at 0.5 m SLR[4]:	**28.71 km^2**
Total projected area (excluding urban areas) available for intertidal vegetation at 1.5 m SLR[4]:	**2.56 km^2**

Area of high potential for future intertidal vegetation identified (<3 m AHD):	**4.09 km^2**
Number of hotspots identified:	**21**
Key Threatening Processes addressed:	**21 Key Threatening Processes listed under the EPBC Act, BC Act and FM Act.**
Benefits to Threatened Ecological Communities (TECs) and threatened species:	**Improved management and/or conservation outcomes for up to 15 TECs and 71 threatened species listed under the EPBC Act, BC Act and FM Act.**

[1]NSW Land use mapping (2017); [2]NSW DPI Fisheries Estuarine macrophyte mapping (2022); [3]Manly Hydraulics Laboratory (2023) NSW Tidal Planes Analysis. Report MHL2786 April 2023. Report prepared by Manly Hydraulics Laboratory for NSW Department of Planning and Environment. [4]Hughes MG, Glasby TM, Hanslow DJ, West GJ and Wen L (2022) Random forest classification method for predicting intertidal wetland migration under sea level rise. *Frontiers in Environmental Science* 10:749950.

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List of Acronyms

AHD	Australian Height Datum
ACCU	Australian Carbon Credit Unit
BC Act	*Biodiversity Conservation Act 2016*
CMP	Coastal Management Program
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DPE	Department of Planning and the Environment
DPI	Department of Primary Industries
DPIRD	Department of Primary Industries and Regional Development (formerly DPI)
EEC	Endangered Ecological Community
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FM Act	*Fisheries Management Act 1994*
IMVS	Intertidal Marine Vegetation Strategy
KTP	Key Threatening Process
LALC	Local Aboriginal Land Council
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging
MEMA	Marine Estate Management Authority
MEMS	*Marine Estate Management Strategy 2018-2028*
NSW	New South Wales
OEH	Office of Environment and Heritage
RSETs	Rod surface-elevation tables
SLR	Sea Level Rise
SVTM	State Vegetation Type Map
TARA	Threat and Risk Assessment
TEC	Threatened Ecological Community

1. Introduction

Saltmarsh and mangroves are key components of New South Wales (NSW) intertidal marine vegetation. They provide many environmental, economic, cultural and social benefits along the entire NSW coastline. For example, they protect foreshores, capture and store carbon, and regulate nutrients in nearby coastal waters. Community wellbeing throughout NSW is also enhanced by fisheries production, recreation opportunities and cultural values associated with saltmarsh and mangroves.

This document, the *Intertidal Marine Vegetation Strategy* (IMVS)*: Tweed River Estuary,* provides detailed information about 21 saltmarsh and mangrove 'hotspots' in the Tweed River estuary study area. These hotspots are sites that have high potential as saltmarsh and mangrove habitats in the future, given the current physical environment and human activities. The IMVS: Tweed River Estuary recommends actions that mitigate risk to the habitats and support their adaptation, particularly in the context of sea level rise (SLR).

A landholders' right to carry out agricultural or developmental activities on their land are not altered by their properties being identified in this document. Any involvement by a landholder in delivering recommended management actions is entirely voluntary.

The recommendations within the IMVS: *Tweed River Estuary are based on site-specific conditions and available information at the time of writing. As both environmental and anthropogenic conditions are dynamic, appropriate management strategies may be subject to change and current site assessments are required.*

Initiating changes to protect or restore hydrology or sedimentation may be complex and have unanticipated environmental, social, cultural and economic outcomes. When projects proposed in the IMVS: *Tweed River Estuary are planned, expert assessment and a scrutiny of proposed actions by relevant authorities is still warranted as works may result in changes to the key ecological drivers of intertidal wetlands.*

IMVS actions can be delivered with suitable partnership and funding opportunities such as those identified in the IMVS*: Key approaches to mitigate risk and support adaptation.* For example, this could include:

- projects identified in approved Coastal Management Programs
- projects aligned with environmentally focused Non-Government Organisation or community groups
- projects that delivery of climate adaptation actions, including under the Climate Adaptation Strategy and the Blue Carbon Strategy
- Aboriginal land managers who are looking to deliver projects that involve working on and restoring culturally significant areas or habitats
- major developers that are required to offset unavoidable impacts on mangrove or saltmarsh habitat with an identified action under Section 220 of the NSW *Fisheries Management Act 1994*
- a court ordered directive for environmental rehabilitation
- collaborative projects between local government and NSW Government through opportunities such as the Recreational Fishing Trust Flagship or Habitat Action Grant Programs
- private land conservation agreements under the Biodiversity Conservation Trust that facilitate the redistribution of intertidal and adjacent habitats that is underway with sea level rise
- enforceable undertakings under Environment Protection Authority for the purpose of s 253a *Protection of Environment Operations Act 1997*
- opportunities to participate in the emerging nature repair market.

Threats and risks

The sustained delivery of the ecosystem services delivered by saltmarsh and mangroves is threatened by impacts from multiple anthropogenic activities (Newton et al. 2020) and changing environmental parameters such as SLR (Ellison 2014; Gilman et al. 2008). Under sustained pressure, the ecosystem services provided by these habitats can be degraded or even shift to disservices.

Cautious management of intertidal wetland systems is required to improve the resilience of saltmarsh and mangroves. The NSW Marine Estate Management Authority (MEMA) was formed to coordinate policies and programs for maintaining and improving the marine environment. A key output, the statewide *Threat and Risk Assessment* (TARA), identified and prioritised threats and risks to environmental assets and the social, cultural and economic benefits derived from the marine estate (Fletcher and Fisk 2017).

The TARA assessed risk independently for three regions: the Northern Region from the Queensland border to Stockton Beach; the Central Region from Stockton to Shellharbour; and the Southern Region from Shellharbour to the Victorian border.

High risks activities identified for saltmarsh and mangroves in the Northern Region, where the Tweed River estuary is located, were stock grazing of riparian and marine vegetation; extraction, artificial barriers to riverine and estuarine flow, urban drainage and impervious surfaces; estuary entrance modifications; SLR; clearing riparian and adjacent habitat including wetland drainage; and climate and sea temperature rise (Fletcher and Fisk 2017) (Table 1).

Table 1 Activities that cause risk to saltmarsh and mangroves in the Northern Region of NSW. Adapted from the Marine Estate Management Strategy Threat and Risk Assessment (TARA)

Activity	Regional risk to saltmarsh	Regional risk to mangroves
Stock grazing of riparian and marine vegetation	High	High
Extraction, artificial barriers to riverine and estuarine flow, urban drainage and impervious surfaces.	High	High
Estuary entrance modifications	High	Moderate
SLR (50 years)	High	Moderate
Clearing riparian and adjacent habitat including wetland drainage	High	Moderate
Climate and sea temperature rise	High	Moderate
Foreshore development	Moderate	Moderate
Agricultural diffuse source runoff	Moderate	Moderate
Urban stormwater discharge	Moderate	Moderate
Ocean acidification	Moderate	Moderate
SLR (20 years)	Moderate	Low
Altered storm/cyclone activity	Moderate	Low
Four-wheel driving	Moderate	Minimal
Small commercial vessels	Low	Low
Industrial discharges	Minimal	Minimal
Large commercial vessels and port activities and industries	Minimal	Minimal
Service infrastructure	Minimal	Minimal

Methods

The *Marine Estate Management Strategy 2018-2028* (MEMS) aims to deliver a coordinated response to the priority threats to water quality, habitats and biodiversity of the State's coastal waters and estuaries identified in the TARA. A management action identified by MEMS was to develop marine vegetation management plans that maximise resilience, accommodate SLR, address key threats, facilitate rehabilitation opportunities and reduce red tape for low impact works.

Each marine park or estuary specific IMVS aims to provide a cohesive and meaningful set of actions to ensure that saltmarsh and mangroves in NSW continue to provide ecosystem services and their numerous social, cultural and economic benefits into the future.

The IMVS: *Methodology report* explains the methods used to identify hotspot sites where saltmarsh and mangrove ecosystems are likely to persist into the future within study areas given current and projected SLR. These methods are described in Asbridge and Dwyer (2023) (Figure 1). The IMVS method used DPIRD Fisheries estuarine macrophyte mapping (see West et al. (2025), data defining current geophysical conditions, the degree of anthropogenic exposure, and projections of future wetland locations by Hughes et al. (2022) under two SLR scenarios (0.5 m and 1.5 m).

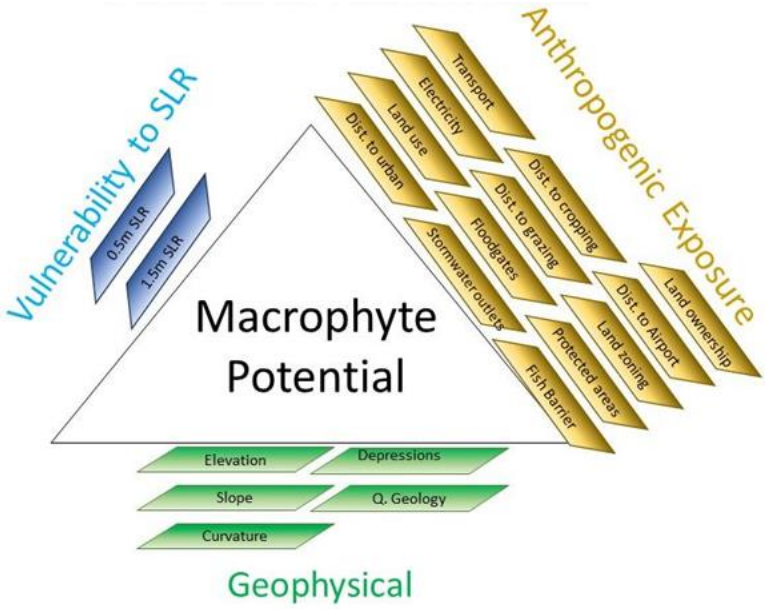


Figure 1 Spatial data layers used in the macrophyte potential model to identify hotspots. Source: Asbridge and Dwyer (2023)

The methods employed by Hughes et al. (2022) applied no restrictions on future locations other than exclusion from urban areas, so the IMVS method allows a more detailed examination of future potential available space for intertidal vegetation. In addition, the IMVS method incorporated two SLR scenarios recognising that some intertidal vegetation may be able to accrete sediments and biological mass to keep pace with SLR rates up to approximately 7 mm / year, and, that new intertidal spaces may become available at 1.5m SLR.

Each study area was, by design, greater in extent than the current or future modelled distributions of intertidal marine vegetation. However, land above 10 m in elevation was excluded from study areas because it is unlikely to support intertidal marine vegetation and most direct threats and risks occur below that elevation.

Results of the IMVS model were mapped areas of high future macrophyte potential scores within each study area. In the Tweed River estuary study area these scores were equivalent to 112, 113 and 114. Clusters or 'hotspots' of high macrophyte potential scores recorded in areas less than 3m Australian Height Datum (AHD) were identified with kernel density analysis (KDA). This elevation incorporates all possible future intertidal habitats to a SLR of 1.5m within the Tweed River estuary study area. The Tweed River average annual high high water solstice springs (HHWSS) sea level is currently 1.004 AHD (Manly Hydraulics

Laboratory 2023), so with a SLR of 1.5 m AHD saltmarsh and mangrove habitats would not be expected to occur beyond a maximum 2.5 m AHD. An error margin of approximately 0.5 m was allowed to ensure all potential hotspots are identified given data limitations (see below).

For each hotspot, management actions have been recommended to increase the resilience of intertidal marine vegetation by mitigating risk and supporting adaption. Data used to develop management recommendations included:

- Estuarine macrophyte and R&H SEPP 2021 Coastal Wetlands and Littoral Rainforests maps available at DPIRD Fisheries Spatial Data Portal
- Mapped and projected intertidal habitats and 4WD damage in saltmarsh habitats available at NSW Estuarine Habitat Dashboard
- Digital Elevation Models (DEMs) (1 m resolution) available at Elvis (Elevation and Depth - Foundation Spatial Data)
- Floodplain infrastructure, floodgate vulnerability to SLR, acid sulfate soils and blackwater prioritisation available at Coastal Floodplain Desktop Tool
- Quaternary geology available at DIGS Geological Survey of NSW
- Historical imagery available at Historical Imagery
- Land ownership and Local Aboriginal Land Councils (LALCs) available at IndustryView
- NSW State Vegetation Type Map (SVTM) (SEED dataset) available at NSW SVTM
- Atlas of Living Australia flora records available at The Australasian Virtual Herbarium
- Land zoning available at NSW Planning Portal Spatial Viewer (for definitions see Appendix 1).

Limitations

It is important to note that there are data limitations associated with the modelling approach. Due to this, hotspots boundaries are flexible and may change over time. On-ground assessments will be needed to define the focus for actions associated with hotspot management units.

DEMs used to define study areas and inform SLR scenarios are subject to errors influenced by the type of ground cover, geographic location and atmospheric activity. There are many other factors that will influence the future distributions of saltmarsh and mangroves, but state-wide data layers are not available. Examples include changes in catchment inflows, estuary entrance conditions, bathymetry and sediment supply; climate impacts on species present; existing tidal exclusion infrastructure; presence of other vegetation; the ability of ecosystems to vertically accrete sediments; and the impacts management actions and land uses.

The focus in this document is clusters of high macrophyte potential ('hotspots') which are important from the perspective of maximising efficient and effective delivery of actions. High macrophyte potential can also occur along linear features such as riverbanks and creeks, but this is less well captured by the IMVS methodology. These narrow corridors of mangroves provide ecosystem services, including habitat connectivity, and sometimes are dominated by River Mangrove *Aegiceras corniculatum* rather than the Grey Mangrove *Avicennia marina* which often form larger stands in the lower estuary.

As the upper estuary becomes more saline with SLR, the terrestrial and freshwater riparian vegetation upstream of the current mangrove limit will senesce. To ensure the ongoing provision of ecosystem services provided by vegetated banks it will be important to enable the upstream migration of saltmarsh and mangroves along these narrow corridors of habitat. Effective site-specific management of these corridors is not well addressed by the IMVS methodology and strategies focusing on riverbanks and associated infrastructure provide valuable guidance. These include the MEMS Domestic waterfront structure strategies and the MEMS Estuary bank management strategies. Protections for corridors of marine and freshwater riparian vegetation are also detailed in the *DPI Policy and guidelines for fish habitat conservation and management (Update 2013)*. Other guidance for managing riparian and intertidal vegetation include *Controlled activities – Guidelines for riparian corridors on waterfront land*, and, *Good practices in riparian rehabilitation*.

Key Documents

The IMVS aim to increase the resilience of intertidal macrophyte systems by identifying actions that mitigate risk mitigation and support adaptation to maintain their social, cultural and economic values. Priority threats that generate risk to intertidal marine vegetation systems in NSW were identified in the Marine Estate Management Authority's statewide TARA (Fletcher and Fisk 2017).

The IMVS*: Methodology report* (described in Methods section above) is a key companion document that explains the methods used to identify hotspot sites where saltmarsh and mangrove ecosystems are likely to persist into the future within estuary specific study areas.

The IMVS*: Key strategies to mitigate risk and support adaptation* provides information on the key approaches and actions that may protect and enhance key ecological drivers that build resilience in saltmarsh and mangroves, including natural tidal hydrology, sedimentation and ecological connectivity. It also includes information on partnership and funding opportunities to deliver projects, and legislative protections and approvals.

Actions taken to build resilience for saltmarsh and mangrove habitats may directly or indirectly, and positively or negatively, impact adjacent threatened species and Threatened Ecological Communities (TECs). The document IMVS*: Integrated landscape and seascape conservation* provides detailed lists of these species and communities to foster an integrated approach to landscape and seascape conservation in the NSW coastal zone.

These documents are intended to be used in conjunction with estuary or marine park specific IMVS that recommend and tailor appropriate risk mitigation and adaptation strategies to local conditions. The relationship between the IMVS*: Tweed River Estuary* and these other documents is illustrated in Figure 2.

Figure 2 Relationship between the Marine Estate Management Authority documents.

A collaborative approach between state and local government agencies – including sharing spatial data and incorporating local knowledge – was used to tailor recommended management responses for each estuary. In particular, collaboration with local government provided opportunities for feedback on the location of the hotspots and recommended management options. Where local government identify IMVS hotspots and the proposed rehabilitation actions into their Coastal Management Program, approvals for those works may be streamlined. Appropriate levels of assessment will continue to be required to demonstrate that nature positive outcomes will be achieved.

2. Tweed River estuary study area

The Tweed River estuary study area is in the Northern Rivers district of NSW. Major urban centres include Tweed Heads, Tweed Heads West and Murwillumbah (Figure 3).

The study area incorporates approximately 179 km^2 of low-lying habitats below 10 metres AHD including intertidal and riverine areas, saltmarsh and mangrove habitats, and a large floodplain dominated by agricultural use with some low-lying coastal wetlands.

It includes the following major tributaries of the Tweed River:

- Rous River
- Terranora Creeks associated with the Terranora Broadwater
- Cobaki Creek associated with the Cobaki lakes near the river's entrance.

Saltmarsh and mangrove communities in the Tweed River estuary are impacted by all the moderate and high-risk activities identified for the Northern Region in the TARA (see Table 1).

Threats to ecological values in the Tweed River estuary and catchment are generally managed by the Tweed Shire Council with management strategies outlined in:

- *Tweed River Estuary: Coastal Management Program 2022 – 2032* (Tweed River Estuary CMP) (TSC 2022)
- *Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater* (CZMP for Cobaki Broadwater and Terranora Broadwater) (TSC 2012).

These plans identify environmental threats, outline management strategies, and support the implementation of related NSW Government agency management programs and strategies including the IMVS, MEMS Tweed Domestic Waterfront Structure Strategies, and MEMS Estuary Bank Management Strategies.

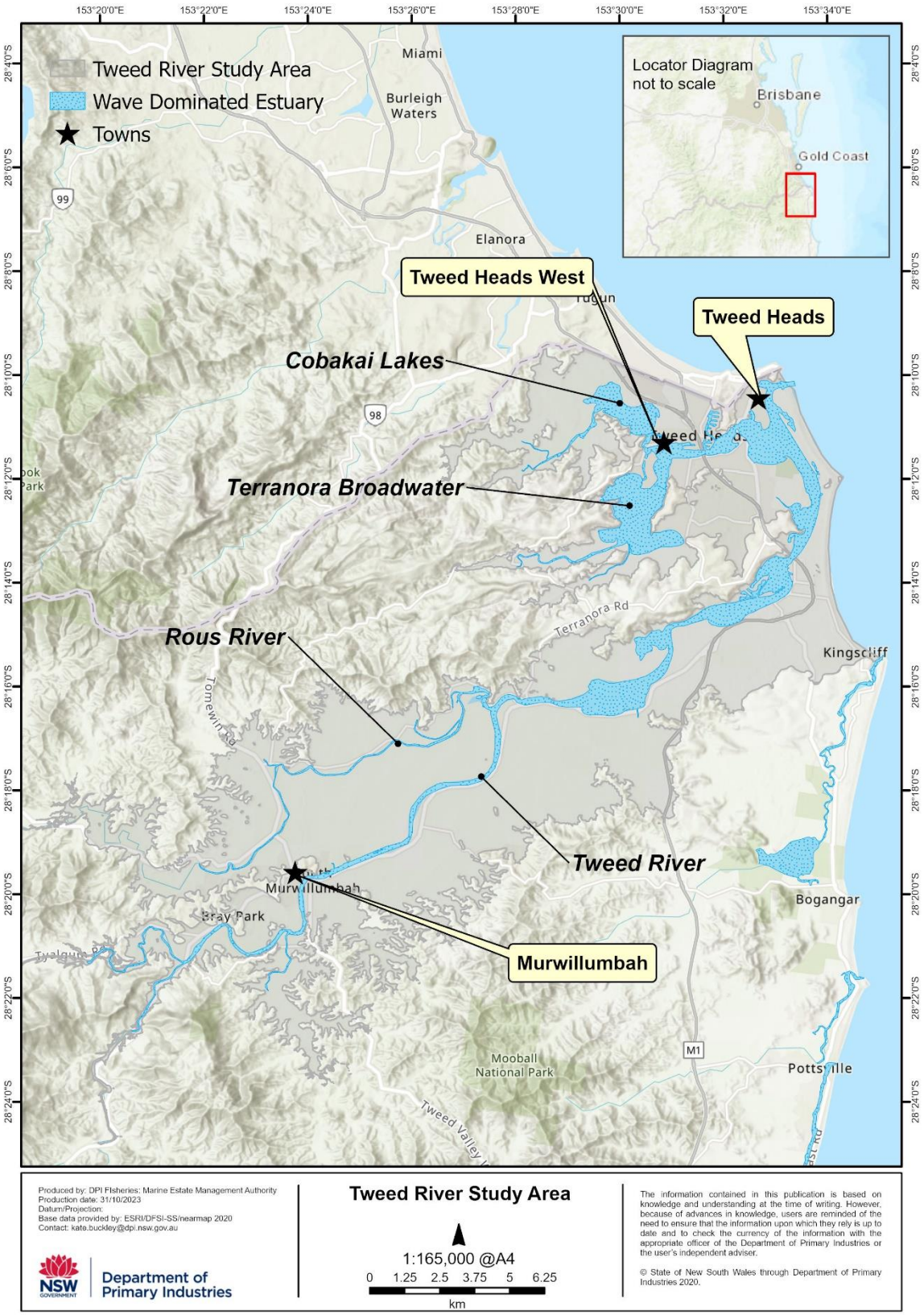


Figure 3 Map of the Tweed River estuary study area.

3. Saltmarsh and mangroves

Saltmarsh and mangrove communities grow in sheltered sedimentary foreshores of the intertidal zone, in between the mean sea level and the highest spring tide. Mangroves can occupy a wider range of the intertidal zone than saltmarsh vegetation (Woodroffe et al. 2016), but saltmarsh can withstand higher salinities and drier soil than mangroves (Clarke and Hannon 1970; Saintilan et al. 2019). As a result, saltmarsh communities typically occur at the higher, landward edge of mangroves where the soil can be hyper-saline as salts from infrequent tidal inundations accumulate in the sediment. They may also occur as isolated islands surrounded by mangroves or at the same or lower elevations than mangroves when access to tidal flows is limited.

The current mapped extent of intertidal vegetation in the Tweed River estuary is shown in Figure 4. This mapping did not focus on saltmarsh that may be obscured by the canopy of upper intertidal and supratidal forests. Satellite imagery and site inspections indicate that there may be other areas of unmapped intertidal vegetation.

It is important to recognise that extensive clearing of mangroves occurred in parts of the Tweed estuary prior to the commencement of aerial photography in the 1930s. Clearing or loss of intertidal habitats occurred due to lime burning, historical aquaculture, rural development, estuary entrance management, catchment modification, and urbanisation.

A general trend of decreasing saltmarsh extent and increasing mangrove extent in the Tweed River estuary has been determined since the 1930s via aerial photo analysis.

- Between 1930 and 1994, there was a recorded 75% increase in overall coastal wetland extent in the Tweed River catchment, largely due to the expansion of mangroves in the fluvial channel, tidal channel and broadwaters (Saintilan 1998).
- In some areas, mangroves or terrestrial vegetation replaced saltmarsh, such as on Ukerebagh Island between 1968 and 1998 where this was associated with prograding intertidal salt flats resulting in a 20% decline in saltmarsh (Saintilan 1997).
- Between 2000 and 2002, the total mangrove extent in the Tweed River estuary was estimated as increasing by 2.66%, while saltmarsh decreased by 4.08% (Rogers et al. 2003).
- By 2012, mangrove had again increased by just over 0.1 km^2 (2.7%) while saltmarsh concurrently declined by over 0.3 km^2 (45.1%) (Rogers et al. 2012).
- In 2022, DPIRD recorded 4.66 km^2 of mangroves, 0.42 km^2 of saltmarsh, and 0.56 km^2 of seagrass in the study area (Figure 4).
- Under SLR scenarios projected by Hughes et al. (2022) (with no restriction on future wetland locations in the landscape other than exclusion from urban areas) the extent of area potentially available for intertidal marine vegetation may be 28.71 km^2 at 0.5 m SLR, declining significantly to 2.56 km^2 as SLR progresses to 1.5 m, due to complete inundation of low-lying areas and coastal squeeze rendering sites no longer suited to saltmarsh or mangrove systems.

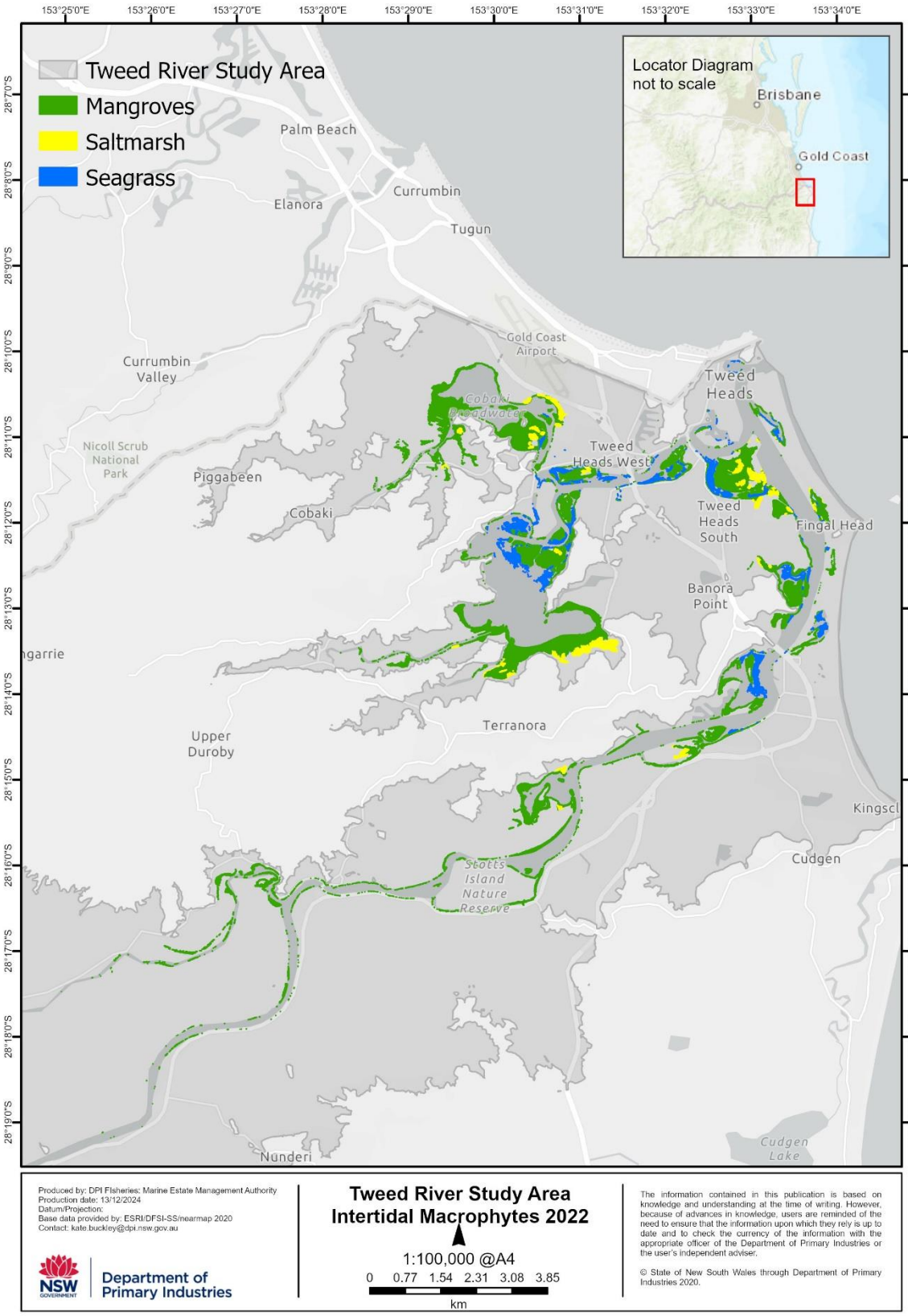


Figure 4 Intertidal macrophytes in the Tweed River. Data source: DPIRD Fisheries Estuarine Macrophytes of NSW Estuaries - Latest mapped extent (2022).

Saltmarsh species

Saltmarsh occurs downstream of Stotts Island and historically was most extensive on Ukerebagh Island and Letitia Spit (Public Works Department 1991). Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions is listed as a Threatened Ecological Community (TEC) under the *Biodiversity Conservation Act 2016* (BC Act); and Subtropical and Temperate Coastal Saltmarsh is listed as a Vulnerable Ecological Community under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Fisheries Management (General) Regulation 2019 explains that saltmarsh means the ecological community (assemblage of species of marine vegetation occupying a particular area) in which one or more of the ten saltmarsh species listed in the regulation is present. In the Tweed River estuary, eight of those species, listed below, occur in saltmarsh areas:

- Saltwater Couch (*Sporobolus virginicus*)
- Seablite (*Suaeda australis*)
- Beaded Glasswort (*Sarcocornia quinqueflora*)
- Sea Rush (*Juncus kraussii*)
- Streaked Arrow-grass (*Triglochin striata*)
- Bare Twig-rush (*Baumea juncea*)
- Creeping Brookweed (*Samolus repens*)
- Prickly Couch (*Zoysia macrantha*).

Mangrove species

Mangroves in the Tweed River estuary occur as far upstream as Murwillumbah and include all the species known from NSW.

Most of the mangrove vegetation occurs on islands along the lower Tweed River (particularly Terranora Inlet) and around the shores of the five broadwaters. There are also narrow areas of fringing mangroves on the river banks of the lower Tweed River and its' tributaries.

The two dominant species are Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) (Figure 5).

Other mangrove species recorded are:

- Large-leafed Mangrove (*Bruguiera gymnorrhiza*)
- Milky Mangrove (*Excoecaria agallocha*)
- Stilted Mangrove (*Rhizophora stylosa*)
- Mangrove Fern (*Acrostichum speciosum*).

Figure 5 The two most common mangrove species in the Tweed River estuary. Grey Mangrove (background and top right) and River Mangrove (foreground and bottom right).

4. Hotspot recommendations

In total, 4.09 km^2 of area in the Tweed River estuary was identified as having a high potential to support future intertidal marine vegetation. Within this area 21 hotspots were identified, extending from near the entrance of the Tweed River upstream to its confluence with the Rous River (Figure 6). Each hotspot has site-specific landscape characteristics (size, geomorphology, hydrology, land use) and ecological, social or economic values.

Hotspots were identified in the following areas:

- Cobaki Broadwater (hotspots 1–4)
- Terranora Broadwater (hotspots 5–9)
- Tweed River tidal channel (hotspots 10–13) and
- fluvial channel (hotspots 14–20).

Hotspot 21 is an artificial freshwater wetland north-west of Kingscliff.

The identification of hotspots may assist with the management of marine vegetation and planning for future developments. For example, permits to harm marine vegetation under Section 205 of the *Fisheries Management Act* may include conditions recognising the significance of the high macrophyte potential areas of intertidal marine vegetation and development in hotspots should be avoided.

In areas where macrophyte potential is high due to SLR such as migration pathways, proposals for developments that may erode the ability of marine vegetation to adapt, should incorporate into their proposal actions to minimise or avoid such impacts.

Where developments have unavoidable impacts on marine vegetation within the Tweed River estuary, offsets are generally required. Offsets need to deliver an on-ground outcome and project proponents are encouraged to consider developing offset proposals from the portfolio of actions that deliver on management recommendations for Tweed River estuary IMVS hotspots.

Intertidal vegetation that occurs outside hotspot areas continue to be important and proposals that could result in harm will be assessed in accordance with the *DPI Policy and guidelines for fish habitat conservation and management (Update 2013)*.

Hotspot specific characteristics influence the suitability of specific management actions. The recommended actions for Tweed River estuary hotspots are provided in Table 2. This summary of management recommendations is not exhaustive and represent a starting point for further investigation of the hotspot for ongoing actions.

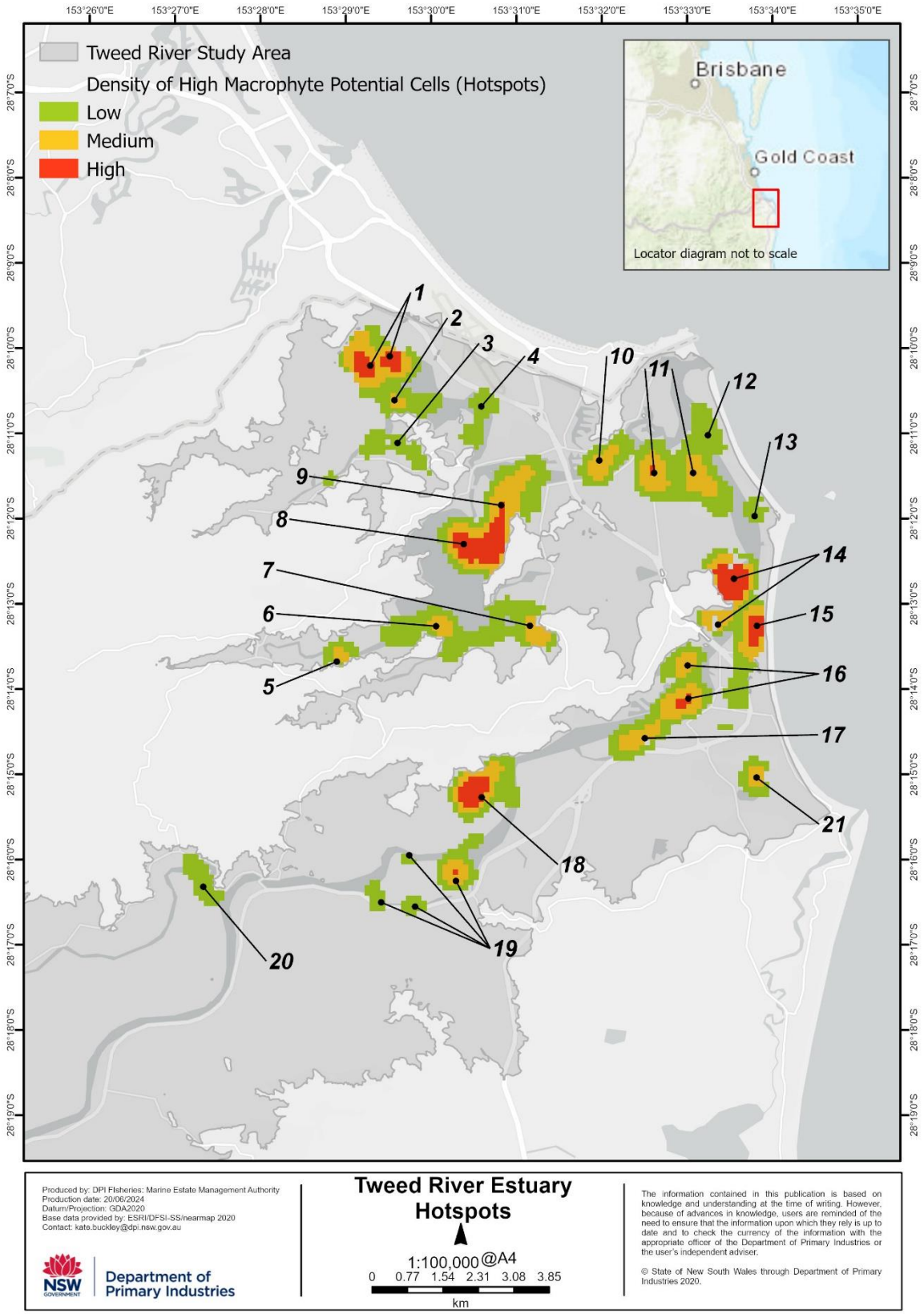


Figure 6 Tweed River estuary hotspots. Hotspots identified with kernel density analysis using high (112, 113, 114) macrophyte potential scores <3m AHD.

Table 2 Summary of management recommendations for hotspots identified in the Tweed River estuary study area.

	Reinstate and maintain natural tidal hydrology and catchment connectivity	Reduce flow velocities and raise groundwater levels	Strategic limitation of mangrove expansion	Protect intertidal vegetation from erosion	Promote sediment accretion to restore intertidal habitats	Prevent sediment smothering intertidal habitats	Minimise disturbances to riparian or intertidal vegetation	Create vegetation buffers around intertidal vegetation and waterways	Manage feral or invasive species including weeds	Provide migration pathways for saltmarsh and mangroves to adapt to SLR	Manage unauthorised activities	Manage urbanisation
Hotspot 1 North Cobaki Broadwater	*		*				*		*	*		*
Hotspot 2 Cobaki Creek	*	*	*		*			*	*	*	*	*
Hotspot 3 Piggabeen Road	*	*	*		*			*	*	*		
Hotspot 4 East Cobaki Broadwater				*			*		*	*		*
Hotspot 5 Bilambil Creek	*	*					*	*	*	*		
Hotspot 6 Charles Bay to Duroby Creek	*	*	*		*		*	*	*	*		
Hotspot 7 Trutes Bay and Tommys Island	*	*	*		*		*	*	*	*		*
Hotspot 8 Meebun, Womgin and Big Islands	*			*	*		*		*	*	*	
Hotspot 9 Daveys and Caddys Islands	*			*	*		*		*	*	*	*
Hotspot 10 Terranora Creek Islands	*			*	*		*			*		*

	Reinstate and maintain natural tidal hydrology and catchment connectivity	Reduce flow velocities and raise groundwater levels	Strategic limitation of mangrove expansion	Protect intertidal vegetation from erosion	Promote sediment accretion to restore intertidal habitats	Prevent sediment smothering intertidal habitats	Minimise disturbances to riparian or intertidal vegetation	Create vegetation buffers around intertidal vegetation and waterways	Manage feral or invasive species including weeds	Provide migration pathways for saltmarsh and mangroves to adapt to SLR	Manage unauthorised activities	Manage urbanisation
Hotspot 11 Ukerebagh	*			*	*		*		*	*	*	*
Hotspot 12 Kerosene Inlet						*	*		*	*	*	
Hotspot 13 Sponsors Lagoon					*		*		*	*	*	
Hotspot 14 Tonys and Tims Islands	*	*			*		*	*	*	*		*
Hotspot 15 Wommin Lake	*				*		*			*		
Hotspot 16 Chinderah Bay	*			*	*		*		*	*		*
Hotspot 17 Dodds Island and Chinderah Island	*		*	*	*			*		*		
Hotspot 18 Tweed Broadwater	*	*	*		*		*	*		*		
Hotspot 19 Stotts Island	*	*			*		*		*	*		
Hotspot 20 Rous River, North Tumbulgum	*	*						*	*	*		
Hotspot 21 Noble Lake	*	*								*		

Many of the actions recommended in Table 2 are multi-stage long term projects that will progress as SLR advances. Other actions, such as those highlighted in Figure 7, may be feasible to implement more quickly to achieve improved resilience of intertidal marine vegetation in hotspot areas.

Hotspot 3: Piggabeen Road

- Slashing for weed control at Cobaki Nature Reserve is impacting saltmarsh and preventing the migration of saltmarsh and Coastal Swamp Oak habitats in advance of the adjacent mangroves.
- Alter weed management at Cobaki Nature Reserve to avoid slashing saltmarsh habitats. Install bollards/barriers above HAT and incorporate a buffer zone to allow habitat migration with SLR.

Hotspot 4: East Cobaki Broadwater

- Extensive areas of the TEC Coastal Saltmarsh and mangroves occur in Deferred Matter zoned areas on Crown Land adjacent to the Cobaki Nature Reserve.
- Protect these ecologically significant habitats and SLR migration pathways by rezoning and incorporating into the Cobaki Nature Reserve

Hotspot 6: Charles Bay to Duroby Creek

- Stock grazing is impacting riparian areas along Bilambil and Duroby Creeks causing erosion and damage to native vegetation.
- Crate fenced vegetation buffers above HAT along Bilambil Creek and Duroby Creek to improve the resilience of intertidal vegetation and provide upstream SLR migration pathways. Maintain fencing and ongoing weed control in the buffer zones.

Hotspot 11: Ukerebagh

- Boardwalks through intertidal habitats remain closed due to flood damage.
- Repair and reopen boardwalks to provide appropriate access and interpretation to facilitate public awareness of the ecological and cultural values of saltmarsh and mangrove habitats.

Hotspot 16: Chinderah Bay

- Large amounts of anthropogenic debris have accumulated in mangrove habitats and is at risk of burial.
- Remove anthropogenic debris to prevent changes to hydrology or sedimentation and ongoing degradation of ecological values.

Figure 7 Five 'quick' actions for improved resilience of intertidal marine vegetation in the Tweed River estuary.

Hotspot 1: North Cobaki Broadwater

North Cobaki Broadwater hotspot is centred on Crown land to the north of the Cobaki Broadwater. It incorporates substantial areas of mangroves and coastal wetland habitats (Figure 8). Existing habitats may also include TECs (listed under the BC Act) Swamp Sclerophyll Forest, Freshwater Wetlands, Littoral Rainforest and Lowland Rainforest.

Most of the hotspot is zoned Deferred Matter (DM) or Natural Waterways (W1). In the north the hotspot is fringed by land zoned Private Recreation (RE2) zoned land. Major surrounding land uses are the Gold Coast Airport; Tugun Bypass and urban areas to the north, south and east; and the large and developing residential development of Cobaki Lakes to the west.

Hotspot mapping indicates a high potential for future intertidal habitats to occur through most of the Crown land north of the Broadwater except for an area of Wet Heathland to Shrubland in the north-east.

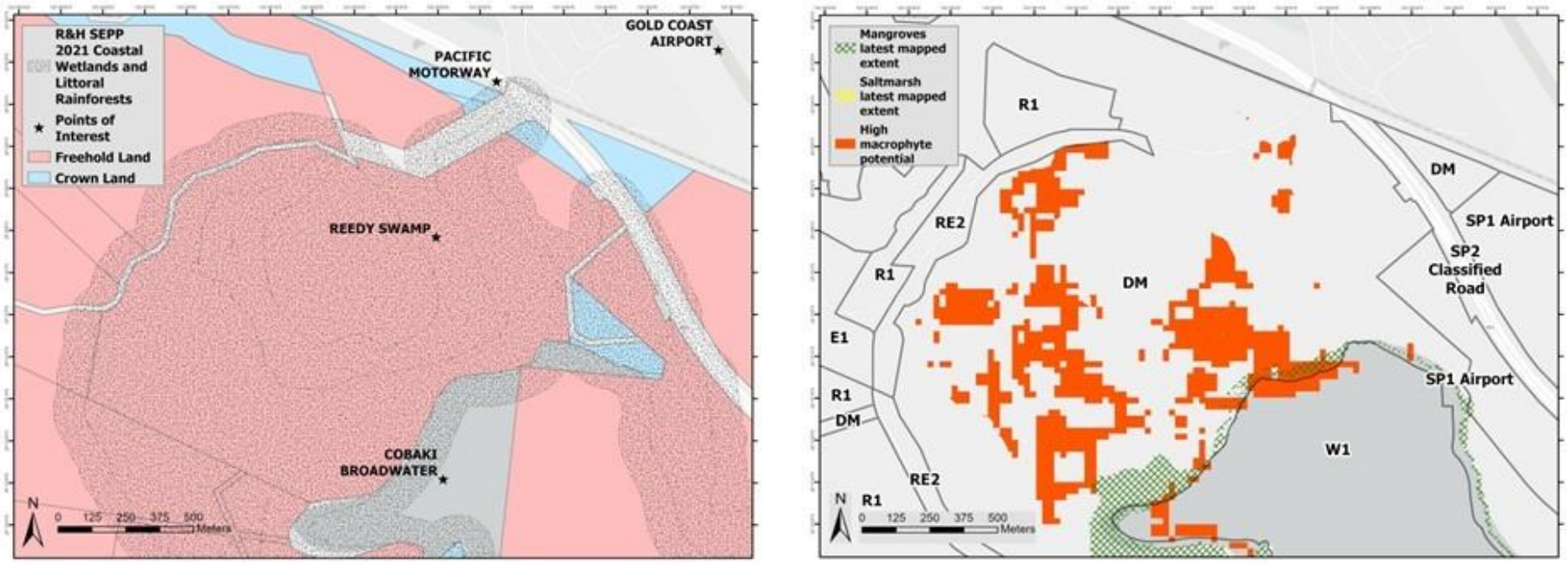


Figure 8 Tweed Hotspot 1: North Cobaki Broadwater. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 1:

North Cobaki Broadwater

Manage new developments in adjacent developing urban area to the west, to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations where and how discharges occur.

Investigate Sandy Lane legacy infrastructure to determine impacts on hydrology and options to reinstate more natural flows.

Limit accelerated mangrove expansion and incursion of tides into Reedy Swamp freshwater wetlands by de-coupling or filling legacy drains and ditches to favour upslope SLR migration pathways for freshwater wetlands, saltmarsh and mangroves.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats and in cleared areas near the Tugun Bypass.

Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid within Cobaki Broadwater, to prevent its burial and lasting impacts.

Provide SLR migration pathways north onto Crown land, and on to Boyd Street and the future Cobaki Park Way. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome. Undertake stakeholder engagement to manage current and future access.

Hydrology

Legacy infrastructure may be affecting natural hydrology at Hotspot 1. In the north-east, Sandy Lane (Figure 9A) has fallen into disuse and could be investigated to determine if impacts to local hydrology are occurring. Removal, moving or retrofitting of infrastructure may be required to reinstate more natural flows.

A legacy drainage ditch network in the southern area (Figure 9B) may be creating artificial connectivity between freshwater and estuarine ecosystems, accelerating the expansion of mangroves into the TECs Swamp Oak Floodplain Forest and Swamp Sclerophyll Forest. The drains should be investigated to determine if this artificial connection should be decoupled, or legacy drainage infilled, to limit accelerated incursion of tides into freshwater wetlands and mangrove expansion and provide a viable upslope SLR migration pathway for intertidal marine vegetation.

Dynamic changes to vegetation types are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TECs 'Freshwater Wetlands' and 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal marine vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS*: Integrated landscape and seascape conservation*.

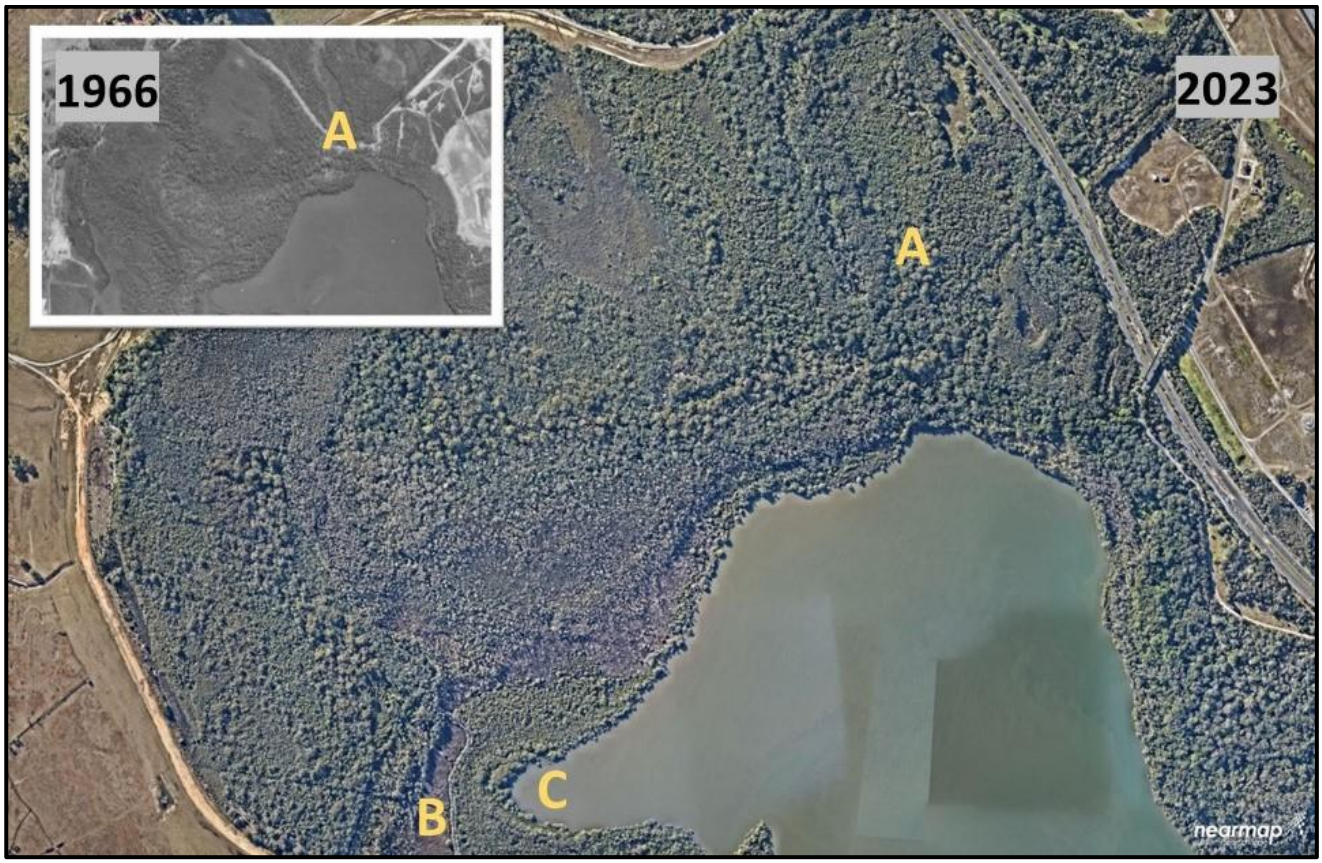


Figure 9 Legacy infrastructure and mangrove expansion at north Cobaki Broadwater. A, legacy track infrastructure. B, drainage infrastructure. C, area of sediment accretion and mangrove expansion. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Vegetation

Weeds near the Tugun Bypass and airport areas have been identified as a potential threat in the *Vegetation Management Plan* (Kingston et al. 2004) and the 2017 *Gold Coast Airport Pty Ltd Masterplan*; and feral herbivores are likely to be causing widespread damage to habitats in the Cobaki Broadwater area. Feral animals and weeds in the North Cobaki Broadwater hotspot should be managed to minimise impacts on intertidal vegetation, prioritising SLR migration pathways, especially those adjacent to saltmarsh

habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS*: Weed Management Guide.*

In some areas, sediment is accreting in intertidal habitats and mangroves are expanding (Figure 9C). In areas of active sediment accretion, accumulated anthropogenic debris should be removed to prevent burial and lasting impacts. Sources of the debris should be investigated and managed.

People and Planning

Multiple management issues may impact intertidal vegetation at Hotspot 1, but access is restricted due to its current use as a Crown land grazing lease. Stakeholder engagement should be undertaken to improve access and management outcomes. In the long term, a review of the grazing lease at this site may be needed to allow effective management.

There is potential for SLR migration pathways for intertidal vegetation northward onto the Crown land areas and further north under Boyd Street and the future Cobaki Park Way. A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these areas, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

To protect intertidal vegetation from impacts associated with poor water quality, new urban developments should use water sensitive designs and nature-based solutions to pollution, especially in the immediately adjacent developing urban area to the west. It is important that compliance with pollution and stormwater control regulations is ensured. More information on best practice urban design for development in the coastal zone can be found in the *NSW Coastal Design Guidelines 2023*.

Hotspot 2: Cobaki Creek

The Cobaki Creek hotspot covers areas along Cobaki Creek and includes a series of small narrow islands in the Cobaki Broadwater that were opportunistically formed, or consolidated, from dumping of dredge spoil from works in Cobaki Creek (Figure 10). These dredge spoil islands have now formed dynamic overwash mangrove habitats. The boundary of the hotspot is indicated by the white dotted line in Figure 11. Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 1 and 3 — may be influenced by management actions in this hotspot, and vice versa.

Large areas of mangroves occur throughout the area, and a small area of the TEC Coastal Saltmarsh occurs north of the Cobaki Broadwater Village. Other TECs (listed under the BC Act) that may occur in the hotspot area are Swamp Oak Floodplain Forest, Freshwater Wetlands, Lowland Rainforest, Swamp Sclerophyll Forest and Subtropical Coastal Floodplain Forest. Hotspots in the Cobaki Creek area are almost all zoned Deferred Matter (DM), expect the Cobaki Broadwater which is zoned as Natural Waterways (W1).

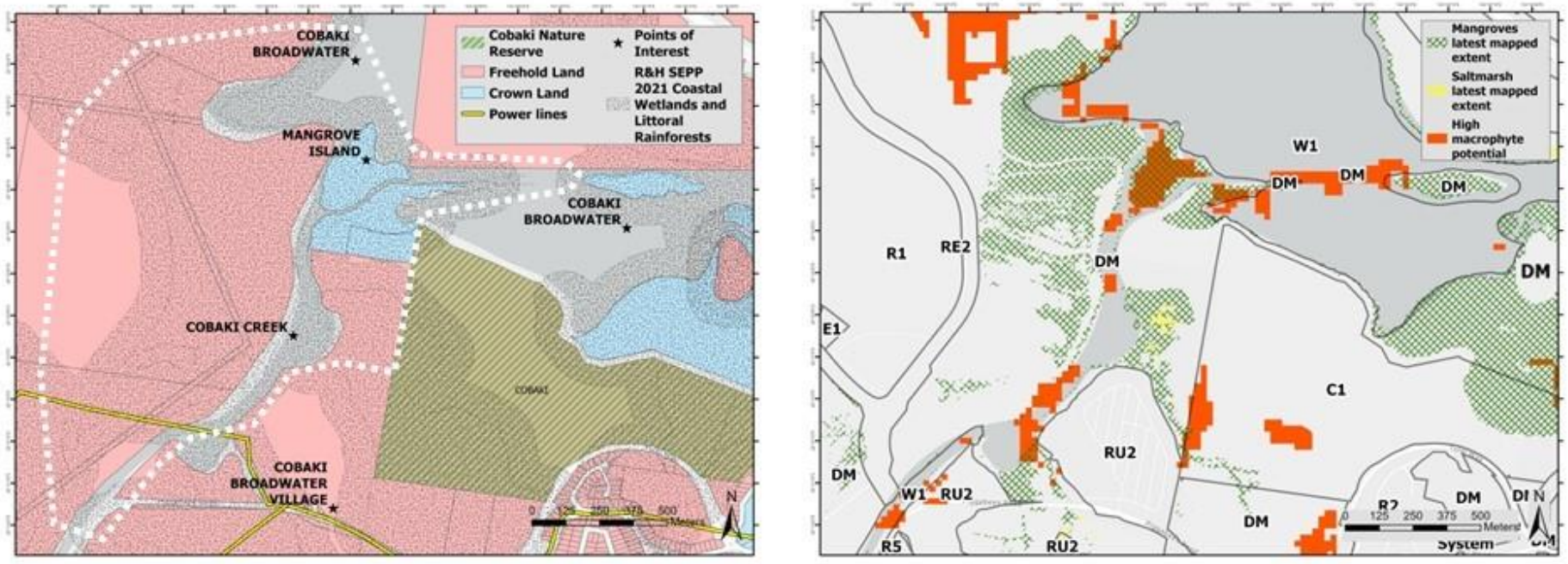
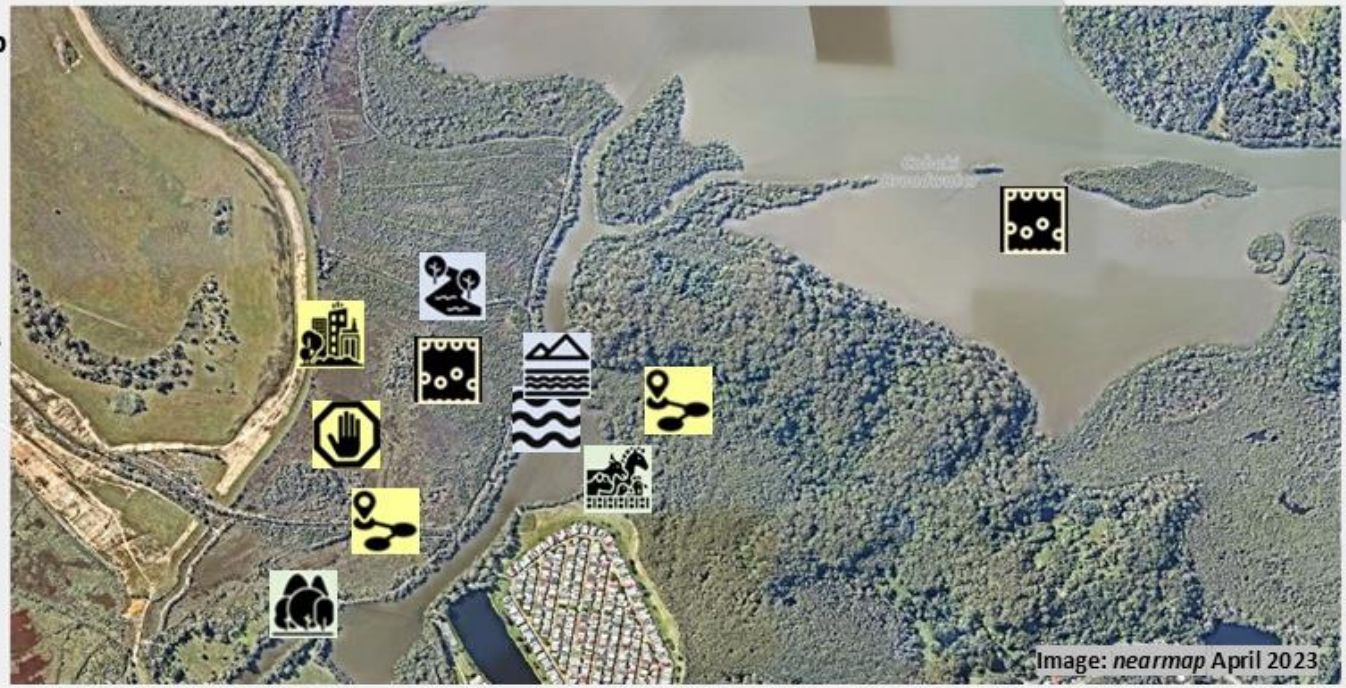


Figure 10 Tweed Hotspot 2: Cobaki Creek. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 2:

Cobaki Creek



Manage foreshore access at planned Leda Cobaki Lakes urban development.

Monitor elevations of Cobaki historical dredge spoil islands in the Cobaki Broadwater to assess if sediment accretion is sufficient to keep pace with SLR.

Restore ground surface elevations at the Leda Development Saltmarsh Rehabilitation Site by restoring natural sediment supplies. Encourage the growth of intertidal vegetation for biological build of ground surface.

Investigate the drainage network at the Leda Development Saltmarsh Rehabilitation Site to determine impacts on hydrology and identify options to facilitate overland tidal flows.

Limit accelerated mangrove expansion into freshwater wetlands at the Leda Development Saltmarsh Rehabilitation Site by de-coupling or filling legacy drains and ditches to provide a viable upslope SLR migration pathway for all habitats.

Investigate levee infrastructure along the edge of Cobaki Creek at the Leda Development Saltmarsh Rehabilitation Site to determine impacts on hydrology and options to remove and reinstate tidal flows.

Continue to establish and maintain fenced vegetation buffers above the level of the highest astronomic tide along Cobaki Creek.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats such as those adjacent to Cobaki Broadwater Village.

Provide SLR migration pathways for intertidal vegetation at the Leda Development Saltmarsh Rehabilitation Site and north of the Cobaki Broadwater Village. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.

Manage Leda Cobaki Lakes Development to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations where discharges occur.

Hydrology

Two lots of previously cleared and drained land to the east of the Cobaki Parkway are subject to a saltmarsh rehabilitation offset plan for the development (Figure 11A and B). However, this area retains extensive legacy infrastructure interrupting natural hydrology, including a levee, ring drain, floodgates and radial drains. Mangroves are advancing along drains into saltmarsh areas due to unmanaged tidal flushing.

The prioritised restoration of natural hydrology at this hotspot is recommended, including removal of the levee and filling the ring drain to support overland flows. Many of the radial drains could also be infilled. Drain outlets may be modified in the short term with vinyl sheet piling to raise groundwater levels, reduce flow velocities, promote overland flows and limit the transportation of mangrove propagules.

Decoupling wetland areas and filling legacy drains and ditches may help limit accelerated mangrove incursion and help provide a viable upslope SLR migration pathway for freshwater wetlands, saltmarsh and mangroves. The strategic removal of already established mangroves that are dropping propagules may facilitate saltmarsh rehabilitation but should only occur after the hydrological regime has been changed to one that is more suitable for saltmarsh. Monitoring has demonstrated natural and sustained establishment of saltmarsh is occurring and mangroves are in senescence. These actions are consistent with the CZMP for Cobaki Broadwater and Terranora Broadwater *Action 2.15: all foreshore vegetation in this area to be restored including saltmarsh* (TSC 2012).

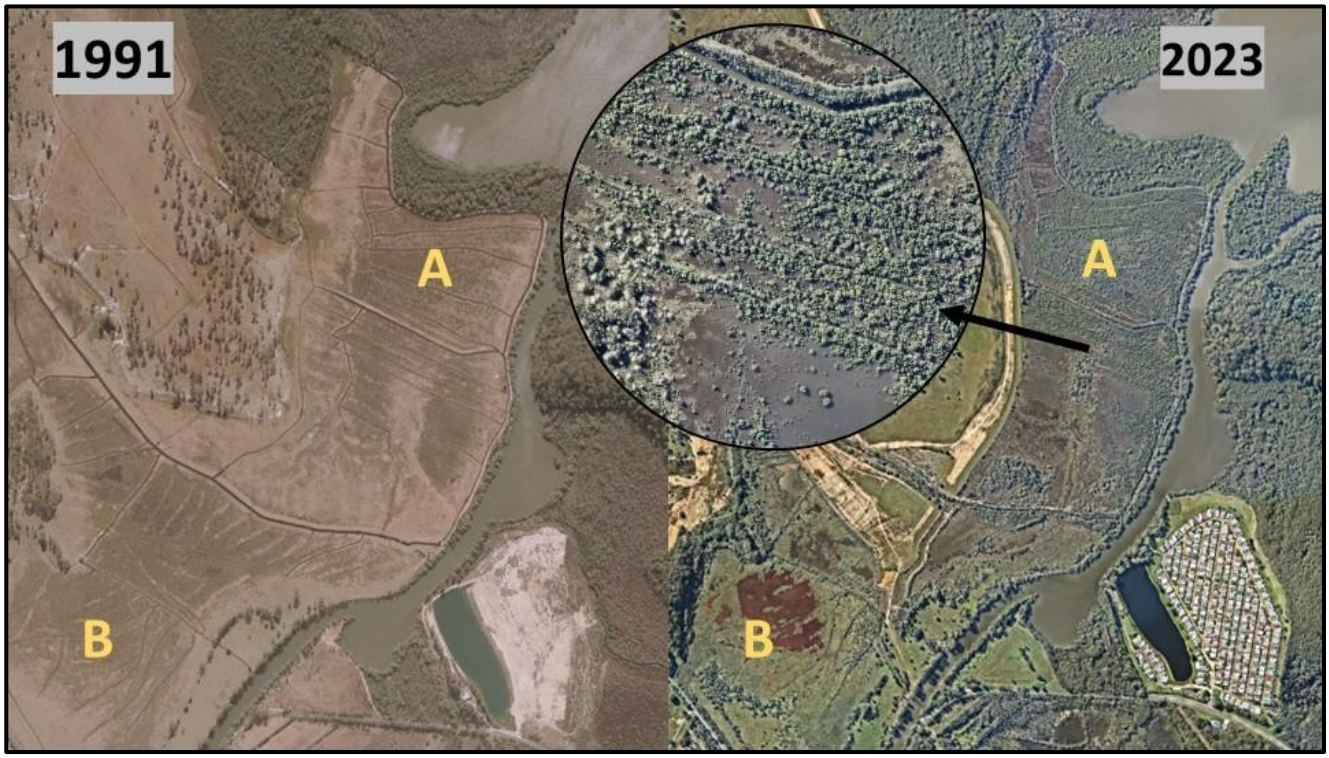


Figure 11 Legacy drainage infrastructure at Cobaki Creek. Two lots (A and B) comprise a Saltmarsh rehabilitation area. Inset shows mangrove incursion facilitated by drains. Images: NSW Government Spatial Services (left) and *Nearmap* (right and inset).

Sediments

Assessing the ability of the dredge spoil islands in the Cobaki Broadwater to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes in ecosystem extent, is advised. If sediment accretion is insufficient to keep pace with SLR management interventions may become appropriate. At this site investigations into developing suitable techniques for the use of dredge spoil to supplement sedimentation may be warranted given the previous albeit unplanned success of the strategy.

Digital elevation models indicate that some subsidence may have occurred on the left bank of Cobaki Creek (Figure 12). The distribution of the low-lying areas indicate that these areas are lower than the original ground surface level. This is reflected in the current distribution of mangroves which have colonised many areas lower than 0.35 m AHD.

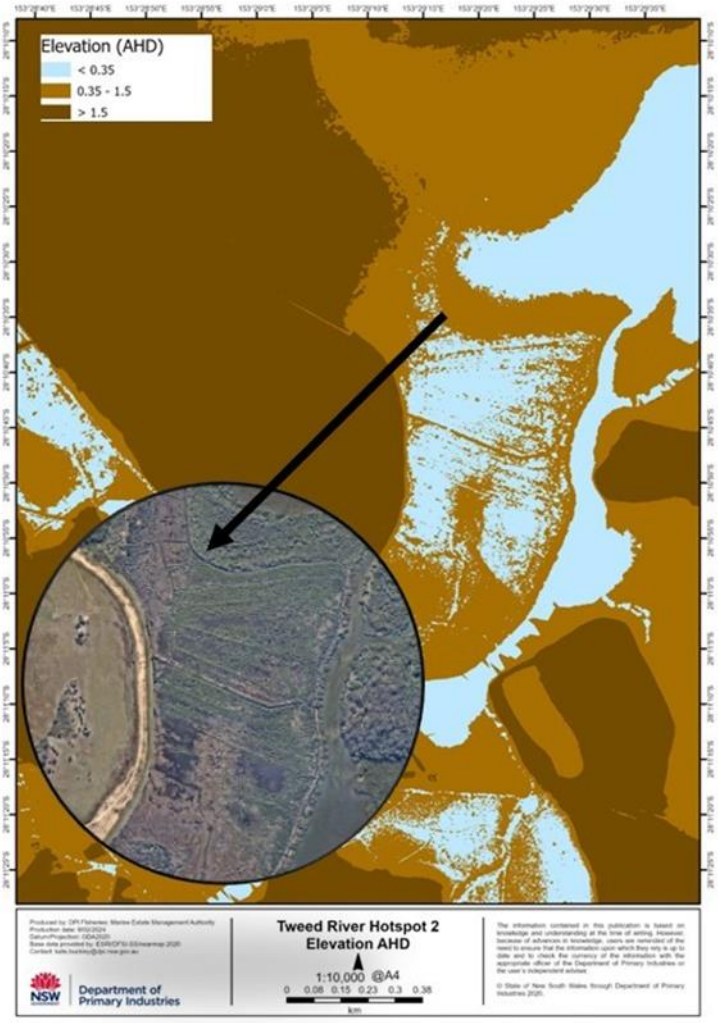


Figure 12 Land subsidence on the left bank of Cobaki Creek. Digital Elevation Model of left bank. Images: *Nearmap.* Data Source: Elvis (Elevation and Depth - Foundation Spatial Data).

The restoration or enhancement of ground surface elevation may be warranted at this site. It is also crucial to facilitate sediment accretion, for example by maintaining sediment supplies by removing any barriers to overland flows or encouraging the growth of root mats by restoring degraded habitats. This will help protect adjacent saltmarsh and freshwater habitats from accelerated mangrove incursion.

Vegetation

The Tweed Shire Council has already identified priority areas for rehabilitation that are currently impacted by stock grazing along Cobaki Creek. This Tweed Shire Council proposal suggests the use of incentives such as grant schemes to work with floodplain landholders to create fenced vegetation buffers around waterways, wetlands and riparian areas (TSC 2012). The continuation of this work is crucial to improve the resilience of intertidal vegetation and provide migration pathways inland as sea levels rise.

Where feral herbivores and weeds are detected, ongoing management actions should be undertaken in co-operation with landowners to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats such as areas north of the Cobaki Broadwater Village. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS*: Weed Management Guide.*

People and Planning

Opportunity for a SLR migration pathway occurs north of the Cobaki Broadwater Village incorporating existing saltmarsh and mangrove habitats and sharing a boundary with the Cobaki Nature Reserve. An opportunity for a significant SLR migration pathway may also occur on the left bank of Cobaki Creek at the Leda Development Saltmarsh Rehabilitation Site and along the riparian zone. Investigations undertaken as part of the *Tweed River Floodplain Prioritisation Study* (Tucker et al. 2023) show that the floodgate outlets to Cobaki Creek have compromised functionality with drain invert levels and adjacent estuarine tidal levels combining to effectively limit drainage to between 50 – 95% of the time for most structures and for less than 50% of the time for others. More information can be found in the MEMS Coastal floodplain prioritisation studies. With future SLR, low-lying grazing areas on the left bank of Cobaki Creek will have reduced drainage and could transition to estuarine wetlands as a viable migration pathway for intertidal marine vegetation (Tucker et al 2023).

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Areas within this hotspot are marked for urban growth such as Cobaki Lakes. The protection of existing intertidal marine vegetation during developments should be prioritised, consistent with the recommendations of the *Tweed River Floodplain Prioritisation Study* (Tucker et al 2023). As the Cobaki Lakes residential development to the west of this hotspot progresses, it will be important to minimise impacts on mangrove and saltmarsh habitats. To protect intertidal vegetation from impacts associated with poor water quality, the new developments should use nature-based water sensitive designs and solutions to pollution. It is important that compliance with pollution and stormwater control regulations is ensured. Freshwater impacts from stormwater outlets on saltmarsh habitats need to be avoided. An anticipated increase in foreshore access should be managed to prevent impacts.

Hotspot 3: Piggabeen Road

The Piggabeen Road hotspot reaches from the Cobaki Nature Reserve to Piggabeen Road, close to the Banksia Waters Lifestyle Community (formerly Cobaki Broadwater Village) (Figure 13). Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspots 2 and 4 — may be influenced by management actions in this hotspot, and vice versa.

There are substantial areas of mangroves and some areas of the TEC Coastal Saltmarsh in the hotspot. TECs (listed under the BC Act) that may be present include Freshwater Wetlands, Swamp Sclerophyll Forest and Lowland Rainforest.

Most of the high macrophyte potential areas at this hotspot are undeveloped and zoned as Deferred Matter (DM), National Parks and Nature Reserves (C1) or Natural Waterways (W1). Much of the surrounding land is zoned for as Rural Landscape (RU2) or Residential (R1, R2, R3, R5).

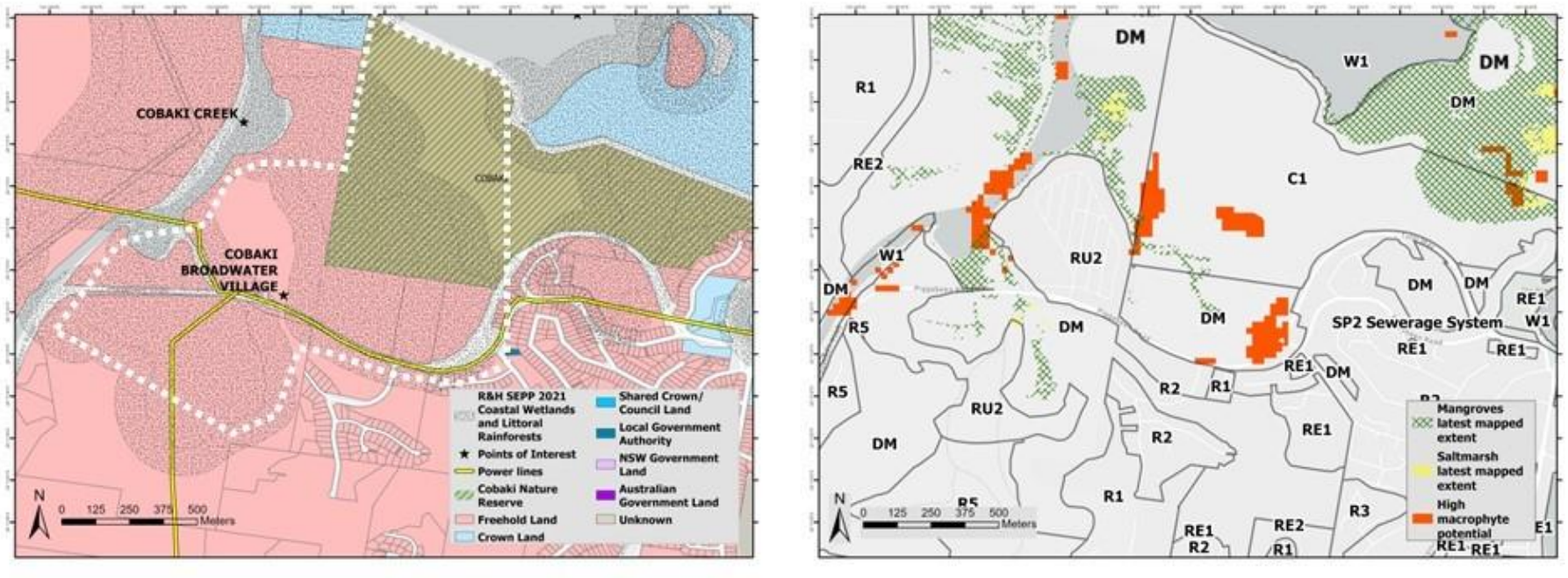
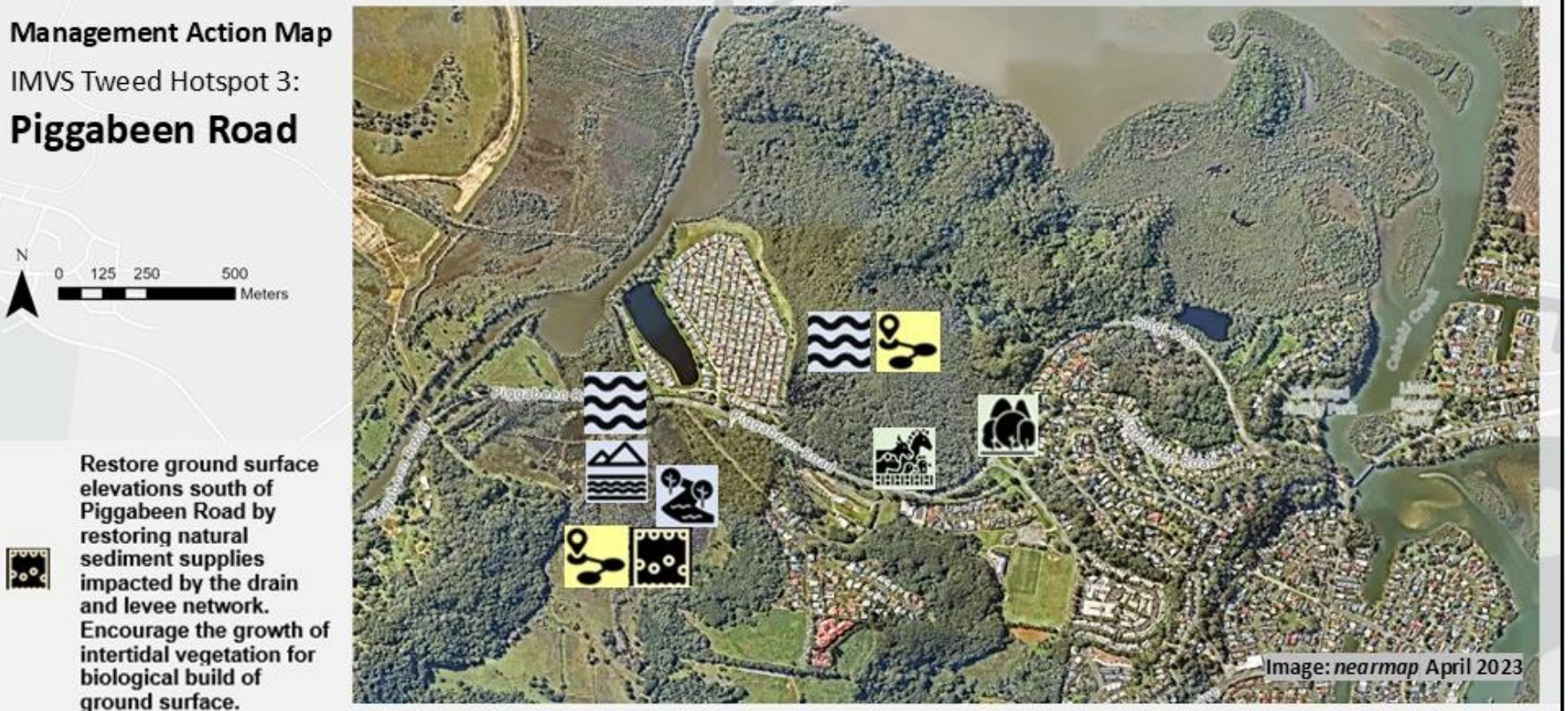


Figure 13 Tweed Hotspot 3: Piggabeen Road. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 3:

Piggabeen Road



Restore ground surface elevations south of Piggabeen Road by restoring natural sediment supplies impacted by the drain and levee network. Encourage the growth of intertidal vegetation for biological build of ground surface.

Limit accelerated mangrove expansion and incursion of tides via drains and ditches into freshwater wetlands south of Piggabeen Road to provide a viable upslope SLR migration pathway for freshwater wetlands, saltmarsh and mangroves.

Hydrological assessment to determine options to reinstate more natural tidal hydrology and connectivity at Piggabeen Road's deteriorating floodgated culverts and at the degrading levee east of the Cobaki Broadwater Village.

Infill drains to decouple artificially connected estuarine and freshwater wetland south of Piggabeen Road and provide a viable SLR migration pathway that maximises overland tidal flows.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways e.g. south of Cobaki Nature Reserve and especially near saltmarsh habitats.

Establish vegetation buffers above the level of the highest astronomic tide adjacent to saltmarsh in the Cobaki Nature Reserve.

Provide SLR migration pathways south of Piggabeen Road and south of the Cobaki Nature Reserve. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome. Change weed management at Cobaki Nature Reserve to be compatible with migration pathways.

Hydrology

A levee running roughly along the southern boundary of the Cobaki Nature Reserve, east of the Cobaki Broadwater Village, was formed during the installation of powerlines in the 1960s (Figure 14A). This levee may be overtopped during high tides as mangrove propagules have established close to Piggabeen Road and tidal inundation landward of the levee is visible in imagery taken during dry conditions in 2019 (Figure 14B). However, where tidal flushing is limited disservices such as odours from rotting mangrove propagules can occur and residents from the Cobaki Broadwater Village have complained about this impact. It is recommended that a hydrological assessment is undertaken to better understand if the levee is causing disservices and assess options to provide a viable migration pathway for intertidal marine vegetation southward from the current boundary of the Cobaki Nature Reserve.

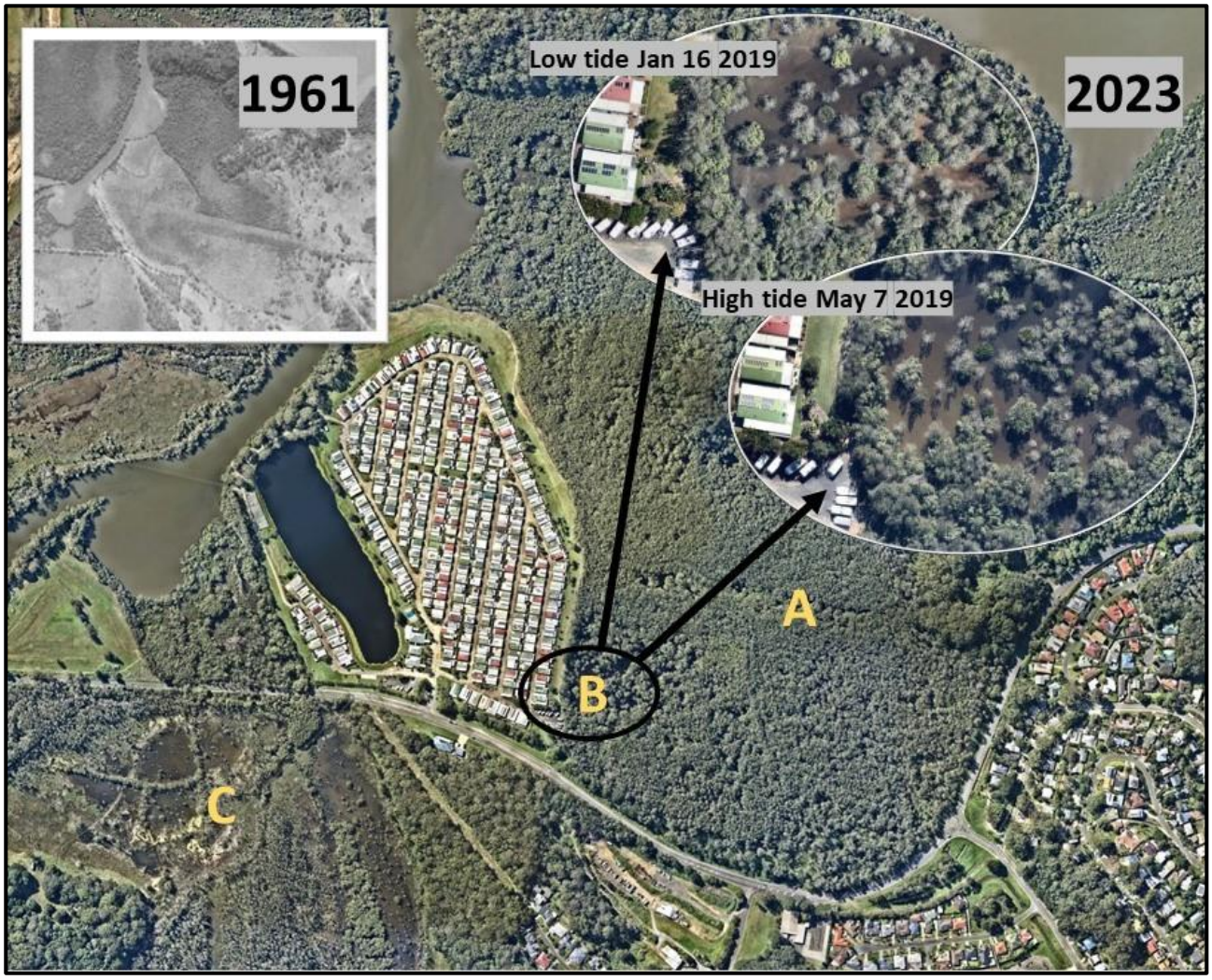


Figure 14 Legacy levee and degraded wetland at Piggabeen Road. A, legacy levee. B, tidal inundation to the landward side of the levee. C, degraded freshwater wetland. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Although not currently apparent, dieback of Coastal Swamp Oak (*Casuarina glauca*) may occur in this area as salinity increases during El Niño conditions. Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TECs 'Freshwater Wetlands' and 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS*: Integrated landscape and seascape conservation*.

Most drainage infrastructure in the hotspot has compromised functionality with drain invert levels submerged by tidal levels between 50 – 95% of the time. South of Piggabeen Road, estuarine flows are flushing into previously drained and cleared Freshwater Wetland via the legacy drainage network (Figure 14C). Here, an unmaintained flood gated culvert (Structure 246) (Figure 15A) directs estuarine flows into the wetlands (Figure 15B) and along an artificial drain that runs parallel with the road (Figure 15C). The floodgate has compromised functionality with water able to effectively drain 50% of the time. The drain is also degraded and breached in several places, allowing tidal flows and the establishment of mangrove propagules in the Freshwater Wetland, causing extensive dieback of Coastal Swamp Oak and *Meleleuca* (Figure 15D). It is also likely that mangroves are encroaching on Coastal Saltmarsh habitats at this site. Acid sulfate soils may also be exposed in some parts of the wetland which may be contributing to poor water quality.

Figure 15 Site to the south of Piggabeen Road. A, legacy flood gated culvert. B, natural creek line. C, drain parallel to the road. D, impact of saltwater incursion into previously freshwater habitats. Images: *Nearmap* (base).

It is very important to reinstate more natural tidal hydrology and catchment connectivity to the south of Piggabeen Road for future ecological resilience. A hydrological assessment may be warranted to determine future actions. For example, upgrading of Piggabeen Road and the bridge at Cobaki Creek may provide the opportunity to reinstate more natural overland flows by adding multiple shallow culverts or a spanning bridge along the road.

It is recommended that prioritised action is taken at this site to decouple the Freshwater Wetland from estuarine influence, limiting impacts from tidal incursion and accelerated expansion of mangroves, and thus providing a future SLR migration pathway for intertidal marine vegetation. This may include raising the invert level of the floodgate and partially or completely filling the drains or installing sills and sheet piling into the drainage network.

Infilling or reshaping the drains – including the legacy drain that runs parallel with the road – can also be used to increase groundwater levels in the Freshwater Wetland, minimising saline intrusion and the oxidation of acid sulfate soils. Other management opportunities may include identifying and recovering natural waterways at the site to reduce flow velocities.

Sediments

Digital elevation models indicate that some subsidence may have occurred south of Piggabeen Road (Figure 16). The distribution of the low-lying areas indicate that these areas are lower than the original ground surface level. This is reflected in the current distribution of mangroves which are starting to colonise the area lower than 0.35 m AHD.

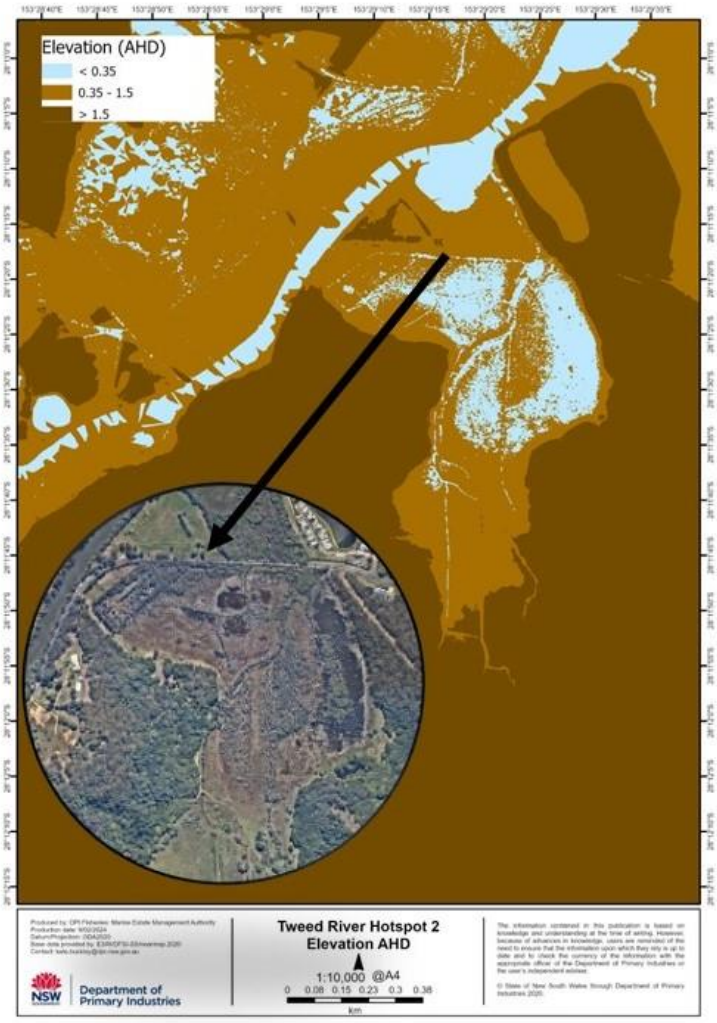


Figure 16 Land subsidence south of Piggabeen Road. Images: *Nearmap.* Data Source: Elvis (Elevation and Depth - Foundation Spatial Data).

The restoration or enhancement of ground surface elevation may be warranted at this site. This can be achieved by restoring sediment supplies by promoting or restoring more natural tidal hydrology and overland flows (for example, by filling drains and lowering levees). The growth of root mats for natural sediment accretion may be encouraged by rehabilitating degraded saltmarsh and mangrove habitats. This will help protect adjacent saltmarsh and freshwater habitats from accelerated mangrove incursion.

Vegetation

Priority weeds (for example, *Lantana*) and feral animals should be controlled to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS*: Weed Management Guide.*

In the Cobaki Nature Reserve slashing for weed control is occurring in areas of saltmarsh habitats (Figure 17). Disturbances the saltmarsh should be minimised to improve resilience to stressors. This can be achieved by the installation of a vegetation buffer zone adjacent to impacted saltmarsh habitats that extends above the level of the highest astronomic.

People and Planning

There are potential intertidal vegetation SLR migration pathways in both the Cobaki Nature Reserve and to the south of Piggabeen Road. Where they are not already part of the Cobaki Nature Reserve, a measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

In the Cobaki Nature Reserve slashing is occurring in areas of saltmarsh habitats (Figure 17). This activity may be preventing the successful migration of saltmarsh and Coastal Swamp Oak habitats in advance of the adjacent mangroves (although over the long term, saltmarsh is likely to be extinguished due to the adjacent hillside creating natural coastal squeeze). This vegetation management approach could be modified to provide a SLR migration pathway enabling the expansion of saltmarsh, mangrove, *Melaleuca* and Coastal Swamp Oak habitats. This could involve the installation of bollards/barriers to delineate the contour reached by the highest astronomical tide, plus a suitable buffer zone, and exclusion of this area from slashing.

Figure 17 Slashing at Cobaki Nature Reserve. Adjacent to or within mangrove, *Melaleuca*, Coastal Swamp Oak (left) and saltmarsh habitats (right).

Hotspot 4: East Cobaki Broadwater

The East Cobaki Broadwater hotspot includes extensive areas of mangrove and the TEC Coastal Saltmarsh on Crown land that is currently used as Tweed Heads Pony Club, and land to the south on the opposite side of the Cobaki Broadwater (Figure 18). Other TECs (listed under the BC Act) that may be present near hotspot areas include Littoral Rainforest, Swamp Oak Floodplain Forest, and (particularly to the north) Lowland Rainforest, Swamp Sclerophyll Forest and Freshwater Wetlands.

Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 3 — may be influenced by management actions in this hotspot, and vice versa.

The majority of the existing intertidal marine vegetation and hotspot areas are zoned Deferred Matter (DM). The surrounding land zoning is complex due to urban developments and infrastructure.

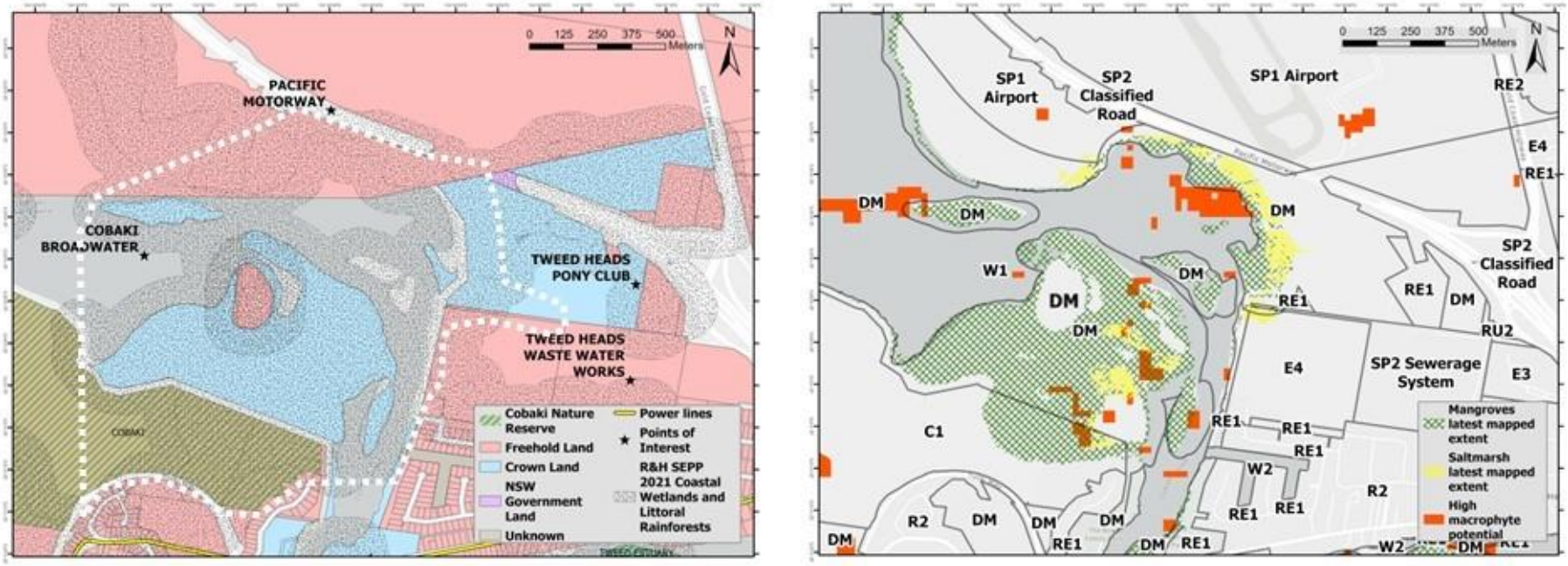
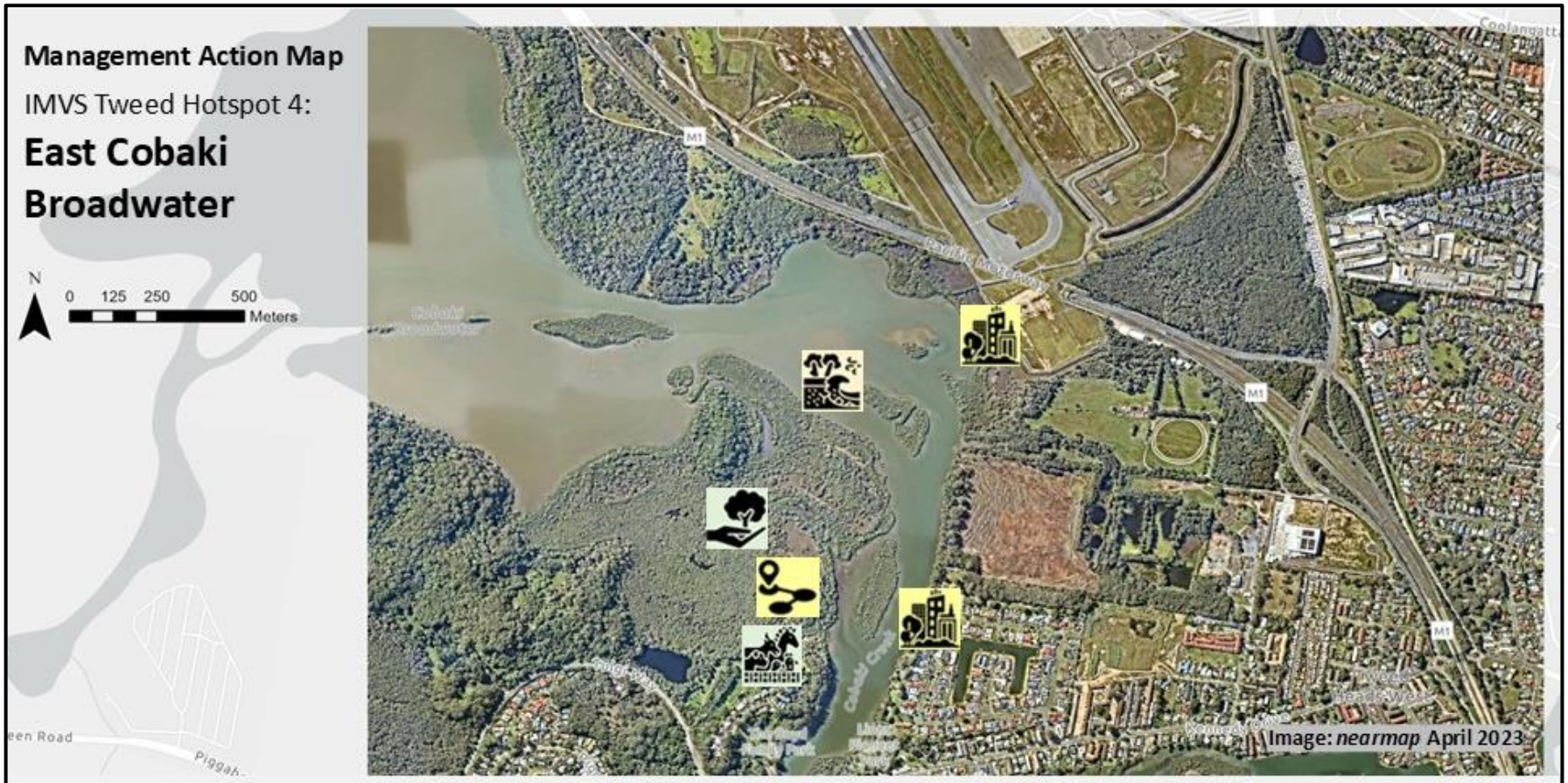


Figure 18 Tweed Hotspot 4: East Cobaki Broadwater. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 4:

East Cobaki Broadwater



Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid north-east of Cobaki Nature Reserve, to prevent its burial and lasting impacts.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats north-east of Cobaki Nature Reserve.

Minimise actions that may cause erosion of intertidal areas including dredging and boat wake damage near the Cobaki Boating No Wash Zone

Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur to minimise impact from the Gold Coast Airport and urban and industrial developments on the eastern foreshore of Cobaki Broadwater.

Provide a SLR migration pathway north-east of the Cobaki Nature Reserve. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Uncertainties

Prioritisation mapping for the IMVS was undertaken with data gathered prior to an airport extension. The expansion of the airport has significantly impacted a potential migration pathway for intertidal vegetation including saltmarsh near the Tweed Heads Pony Club (Figure 19A) as connectivity with the broader hotspot area on the other side of the Pacific Motorway to the east is practically extinguished (Figure 19B). In addition, mangroves are incompatible with safety requirements around airport runway clearances and would require trimming if they established in this area. Damage to saltmarsh habitats at this site was mapped by DPIRD in 2022 (NSW Estuarine Mapping) but access to this area is now limited due to the airport extension.

Figure 19 Progressive ecological degradation of east Cobaki Broadwater. A, airport extension. B, hotspot area now isolated from other intertidal habitats. C, Tringa Street Industrial Subdivision. Images: *Nearmap.*

A potentially ecologically valuable site to the south of the Tweed Heads Pony Club has been recently cleared for the Tringa Street Industrial Subdivision (Figure 19C). The site hosted TECs, including Swamp Oak Floodplain Forest and Coastal Saltmarsh. A legacy development approval granted prior to threatened species legislation has been reactivated by the developer, which limits the current protections afforded to habitats now listed as TECs. Although a saltmarsh rehabilitation plan has been prepared as part of the updated proposal, the rehabilitation plan has not commenced to date and the site remains degraded due to clearing and vehicular damage (Figure 20).

These recent developments, not captured in the modelling, limit the habitat available for the migration of intertidal habitats with SLR and generate ongoing impacts in this hotspot. Although it is noted that the Pony Club management have a long history of protecting and rehabilitating intertidal marine vegetation, this area therefore cannot be considered a primary focus for actions to support the resilience of intertidal vegetation at the East Cobaki Broadwater.

Figure 20 Saltmarsh rehabilitation site associated with the Tringa Street Industrial Subdivision. Orange flagging delineates rehabilitation site. Images: *Nearmap.*

Sediments

Historical imagery indicates that the extensive intertidal habitats north-east of the Cobaki Nature Reserve are expanding over time (Figure 21). SLR migration pathway options for saltmarsh and mangroves include increased ground surface elevation at a pace that keeps up with SLR, the expansion and merging of islands, and migration upslope towards the Cobaki Nature Reserve. Any activities that may cause erosion of intertidal areas including dredging and boat wake damage should be minimised. This is consistent with the *Tweed Estuary Boating Plan* (2006 – 2010) that recognises the need to reduce potential boating impacts on environmental values in the Cobaki Broadwaters by discouraging any improvements in boating access and enforcing compliance with boating regulations including provisions under the NSW Fisheries 'Fish Habitat Protection Plan No.2: Seagrasses'.

Figure 21 Changes to the morphology of intertidal habitats in the Cobaki Broadwater over time. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Vegetation

The southern part of the East Cobaki Broadwater hotspot comprises extensive areas of mangrove and Coastal Saltmarsh adjacent to the protected area of Cobaki Nature Reserve, which increases the ecological value of this area. Disturbances to these intertidal habitats should be minimised to maximise their resilience to stressors.

Weeds and feral herbivores are likely to be causing widespread damage to intertidal habitats in this area. They should be actively managed through exclusion and removal programs to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS*: Weed Management Guide.*

In areas of active sediment accretion north-east of Cobaki Nature Reserve, where intertidal habitats are expanding over time (see Sediments, above), accumulated anthropogenic debris should be removed to prevent burial and lasting impacts, and sources of the debris investigated and managed.

People and Planning

It is crucial that compliance with pollution control regulations is enforced for nearby urban developments to maintain the integrity and resilience of intertidal marine vegetation ecosystems in the Cobaki Broadwater. For example, the CZMP for Cobaki Broadwater and Terranora Broadwater indicates the potential for long term deleterious impacts from contaminated airport stormwater runoff discharging to Cobaki Broadwater, although in 2017 a report for Airservices Australia on potential pollution from the Gold Coast Airport (GHD 2017) indicated that PFAS contaminant levels were acceptable.

The southern part of the hotspot is on Crown land (zoned DM), with ecologically significant and extensive areas of saltmarsh and mangroves, as well as areas of seagrass and a patch of the TEC Littoral Rainforest, into which the hotspot areas do not extend. This area is adjacent to the Cobaki Nature Reserve and this may provide a substantial migration pathway for intertidal vegetation in the Tweed River catchment.

Where they are not already part of the Cobaki Nature Reserve, a measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 5: Bilambil Creek

The Bilambil Creek hotspot includes riparian and mangrove areas associated with a shallow backwater channel on Bilambil Creek (Figure 22). The surrounding land is privately held. TECs (listed under the BC Act) that may be present include Swamp Oak Floodplain Forest, Swamp Sclerophyll Forest, Lowland Rainforest and Coastal Saltmarsh.

The hotspot lies in an area zoned Deferred Matter (DM), within an area zoned Rural Landscape (RU2).

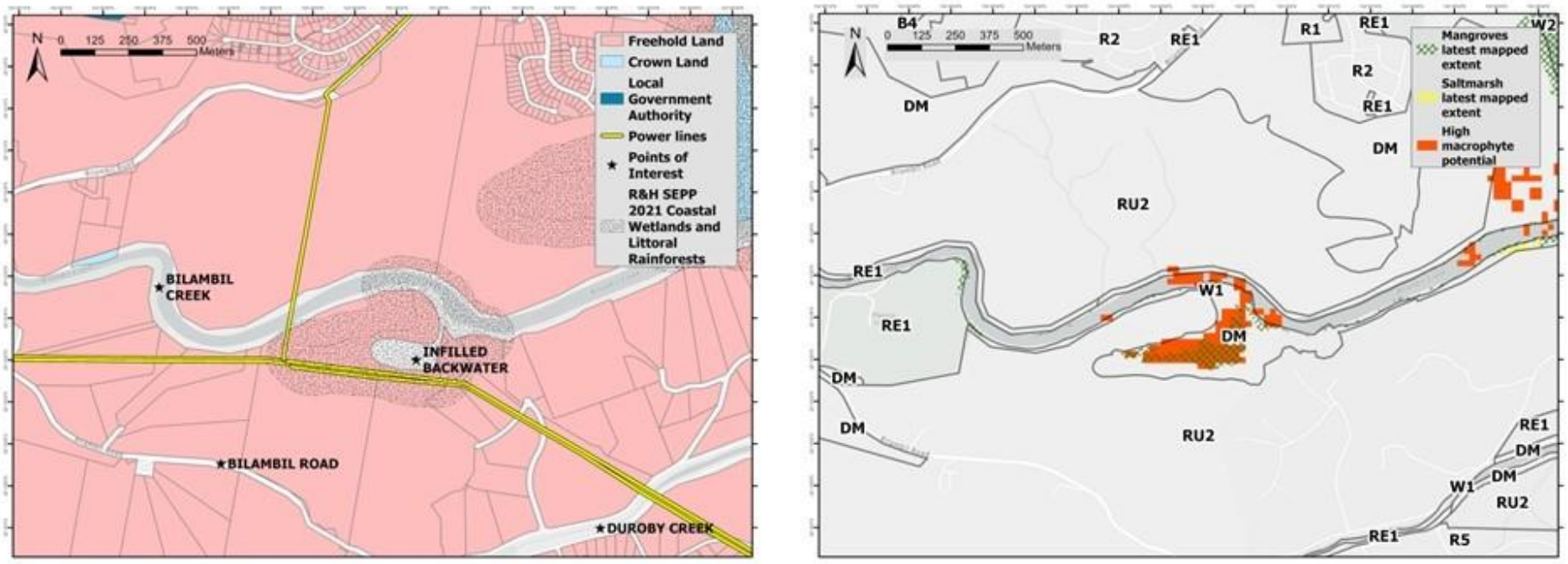
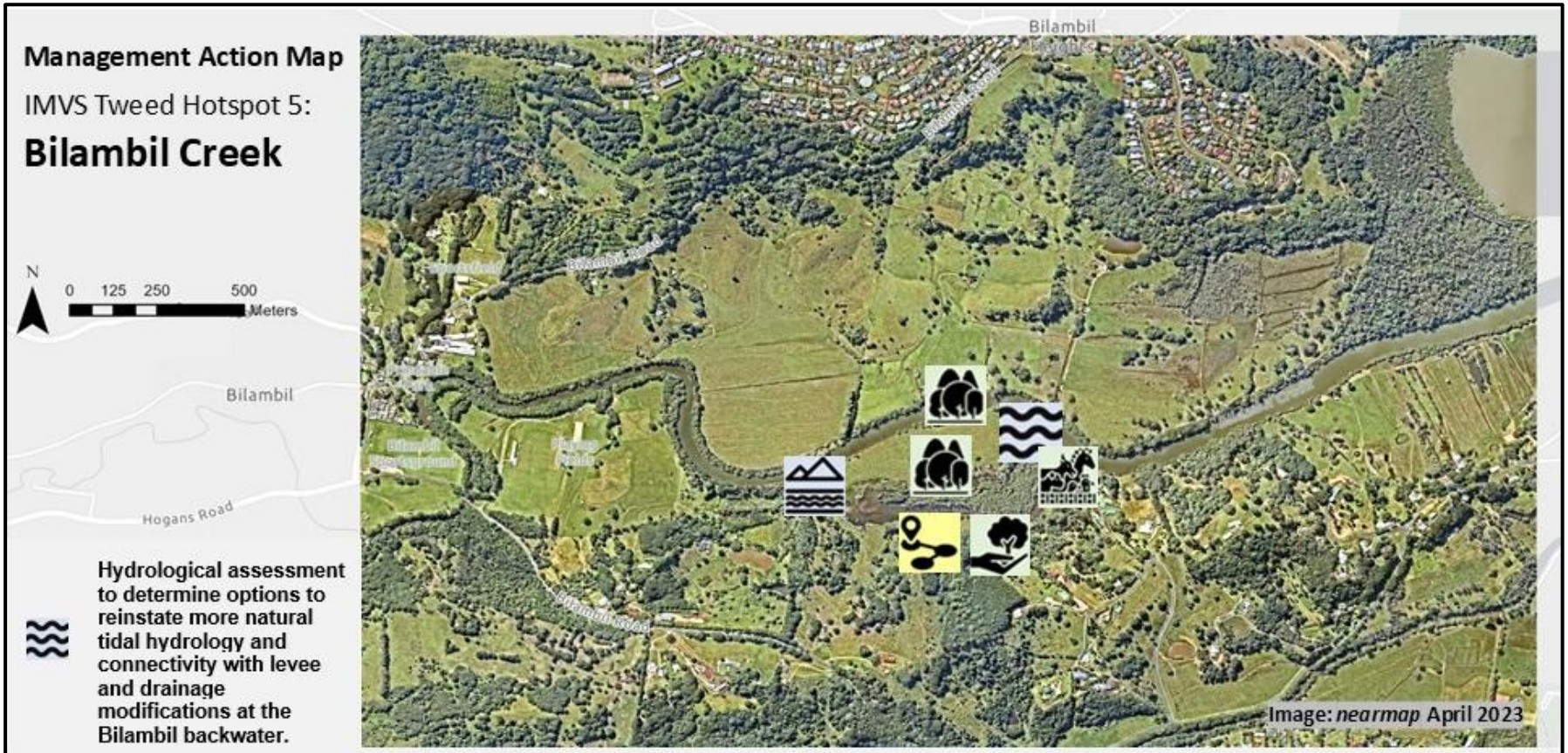


Figure 22 Tweed Hotspot 5: Bilambil Creek. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 5:

Bilambil Creek



Hydrological assessment to determine options to reinstate more natural tidal hydrology and connectivity with levee and drainage modifications at the Bilambil backwater.

Investigate the invert level of the drainage ditch at the western end of the wetland network at Bilambil backwater to determine its impact on hydrology and identify options to reduce the extent of drainage and facilitate overland tidal flows

Manage weeds in fenced vegetation buffers around the Bilambil backwater to allow re-establishment of native vegetation.

Complete a fenced vegetation buffer around the wetland at Bilambil backwater and continue to establish and maintain fenced vegetation buffers above the level of the highest astronomic tide along Bilambil Creek.

Use environmental best management practices to minimise disturbances during unavoidable infrastructure and powerline maintenance at Bilambil backwater.

Undertake stakeholder engagement to determine management options. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome. Realign powerlines away from wetland to allow mangrove growth without trimming.

Hydrology

With landholder cooperation, work has been recently undertaken to maintain improved tidal flushing of the Bilambil Creek backwater. Dieback of Coastal Swamp Oak is evident at the hotspot from increased tidal flushing via a damaged floodgate (Figure 23A). The Tweed Shire Council replaced the floodgate with culvert pipes (Figure 23C), allowing a continuation of the improved tidal flushing and connectivity with Bilambil Creek. This work is aligned with objectives of the IMVS to reinstate more natural tidal hydrology to improve the resilience of intertidal wetlands.

However, altered hydrology may still impact intertidal vegetation at this site. The drain on the western edge of the wetland running through the new culvert pipes may depress groundwater levels (Figure 23B); and a legacy levee on the eastern edge of the wetland (Figure 23C) is likely to be interrupting overland flows. A hydrological assessment, considering potential impacts from the levee, drain and invert levels, could be completed to determine further options to reinstate more natural tidal hydrology, reduce the extent of drainage and facilitate overland tidal flows within the wetland area.

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Oak Floodplain Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

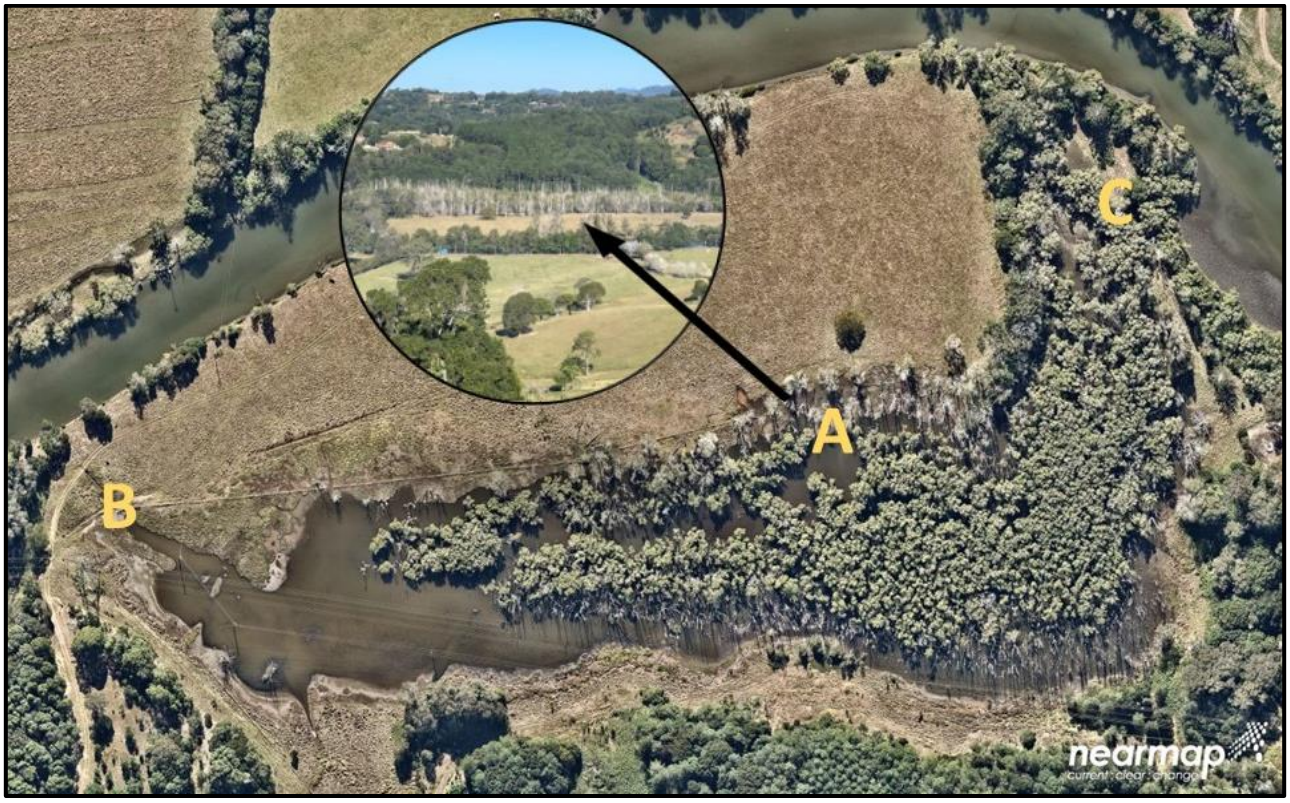


Figure 23 Legacy infrastructure and dieback of intertidal vegetation at Bilambil Creek. A, dieback of freshwater wetland vegetation. D, drain under access track. C, site of legacy levee. Images: *Nearmap* (base).

Vegetation

The hotspot is located on a grazing property. Fencing of wetland areas is currently incomplete, and the site is impacted by livestock grazing, possibly including saltmarsh habitats. A priority action could be completing fencing of the wetland areas with concurrent invasive weed management. The fenced area could include the establishment of a native vegetation buffer to further minimise impacts from grazing, runoff or human disturbances. The Tweed Shire Council is currently working with the landholder to fence riparian vegetation at the site as per CZMP for Cobaki Broadwater and Terranora Broadwater *Action 3.1: Site-based action*

plans for Level 1 rehabilitation zones (mid and transition of all creeks, including ephemeral drainage lines) (TSC 2012).

To improve the extent and resilience of intertidal habitats to stressors at Hotspot 5, the establishment of native vegetation buffers above the level of the highest astronomic tide on the right bank of Bilambil creek should be prioritised. This is consistent with CZMP for Cobaki Broadwater and Terranora Broadwater *Action 3.1: Site-based action plans for Level 1 rehabilitation zones (mid and transition of all creeks, including ephemeral drainage lines)* (TSC 2012).

Weed control may be required after the establishment of vegetation buffers, as the growth of weeds after removal of grazing may prevent the natural regrowth of riparian vegetation. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.*

There are powerlines passing through the hotspot which require periodic access for inspection and trimming of mangroves to maintain safety clearances. Environmental Best Management Practices should be used to minimise disturbances to riparian and intertidal vegetation during unavoidable powerline maintenance.

People and Planning

As the hotspot is surrounded with private land, effective management is dependent on landholder engagement and collaboration.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

In the long term, re-alignment of the powerline infrastructure away from the hotspot areas would allow the uninterrupted migration of mangroves with SLR and minimise current trimming requirements.

Hotspot 6: Charles Bay to Duroby Creek

Hotspot 6 includes extensive areas of mangroves in the western part of the Terranora Broadwater, along the edge of Charles Bay, Bilambil and Duroby Creeks. The TEC Coastal Saltmarsh occurs in a few sites, particularly on the right bank of Duroby Creek (Figure 24). Other TECs (listed under the BC Act) that may be present include Swamp Oak Floodplain Forest, Subtropical Coastal Floodplain Forest, Lowland Rainforest, Swamp Sclerophyll Forest, and Littoral Rainforest.

Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 7 — may be influenced by management actions in this hotspot, and vice versa.

Most of the existing intertidal marine vegetation is within Deferred Matter (DM) and Natural Waterways (W1) zoned areas. Surrounding land is mostly zoned as Rural Landscape (RU2), Residential (R1, R2) or Village (RU5).

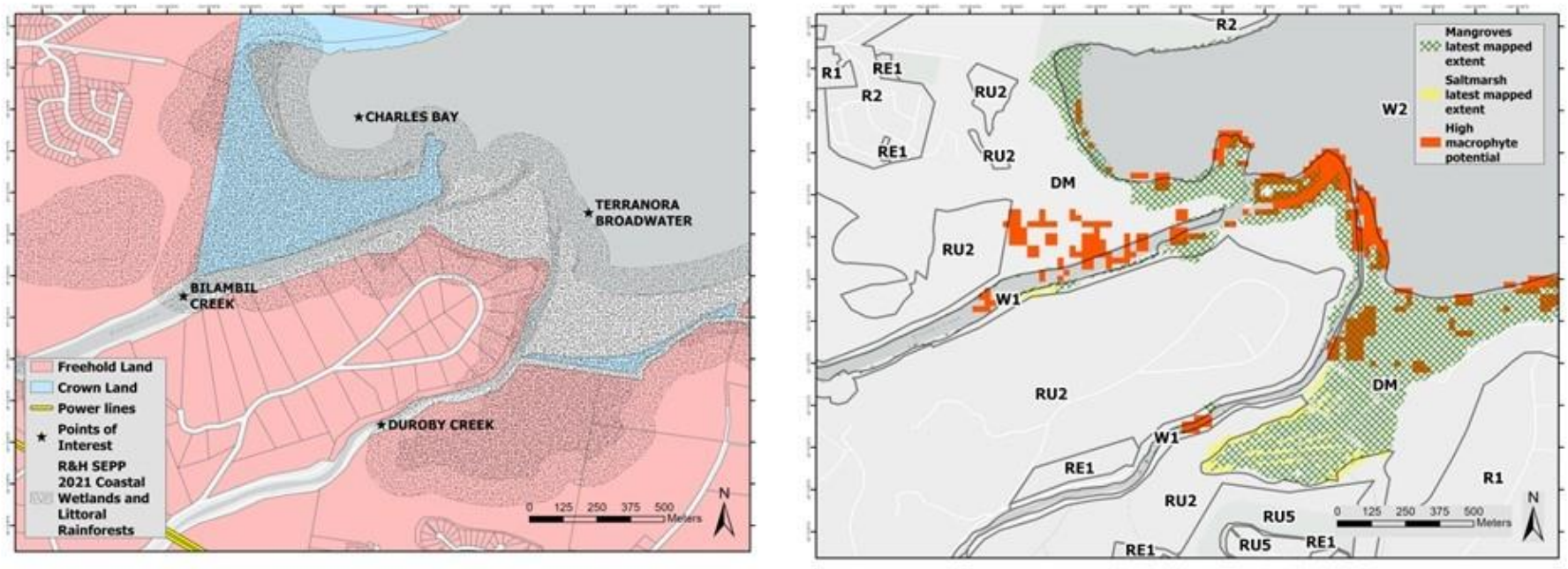
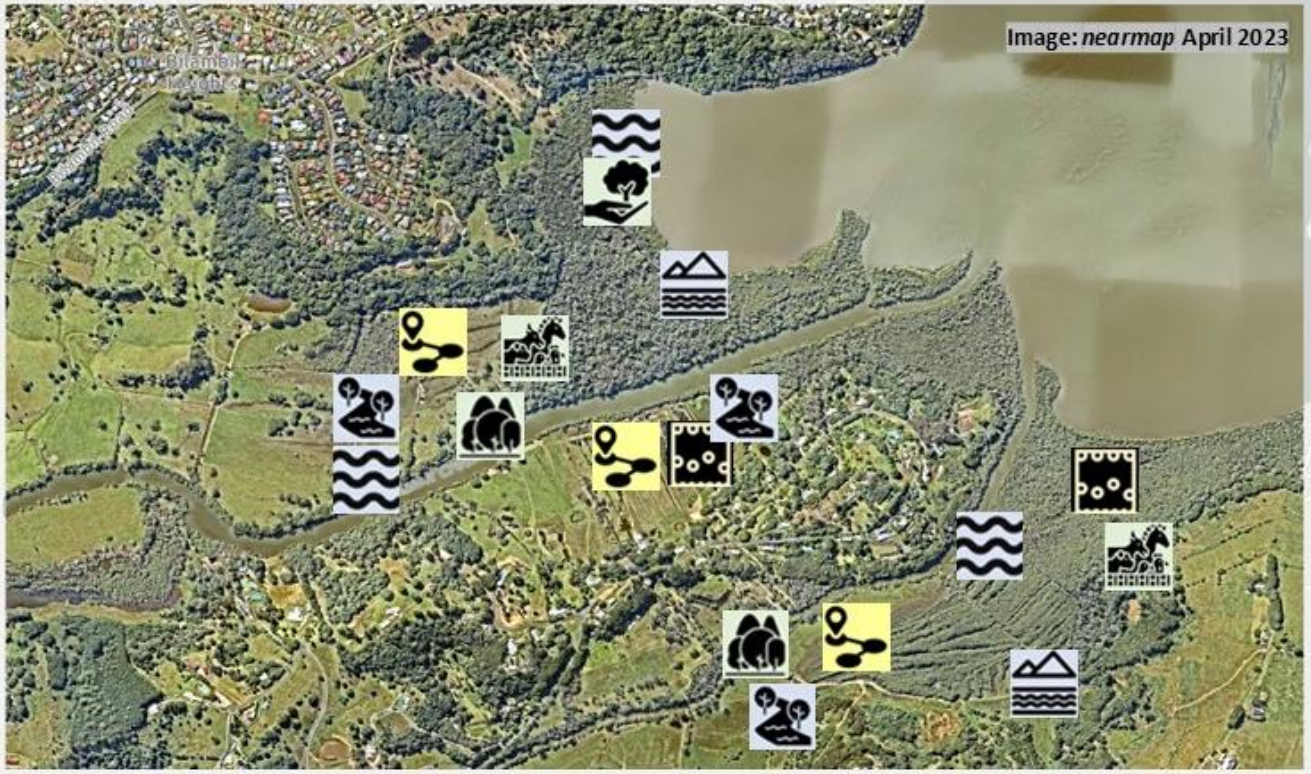


Figure 24 Tweed Hotspot 6: Charles Bay to Duroby Creek. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 6:

Charles Bay to Duroby Creek



Investigate legacy levee infrastructure within Charles Bay and Duroby Marsh tidal wetlands to determine impacts on hydrology and options to remove and reinstate tidal flows. Hydrological assessment of options to use the failed drainage infrastructure north of Bilambil Creek to foster the currently establishing tidal wetland.

Provide SLR migration pathways at Bilambil Creek and Duroby Marsh. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.

Restore ground surface elevations south of Bilambil Ck and at the Terranora Fish In Mozzies Out site by restoring natural sediment supplies impacted by the drain and levee network. Encourage the growth of intertidal vegetation for biological build of ground surface.

Investigate the legacy ring drain infrastructure within Charles Bay and Duroby Marsh tidal wetlands to determine impacts on hydrology and identify options to reduce the extent of drainage and facilitate overland tidal flows.

Limit accelerated mangrove expansion and incursion of tides into freshwater wetlands via drains and ditches north and south of Bilambil Creek and at Duroby Marsh to provide a viable upslope SLR migration pathway for freshwater wetlands, saltmarsh and mangroves.

Create fenced vegetation buffers above the level of the highest astronomic tide and riparian zones along Bilambil and Duroby Creeks.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats at Charles Bay, Bilambil Creek, Duroby Marsh and Terranora Fish In Mozzies Out.

Remove anthropogenic debris accumulating in depositional areas of Charles Bay where sediment accretion is rapid, to prevent its burial and lasting impacts.

Hydrology

Tidal flows in Charles Bay are penetrating areas of Swamp Oak Floodplain Forest and as SLR continues will advance towards areas of Lowland Rainforest. These flows are generally occurring via a failing legacy constructed drainage network. The unmanaged artificial connection to tidal flows is resulting in dieback of Coastal Swamp Oak and the accelerated landward advancement of mostly Grey Mangroves. The ring drain system at Charles Bay includes a legacy levee in the intertidal zone (Figure 25A), which has breached in several locations. A hydrological assessment should be undertaken to determine the extent of unmanaged connections between the constructed drainage system and tidal flows, impacts to natural hydrology, and if it will naturally degrade over time. More active interventions such as filling or reshaping drains and lowering levees to facilitate overland flows may be required to mitigate accelerated impacts of saltwater incursion on adjacent TECs and provide a viable SLR migration pathway for intertidal marine vegetation upslope.

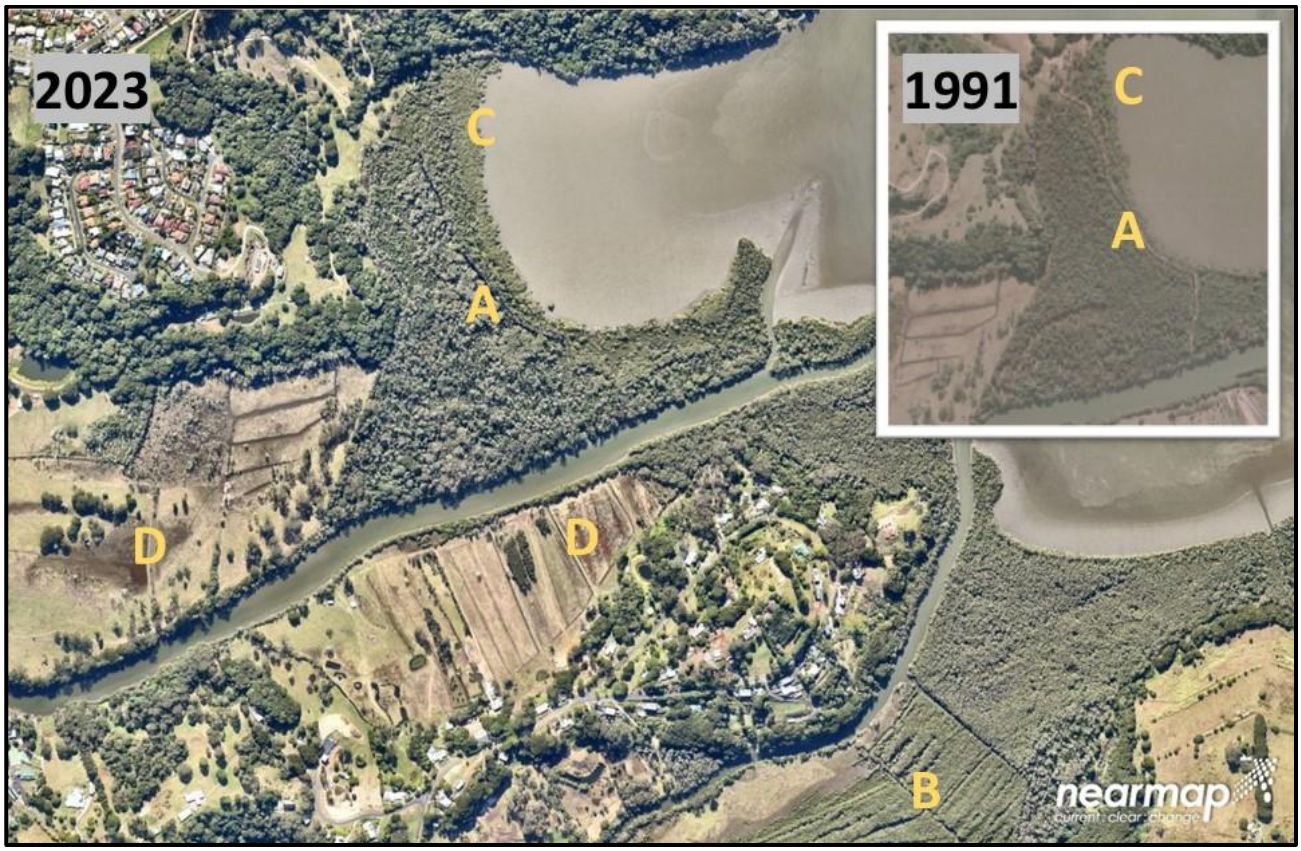


Figure 25 Legacy infrastructure and mangrove expansion at Charles Bay and Duroby Creek. A, legacy levee. B, legacy drainage ditches. C, sediment accretion and mangrove expansion. D, low-lying land immediately adjacent to hotspot areas. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Dynamic changes to vegetation types are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Oak Floodplain Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

At lower Duroby Creek mangroves are rapidly expanding along legacy constructed drainage ditches into Duroby Marsh and adjacent areas that were drained for grazing land (Figure 25B). This site requires a hydrological assessment to determine future management options, which may include filling constructed drainage ditches and the removal of any legacy levees to facilitate overland flows and increase the potential for a mosaic of mangrove, saltmarsh and freshwater wetland habitat types.

Management recommendations from Tucker et al. (2023) are consistent with actions recommended above to support the long-term resilience of intertidal vegetation at Hotspot 6, with the recommendation as follows:

'*Within Bilambil Creek and Duroby Creek, sea level rise will impact existing drainage. Low-lying areas should be opportunistically converted to estuarine wetlands when current land uses are no longer viable'*.

Actions to opportunistically convert areas to estuarine wetlands can include modifying drainage infrastructure to raise ground water levels with fresh catchment flows, and strategically removing levees to return tidal flows in low-lying areas adjacent to creeks for intertidal habitats.

Sediments

Riverbank erosion and agricultural runoff from adjacent properties and elsewhere in the catchment is contributing to the degradation of water quality and increased sedimentation in the Terranora Broadwater. This sedimentation is potentially contributing to expansion of mangroves at Charles Bay, evident in the aerial photographic record (Figure 25C).

Digital elevation models indicate that subsidence may have occurred in several sites at Hotspot 6, particularly to the south of Duroby and Bilambil Creeks (Figure 26). The distribution of the low-lying areas indicate that these areas are lower than the original ground surface level. This is reflected in the current distribution of mangroves which have colonised most areas lower than 0.35 m AHD.

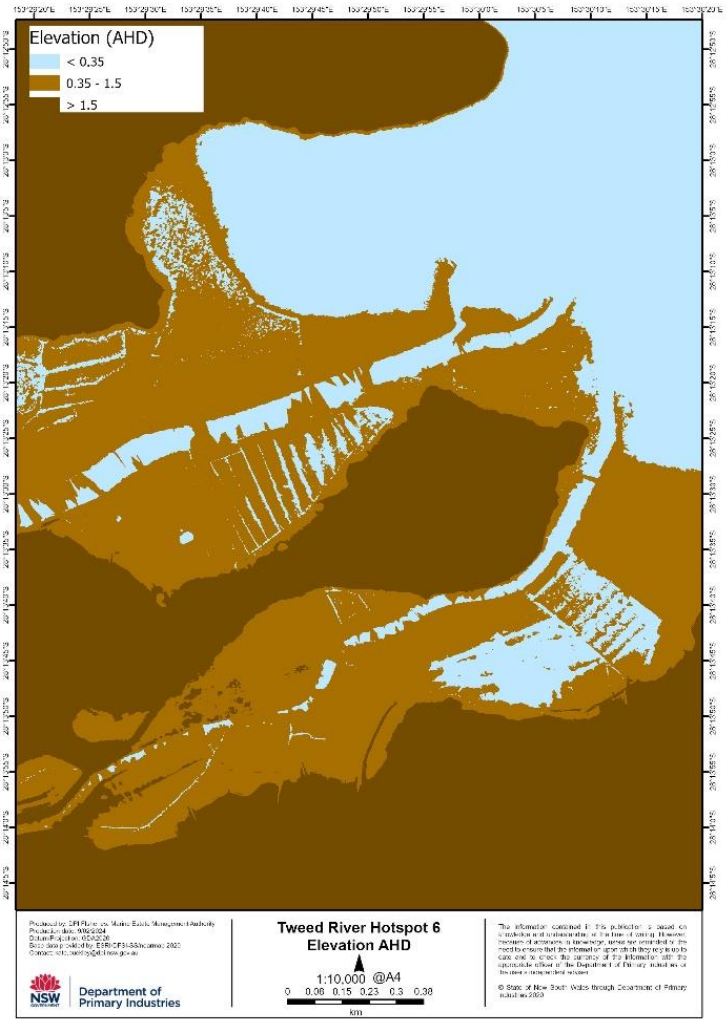


Figure 26 Land subsidence and failed grid drainage systems at Charles Bay and Duroby Creek. Data Source: Elvis (Elevation and Depth - Foundation Spatial Data).

The restoration or enhancement of ground surface elevation may be warranted in subsided areas, and it is crucial to facilitate sediment accretion in these areas. Increased ground surface elevation may also help protect adjacent TECs including Lowland Rainforest and Swamp Oak Floodplain Forest from accelerated mangrove incursion. This can be achieved by restoring sediment supplies by promoting or restoring more

natural tidal hydrology and overland flows (for example, by filling drains and lowering levees). The growth of root mats for natural sediment accretion may be encouraged by rehabilitating degraded saltmarsh and mangrove habitats.

Vegetation

To improve the resilience of intertidal habitats to stressors at Hotspot 6, the establishment of native vegetation buffers beyond the current intertidal zone should be prioritised. This is consistent with CZMP for Cobaki Broadwater and Terranora Broadwater *Action 3.1: Site-based action plans for Level 1 rehabilitation zones (mid and transition of all creeks, including ephemeral drainage lines)* (TSC 2012).

Grant schemes are currently used to encourage floodplain landholders to create riparian vegetation buffers around waterways, wetlands and riparian areas in priority rehabilitation areas along Bilambil and Duroby creeks. Weed control may be required after the establishment of vegetation buffers, as the growth of weeds after removal of grazing may prevent the natural regrowth of riparian vegetation (Figure 27). Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.*

Figure 27 Fenced riparian zone with excessive weed growth at Duroby Creek.

In some areas, sediment is accreting and mangroves habitats are expanding. In areas of active sediment accretion, accumulated anthropogenic debris should be removed to prevent burial in intertidal habitats, and sources of debris should be investigated and managed.

People and Planning

There could be viable intertidal vegetation migration pathways along Bilambil and Duroby creeks and their floodplains. The limits of the constructed drainage system are documented in *Tweed River Floodplain Prioritisation Study* (Tucker et al. 2023). It shows that floodgates along both Bilambil and Duroby creeks have compromised functionality for landholders on the lowest parts of the adjacent floodplain. Tucker et al. (2023) used drain invert levels and tidal levels to categorise each individual floodgate in this site as 'moderately' to 'most vulnerable' to inundation at the present time, meaning the structure can only drain effectively between 50 – 95% of the time and for less than 50% of the time, respectively (Tucker et al. 2023). More information can be found in the MEMS Coastal floodplain prioritisation studies.

Low-lying privately owned land to the north and south of Bilambil Creek (Figure 25D) may have potential as blue carbon, nature repair market or development offset sites because they are close to hotspot areas and in some areas have established (unmapped) saltmarsh habitats. Stakeholder engagement to identify options for a SLR migration pathway for saltmarsh on the lot immediately upstream of this site (on the left bank)

would be appropriate and consistent with the CZMP for Cobaki Broadwater and Terranora Broadwater *Action 2.6: Investigate saltmarsh rehabilitation in collaboration with landowner* (TSC 2012).

An examination in more detail of the low-lying land south of Duroby Creek is warranted (Figure 31B), including stakeholder engagement with a focus on potential management for saltmarsh habitats. This action is consistent with the CZMP for Cobaki Broadwater and Terranora Broadwater *Action 2.3: All remnant vegetation, including saltmarsh community at confluence of Duroby Creek to be rehabilitated …*, while noting that the growth of mangroves at 'Duroby Marsh' has reduced the suitability of shorebird roosts (TSC 2012). Currently part of the site is used for grazing and areas with high potential for saltmarsh recovery are regularly impacted and pugged from unrestricted grazing from cattle and horses. Pugging can increase the risk of mosquito hazard and the potential for accelerated expansion of mangroves.

The CZMP for Cobaki Broadwater and Terranora Broadwater recommends rezoning the foreshore for conservation (*Action 2.4: Investigate the area between the foreshore and houses and consider rezoning for conservation*) which would provide connectivity among hotspot areas. A further measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 7: Trutes Bay and Tommys Island

Trutes Bay and Tommys Island occur in the eastern part of the Terranora Broadwater. Large areas of the TEC Coastal Saltmarsh as well as mangroves occur adjacent to urban areas to the north and east, and grazing land to the south (Figure 28). Other TECs (listed under the BC Act) that may be present near hotspot areas include Freshwater Wetlands, Swamp Oak Floodplain Forest, Swamp Sclerophyll Forest, Lowland Rainforest and Subtropical Coastal Floodplain Forest.

Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 6 — may be influenced by management actions in this hotspot, and vice versa.

Most of the existing intertidal marine vegetation and hotspot areas occur within areas currently zoned as Deferred Matter (DM). The CZMP for Cobaki Broadwater and Terranora Broadwater (TSC 2012) identifies most of the south of the Broadwater as 'Area E', flagged for future urbanisation.

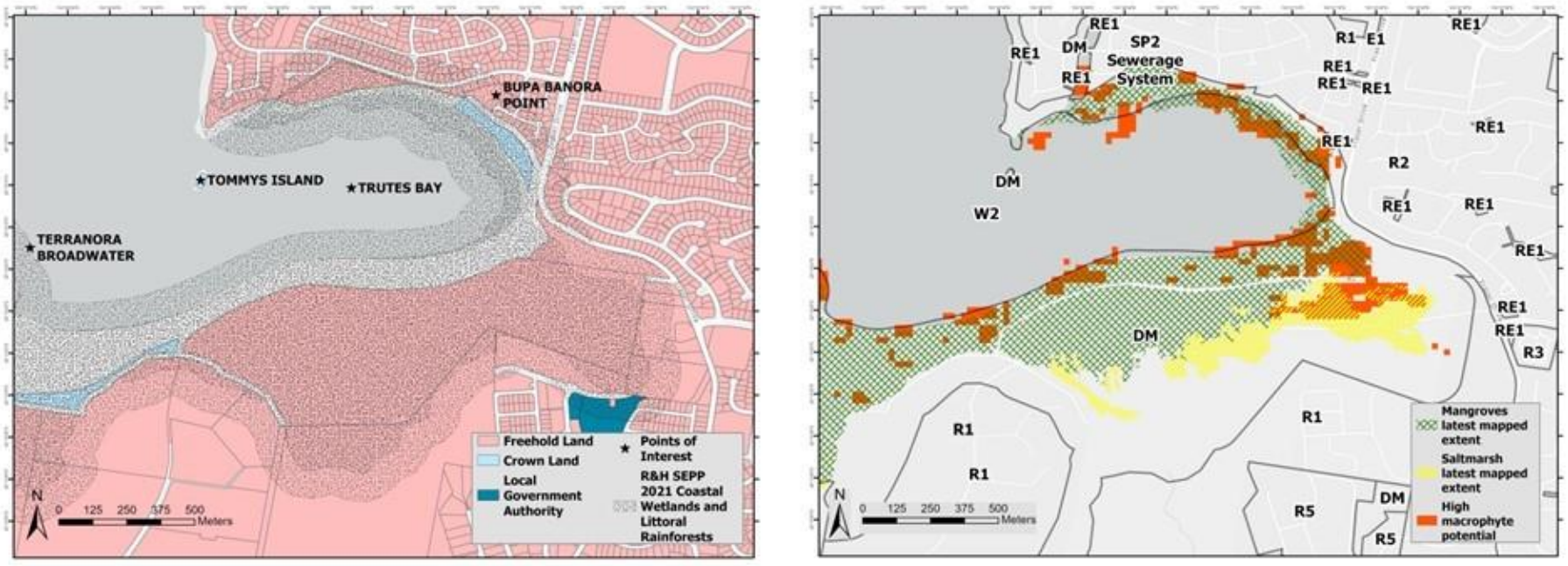
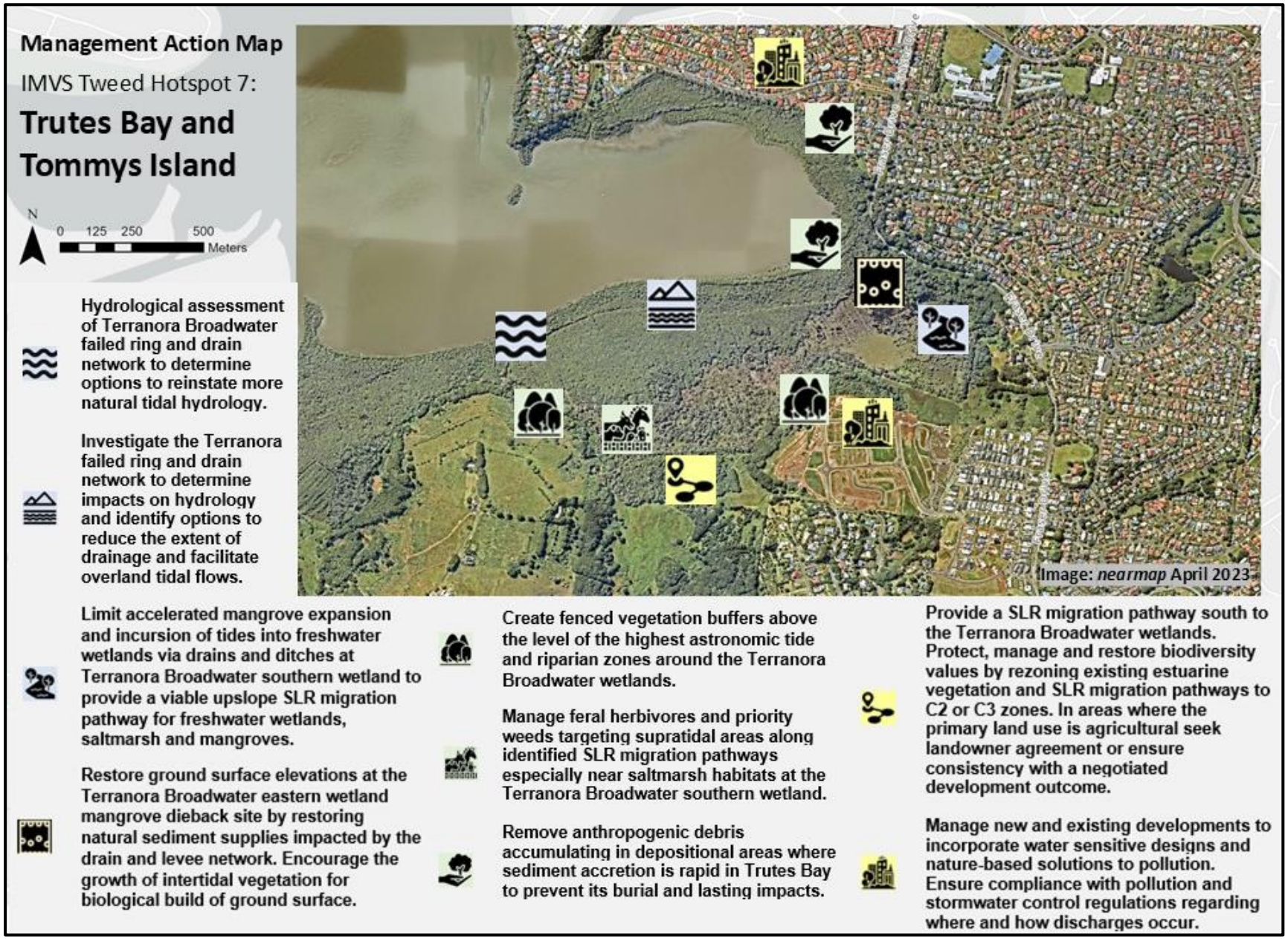


Figure 28 Tweed Hotspot 7: Trutes Bay and Tommys Island. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.


Management Action Map
IMVS Tweed Hotspot 7:
Trutes Bay and Tommys Island
N
0 125 250 500
Meters
Hydrological assessment of Terranora Broadwater failed ring and drain network to determine options to reinstate more natural tidal hydrology.
Investigate the Terranora failed ring and drain network to determine impacts on hydrology and identify options to reduce the extent of drainage and facilitate overland tidal flows.
Image: nearmap April 2023
Limit accelerated mangrove expansion and incursion of tides into freshwater wetlands via drains and ditches at Terranora Broadwater southern wetland to provide a viable upslope SLR migration pathway for freshwater wetlands, saltmarsh and mangroves.
Restore ground surface elevations at the Terranora Broadwater eastern wetland mangrove dieback site by restoring natural sediment supplies impacted by the drain and levee network. Encourage the growth of intertidal vegetation for biological build of ground surface.
Create fenced vegetation buffers above the level of the highest astronomic tide and riparian zones around the Terranora Broadwater wetlands.
Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats at the Terranora Broadwater southern wetland.
Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid in Trutes Bay to prevent its burial and lasting impacts.
Provide a SLR migration pathway south to the Terranora Broadwater wetlands. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.
Manage new and existing developments to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur.

Hydrology

In the southern part of Trutes Bay, a levee and ring drain system (Figure 29A) was constructed in the early 1980s. Within the ring drain system, clearing of the mangrove fringe at the edge of waterway and large areas of Swamp Oak Floodplain Forest and Swamp Sclerophyll Forest occurred. This drainage scheme was unsuccessful, instead initiating subsidence of the ground surface (see Figure 30). The aerial photographic record shows rapid colonisation of the site by a landward advance of mangroves.

Without existing vegetation or freshwater flows limiting their incursion, mangroves have since advanced into Coastal Saltmarsh, Swamp Oak Floodplain Forest, Swamp Sclerophyll Forest and other habitats; and continue to advance toward the Lowland Rainforest (Figure 29B). A hydrological investigation of legacy drainage structures such as the ring drain is recommended for this site to identify actions that could reinstate a more natural hydrology including promoting overland rather than in drain flows. This could include infilling or reshaping constructed drainage ditches. This may mitigate artificially accelerated mangrove expansion and provide viable SLR migration pathways for both intertidal vegetation and adjacent upslope vegetation.

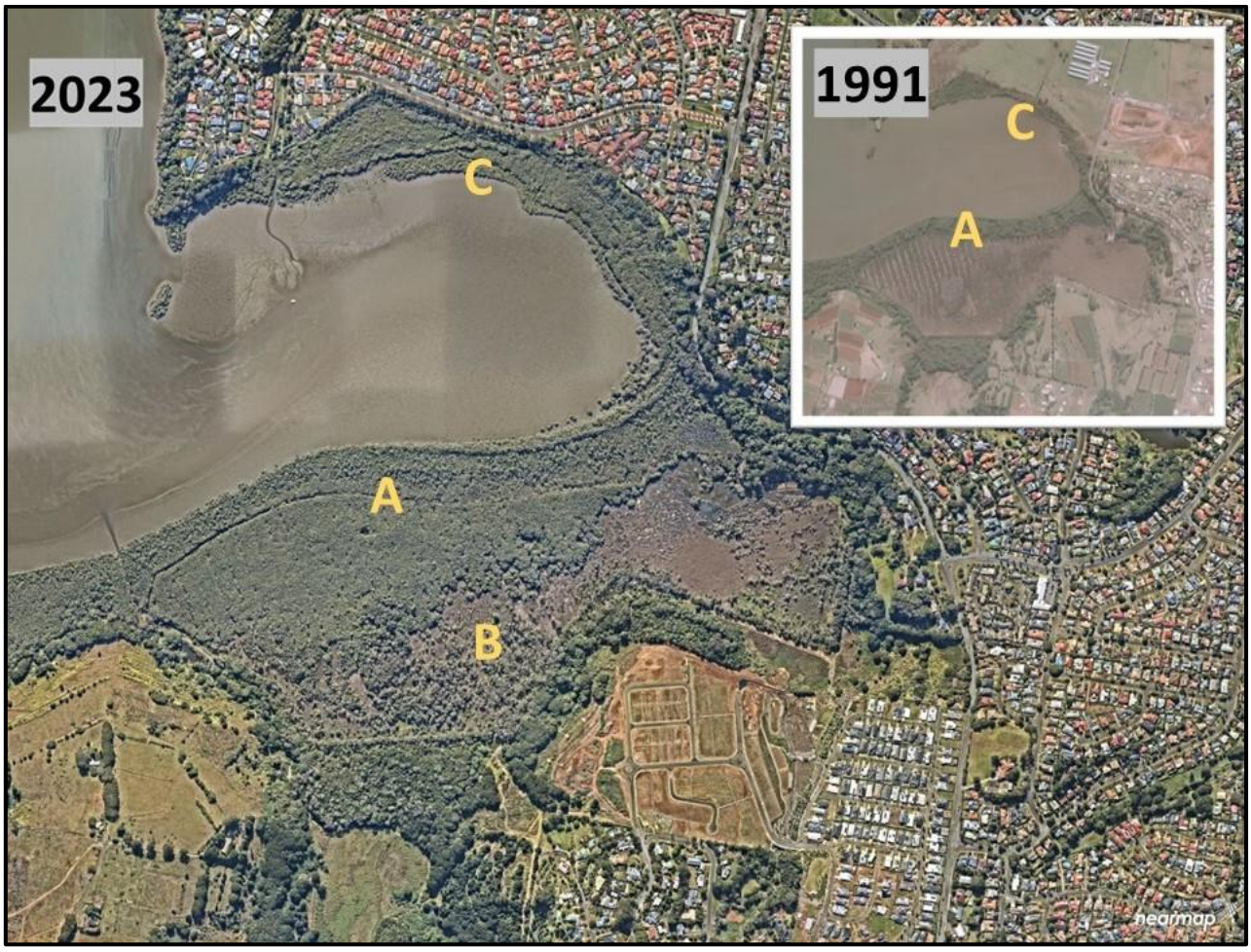


Figure 29 Trutes Bay and Tommys Island including land use changes over time. A, area of mangrove expansion. B, mangroves continuing to advance into adjacent habitats via the drainage network and subsided areas. C, expanding seaward mangrove habitats. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Oak Floodplain Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Sediments

A seaward expansion of mangroves is evident in the aerial photographic record at Trutes Bay and around Tommys Island (Figure 29C). Estuary entrance training and dredging activities (Druery and Curedale 1979) may have increased the tidal amplitude and periodic lowering of water levels in the estuary, increasing turbidity and flood tide sedimentation at Terranora Creek (Saintilan 1998; TSC 2012). These changes are likely to have contributed to both the seaward and landward extension of mangroves, displacing saltmarsh in some areas of the Terranora Broadwater (Saintilan 1998).

Digital elevation models indicate that subsidence has occurred in the southern part of Trutes Bay (Figure 30). The distribution of the low-lying areas indicate that these areas are lower than the original ground surface level. This is reflected in the current distribution of mangroves which have colonised most of the low-lying areas.

Figure 30 Ring drain and land subsidence at Trutes Bay. Data Source: Elvis (Elevation and Depth - Foundation Spatial Data).

The restoration or enhancement of ground surface elevation may be warranted in subsided areas, and it is crucial to facilitate sediment accretion at this site. Increased ground surface elevation may also help protect adjacent TECs including Coastal Saltmarsh, Swamp Oak Floodplain Forest, and Swamp Sclerophyll Forest from accelerated mangrove incursion.

Ground surface elevation can be enhanced by restoring sediment supplies with more natural tidal hydrology and overland flows (for example, by removing tidal or flood flow barriers such as the levee and ring drain to promote overland flow of tides and inundation during floods). The growth of root mats for natural sediment accretion may be encouraged by rehabilitating degraded saltmarsh and mangroves. This action is consistent

with the CZMP for Cobaki Broadwater and Terranora Broadwater *Action 2.1 Site T4 Protect, maintain and expand remaining remnant* (of high conservation value vegetation).

Consideration may be given to reinstating overland flows for increased sediment supplies in subsided parts of Trutes Bay, concurrently improving discharged water quality. However, this action must be carefully assessed to avoid smothering intertidal vegetation particularly saltmarsh habitats. For example, catchment flows are currently channelled within the constructed drainage network with outlets bypassing intertidal areas and discharging directly into the Terranora Broadwater. Shallowing drains and promoting part of catchment flows to slowly move over the surface of the wetland could promote sediment supplies.

Vegetation

Significant areas of Coastal Saltmarsh occur near existing and new developments (Figure 31A) and due to associated drainage infrastructure (Figure 31B) may be at risk from urban stormwater runoff. Increased, unmanaged freshwater flows into the saltmarsh can reduce the hypersalinity that limits mangrove encroachment. It is important that action is taken to reduce stormwater influences, for example by maintaining a native vegetation buffer to absorb nutrients, moderate strong overland flows and minimise erosion.

Where feral and invasive species (including weeds) are detected, management actions in co-operation with landowners should be undertaken to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.*

In intertidal areas impacted by run-off or undergoing active sediment accretion (e.g., Figure 29C), accumulated anthropogenic debris should be removed to prevent burial and lasting impacts, and sources of this debris investigated and managed.

Figure 31 Saltmarsh habitats adjacent to new development at Trutes Bay. A, saltmarsh habitat. B, development with drainage infrastructure. Images: *Nearmap* (base).

People and Planning

While most of Hotspot 7 is now owned and managed by Tweed Shire Council, neighbour and stakeholder liaison is necessary to determine management options and possible migration pathways considering master plan approvals have been obtained for much of the adjacent area to the south.

Low-lying land in this area, such as the Terranora Broadwater wetlands, have potential as future blue carbon or development offset sites to facilitate intertidal vegetation SLR migration pathways, particularly for saltmarsh habitats. This is consistent with the CZMP for Cobaki Broadwater and Terranora Broadwater *Action 2.1 Site T5 All remnant vegetation, including saltmarsh community at confluence of Duroby Creek, to be rehabilitated*. In the long term, however, the hill side is likely to create natural coastal squeeze that may extinguish suitable habitat space for saltmarsh.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Urban stormwater runoff from the Banora Point Drainage System (also referred to as the 'Western Drainage Scheme') flows into northern Trutes Bay. This contributes to high nutrient loading and sedimentation exacerbated by the poor tidal exchange. The recycling of nutrients from the Banora Point facility has been identified as posing a threat to ecosystem health (TSC 2012), and it is important that nature-based water sensitive urban designs and solutions to pollution are used to address risks to intertidal vegetation.

Ongoing urbanisation in this area should be managed to avoid impacts to valuable saltmarsh habitats. This may include encouraging nature-based water sensitive urban designs and solutions to pollution. Compliance with pollution control regulations outlined in the *Tweed Urban Stormwater Quality Management Plan* (2000) should be enforced to minimise potential impacts to intertidal ecosystems. Access to saltmarsh areas from the new developments should be pre-emptively managed to ensure that damage to saltmarsh vegetation does not occur.

Hotspot 8: Meebun, Womgin and Big Islands

Hotspot 8 includes Meebun, Womgin and Big Islands and unmapped islands in Birds Bay (Figure 32). Meebun, Womgin and Big Islands are managed by NSW National Parks and Wildlife Service via the *Tweed Estuary Nature Reserve Plan of Management* (2010). Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 9 — may be influenced by management actions in this hotspot, and vice versa.

They are a series of mangrove dominated islands at the mouth of the Terranora Broadwater and in Birds Bay. Some areas of the TECs (listed under the BC Act) Coastal Saltmarsh and Swamp Sclerophyll Forest may be present. Large areas of seagrass occur in this area, particularly in the shallow areas around the islands.

Most of the existing intertidal vegetation and hotspot areas are zoned Deferred Matter (DM) or National Parks and Nature Reserves (C1). The surrounding land zoning is complex due to urban developments.

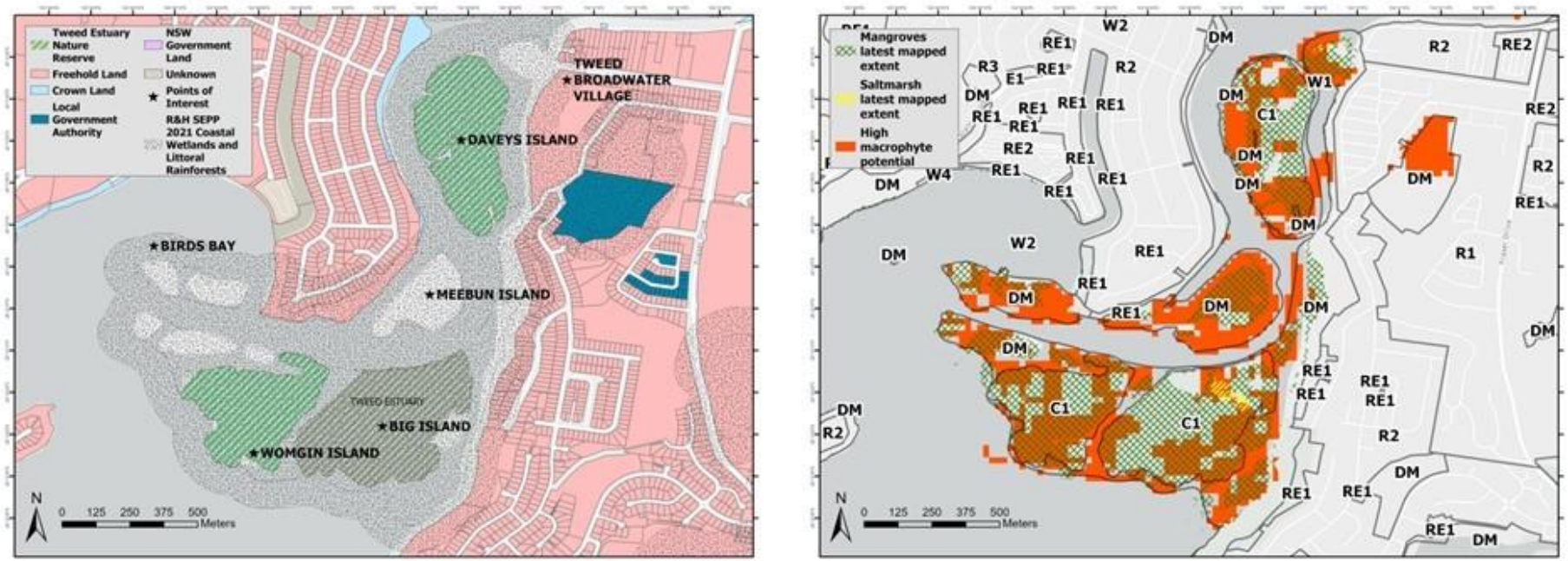


Figure 32 Tweed Hotspot 8: Meebun, Womgin and Big Islands. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 8:

Meebun, Womgin and Big Islands

Prioritise minimal modifications to estuary channels and entrance including Terranora Channel.

Monitor ground surface elevations of Meebun Island to assess if sediment accretion is sufficient to keep pace with SLR.

Minimise actions that may cause erosion of intertidal areas at the north-west bank of Meebun Island including dredging and boat wake damage.

Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid such as Womgin Island to prevent its burial and lasting impacts.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats on Big Island in accordance with Tweed Estuary NR PoM.

Manage unauthorised activities particularly at Big Island landing area in accordance with the Tweed Estuary NR PoM to prevent impacts on ecological values particularly saltmarsh habitat.

Provide SLR migration pathways for intertidal vegetation on Meebun Island and nearby unnamed islands. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. Progress incorporation into the Tweed Estuary NR In accordance with the Tweed Estuary NR PoM.

Hydrology

It is crucial to maintain the key ecological drivers of natural tidal hydrology and catchment connectivity for these island-based ecosystems. This can increase resilience to ongoing stressors including SLR.

Minimal modifications to catchment and tidal flows should be prioritised. For example, proposals for nearby dredging works should consider the potential for causing localised changes in tidal amplitude which could accelerate landward or seaward expansions of mangroves.

Sediments

The only SLR migration pathway options for saltmarsh and mangroves on islands in Hotspot 8 are increased ground surface elevation at a pace that keeps up with SLR, or the expansion and merging of islands. The islands change size and shape over time, and a recent expansion of mangroves is apparent (Figure 33). Mangrove expansion is likely to continue on the fringes of the islands, and in parts of the off-channel passages. This process may help sustain the saltmarsh in the centre of the islands.

Assessing the capacity of the islands to maintain elevation relative to SLR with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as repairing erosion or restoring ground surface levels may become appropriate if the islands fail to accrete sediment at a rate that keeps pace with SLR as this may cause accelerated impacts on adjacent vegetation communities. This action may be particularly important to ensure saltmarsh habitats are maintained on Big Island.

Actions that may cause erosion of intertidal areas including dredging and vessel wake damage, should be minimised, particularly at exposed sites that may be vulnerable to erosion such as the north-west bank of Meebun Island. If dredging is deemed essential, the investigation of the use of dredge spoil to restore ground surface elevation may be warranted in some areas.

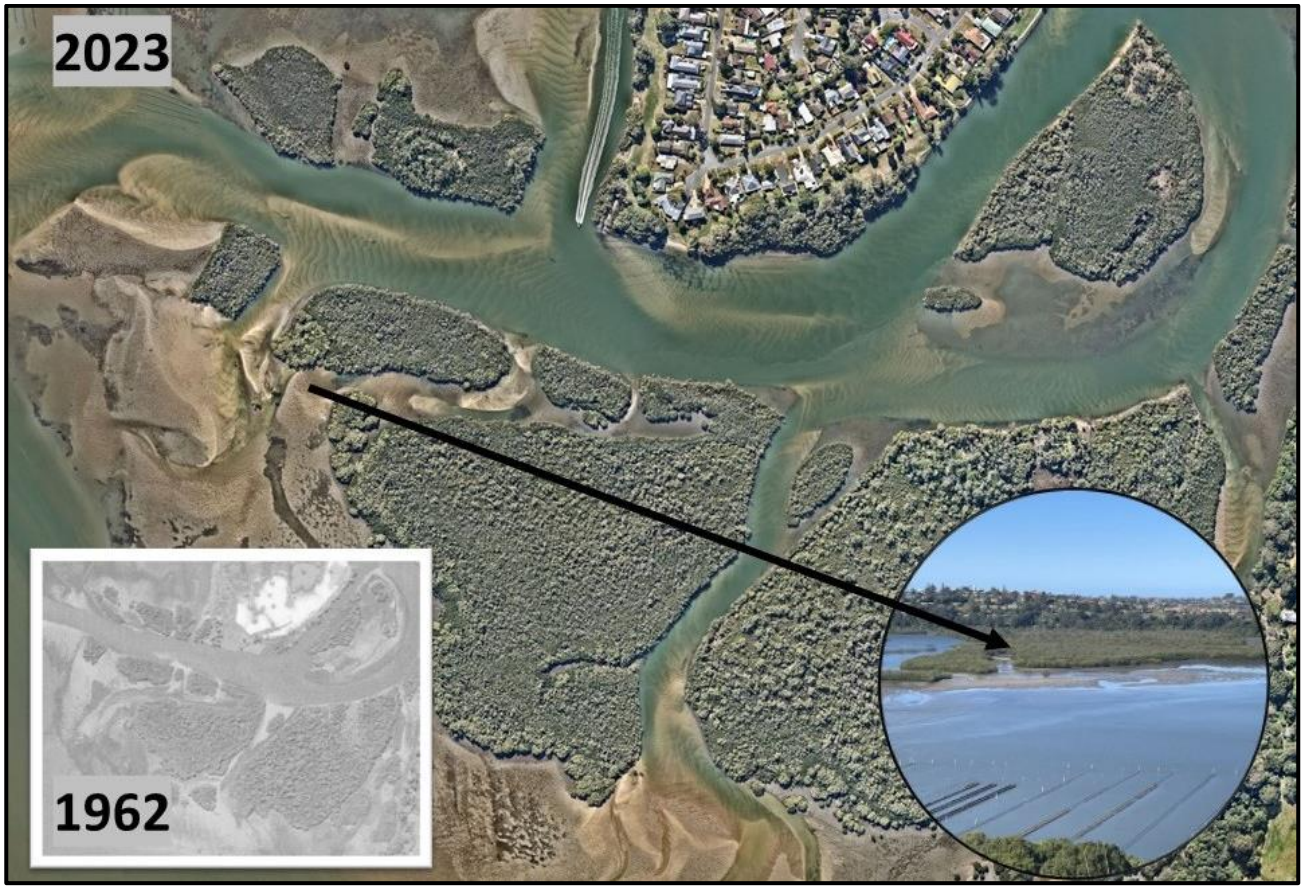


Figure 33 Changes to the morphology of Meebun, Womgin and Big Islands over time. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Vegetation

The primary recommended management action for Hotspots 8 is to minimise disturbances of the extensive areas of intertidal marine vegetation. This will best enable the site to accommodate natural disturbances such as lightning strike, hail or periods when the islands host colonies of Black Flying-fox *Pteropus alecto* or Grey-headed Flying-fox *Pteropus poliocephalus*.

The *Tweed Estuary Nature Reserve Plan of Management* (2010) identifies that weeds are impacting ecological values particularly on Big Island. These weeds include *Lantana camara*, Asparagus Fern *Asparagus aethiopicus*, Groundsel Bush *Baccharis halimifolia*, Coastal Morning Glory *Ipomoea cairica* and Bitou Bush *Chrysanthemoides monilifera.* Where these weeds are detected, management actions should be undertaken to actively control them to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.* This action is in accordance with recommendations in the *Tweed Estuary Nature Reserve Plan of Management*.

In areas of active sedimentation, such as on Womgin Island where recent expansion of mangroves is apparent (see Figure 33), anthropogenic debris should be removed to prevent accumulation and burial, and sources of the debris identified and controlled.

People and Planning

The *Tweed Estuary Nature Reserve Plan of Management* (2010) identifies that inappropriate visitor use of Big Island may damage ecological values. Visitor access should be monitored for future potential impacts and minimal access should be encouraged to prevent degradation of the vegetation, particularly in saltmarsh areas.

Potential SLR migration pathways for saltmarsh and mangroves on islands in Hotspot 8 are increased ground surface elevation at a pace that keeps up with SLR, or the expansion and merging of islands. Where they are not already part of the Tweed Estuary Nature Reserve, a measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Meebun Island and the unmapped islands in Birds Bay could also be considered for zoning National Parks and Nature Reserves (C1) and incorporation into the Tweed Estuary Nature Reserve.

These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 9: Daveys and Caddys Islands

Daveys and Caddys Islands are in the Tweed Estuary Nature Reserve immediately downstream of Hotspot 8 in Terranora Creek (Figure 34). The islands are dominated by mangroves. TECs (listed under the BC Act) that may be present include Swamp Sclerophyll Forest, and small areas of Coastal Saltmarsh generally adjacent to terrestrial vegetation. They are surrounded by extensive seagrass beds.

Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 8 — may be influenced by management actions in this hotspot, and vice versa.

Most of the existing intertidal marine vegetation and hotspot areas are zoned Deferred Matter (DM), National Parks and Nature Reserves (C1) or Natural Waterways (W1). The surrounding land zoning is complex due to urban developments.

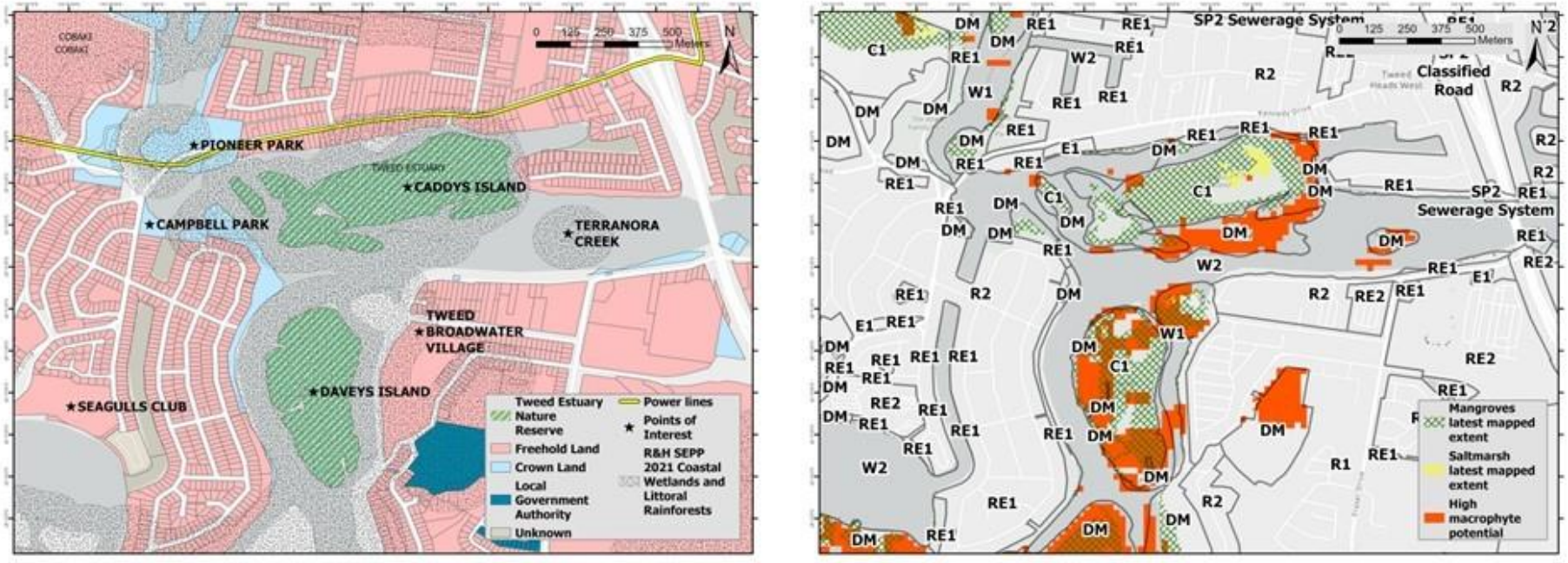
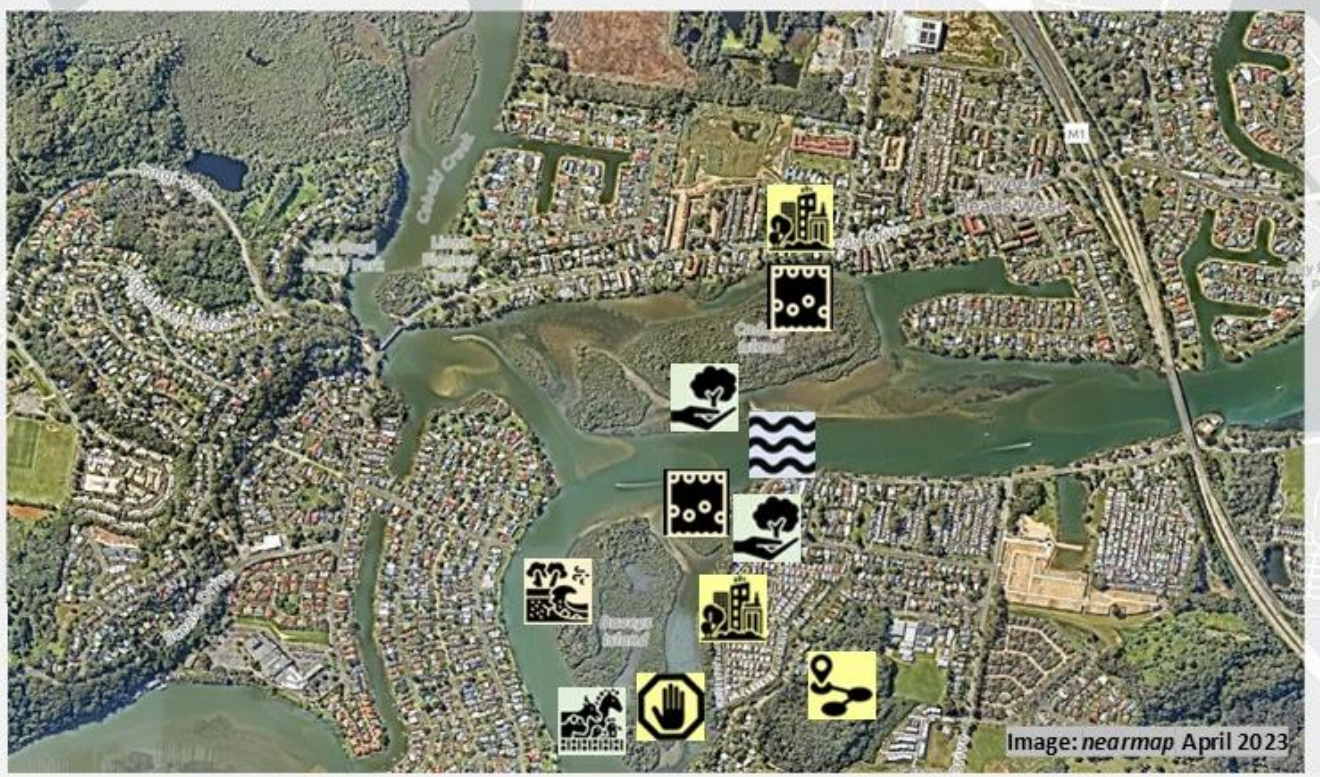


Figure 34 Tweed Hotspot 9: Daveys and Caddys Islands. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 9:

Daveys and Caddys Islands



Prioritise minimal modifications to estuary channels and entrance including Terranora Channel.

In accordance with Tweed Estuary NR PoM remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid to prevent its burial and lasting impacts both within the Tweed Estuary NR and on nearby islands outside the reserve.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats on Daveys Island in accordance with Tweed Estuary NR PoM.

Seek landowner agreement or ensure consistency with a negotiated development outcome to provide a SLR migration pathway east of the James Street culvert. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Manage new and existing developments at Tweed Broadwater Village and Kennedy Drive urban area to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur.

Manage Daveys Island foreshore access from nearby urban areas in accordance with Tweed Estuary NR PoM to prevent damage to sensitive intertidal habitats.

Monitor ground surface elevations of Caddys Island or Daveys Island, the unnamed island and adjacent areas, to assess if sediment accretion is sufficient to keep pace with SLR.

Minimise actions that may cause erosion of intertidal areas at the west bank of Daveys Island including dredging and boat wake damage.

Hydrology

It is crucial to maintain the key ecological drivers of natural tidal hydrology and catchment connectivity for these island-based ecosystems. This can increase resilience to ongoing stressors including SLR. Large scale dredging (800,000 m^3) changing tidal amplitude and flow in this part of the Tweed River estuary was documented by Druery and Curedale (1979).

Minimal modifications to catchment and tidal flows should be prioritised. For example, proposals for nearby dredging works should consider the potential for causing localised changes in tidal amplitude which could accelerate landward or seaward expansions of mangroves.

Sediments

Historical imagery shows a recent expansion of mangroves, particularly on Daveys and Caddys Islands (Figure 35) and this pattern is likely to continue in the future. The only SLR migration pathway options for saltmarsh and mangroves on these, and nearby unnamed, islands is increased ground surface elevation at a pace that keeps up with SLR, or the expansion and merging of islands. Assessing the capacity of these sites to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as the restoration of ground surface elevation or erosion management may become appropriate if the islands fail to accrete sediment at a rate that keeps pace with SLR as this may cause accelerated impacts on adjacent vegetation communities. This action may be particularly important for saltmarsh habitats in the DM zoned area north-west of the Tweed Broadwater Village and on Caddys Island. If dredging is deemed essential, the investigation of the use of dredge spoil to restore ground surface elevation may be warranted in some areas.

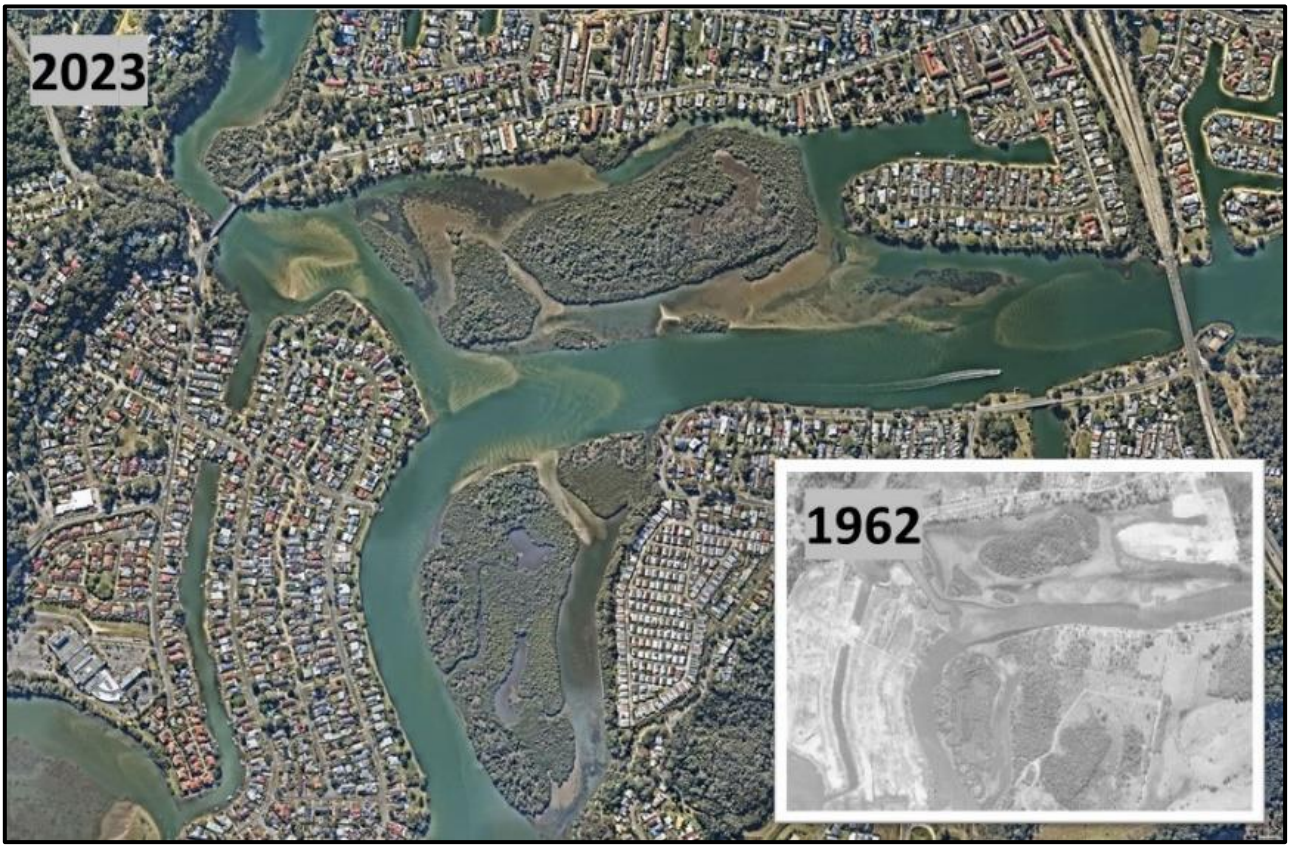


Figure 35 Changes to the morphology of Daveys and Caddys Islands over time. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

The impact of dredging of the Terranora Inlet to maintain navigation channels for commercial fishing and tourism charter vessels is unknown. It is important to minimise any dredging and channelisation activities that

may result in accelerated erosion in some areas of the intertidal habitat and accretion in others (Mamo et al. 2021).

The operation of existing boating operations and the impact of future boating infrastructure should consider the potential for exacerbating bank erosion on these islands. This may impact the ability of intertidal marine vegetation to accrete sediments at a rate that matches SLR. Guidance may be found with referral to the MEMS Domestic waterfront structure strategies.

Vegetation

Minimal disturbances and the conservation of the extensive areas of existing natural intertidal vegetation at Daveys and Caddys Islands is recommended.

The *Tweed Estuary Nature Reserve Plan of Management* (2010) identifies that weeds are impacting ecological values particularly on Daveys Island where unauthorised camping has facilitated weed invasion. These include Lantana *camara*, Asparagus Fern *Asparagus aethiopicus*, Groundsel Bush *Baccharis halimifolia*, Coastal Morning Glory *Ipomoea cairica* and Bitou Bush *Chrysanthemoides monilifera*). Where these weeds are detected, management actions should be undertaken to actively control them to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.* This recommendation is in accordance with the *Tweed Estuary Nature Reserve Plan of Management*.

In areas of active sedimentation both within the Tweed Estuary Nature Reserve and nearby islands outside the reserve, anthropogenic debris should be removed to prevent burial and lasting impacts. Sources of the debris should be identified and controlled. Rubbish and builders' waste left by visitors on Daveys Island should also be removed to prevent impacts on hydrology or sedimentation.

People and Planning

The *Tweed Estuary Nature Reserve Plan of Management* (2010) identifies that unauthorised camping on Daveys Island may threaten ecological values through damage to native vegetation and the introduction of rubbish, builders' waste materials and weeds. Visitor access should be monitored for future potential impacts and minimal access should be encouraged to prevent degradation of the vegetation.

Stakeholder consultation should be undertaken to generate support for management actions in areas directly adjacent to residential areas (for example at Tweed Heads South), particularly due to potential impacts on adjacent TECs such as Swamp Sclerophyll Forest. Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Four floodgated drains flow into Terranora Creek adjacent to Hotspot 9 from urban areas including the Tweed Broadwater Village and north of Kennedy Drive. Compliance with pollution control regulations outlined in the *Tweed Urban Stormwater Quality Management Plan* (2000) should be enforced to protect intertidal vegetation and water quality. Ongoing urbanisation in this area should be managed to avoid further impacts to intertidal vegetations and may include encouraging nature-based water sensitive urban designs and solutions to pollution for new and existing developments.

A potential SLR migration pathway for intertidal vegetation at Hotspot 9 is towards low-lying land east of the James Street culvert. A measure to protect or enhance biodiversity values throughout the hotspot could include rezoning coastal wetlands mapped in the R&H SEPP in this area to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). East of the James Street culvert this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 10: Terranora Creek Islands

Hotspot 10 comprises several very low-lying islands towards the mouth of Terranora Creek zoned Deferred Matter (DM), including Boyds Island, Turners Island and Dock Island (Figure 36). The surrounding land zoning is complex due to urban developments.

Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 11 — may be influenced by management actions in this hotspot, and vice versa.

The islands incorporate substantial areas of existing mangroves. TECs (listed under the BC Act) that may be present include Coastal Saltmarsh, Swamp Sclerophyll Forest and Swamp Oak Floodplain Forest. Large areas of seagrass occur in the vicinity of the islands.

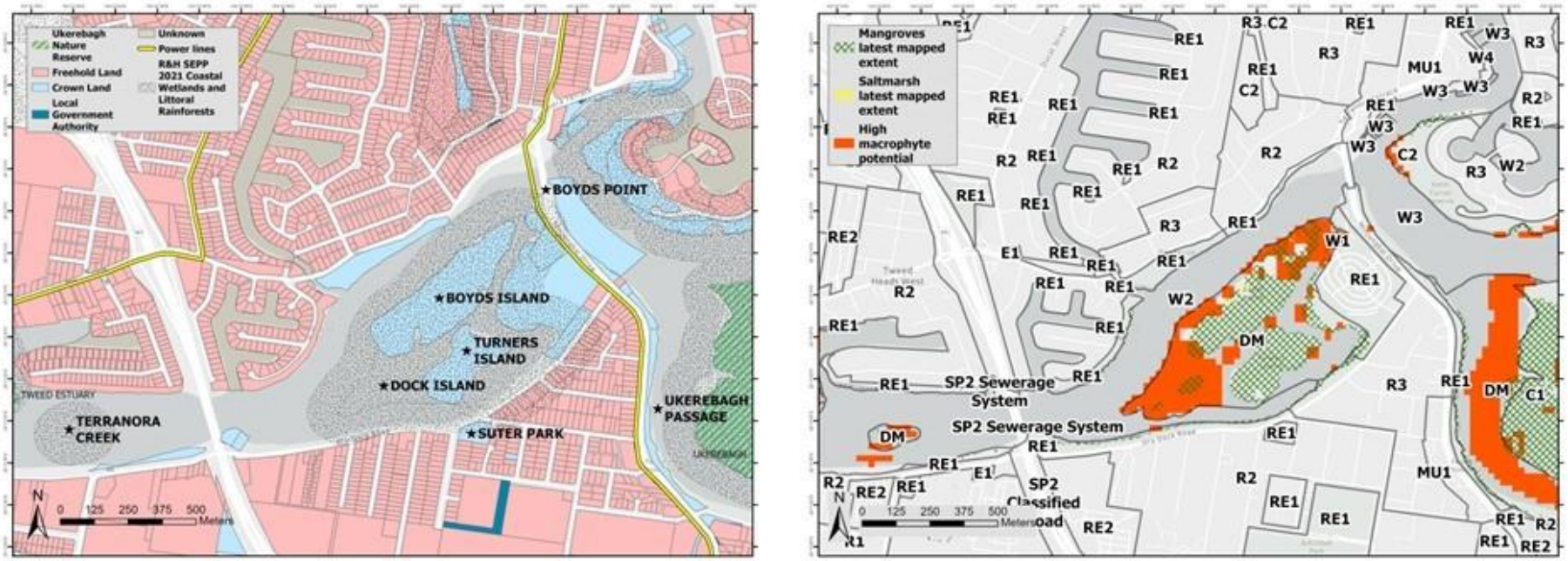


Figure 36 Tweed Hotspot 10: Terranora Creek Islands. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 10:

Terranora Creek Islands

Prioritise minimal modifications to estuary channels and entrance including Terranora Channel.

Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid in infilling back channels, to prevent its burial and lasting impacts.

Monitor ground surface elevations of Boyds, Turners and Dock islands to assess if sediment accretion is sufficient to keep pace with SLR.

Minimise actions, including dredging and boat wake damage, that may cause erosion of intertidal areas such as the Boyds Island channel bank.

Manage developments, for example near Ray Pascoe Park, to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur such as at the Suter Park stormwater outlet, Dry Dock Road.

Provide SLR migration pathways on Boyds, Turners and Dock Islands. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. Progress incorporation into the Tweed Estuary NR in accordance with the Tweed Estuary NR PoM.

Hydrology

It is crucial to maintain the key ecological drivers of natural tidal hydrology and catchment connectivity for these island-based ecosystems. This can increase resilience to ongoing stressors including SLR. Large scale dredging (800,000 m^3) changing tidal amplitude and flow in this part of the Tweed River estuary was documented by Druery and Curedale (1979).

Minimal modifications to catchment and tidal flows should be prioritised. For example, proposals for nearby dredging works should consider the potential for causing localised changes in tidal amplitude which could accelerate landward or seaward expansions of mangroves.

Sediments

The Terranora Creek islands are historically dynamic in size and shape, and the recent expansion of mangroves is likely to continue, particularly as sediments accrete in the channels between islands (Figure 37). As with the other islands, the only SLR migration pathway options for intertidal marine vegetation on these islands increased ground surface elevation at a pace that keeps up with SLR, or the expansion and merging of islands.

Figure 37 Changes to the morphology of the Terranora Creek Islands over time. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Assessing the capacity of the Terranora Creek islands to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as the restoration of ground surface elevation or erosion management may become appropriate if the islands start to erode, subside or fail to accrete sediment at a rate that keeps pace with SLR. This action may be particularly important to minimise accelerated impacts on saltmarsh habitats on Boyds Island.

There is a long-established public boat ramp at this site and Tweed Shire Council periodically maintains a navigable channel with dredging activities. It is important to minimise any dredging and channelisation activities that may result in accelerated erosion in some areas of the intertidal habitat and accretion in others

(Mamo et al. 2021). If dredging is deemed essential, the investigation of the use of dredge spoil to restore ground surface elevation may be warranted in some areas.

Vegetation

Minimal disturbances and the conservation of the extensive areas of existing natural intertidal vegetation at the Terranora Creek islands is recommended.

In areas of active sedimentation such as in the channels between islands, anthropogenic debris should be removed to prevent burial and lasting impacts. Sources of the debris should be identified and controlled.

People and Planning

Fourteen floodgated drains flow into Terranora Creek adjacent to Hotspot 10 from urban areas, mostly from along Dry Dock Road in the south. It is important that any discharges are compliant with stormwater control regulations to protect intertidal vegetation and water quality. Compliance with pollution control regulations outlined in the *Tweed Urban Stormwater Quality Management Plan* (2000) should be enforced to protect intertidal vegetation and water quality. Existing urban areas, for example near Ray Pascoe Park, should be managed to avoid ongoing impacts to intertidal vegetation and this may include encouraging nature-based water sensitive urban designs and solutions to pollution.

These largely urban drain outlets were surveyed as part of the *Tweed River Floodplain Prioritisation Study* (Tucker et al. 2023). It showed the majority of floodgates in the hotspot have drain invert levels that categorised them as compromised in their function at ‘moderately’ to ‘most vulnerable’ to inundation at the present time meaning the structure can only drain effectively between 50 – 95% of the time and for less than 50% of the time, respectively (Tucker et al. 2023). Such design constraints are unable to be managed or resolved by regularly cleaning out sediment build up around the outlet structure. More information can be found in the MEMS Coastal floodplain prioritisation studies.

Potential SLR migration pathways for saltmarsh and mangroves on islands in Hotspot 10 are increased ground surface elevation at a pace that keeps up with SLR, or the expansion and merging of islands. A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). The Terranora Creek Islands could be considered for zoning National Parks and Nature Reserves (C1) and incorporation into the Tweed Estuary Nature Reserve.

These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to ‘*Review LEP zoning to incorporate areas for estuary vegetation migration*’. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 11: Ukerebagh

Hotspot 11 encompasses the nationally important wetlands of Ukerebagh Nature Reserve and Ukerebagh Passage (Figure 38), which is managed by the NSW National Parks and Wildlife Service (NPWS). It also extends into the Tweed Heads historic site. Ukerebagh has substantial areas of the TEC Coastal Saltmarsh and mangroves, extensive seagrass beds in the passage. Other TECs (listed under the BC Act) that may be present in the hotspot include Littoral Rainforest, Freshwater Wetlands, Swamp Sclerophyll Forest, Subtropical Coastal Floodplain Forest and Swamp Oak Floodplain Forest.

Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 10 — may be influenced by management actions in this hotspot, and vice versa.

The hotspot areas and existing intertidal marine vegetation are mostly zoned Deferred Matter (DM) or National Parks and Nature Reserves (C1). Much of the foreshore areas and Ukerebagh Passage are Crown land. The surrounding land zoning is complex due to urban developments.

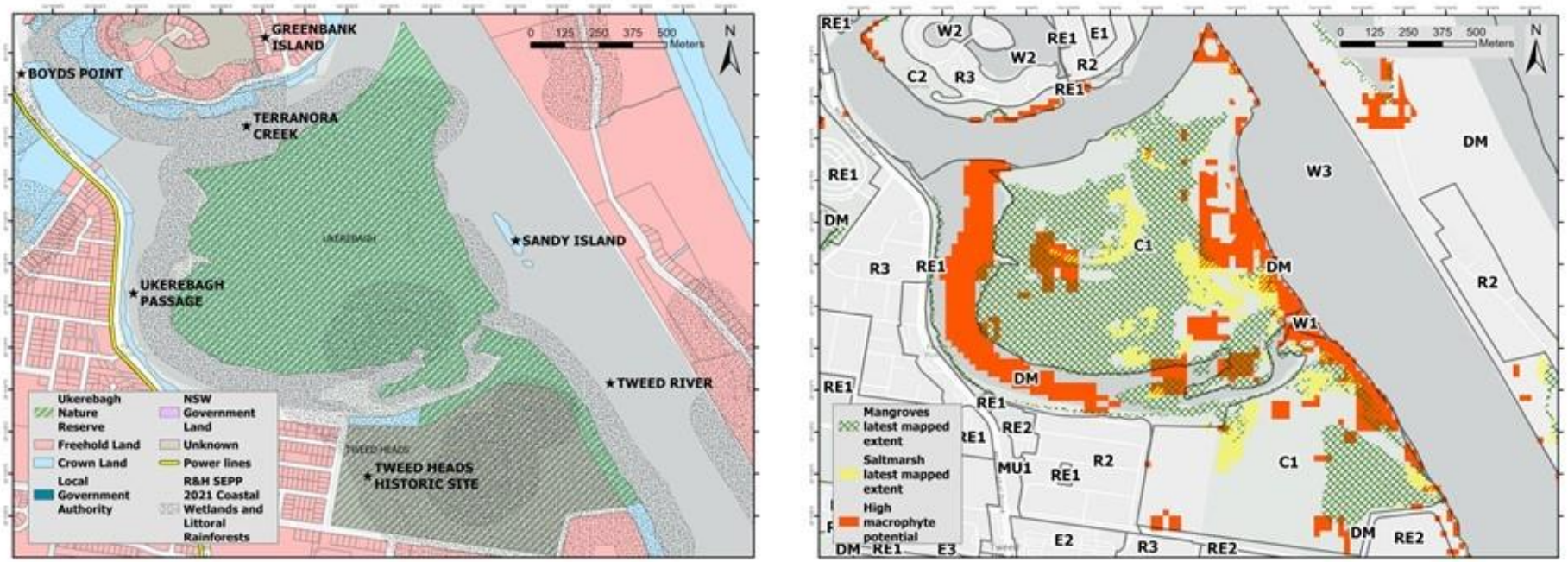


Figure 38 Tweed Hotspot 11: Ukerebagh. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 11:

Ukerebagh

Prioritise minimal modifications to estuary channels and entrance including Ukerebagh Passage. Hydrological assessment to determine options to reinstate more natural tidal hydrology and connectivity at the Minjungbal Trail eastern levee.

Ongoing long term ground surface monitoring of Ukerebagh Island undertaken by University of Wollongong to assess if ground elevation in saltmarsh and mangrove habitats is keeping pace with SLR.

Minimise actions that cause erosion of intertidal habitats and protect and stabilise banks with bio-engineering approaches, for example at eastern Ukerebagh Island and the western end of the Ukerebagh training wall.

Repair *Walk on Water* mangrove walkways to manage foreshore access, provide signage and information for educational and recreational opportunities.

Support Aboriginal managers with information and resources to assist their management of feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats, for example where there is *Casuarina* dieback.

Manage new and existing developments such as Island Drive or Greenbank Island to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur, for example at the Minjungbal Drain outlet and the Water Street stormwater outlet.

Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid, such as at the east Ukerebagh Passage, to prevent its burial and lasting impacts.

Seek landowner agreement to provide a SLR migration pathway south of the Minjungbal Trail eastern levee. Support Aboriginal managers with information and resources to assist their management of cultural assets. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. Progress incorporation of the Ukerebagh Passage into the Ukerebagh NR in accordance with the Ukerebagh NR PoM.

Hydrology

As sea levels rise, it is likely that the mangroves will extend towards the centre of Ukerebagh Island, possibly leading to the replacement of the TECs Coastal Saltmarsh, Swamp Oak Floodplain Forest and Littoral Rainforest. Mangroves have already been recorded replacing saltmarsh on the western side of Ukerebagh Island (Saintilan 1997). Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TECs 'Freshwater Wetlands', 'Swamp Oak Floodplain Forest' and 'Swamp Sclerophyll Forest', 'changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Minimal modifications to catchment and tidal flows should be prioritised. For example, proposals for nearby dredging works should consider the potential for causing localised changes in tidal amplitude which could accelerate landward or seaward expansions of mangroves.

A levee used, in part, as the *Minjungbal Trail* (Walk on Water Walking Track) (Figure 39A) is impeding overland flows from the Tweed River into saltmarsh habitats on the south-eastern corner of the Island at the Tweed Heads Historic Site (Figure 39B). The connectivity of this site to the broader Ukerebagh Nature Reserve indicates that the area may constitute a viable saltmarsh migration pathway, and it is recommended that an expert hydrological assessment is undertaken to determine options to reinstate more natural tidal hydrology and connectivity. This could occur, for example, by lowering the height of the levee or installing culverts. However, this site has Aboriginal cultural and heritage values that could be damaged if deterioration of the levee occurred while unaccompanied by a strategy to manage the Aboriginal values.

Figure 39 Levee around Tweed Heads Historic Site impacting natural hydrology at Ukerebagh Passage. A, levee used as a walkway. B, saltmarsh habitat. Images: *Nearmap* (base).

Sediments

Parts of the eastern side of Ukerebagh Island adjacent to the main channel are eroding possibly exacerbated by dredging in the nearby Tweed River channel altering tidal and flood flow velocities. The north eastern corner of Ukerebagh Island was armoured with rock during the training of the Tweed River entrance in the early 1900s. It is important to minimise any dredging and channelisation activities that may result in accelerated erosion in some areas of the intertidal habitat and accretion in others (Mamo et al. 2021).

In the Ukerebagh Channel significant bank erosion has been caused by boat wake damage in the past. Currently, this area is managed with boating regulations restricting power vessels (Tweed Estuary Boating Plan 2006 – 2010). It is important to maintain compliance to these to ensure no further damage to these significant intertidal habitats occurs. Despite these areas of erosion, the overall trajectory of Ukerebagh Island is expansion to the west and south, particularly in backwater areas (Figure 40). This is accompanied with some sedimentation of seagrass habitats. There has also been a history of dune instability smothering saltmarsh on Ukerebagh Island (Saintilan 1998).

Figure 40 Changes to the morphology of Ukerebagh Island and Ukerebagh Passage over time. Images: GoogleEarth (right).

Sediment accretion at Ukerebagh Island has been monitored with RSETs for almost 25 years (Saintilan et al. 2023). Continued monitoring of the ability of these habitats to naturally accrue sediments and maintain elevation relative to SLR with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. This should continue to identify when management interventions may become appropriate, such as if the island fails to maintain elevation relative to SLR. If this occurs, actions such as the restoration of ground surface elevation may be appropriate as impacts on TECs adjacent to mangrove habitats (particularly Coastal Saltmarsh) is likely to accelerate. If dredging is deemed essential, the investigation of the use of dredge spoil to restore ground surface elevation may be warranted in some areas.

Vegetation

Minimal disturbances and the conservation of the extensive areas of existing natural intertidal vegetation at Hotspot 11 is recommended. Feral and invasive species are present and should be managed to minimise impacts on vegetation, as indicated by the *Ukerebagh Island Plan of Management* (NPWS 1999). Weed control for improved resilience of intertidal vegetation may prioritise SLR migration pathways, particularly areas adjacent to saltmarsh habitats. For example, a priority site may occur where there is *Casuarina* dieback from saltwater incursion at the Tweed Heads Historic Site north of the Coolangatta and Tweed Heads Golf Club. Support may be provided to Aboriginal managers with information and resources to manage weeds that impact on saltmarsh and mangrove migration. More information is detailed in IMVS: *Weed Management Guide.*

In areas of active sedimentation, anthropogenic debris should be removed to prevent sediment accumulation and debris burial. Sources of debris should be investigated and actions taken to manage identified sources, particularly in Ukerebagh Passage which may be impacted from stormwater runoff from adjacent urban areas. This action is consistent with the Tweed River Estuary CMP recommended action to *'Install trash racks on all stormwater discharges into Ukerebagh Passage'* (TSC 2022).

People and Planning

Extensive stakeholder and community engagement is recommended to investigate long term management of intertidal marine vegetation at Hotspot 11. This is recognising that while the removal of the levee may provide a migration pathway for intertidal vegetation into Tweed Heads Historic Site this could also have impacts on important heritage and living culture. It will be particularly important to support Aboriginal managers with information and resources to assist their management of cultural assets south of the Minjungbal Trail eastern levee, and to protect, manage and restore the area of high ecological value and importance as a SLR migration pathway. Stakeholders that should be consulted include, for example, the Minjungbal Museum and Cultural Centre, Traditional Owners, Tweed Shire Council, NPWS, and local residents.

Mangrove boardwalks, part of the *Minjungbal Trail* (Walk on Water Walking Track) that extends from the Minjungbal Aboriginal Cultural Centre to the Ukerebagh Passage, were decommissioned by NPWS and Crown Lands after the 2022 floods due to safety concerns (Figure 41). It is recommended that these boardwalks are repaired and reopened to facilitate public awareness and education about the ecological and cultural values of mangrove and saltmarsh habitats. This action is consistent with the Tweed River Estuary CMP *Fundamental Management Action B4: Provide additional nature-based educational opportunities including signage and information at the proposed Ukerebagh Passage Conservation Zone* (TSC 2022).

Figure 41 Damaged mangrove boardwalks at Ukerebagh Passage.

Fourteen floodgated drains flow into Terranora Creek adjacent to Hotspot 10 from urban areas and the Ukerebagh Passage is known to collect anthropogenic debris from stormwater discharges. It is important that any discharges are compliant with stormwater control regulations to protect intertidal vegetation and water quality.

Where they are not already part of the Ukerebagh Nature Reserve, a measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Ukerebagh Passage could also be considered for zoning National Parks and Nature Reserves (C1) and incorporation into the Ukerebagh Nature Reserve. This action is in accordance with the objectives of the *Ukerebagh Island Plan of Management*.

These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 12: Kerosene Inlet

Kerosene Inlet is located on Letitia Spit, approximately 4km from Fingal Head to the Tweed River mouth (Figure 42). Letitia Spit was formed by the northward drift of sand, and the establishment of the southern Tweed breakwater and eastern training wall in 1902 consolidated the sediments. Sand prograded east following the extension of the breakwaters during the 1960s, and revegetation occurred after sand mining ceased. Since the Tweed River sand bypass system commenced operation, the Spit has returned to a dynamic equilibrium (Silva et al. 2021). It is the only site in the Tweed River estuary suitable for large flocks of shorebirds during spring high tides (Rohweder 2007).

Kerosene Inlet and its foreshore are zoned Deferred Matter (DM) and is owned and managed by the Tweed Byron LALC. Sand tends to build up at the entrance to the Inlet and periodic dredging occurs in the Tweed River entrance and channel to maintain a navigable depth. Intertidal vegetation is restricted to a narrow fringe of mangroves, patches of saltmarsh and some seagrass within the inlet. TECs (listed under the BC Act) that may be present include Coastal Saltmarsh and Littoral Rainforest.

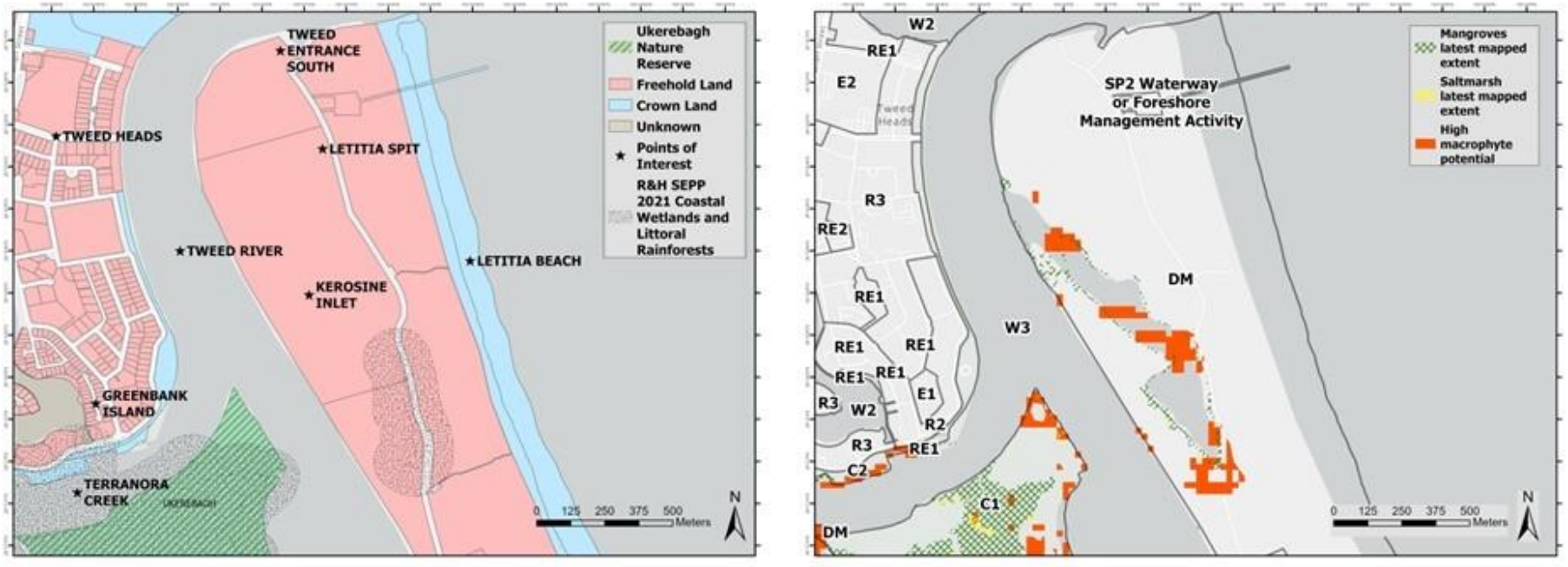
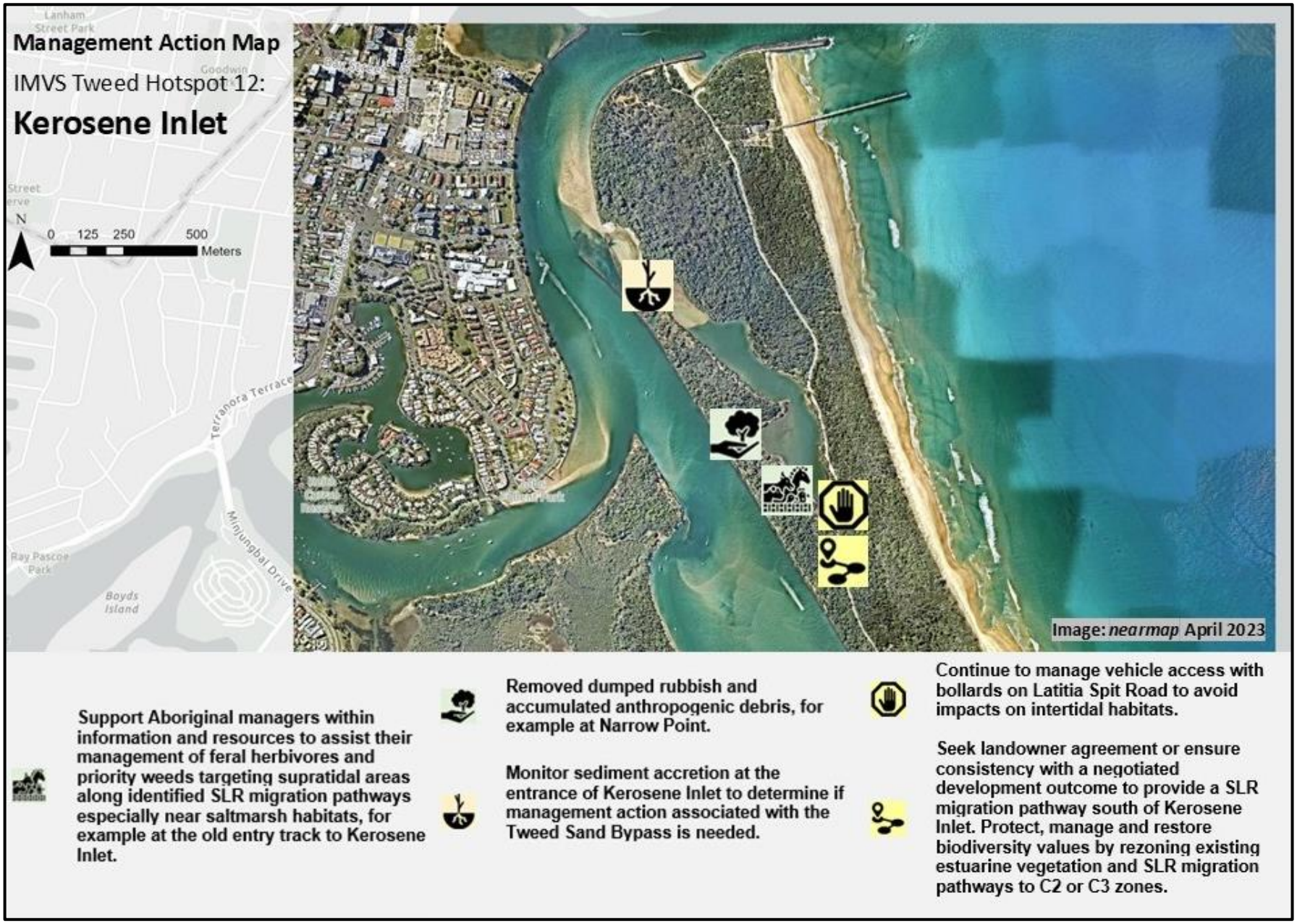


Figure 42 Tweed Hotspot 12: Kerosene Inlet. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.


Management Action Map
IMVS Tweed Hotspot 12:
Kerosene Inlet
N
0 125 250 500
Meters
Terranora Terrace
Minjungbal Drive
Ray Pascoe Park
Boyds Island
Image: nearmap April 2023
Support Aboriginal managers within information and resources to assist their management of feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats, for example at the old entry track to Kerosene Inlet.
Removed dumped rubbish and accumulated anthropogenic debris, for example at Narrow Point.
Monitor sediment accretion at the entrance of Kerosene Inlet to determine if management action associated with the Tweed Sand Bypass is needed.
Continue to manage vehicle access with bollards on Latitia Spit Road to avoid impacts on intertidal habitats.
Seek landowner agreement or ensure consistency with a negotiated development outcome to provide a SLR migration pathway south of Kerosene Inlet. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Sediments

As sediments accrete over time, mangroves are likely to expand into the open water of Kerosene Inlet. This may reduce the suitability of the site as a shorebird roost (Rohweder 2007). Management approaches should address and resolve priorities between maximising the resilience of intertidal vegetation versus minimising impacts on critical shorebird habitats. Sedimentation, particularly at the entrance of Kerosene Inlet, should be monitored to detect any adverse impacts to intertidal marine vegetation such as smothering. If this occurs, management actions to reduce sedimentation or remove excess sediments may be warranted.

Vegetation

Historically, intertidal marine vegetation at Kerosene Inlet has been subject to extensive disturbances from weeds (particularly Bitou Bush) and rubbish dumping. A project aim of the Fingal Wetland Rehabilitation Project was to restore the saltmarsh community in this area (Alletson et al. 2005). Disturbances to areas of natural vegetation at this hotspot should continue to be managed to enhance ecosystem values and resilience. Where feral and invasive species (including weeds) are detected, including at the old entry track to Kerosene Inlet, management actions should be undertaken to actively control them to minimise impacts on intertidal vegetation, prioritising SLR migration pathways adjacent to saltmarsh habitats. Support may be provided to Aboriginal managers with information and resources to manage weeds that impact on saltmarsh and mangrove migration. More information is detailed in IMVS: *Weed Management Guide.*

In areas of active sediment accretion, such as at Narrow Point, accumulated anthropogenic debris should be removed to prevent burial in intertidal habitats, and sources of debris should be investigated and managed.

People and Planning

Historical vehicular access near Kerosene Inlet has been managed with bollards, and damaged intertidal vegetation has shown substantial recovery since 2012 (Figure 43). As the area is highly accessible, being close to Letitia Spit Road, it should be monitored for future potential impacts. Minimal access should be encouraged to prevent degradation of the vegetation, particularly saltmarsh areas. This is consistent with an assessment of shorebird habitat in 2003 that found disturbance levels are very high due at Kerosene Inlet to public access, potentially affecting the areas important shorebird habitat during spring high tides (Rohweder 2007).

Figure 43 Restricting vehicular access to Kerosene Inlet. A, extensive vehicular damage to saltmarsh and mangrove habitats in 2012. B, avoidance of installed bollards in 2014. C, access point shifted after bollard reinforcement in 2017. D, pedestrian access only in 2023 with substantial recovery of intertidal and terrestrial vegetation. Images: *Nearmap.*

Due to the multiple stakeholders for Letitia Spit, engagement will be crucial for effective management of intertidal vegetation. This includes the Tweed Byron Local LALC, Tweed Shire Council, the Fingal Head Coastcare group and others.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. This rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 13: Sponsors Lagoon

Sponsors Lagoon is located close to the right bank of the Tweed River near Fingal Head, which is of sacred and spiritual importance to the Ngarakbal Githabal Aboriginal people (TSC 2017) (Figure 44). The Lagoon and foreshore are owned and managed by the Tweed Byron LALC.

The southern and eastern edge of the lagoon is close to where the bank of the Tweed River was before the Tweed River entrance training walls were installed. Mangrove habitats and the TEC Coastal Saltmarsh surround Sponsors Lagoon, extending close to residential and built up areas. Seagrass lines the lagoon and entrance channel. Other TECs (listed under the BC Act) that may be present near hotspot areas include Freshwater Wetlands and Swamp Sclerophyll Forest. Patches of Littoral Rainforest and Lowland Rainforest may occur nearby.

The hotspot area and existing intertidal marine vegetation falls mainly within a Deferred Matter (DM) zoned area and is surrounded with Public Recreation (RE1) and Low Density Residential (R2) areas.

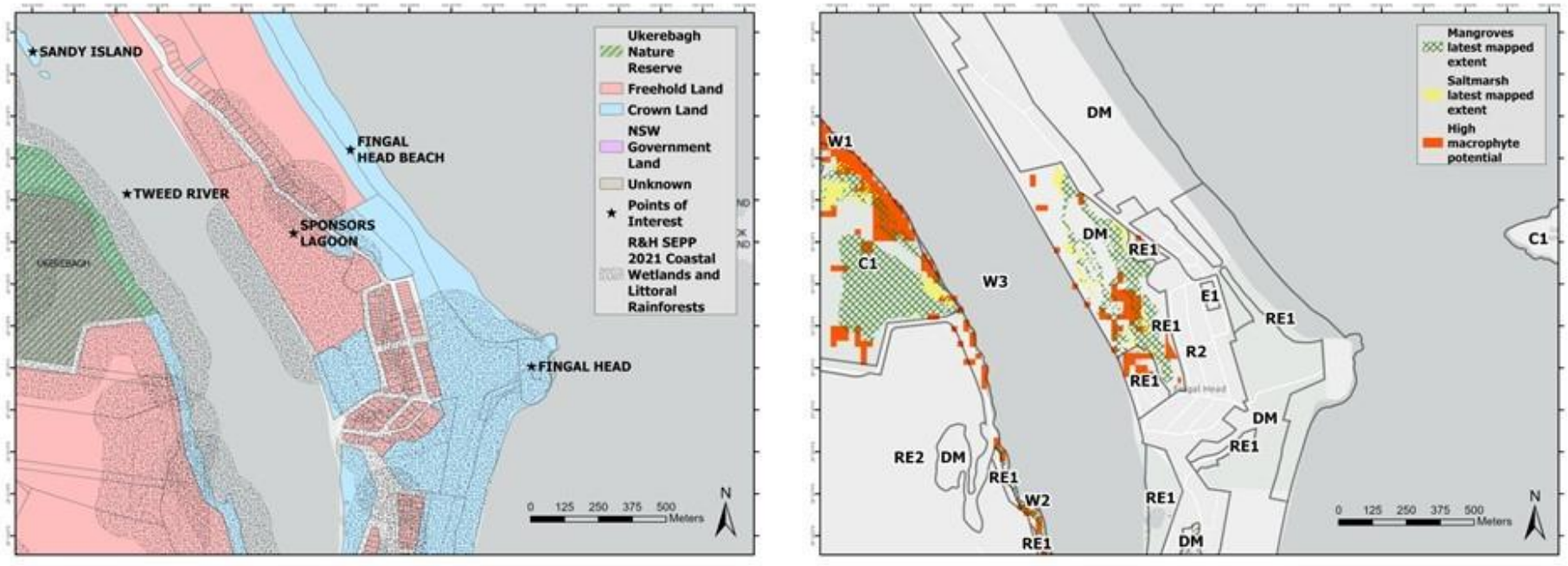
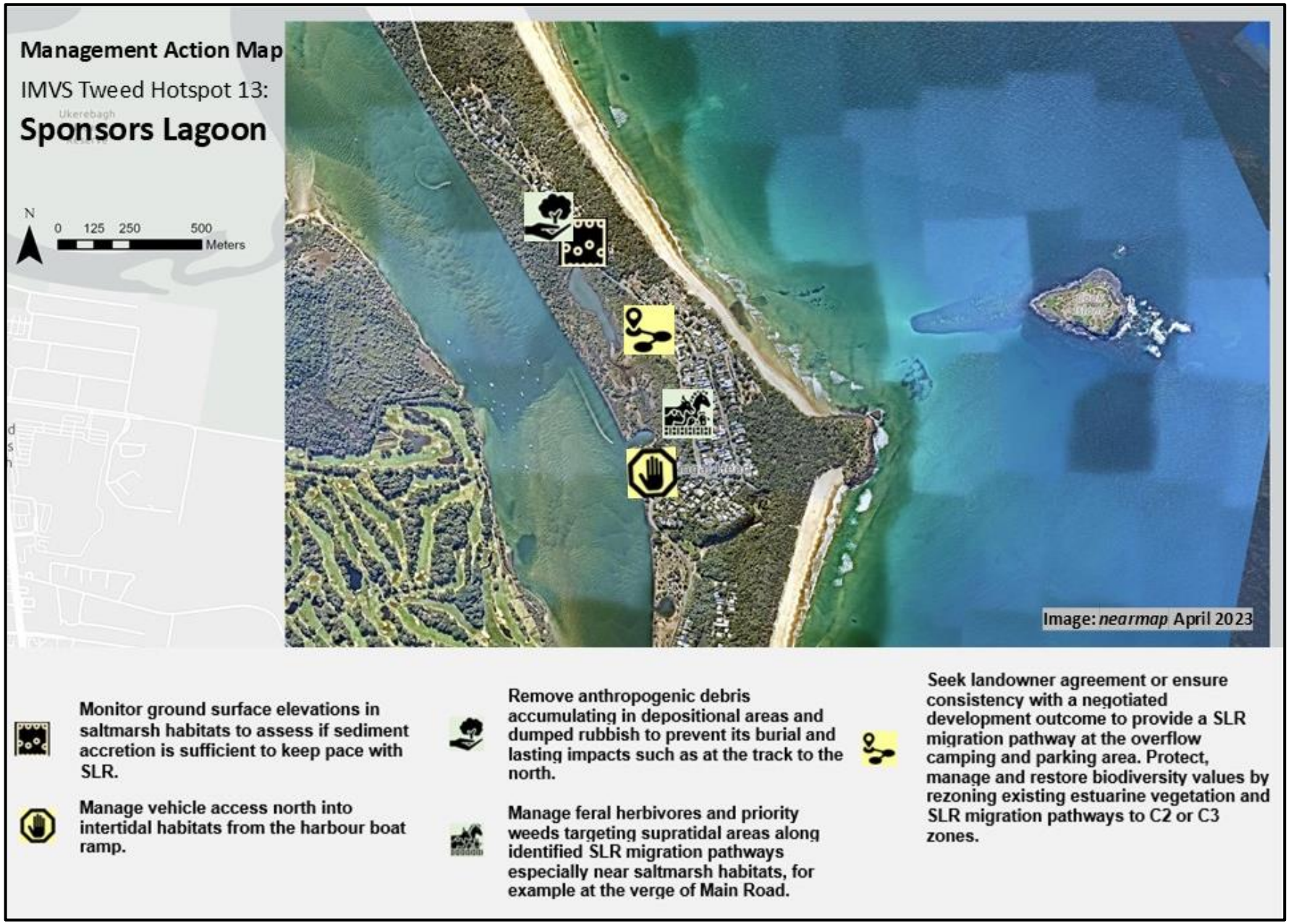


Figure 44 Tweed Hotspot 13: Sponsors Lagoon. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.


Management Action Map
IMVS Tweed Hotspot 13:
Sponsors Lagoon
N
0 125 250 500
Meters
Image: nearmap April 2023
Monitor ground surface elevations in saltmarsh habitats to assess if sediment accretion is sufficient to keep pace with SLR.
Manage vehicle access north into intertidal habitats from the harbour boat ramp.
Remove anthropogenic debris accumulating in depositional areas and dumped rubbish to prevent its burial and lasting impacts such as at the track to the north.
Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats, for example at the verge of Main Road.
Seek landowner agreement or ensure consistency with a negotiated development outcome to provide a SLR migration pathway at the overflow camping and parking area. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Sediments

Built coastal squeeze from surrounding urban developments and infrastructure (such as roads) is restricting the expansion of intertidal marine vegetation at Sponsors Lagoon. Vertical sediment accretion at a pace that keeps up with SLR will be needed to ensure these habitats persist into the future.

Assessing the capacity of intertidal areas fringing Sponsors Lagoon, particularly saltmarsh habitats, to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as the restoration of ground surface elevation or erosion management may become appropriate if intertidal areas fail to accrete sediment at a rate that keeps pace with SLR, because this may cause accelerated impacts on the TEC Coastal Saltmarsh or adjacent urban areas. If dredging is deemed essential, the investigation of the use of dredge spoil to restore ground surface elevation may be warranted in some areas.

Vegetation

Coastal Saltmarsh communities around Sponsor's Lagoon was the subject of a restoration project from 2003 to 2007 after degradation due to sand mining, rubbish dumping, weed encroachment (particularly Bitou Bush) and vehicular damage (Alletson et al. 2005; Green et al. 2009). These saltmarsh areas should be conserved by minimising disturbances and actively managing invasive weeds. Weeds that impact on saltmarsh are detailed in IMVS: *Weed Management Guide.*

In areas of active sediment accretion, or where intertidal habitats are accessed and rubbish is dumped such as the track to the north, accumulated anthropogenic debris should be removed to prevent burial and lasting impacts.

People and Planning

As sea levels rise, intertidal vegetation may expand into adjacent habitats particularly in the south of Sponsors Lagoon and along the coastal strip. The overflow camping and parking area north of the school is adjacent to mapped saltmarsh habitats and could provide a viable SLR migration pathway. However, due to the multiple stakeholders for Letitia Spit and landowners including residential areas to the south, engagement will be crucial for effective management of intertidal vegetation. This would include consulting with the Tweed Byron LALC, Tweed Shire Council, the Fingal Head Coastcare group and others.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. This rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

In intertidal areas impacted by vehicles or pedestrians, such as near the harbour boat ramp, further action should be taken to manage foreshore access (see Green et al. 2009).

Hotspot 14: Tonys and Tims Islands

Tonys Island is in Shallow Bay, where the Banora Point stormwater management system outlet channel discharges from Lake Kimberley (Figure 45). Tims Island is south of Banora Point and separated from mainland by a small channel. Both islands are protected as part of a reserved estate and are surrounded by urban developments in the east (including a tourist park to the west of Tims Island) and the Coolangatta and Tweed Heads Golf Club to the north. Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 11 and 16 — may be influenced by management actions in this hotspot, and vice versa.

There is a small patch of the TEC Coastal Saltmarsh on private land adjacent to the water channel that discharges into Shallow Bay. Other TECs (listed under the BC Act) that may occur in the hotspot include Freshwater Wetlands, Lowland Rainforest, Littoral Rainforest and Swamp Sclerophyll Forest. Most of the existing intertidal marine vegetation and hotspot areas are zoned Deferred Matter (DM) and Natural Waterways (W1). To the north of the hotspot is an RE1 zoned area adjacent to the Tweed Heads Golf Club. The surrounding land zoning is complex due to urban developments.

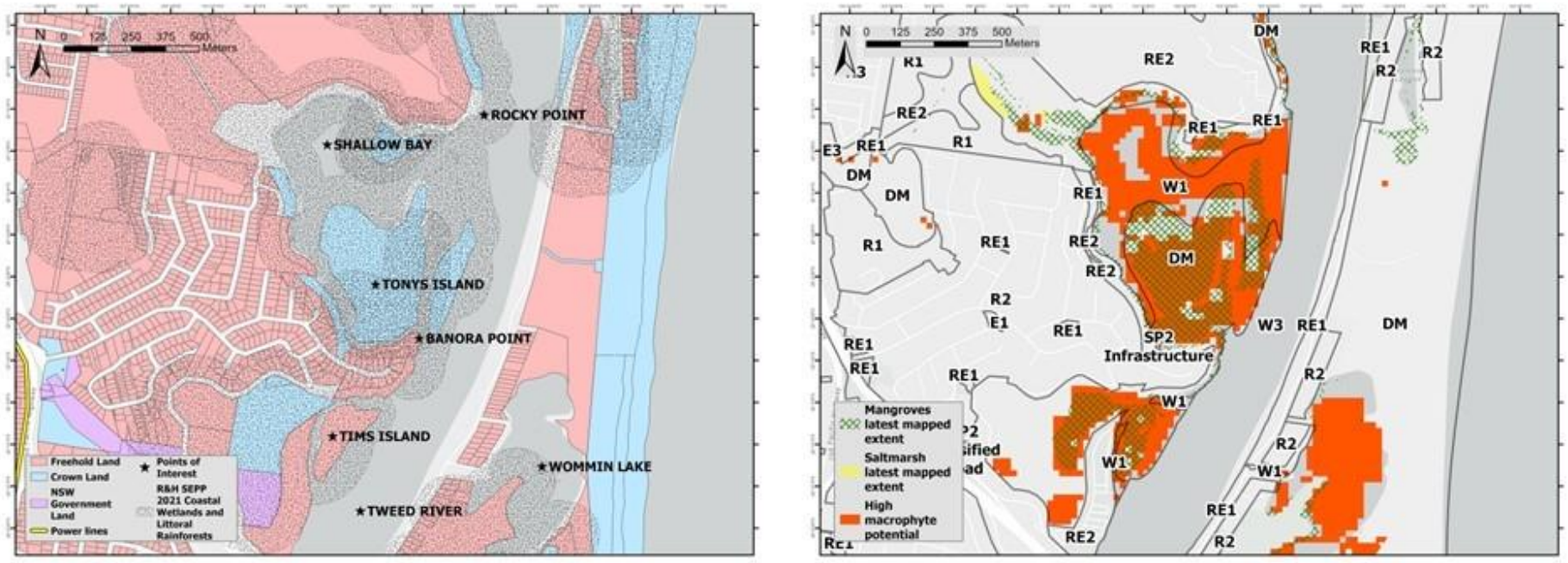


Figure 45 Tweed Hotspot 14: Tonys and Tims Islands. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 14:

Tonys and Tims Islands

Investigate the legacy Shallow Bay canal estate and other legacy infrastructure to determine impact on hydrology and options to reinstate more natural flows in Shallow Bay.

Investigate the legacy drainage works to determine impacts on hydrology at the Shallow Bay wetland and identify options to reduce the extent of drainage and facilitate overland tidal flows.

Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid to prevent its burial and lasting impacts.

Establish and maintain fenced vegetation buffers above the level of the highest astronomic tide near the Shallow Bay wetlands.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways especially near saltmarsh habitats in the Shallow Bay wetland.

Manage new and existing developments to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur. Sites include south of Martinelli Avenue, Trigonie Drive Canal Estate and Lake Kimberley outlet.

Monitor ground surface elevations at Tonys Island to assess if sediment accretion is sufficient to keep pace with SLR.

Seek landowner agreement or ensure consistency with a negotiated development outcome to provide SLR migration pathways at Shallow Bay wetland, Lilly Pilly Drive wetland and Bushland Drive wetland. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Hydrology

Historical imagery indicates that the Shallow Bay inlet channel was previously a natural watercourse that has been modified (Figure 46), probably to form a canal estate and as a connection for the Banora Point drainage scheme. This has impacted Coastal Saltmarsh and mangrove habitats at the Shallow Bay wetlands (Figure 46A). The existing patch of saltmarsh occurs on privately held land and this site may provide an opportunity for a SLR migration pathway. The Tweed River Estuary CMP identifies this area as a high priority to facilitate migration of estuarine vegetation with SLR (TSC 2022).

Consistent with this, a hydrological assessment is recommended to determine management options to reinstate and maintain more natural tidal hydrology and connectivity. The legacy drainage works should be investigated to determine impacts on the Shallow Bay wetlands and identify options to reduce the extent of drainage, particularly where historical drainage works may be impacting saltmarsh habitats. If possible, the natural waterway should be recovered to reflect more natural, shallow and sinuous flow paths, reducing flow velocities and promoting overland flows.

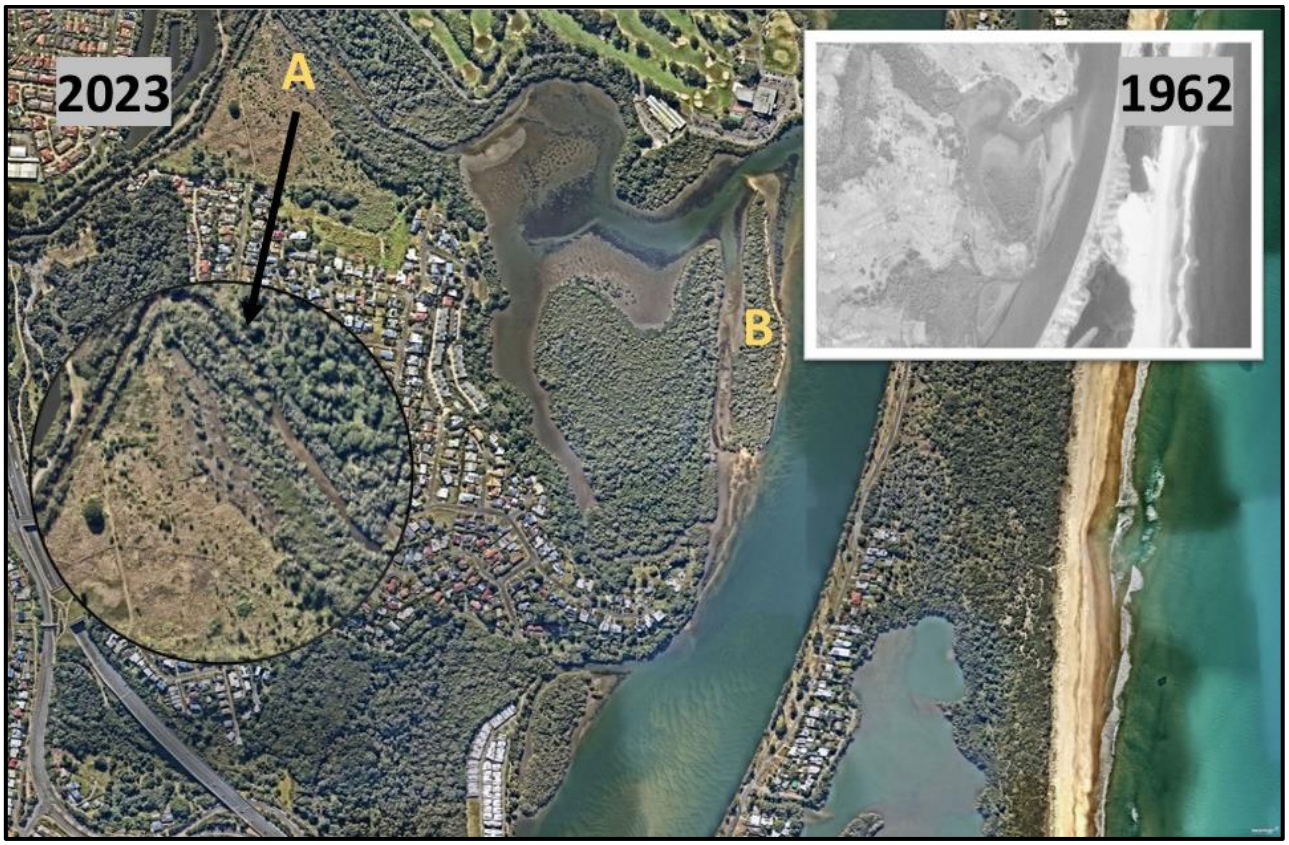


Figure 46 Tonys and Tims Islands including changes over time. A, channelisation of previously natural waterway. B, expansion of intertidal habitats. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Sediments

In the past, sedimentation and mangrove establishment has increased the size of both Tonys and Tims Islands and a sand bank that formed in the 1970s has since become another island consolidated with mangroves (Figure 46B). The expansion of mangroves was noted in the 1991 Tweed Estuary processes study (NSW Public Works, 1991). This pattern may be linked to sediment inputs channelled through the former intertidal area of Shallow Bay and is likely to continue in the future.

Assessing the capacity of Tonys Island to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as the restoration of ground surface elevation or erosion management may become appropriate if the Tonys or Tims Island starts to

erode or fail to accrete sediment at a rate that keeps pace with SLR, as this may cause accelerated impacts on adjacent TECs such as Littoral Rainforest and Swamp Oak Floodplain Forest.

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TECs 'Freshwater Wetlands' and 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Vegetation

Historical imagery indicates that the saltmarsh habitats adjacent to the outlet channel that discharges into Shallow Bay are prone to anthropogenic disturbances. Since 2009, this has included vehicle damage and impacts from agriculture (Figure 47). In addition, adjacent natural vegetation has been cleared and mangroves are advancing.

Figure 47 Anthropogenic impacts on saltmarsh adjacent to the Shallow Bay outlet channel. Clockwise from top left: A, Vehicle damage (2009). B, Clearing of adjacent natural vegetation (2014). C, Further clearing of natural vegetation likely including saltmarsh (2016). D, Vehicle damage and mangrove advancement (2023). Images: *Nearmap*.

Disturbances the saltmarsh at this site should be minimised to improve resilience to stressors. This can be achieved by the installation of a fenced buffer sone that extends beyond the current extent of the wetland, providing a SLR migration pathway upslope in advance of mangroves. Given the site's proximity to urban areas and history of disturbance, this should be accompanied with restoration activities including active weed management, prioritising SLR migration pathways adjacent to saltmarsh habitats. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.*

In areas of active sediment accretion throughout the hotspot, accumulated rubbish and anthropogenic flood debris should be removed to prevent burial and sources of the debris identified and controlled.

People and Planning

Stakeholder liaison is recommended to explore management options to provide a SLR migration pathway for saltmarsh habitats adjacent to the outlet channel, including limiting vehicle access to the site. This action is consistent with the Tweed River Estuary CMP, that identifies the nearby Shallow Bay inlet channel as a high priority to facilitate migration of estuarine vegetation with SLR (TSC 2022). Use of the site for biodiversity offsets under the BC Act may be challenging considering the significant changes to habitat types that will occur with sea level rise, however it is an ideal site for an offset under the FM Act.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE Northern Councils E Zone Review Final Recommendations Report (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In privately owned areas such as Bushland Drive wetland, Lilly Pilly Drive wetland and Shallow Bay wetland, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to 'Review LEP zoning to incorporate areas for estuary vegetation migration'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Stormwater and pollution management at Hotspot 14 will be crucial to maintain the health of the intertidal ecosystems. Discharges from the Banora Point stormwater management system have been identified as a threat to ecosystem health in the CZMP for Cobaki Broadwater and Terranora Broadwater (TSC 2012). Inputs of elevated nutrients and freshwater water flows, if unmanaged, may impact on the long-term viability of the site for saltmarsh and increase the potential for accelerated advance by mangroves.

Compliance with stormwater and pollution control guidelines is essential to maintain the resilience of intertidal vegetation in this area. Consideration may be given to retrofit nature-based water sensitive urban designs and nature-based solutions to pollution within the Shallow Bay catchment to manage stormwater impacts on intertidal marine vegetation.

Hotspot 15: Wommin Lake

Wommin Lake is south of Letitia Spit, and the geomorphologic and hydrological process and changes following the construction of the Tweed River training walls and sand bypass system are similar to Letitia Spit. Its connection to the Tweed River is partially engineered to manage inundation around the lake foreshore. Large parts of the foreshore are owned and managed by the Tweed Byron LALC.

There is a currently extensive areas of existing TECs (listed under the BC Act) surrounding Wommin Lake, particularly to the south. These may include Swamp Sclerophyll Forest, Littoral Rainforest, Lowland Rainforest, and Freshwater Wetlands. Mangroves are recruiting into the southern portion of the lake although this area matches the alignment of the Tweed River prior to the installation of the training wall and it is possible that remnant intertidal vegetation also occurs (Figure 48).

Apart from Low Density Residential (R2) and Public Recreation (RE1) areas to the west of the lake, the hotspot area is zoned Deferred Matter (DM).

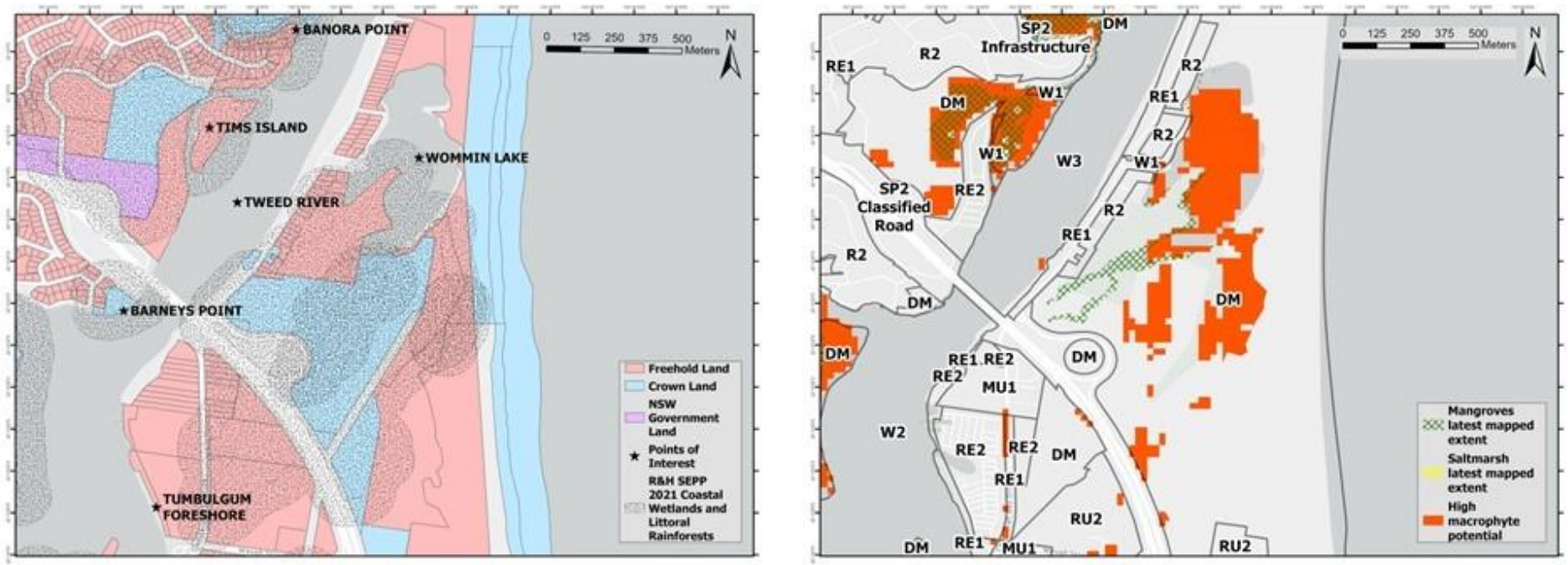
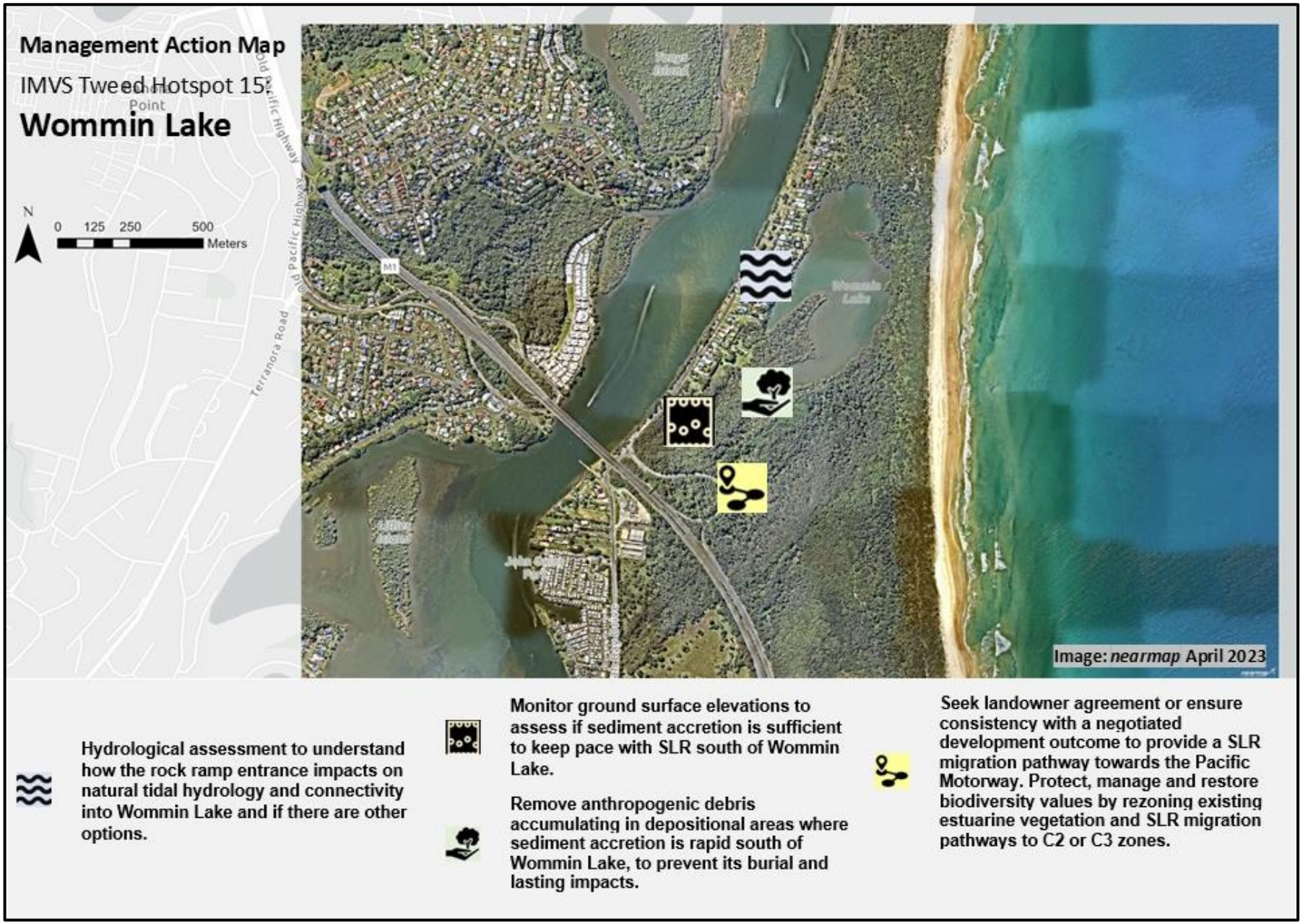


Figure 48 Tweed Hotspot 15: Wommin Lake. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.


Management Action Map
IMVS Tweed Hotspot 15:
Wommin Lake
Chinaman Point
Old Pacific Highway
Terranora Road
M1
N
0 125 250 500
Meters
Image: nearmap April 2023
Hydrological assessment to understand how the rock ramp entrance impacts on natural tidal hydrology and connectivity into Wommin Lake and if there are other options.
Monitor ground surface elevations to assess if sediment accretion is sufficient to keep pace with SLR south of Wommin Lake.
Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid south of Wommin Lake, to prevent its burial and lasting impacts.
Seek landowner agreement or ensure consistency with a negotiated development outcome to provide a SLR migration pathway towards the Pacific Motorway. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Hydrology

Connectivity of Wommin Lake to the Tweed River fluvial channel is via a narrow, shallow opening underneath a bridge (Figure 49). The constriction of the entrance with rock ramps was intended to manage the tidal range within the lake to reflect pre-construction conditions. However, the opening may be causing tidal pumping and heightened water levels, evidenced by the advancement of mangroves into adjacent habitats at the southern extent of the lake. Monitoring of water levels would help inform future management decisions particularly as SLR further increases the depth of water in the lake.

Figure 49 Entrance to Wommin Lake looking towards the Tweed River fluvial channel.

At the southern, low-lying extent of Wommin Lake, saltwater incursion is occurring with a concurrent advancement of mangroves (Figure 50A). This influence is currently impacting terrestrial habitats and is likely to advance into adjacent TECs (Figure 50B).

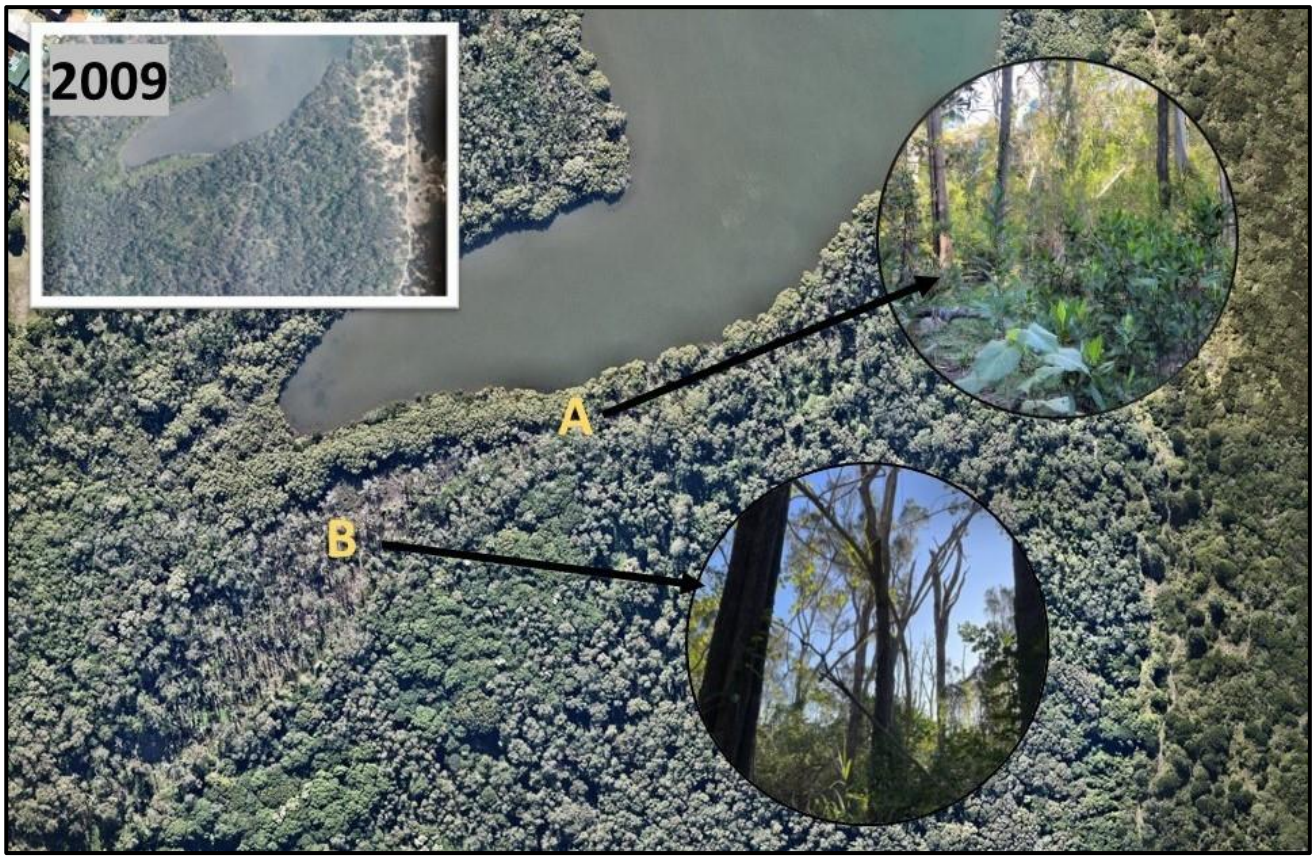


Figure 50 Dieback of Coastal Swamp Oak and advancement of mangroves at Wommin Lake. Images: *Nearmap* (base and inset).

Increased tidal exchange at Wommin Lake may be warranted to reduce tidal pulsing accelerating saltwater intrusion into Swamp Oak Floodplain Forest habitats. This could be achieved with increased connectivity to the Tweed River from lake entrance expansion and modifications. This action may also alleviate concerns from the local community about odours and mosquito hazards from the expanding mangrove habitats. However, any decisions to alter hydrology should be informed by a hydrologic assessment to understand how the rock ramp entrance impacts on natural hydrology and connectivity in Wommin Lake and to determine if there are other options.

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TECs 'Freshwater Wetlands' and 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Sediments

Natural sedimentation should be encouraged in intertidal habitats at the southern extent of Wommin Lake to limit accelerated impacts on adjacent TECs such as Littoral Rainforest and Swamp Oak Floodplain Forest. Actions to restore natural hydrology may improve sediment supplies and facilitate the ability of intertidal marine vegetation to increase elevation in response to SLR. Assessing the capacity of this site to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions may become appropriate if the site fails to accrete sediment at a rate that keeps pace with SLR, as this may cause accelerated impacts on adjacent TECs such as Littoral Rainforest and Swamp Oak Floodplain Forest.

Vegetation

In areas of active sediment accretion, accumulated anthropogenic debris should be removed to prevent burial in intertidal habitats, and sources of debris should be investigated and managed.

People and Planning

A suitable SLR migration pathway for intertidal marine vegetation may occur southwards towards the Pacific Motorway exit onto Fingal Road, along the quaternary peleochannels where intertidal vegetation is already advancing (Figure 51). Extensive stakeholder liaison will be required to inform management decisions about this possible migration pathway, including the Tweed Byron LALC and Transport for NSW.

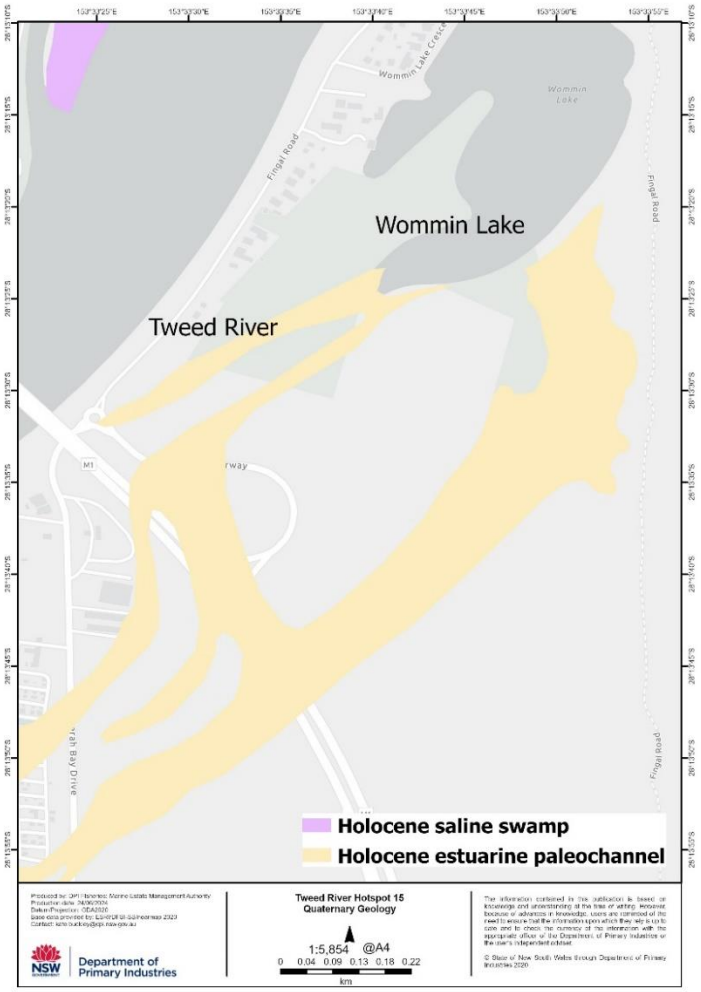


Figure 51 Quaternary geology at Wommin Lake illustrating potential SLR migration pathway. Data source: DIGS Geological Survey of NSW.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In privately owned areas this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 16: Chinderah Bay

The Chinderah Bay hotspot is a broadwater area of the Tweed River with substantial areas of mangroves and the TEC (listed under the BC Act) Swamp Oak Floodplain Forest on Chinderah Spit and islands within the bay including Lillies Island (Figure 52). Patches of the TEC Lowland Rainforest fringe Chinderah Bay. Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspots 14 and 18 — may be influenced by management actions in this hotspot, and vice versa.

Most of the hotspot areas are in Deferred Matter (DM) zoned land. Oxley Cove canal estate including Bosun Boulevard truncates the former catchment flows into Chinderah Bay. Several stormwater outlets discharge into the bay and the canal which has a relatively narrow opening near the spit.

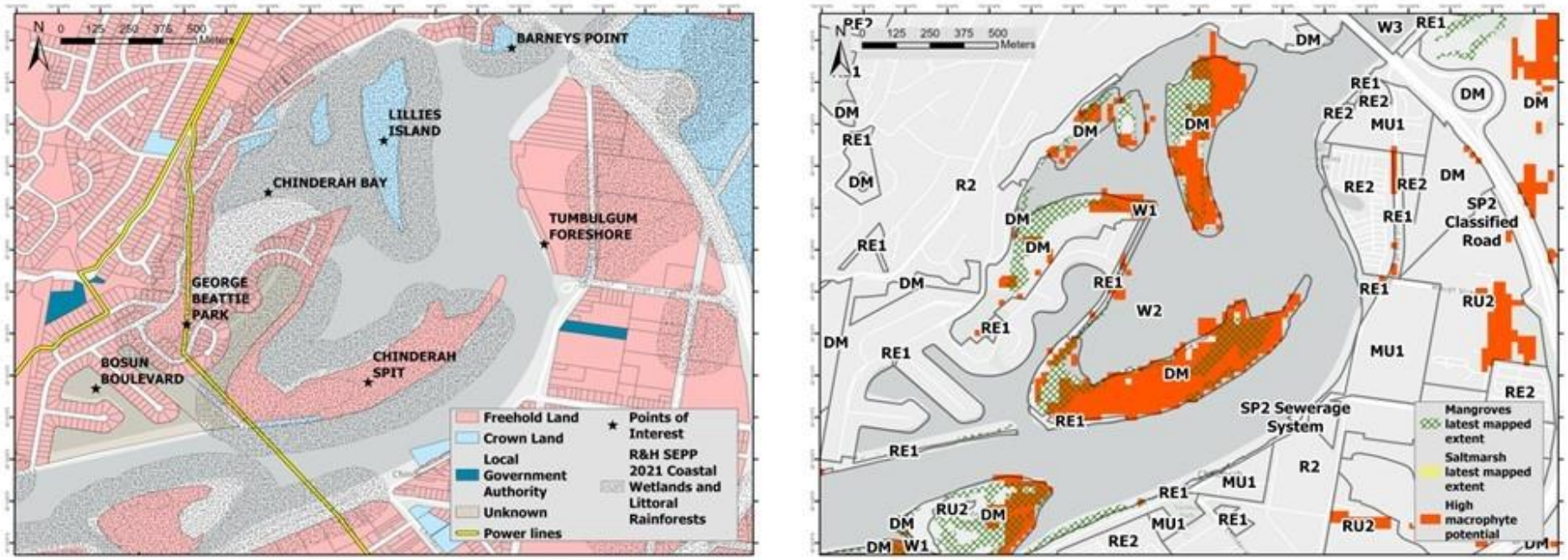


Figure 52 Tweed Hotspot 16: Chinderah Bay. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 16:

Chinderah Bay

Investigate legacy levee at the historical powerlines bund to determine impacts on hydrology and options to remove and reinstate tidal flows.

Monitor ground surface elevations of Lillies Island and adjacent areas to assess if sediment accretion is sufficient to keep pace with SLR.

Minimise actions that may cause erosion of intertidal areas including dredging and boat wake damage at Chinderah Spit. Investigate options to protect and stabilise erosion using bio-engineering approaches.

Manage priority weeds targeting supratidal areas along identified SLR migration pathways at Chinderah Spit.

Manage new and existing developments adjacent to Old Ferry Road and at Oxley Cove Canal Estate to incorporate water sensitive designs and nature-based solutions to pollution. Ensure compliance with pollution and stormwater control regulations regarding where and how discharges occur.

Remove anthropogenic debris accumulating in depositional areas where sediment accretion is rapid at Chinderah Bay spit and the reserve adjacent to Old Ferry Road, to prevent its burial and lasting impacts.

Seek landowner agreement or ensure consistency with a negotiated development outcome to provide a SLR migration pathway at Chinderah Bay. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones.

Hydrology

Legacy impacts to site hydrology occur from ground disturbance during works to install power lines that run through George Beattie Park (Figure 53A). The works created a levee that limits tidal flushing to part of the site causing disservices such as odours and mosquitoes. Opportunities to restore natural hydrology and tidal flushing at this location should be investigated.

Figure 53 Chinderah Bay including changes to morphology over time. A, powerlines crossing the wetland were installed using a levee that continues to impede tidal flows. B, erosion and failed bank armouring. C, active sediment accretion with debris. Images*: Nearmap* (base) and NSW Government Spatial Services (inset).

There has been both seaward and landward advancement of mangroves at Hotspot 16. As sea levels rise, mangroves are likely to expand into parts of Swamp Oak Floodplain Forest. Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Oak Floodplain Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Sediments

Historical imagery shows that Chinderah Spit, Lillies Island and other islands within the bay have accumulated sediments over time, expanding extent of intertidal habitats and mangroves (Figure 53). This trend is likely to continue into the future. Associated increases in ground surface elevation may provide a vertical SLR migration pathway for intertidal vegetation and may limit accelerated impacts on adjacent habitats including Swamp Oak habitats. Assessing the capacity of Lillies Island to maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as the restoration of ground surface elevation or erosion management may become appropriate if the Lillies Island starts to erode or fail to accrete sediment at a rate that keeps pace with SLR, as this may cause accelerated impacts on adjacent TECs such as Swamp Oak Floodplain Forest.

Boat wash may be contributing to the significant erosion at Chinderah Spit near the entrance to Bosun Boulevard, where bank revetment has failed (Figure 53B). The causes of erosion at this site should be investigated. If appropriate, options to minimise impacts of vessel wash should be investigated and this could include enforcing compliance with the existing 4 knot zone within the Bosun Boulevard (Tweed Estuary Boating Plan 2006 – 2010) and education of recreational boaters about the impacts of boating.

This site is a high priority for seawall remediation in the Tweed River Estuary CMP and this action is consistent with *Fundamental Management Action F1: Bank stabilisation works at high priority sites on public land including riparian vegetation rehabilitation* (TSC 2022). It is recommended to investigate options to protect and stabilise the banks with bio-engineering approaches incorporating fish-friendly habitats to enhance intertidal vegetation and recreational fishing opportunities. Guidance to support this action can be found in the MEMS Estuary bank management strategies.

Vegetation

Large amounts of rubbish have accumulated in parts of the hotspot and is likely to be impacting ecosystem resilience at Chinderah Bay spit (Figure 53C). The site is well known for collecting flood debris and Tweed Shire Council developed a flood debris removal policy to maintain foreshore amenity, navigable and recreational access (TSC 2012b). However, much work still needs to be undertaken to remove this rubbish and prevent burial in this and other sites such as the reserve adjacent to Old Ferry Road. Sources of the debris should also be identified and managed.

A large infestation of Singapore Daisy *Sphagneticola trilobata* occurs on the riverbank and in Swamp Oak habitats at Chinderah Spit (Figure 54). This species is has the potential to impact SLR migration pathways for intertidal vegetation. Singapore Daisy and other invasive weeds should be actively controlled at this site to minimise impacts on intertidal vegetation, prioritising upslope SLR migration pathways. Weeds that impact on intertidal vegetation migration are detailed in IMVS: *Weed Management Guide.*

Figure 54 Weed infestation of Singapore Daisy at Chinderah Spit.

People and planning

It is important that compliance with stormwater pollution standards is maintained at Chinderah Bay due to the presence of stormwater outlets into the bay and excessive levels of accumulated rubbish. Options for nature-based solutions to pollution and retrofitting of water sensitive urban designs in new and existing developments, such as Oxley Cove Canal Estate and urban areas adjacent to Old Ferry Road, may help alleviate these issues.

Given the surrounding housing density, stakeholder engagement will be needed to promote community support for the increasing extent of mangroves. A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In privately owned areas this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 17: Dodds Island and Chinderah Island

Dodds Island and Chinderah Island are both low-lying private holdings separated from the right bank of the Tweed River by Boyds Channel (Figure 55). Sites within this area are considered together due to an often close association of management actions and for the ease of discussion. The boundary should not be considered as a hard line. Adjacent hotspots — for example, Hotspot 16 — may be influenced by management actions in this hotspot, and vice versa.

Dodds Island is used for grazing and has a large area of intertidal vegetation zoned DM, including both the TEC Coastal Saltmarsh and mangrove habitats. Other TECs (listed under the BC Act) that may be present include Swamp Sclerophyll Forest, Freshwater Wetlands and Littoral Rainforest. Chinderah Island is also privately owned but remains largely uncleared with extensive mangroves. Based on assessment of historical aerial photographs, this island was used for agriculture in the past.

Most of the existing intertidal marine vegetation and hotspot areas are in Deferred Matter (DM) or Natural Waterway (W1) zoned areas, although saltmarsh habitats also extend into Primary Production (RU1) zoned land on Dodds Island.

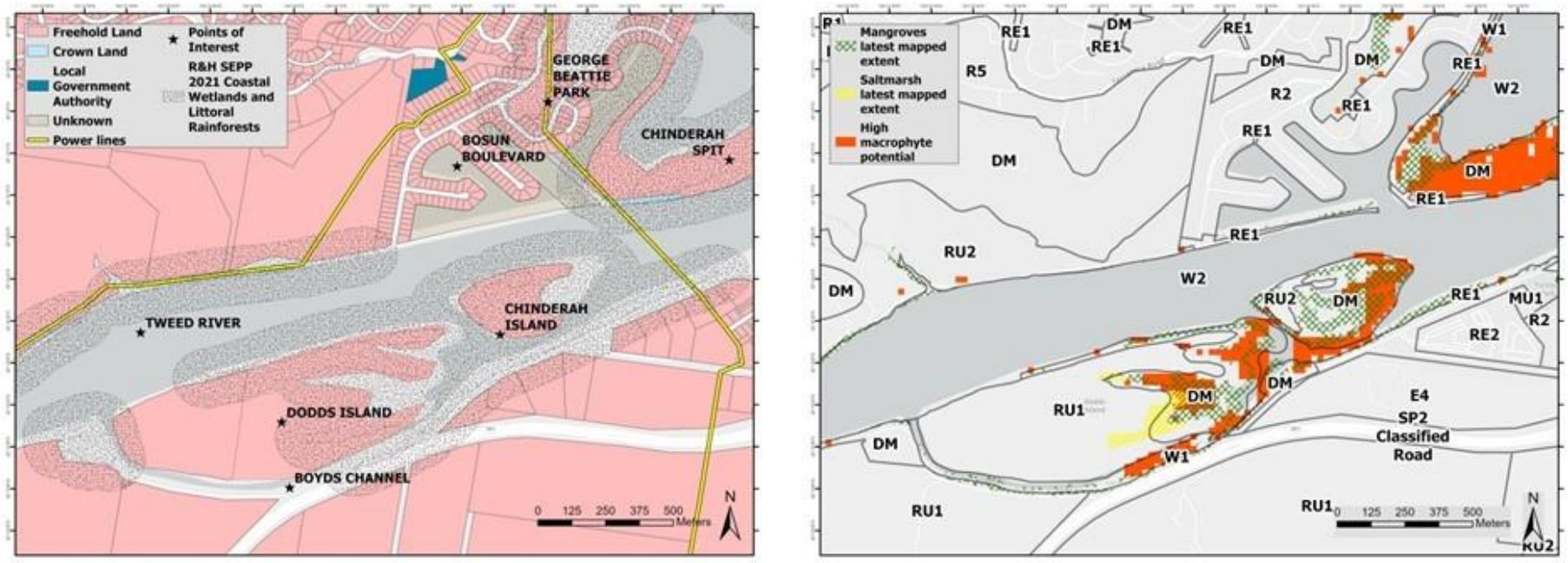
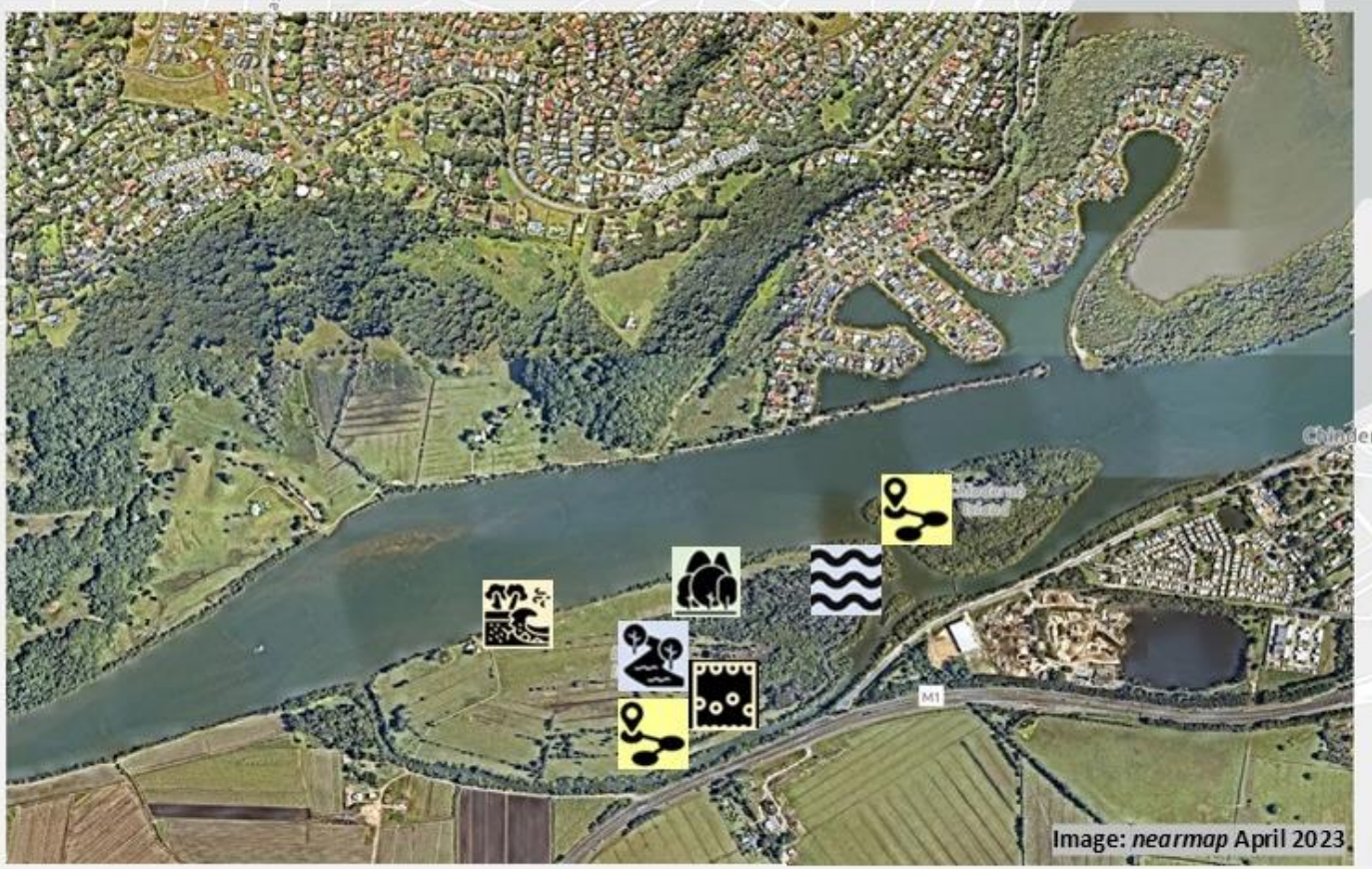


Figure 55 Tweed Hotspot 17: Dodds Island and Chinderah Island. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 17:

Dodds Island and Chinderah Island



Create fenced vegetation buffers above the level of the highest astronomic tide and riparian zones around the wetlands on Dodds Island.

Investigate levee, ring drain and drainage network infrastructure on Dodds Island to determine impacts on hydrology and options to remove and reinstate tidal flows.

Limit accelerated mangrove expansion and incursion of tides into freshwater wetlands via drains and ditches to provide a viable upslope SLR migration pathway for freshwater wetlands, saltmarsh and mangroves on Dodds Island.

Minimise actions that may cause erosion of intertidal areas including dredging and boat wake damage and protect and stabilise the northern bank of Dodds Island with bio-engineering approaches.

Restore natural sediment supplies by increasing overland flows. Encourage the growth of intertidal vegetation for biological build of ground surface.

Provide SLR migration pathways at Dodds Island and Chinderah Island. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.

Hydrology

The complex nature of the legacy drainage infrastructure on the eastern side Dodds Island necessitates a hydrological assessment to determine future management options. Dodds Island was previously cleared and extensive drainage and levee infrastructure installed. Since then, some terrestrial vegetation has re-established. However, the levee has breached in places causing tree dieback from saltwater incursion and the establishment of mangroves (Figure 56A). Mangroves are also expanding into saltmarsh communities, facilitated by constructed drainage lines (Figure 56B).

Management actions may include removing the levee to reinstate more natural hydrology, promote overland flows and improve the connectivity of intertidal habitats. The accelerated expansion of mangroves along drainage lines and into saltmarsh habitats may be managed by infilling drains. After hydrology has been suitably modified, it may be appropriate to remove mangroves that have established in saltmarsh areas. These actions would mitigate accelerated impacts from saltwater incursion and provide a viable SLR migration pathway for intertidal marine vegetation. This is consistent with the Tweed River Estuary CMP, which identifies Dodds Island as a high priority area for further investigation or management of vegetation migration (TSC 2022).

Most drainage infrastructure in the hotspot has compromised functionality with drain invert levels submerged by tidal levels between 50 – 95% of the time. At least 4 floodgates leading into Boyds Channel are at moderate risk of failure in the near future due to SLR (Tucker et al. 2023). Potential short-term management options identified for this area included improving tidal flushing through floodgates, the modification of drainage structures and the installation of weirs leading in the long term to the removal of floodgates and expansion of estuarine wetlands. These management recommendations from Tucker et al. (2023) are consistent with actions to support the long-term resilience of intertidal vegetation at Hotspot 17 and would provide a potential SLR migration pathway to the south of Dodds Island.

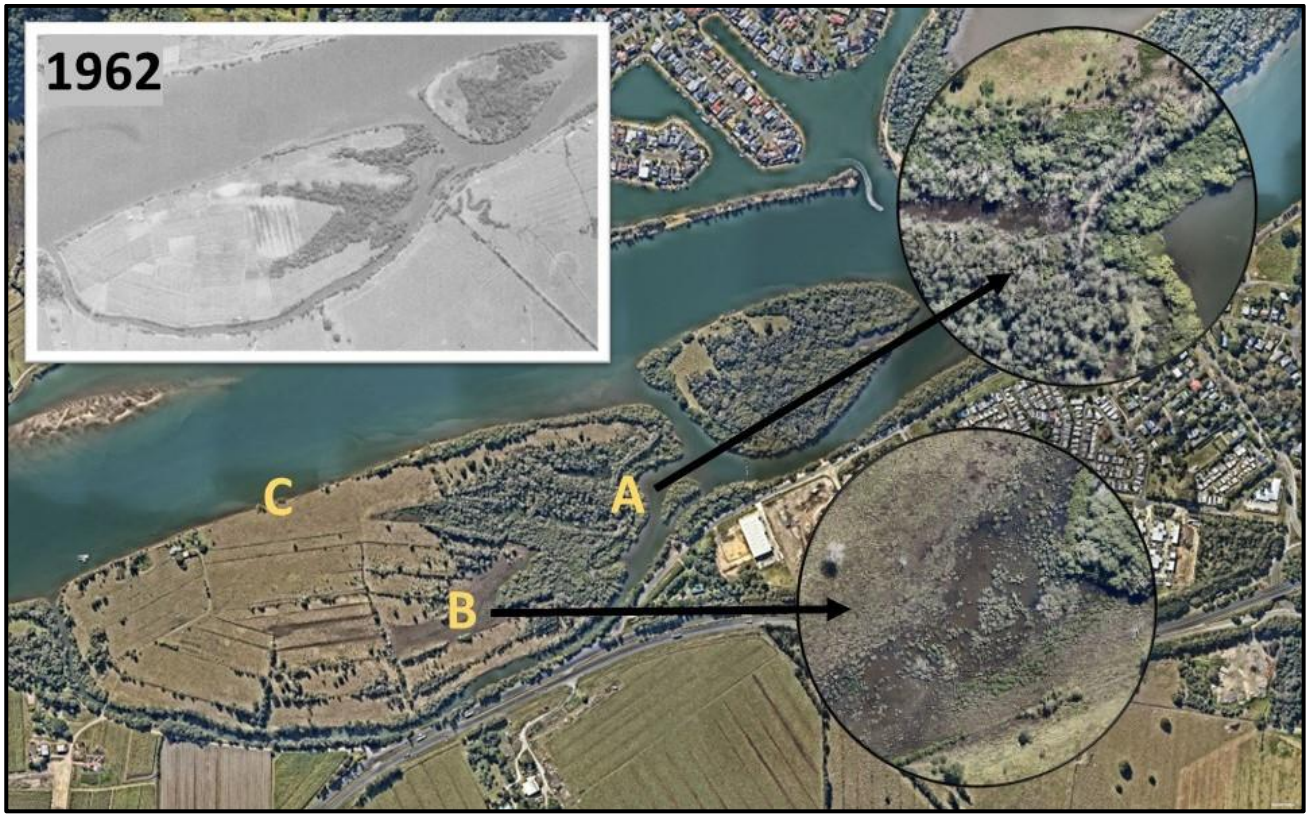


Figure 56 Dodds Island and Boyds Channel including changes over time. A, Breached levee. B, saltmarsh. C, eroding shoreline. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Sediments

As sea levels continue to rise, mangroves are likely to expand into parts of the TECs Coastal Saltmarsh, Swamp Oak Floodplain Forest and Littoral Rainforest. To limit accelerated impacts on adjacent habitats, natural sedimentation should be encouraged by restoring sediment supplies impacted by the drain and levee network, for example by increasing overland flows. Natural sediment accretion should also be facilitated by restoring degraded mangrove and saltmarsh riparian habitats for an increased density of root mats and biological build of ground surface.

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

The *Riverbank Erosion Management Plan* (TSC 2014) identified the north side of Dodds Island at severe or high risk of erosion (Figure 56C). Any activities that may cause erosion of intertidal areas such as dredging in the Tweed River north of Dodds Island should be minimised where possible. Options to protect and stabilise this bank with bio-engineering approaches such as hybrid fillets using rock, timber and/or oyster reefs, should be investigated to halt the erosion, promote sediment accretion and the establishment of intertidal habitats. Guidance to support this action can be found in the MEMS Estuary bank management strategies.

Vegetation

Although there are fences on Dodds Island that offer some degree of protection for intertidal vegetation, the TEC Coastal Saltmarsh is particularly vulnerable to grazing and vehicular traffic. Landowner engagement could be undertaken to explore options to install fences incorporating a vegetation buffer to exclude grazing from these wetlands. This is consistent with the Tweed River Estuary CMP *Fundamental Management Action K2: Provision of buffer zones to facilitate estuary vegetation migration* (TSC 2022).

People and Planning

Management actions to support the resilience of intertidal vegetation at Hotspot 17 will also require landowner engagement and cooperation. Hydrological assessments (see *Hydrology*) may identify blue carbon opportunities at these sites as the suitability for grazing will continue to decline over time. DPIRD investigations at Duck Creek found gross margin for grazing a low coastal floodplain paddock will fall from $1,223 / ha / year in 2020 to $173 / ha / year in 2050 (McGrath 2023). There are significant advantages to undertaking a blue carbon project on an island as the project would have limited to no impact on neighbours and be a land use more resilient to sea level rise and flooding.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

Hotspot 18: Tweed Broadwater

The Tweed Broadwater has fringing mangrove habitats on both the shoreline and the islands (Figure 57). The TEC Coastal Saltmarsh occurs inland of mangroves on the northern shoreline, and on the southern shoreline where it is surrounded by substantially cleared grazing and cane land. Mangroves may be adjacent to TECs (listed under the BC Act) in some parts of the hotspot, including Lowland Rainforest, Littoral Rainforest and Freshwater Wetlands.

The Tweed Broadwater is surrounded by privately held land, excepting one existing small mangrove island that is Crown Land. Most of the existing intertidal marine vegetation and hotspot areas occur in Natural Waterways (W1) zoned areas, with some Deferred Matter (DM) areas — notably including saltmarsh habitats — which also extend into Rural Landscape (RU2) zoned land to the north.

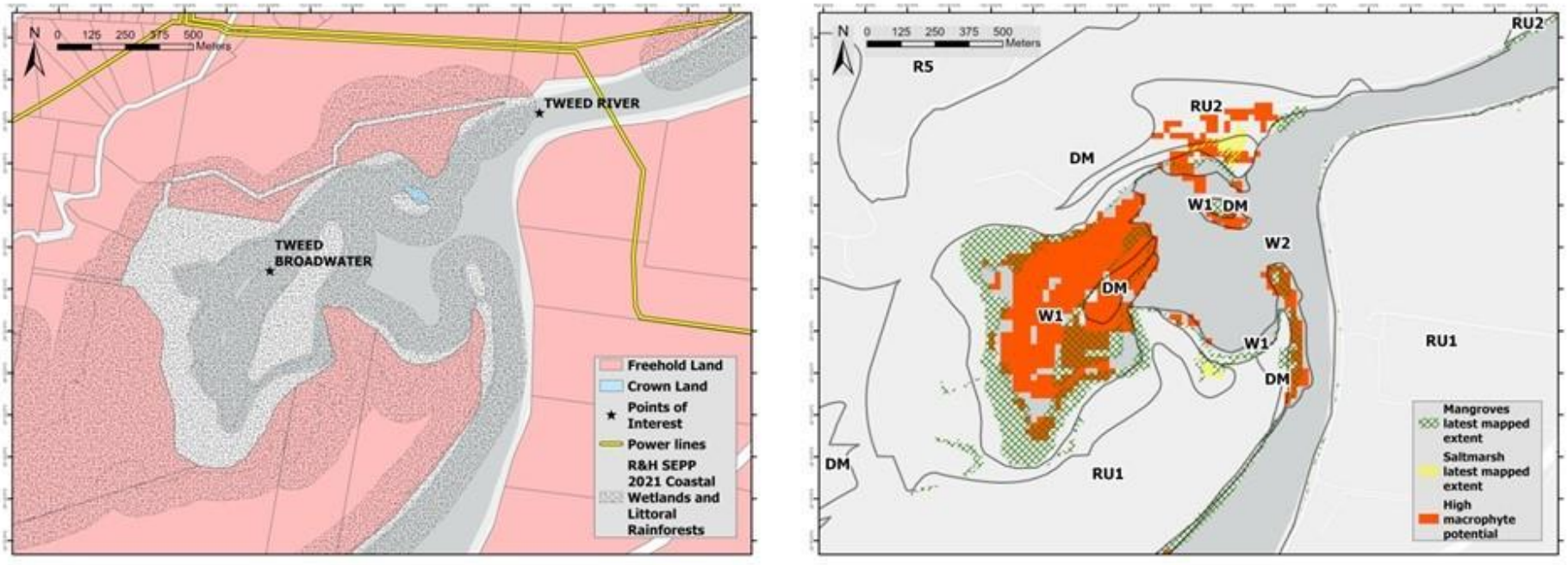
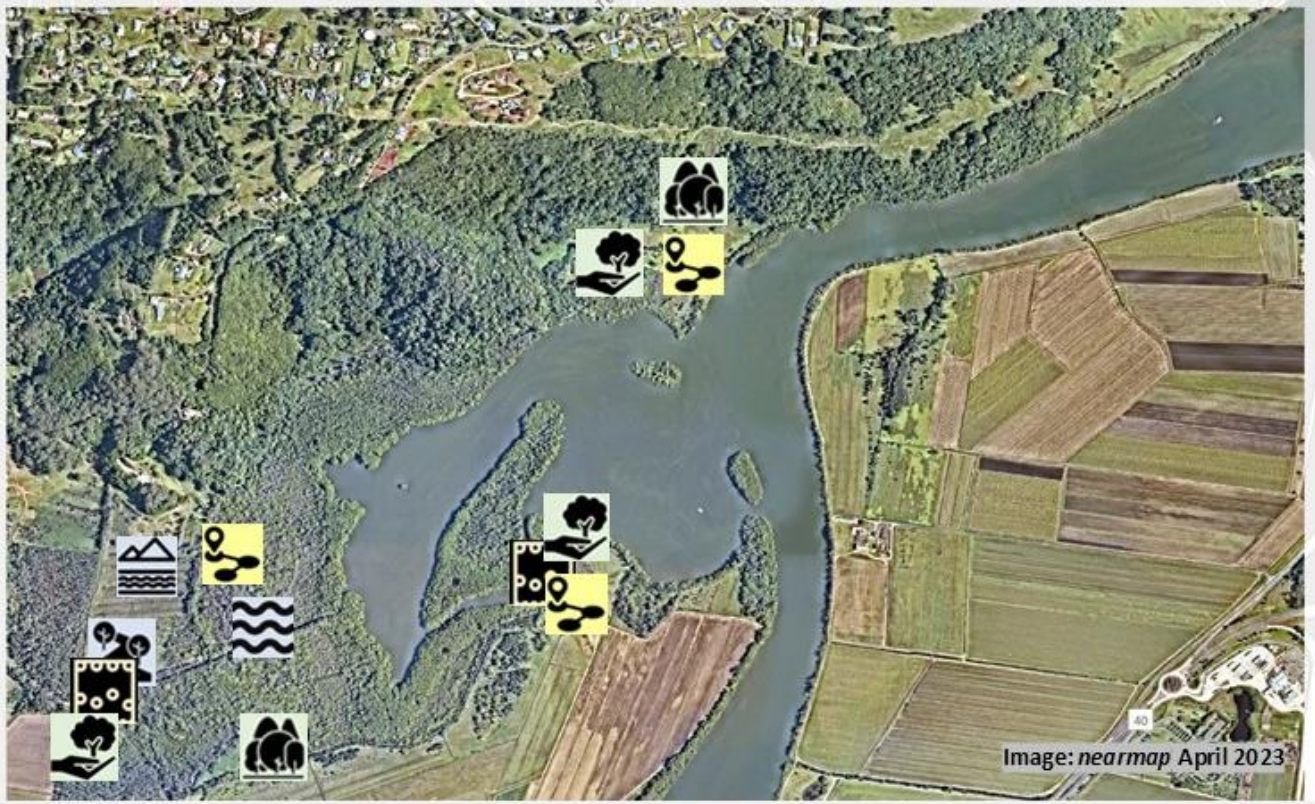


Figure 57 Tweed Hotspot 18: Tweed Broadwater. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 18:

Tweed Broadwater



Restore ground surface elevations by restoring natural sediment supplies impacted by the drain and levee network south and south-west of the Tweed Broadwater. Encourage the growth of intertidal vegetation for biological build of ground surface.

As SLR increases undertake stakeholder liaison regarding raising drain invert levels to increase groundwater levels in farm land to the south-west of Tweed Broadwater to minimise accelerated impacts of saltwater incursion.

Limit accelerated mangrove expansion and incursion of tides into freshwater wetlands south-west of the Tweed Broadwater via drains and ditches to provide a viable upslope SLR migration pathway for freshwater wetlands, saltmarsh and mangroves.

Hydrological assessment to determine impact of SLR on existing agriculture and identify options to reinstate more natural tidal hydrology and connectivity with levee and drainage modifications.

Remove accumulated anthropogenic debris to prevent its burial and lasting impacts north and south of the Tweed Broadwater. Use environmental best management practices to minimise mangrove disturbances during unavoidable infrastructure works such as floodgate maintenance south-west of the Tweed Broadwater.

Create fenced vegetation buffers above the level of the highest astronomic tide and riparian zones around the wetlands north and south of the Tweed Broadwater.

Provide SLR migration pathways north, south and south-west of the Tweed Broadwater. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.

Hydrology

The land surrounding the Tweed Broadwater has been extensively cleared and drained. In some areas salt water incursion may be causing dieback of terrestrial vegetation (Figure 58A). Most drainage infrastructure in the hotspot has compromised functionality with drain invert levels submerged by tidal levels between 50 – 95% of the time, and the expansion of mangroves in some areas is being facilitated by drainage infrastructure (Figure 58B). Given the substantial legacy drainage infrastructure and surrounding land uses, a hydrological assessment and stakeholder liaison is required to identify future management options for intertidal marine vegetation.

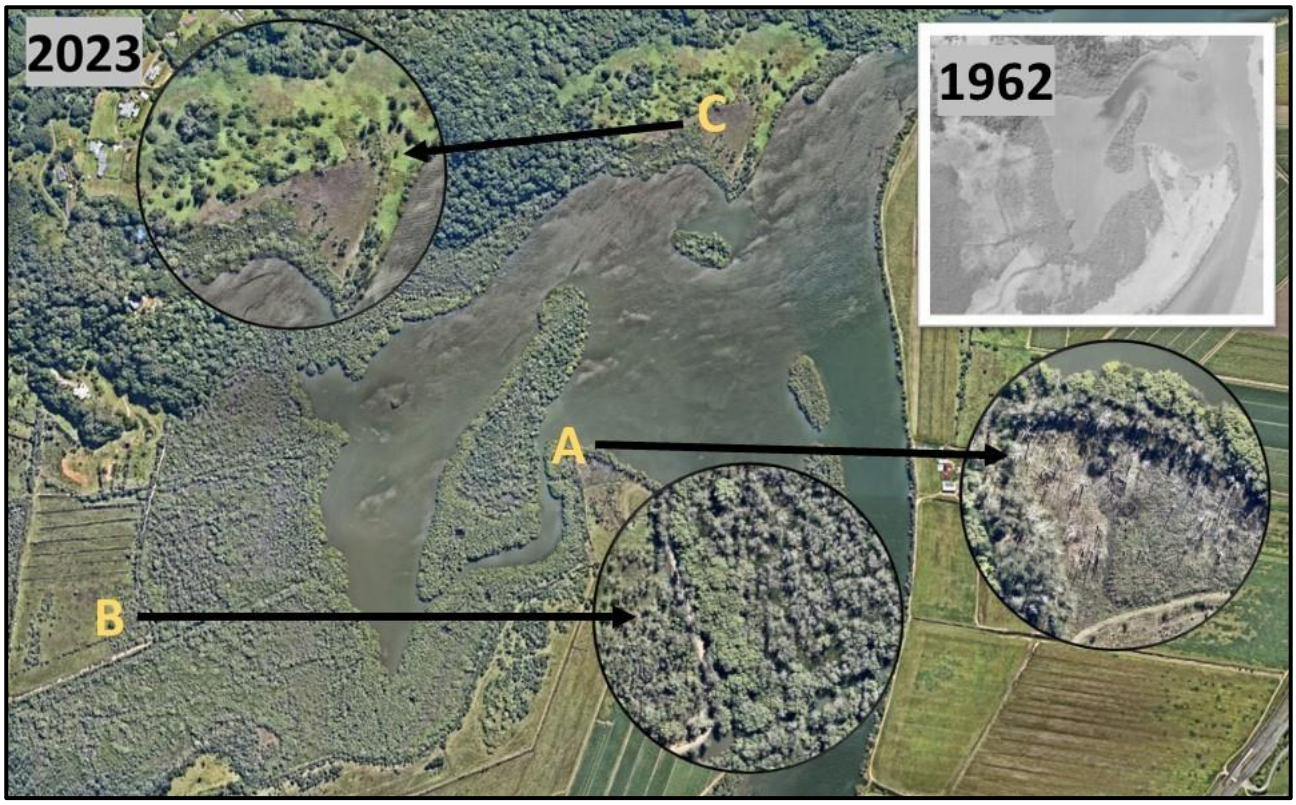


Figure 58 The Tweed Broadwater including morphological changes over time. A, drainage ditches facilitating mangrove encroachment. B, dieback of vegetation due to saltwater incursion. C, saltmarsh habitat. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

To the north of the broadwater intertidal habitats in the future may extend into the open water areas of the Tweed Broadwater and into some areas of the TECs such as Lowland Rainforest. Management actions should concentrate on providing a viable SLR migration pathway for intertidal marine vegetation and minimising accelerated impacts on adjacent habitats. This is consistent with the Tweed River Estuary CMP that identifies the Tweed Broadwater as a high priority to facilitate migration of estuarine vegetation with SLR.

Appropriate management actions may include removing levees to reinstate more natural hydrology, promote overland flows and improve the connectivity of intertidal habitats. The accelerated expansion of mangroves along drainage lines, for example in farm land to the south-west of the Tweed Broadwater, may be managed by infilling or reshaping drains. Drainage modifications can also be used to raise groundwater levels in areas where salt water incursion is causing Coastal Swamp Oak dieback. These actions will help provide a future SLR migration pathway for intertidal marine vegetation.

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. Changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

Sediments

Historical imagery indicates that accumulated sediments have provided expanding intertidal habitats and mangrove vegetation in the Tweed Broadwater (Figure 58). This trend is likely to continue into the future. This natural sedimentation may also allow elevation of the ground surface level providing a vertical SLR migration pathway for intertidal marine vegetation and may limit accelerated impacts on adjacent habitats.

Digital elevation models (Figure 59) indicate that subsidence may have occurred in parts of Hotspot 18 such as the south-west of the Tweed Broadwater. The distribution of the low-lying areas indicate that these areas are lower than the original ground surface level. This is reflected in the current distribution of mangroves that have colonised most of the low-lying areas and evidence of die-back of terrestrial vegetation.

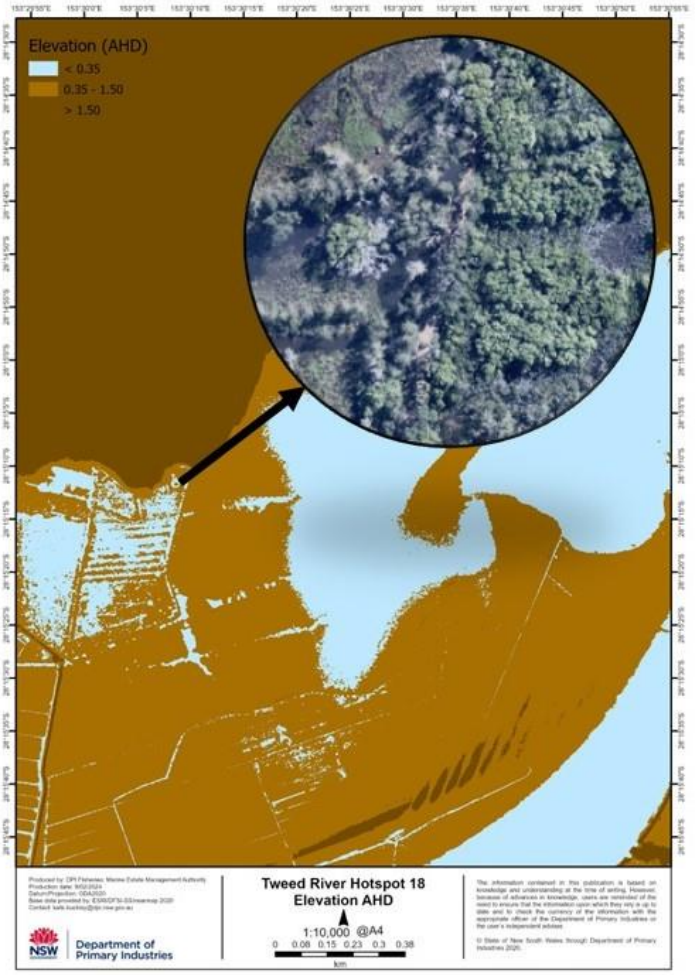


Figure 59 Land subsidence at Tweed Broadwater. Data Source: Elvis (Elevation and Depth - Foundation Spatial Data).

The timing of actions to reinstate tidal flows in these very low areas will be important as the early establishment of mangroves is needed to build ground surface elevation and prevent complete inundation with SLR or the need for the enhancement of ground surface elevation. Restoring sediment supplies impacted by the drain and levee network by reinstating overland flows and restoring degraded intertidal marine vegetation habitats to encourage the growth of root mats will help limit accelerated impacts of SLR on adjacent habitats.

Vegetation

Vegetation buffers should be maintained around the TEC Coastal Saltmarsh in the north and south of the Tweed Broadwater, particularly in the vicinity of agricultural land to the south where this habitat may be particularly vulnerable to anthropogenic impacts. Landowner engagement could be undertaken to explore

options to expand a fenced buffer zone around existing areas of saltmarsh to minimise impacts. This is consistent with the Tweed River Estuary CMP *Fundamental Management Action K2: Provision of buffer zones to facilitate estuary vegetation migration* (TSC 2022).

The extensive intertidal habitats at this hotspot should be conserved to maintain valuable ecosystem services into the long-term. This action is consistent with the proposed Stotts Island Conservation Zone, that would extend from Tweed Broadwater to the upstream end of Stotts Channel (TSC 2022). Disturbances to intertidal marine vegetation throughout the hotspot should be minimised, for example during unavoidable infrastructure works such as floodgate maintenance. In these case environmental best practices should be used to minimise disturbances.

In areas of active sediment accretion and in saltmarsh habitats, accumulated anthropogenic debris should be removed to prevent burial in intertidal habitats, and sources of the debris should be investigated and managed.

People and planning

Investigations undertaken as part of the *Tweed River Floodplain Prioritisation Study* (Tucker et al 2023) show most of the floodgate outlets in this hotspot have compromised functionality with drain invert levels and adjacent estuarine tidal levels combining to effectively limit drainage to between 50 – 95% of the time for most structures and for less than 50% of the time for others. The aerial photographic record indicates that several landholders have shifted from cropping to grazing and have abandoned agricultural endeavours in some of the lowest paddocks. More information can be found in the MEMS Coastal floodplain prioritisation studies.

Management actions to support the resilience of intertidal vegetation at Hotspot 18 will require landowner engagement and cooperation. Hydrological assessments (see *Hydrology*) may identify blue carbon opportunities at these sites as the suitability for agriculture will continue to decline over time. DPIRD investigations at Duck Creek found gross margin for grazing a low coastal floodplain paddock will fall from $1,223 / ha / year in 2020 to $173 / ha / year in 2050 (McGrath 2023).

For example, saltmarsh habitats near cleared private RU2 zoned land to the north of the Broadwater (Figure 58C and 59C) may be at risk of future mangrove incursion. This low-lying area may provide an offset or blue carbon opportunity for the landowner, as a viable saltmarsh migration pathway may occur to the north. Undertaking blue carbon projects in this area would be best achieved by a partnership of landholders to incorporate all areas that face the prospect of future inundation.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

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Hotspot 19: Stotts Island

Stotts Island is a nationally important river island zoned National Parks and Nature Reserves (C1) (Figure 60). It is managed by NSW NPWS in accordance with the *Stotts Island Nature Reserve Plan of Management* (2001). Stotts Island is registered as a critical habitat for the endangered Mitchells Rainforest Snail *Thersites mitchellae.*

Mangrove habitats fringe many parts of Stotts Island in areas zoned Recreational Waterways (W2), and occur on Rawson Island, an area of Crown Land to the west which is zoned Deferred Matter (DM).

Most of the hotspot is on the north-eastern side of the island, where it is concentrated on the TECs (listed under the BC Act) Freshwater Wetlands and Swamp Sclerophyll Forest. The TEC Lowland Rainforest is widespread on Stotts Island and adjacent areas.

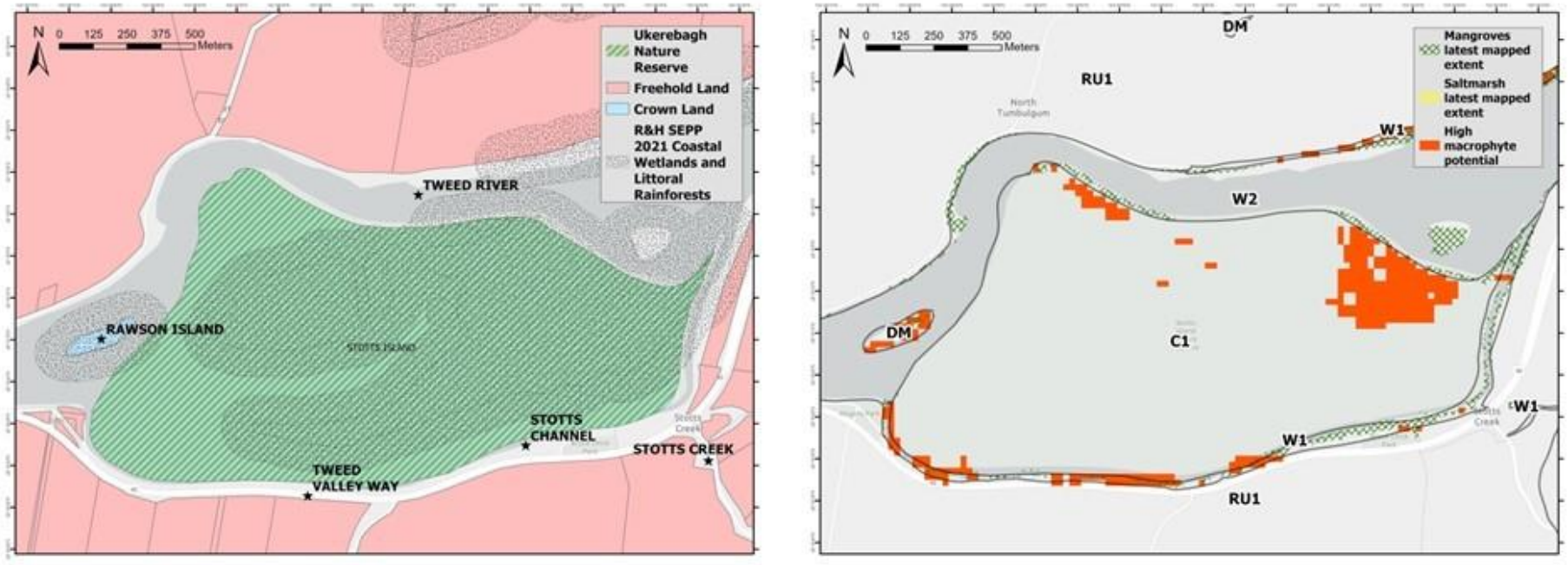
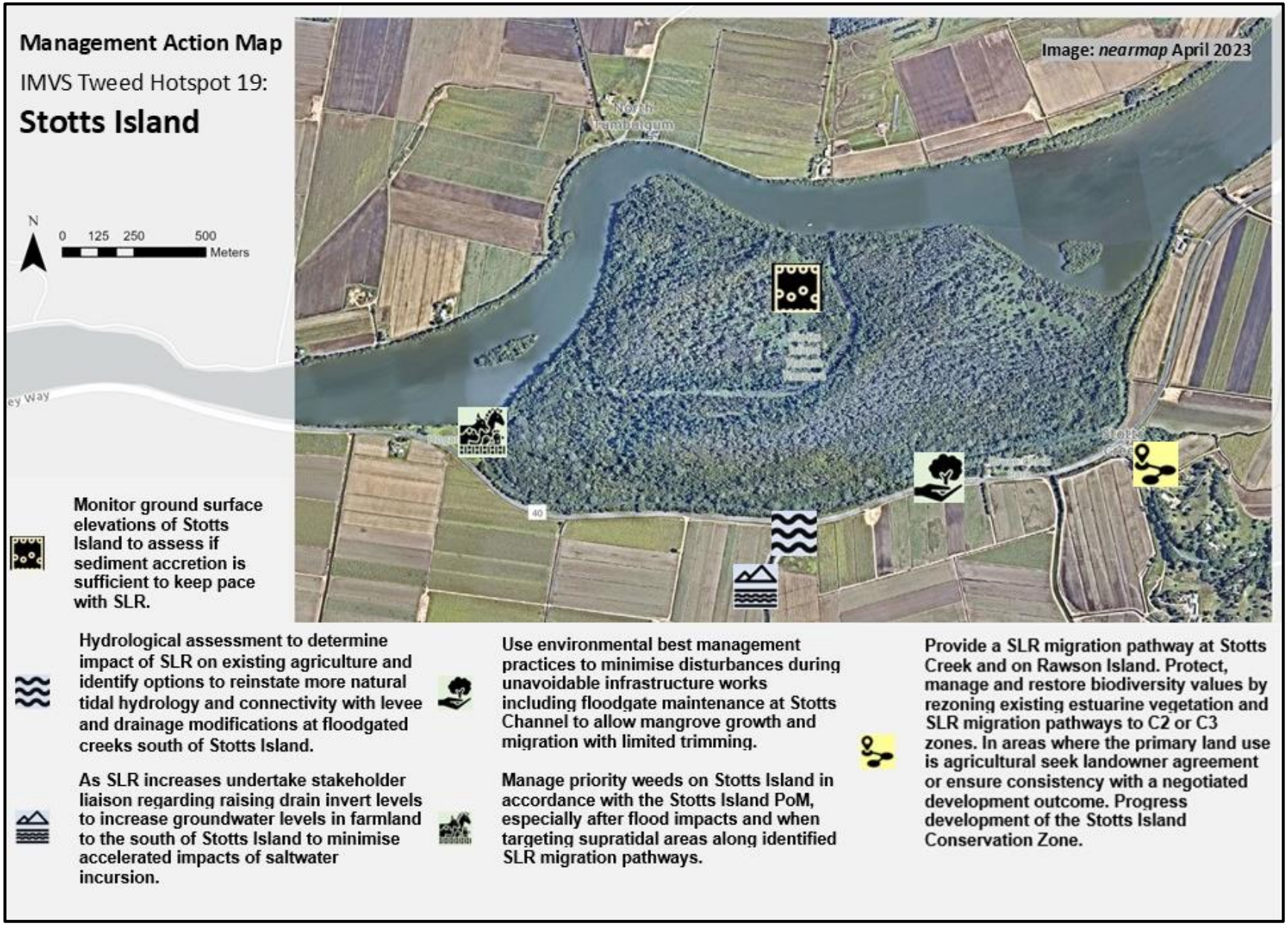


Figure 60 Tweed Hotspot 19: Stotts Island. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 19:

Stotts Island



Monitor ground surface elevations of Stotts Island to assess if sediment accretion is sufficient to keep pace with SLR.

Hydrological assessment to determine impact of SLR on existing agriculture and identify options to reinstate more natural tidal hydrology and connectivity with levee and drainage modifications at floodgated creeks south of Stotts Island.

As SLR increases undertake stakeholder liaison regarding raising drain invert levels to increase groundwater levels in farmland to the south of Stotts Island to minimise accelerated impacts of saltwater incursion.

Use environmental best management practices to minimise disturbances during unavoidable infrastructure works including floodgate maintenance at Stotts Channel to allow mangrove growth and migration with limited trimming.

Manage priority weeds on Stotts Island in accordance with the Stotts Island PoM, especially after flood impacts and when targeting supratidal areas along identified SLR migration pathways.

Provide a SLR migration pathway at Stotts Creek and on Rawson Island. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome. Progress development of the Stotts Island Conservation Zone.

Uncertainties

Hotspot areas on Stotts Island slightly overlap the preferred habitat of Mitchells Rainforest Snail – Broad-leafed Paperbark (Swamp Sclerophyll Forest) and Lowland Rainforest (Williams 2020). However, the hotspot areas occur mainly on the fringes of the island and on Rawson Island where mangrove habitats are already mapped and have not been recorded as habitat for Mitchells Rainforest Snail (Figure 61). In addition, scenarios projecting the available intertidal habitat under 0.5 m SLR do not imply inundation of these habitats (Hughes et al. 2022) (Figure 61). Mangrove incursion may also occur less frequently and more slowly into densely vegetated riverbanks areas than degraded riverbanks with little competing vegetation. It is also less likely to occur where there are few avenues for entry such as failing drainage infrastructure.

It is therefore unlikely that expanding intertidal vegetation habitats will cause substantial issues for this endangered species in the short or medium term. Notably, this conclusion is not consistent with the Tweed River Estuary CMP, that recommends the establishment of an alternative lowland sub-tropical rainforest on the floodplain to offset the potential loss of this vegetation community from Stotts Island (*Fundamental Management Action K3: Identify offsets for Stotts Island vegetation loss).*

Further assessments will therefore be necessary to determine the required management actions to support the migration of habitats with SLR at Stotts Island.

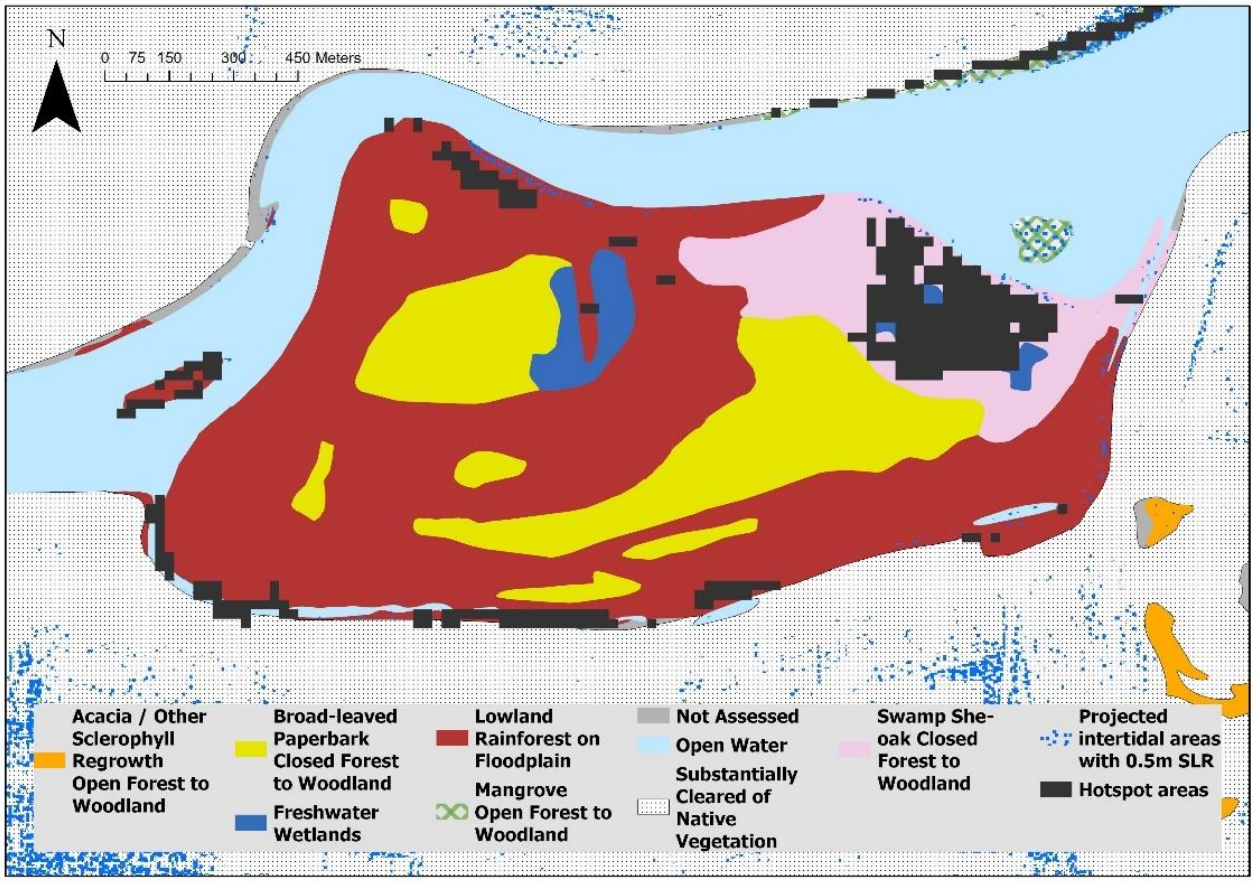


Figure 61 Habitat types, SLR scenarios and hotspot areas on Stotts Island. Data sources: Vegetation, Tweed Shire Council Local Government Area Vegetation Mapping (2009). Projection of future wetlands under 0.5m SLR, Hughes et al. (2022).

Hydrology

Recent modelling undertaken as part of the *Tweed River Floodplain Prioritisation Study* (Tucker et al. 2023) indicates that the farmland to the south of Stotts Island is a moderate to high priority for acid sulphate soil management and high risk areas for blackwater generation. Best practice management by the landholders in this area focuses on rapid removal of standing water before it generates black water, but greater constraints on this management approach occur as sea levels rise. Most drainage infrastructure in this area has compromised functionality with drain invert levels submerged by tidal levels between 50 – 95% of the time.

Some of the floodgates leading into the channel are at moderate to high risk of failure due to SLR in the near future. It was indicated that, in the long term, low-lying areas may develop into estuarine wetlands. More information can be found in the MEMS Coastal floodplain prioritisation studies.

Potential short and long-term management options identified by Tucker et. al (2023) included improving tidal flushing through floodgates, reviewing pumping regimes and raising the invert of drains. These recommended actions are consistent with actions to support the long-term resilience of intertidal vegetation at Hotspot 19. Supported with extensive stakeholder liaison and hydrological assessments to determine the impact of SLR on existing agriculture, options may be identified to reinstate more natural tidal hydrology south of Stotts Island. This may include changes to floodgate management and drainage modifications including raising the invert level of drains and levee modification to improve connectivity while raising groundwater levels. This may help provide a potential SLR migration pathway for intertidal marine vegetation to the south of Stotts Island while minimising the accelerated impacts of salt water incursion.

Sediments

Saltwater incursion has led to some dieback of vegetation that is visible in satellite imagery, and this may be occurring in the TECs Freshwater Wetlands and Swamp Sclerophyll Forest. Facilitating sedimentation, for example by maintaining sediment supplies and restoring degraded intertidal marine vegetation habitats to encourage the growth of root mats, will help sediment accretion. If this occurs at a rate that keeps pace with SLR, it will mitigate accelerated impacts of increased salinity in the adjacent freshwater habitats.

Assessing the capacity of Stotts Island to naturally accrue sediments and maintain elevation relative to SLR by monitoring with RSETs, complimented by ground-truthed LiDAR or satellite remote sensing to detect changes to ecosystem extent, is advised. Management interventions such as the restoration of ground surface elevation or erosion management may become appropriate if the Stotts Island starts to erode or fail to accrete sediment at a rate that keeps pace with SLR, as this may cause accelerated impacts on adjacent TECs such as Freshwater Wetlands and Swamp Sclerophyll Forest.

Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TECs ‘Freshwater Wetlands’ and ‘Swamp Oak Floodplain Forest’, changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

The *Tweed River Bank Erosion Management Plan* (2014) identified that some parts of Stotts Island are actively eroding but that there was no potential for bank armouring. The document also identifies that the reserve should be protected from erosion. This is in contrast to the *Stotts Island Nature Reserve Plan of Management* (2001) that states that, although erosion has probably increased following settlement and land clearing in the Tweed Valley, ‘natural erosion and hydrological processes … (should be) allowed to continue’ and that ‘there is no disturbance to fringing native vegetation’. Decisions surrounding erosion management at this site should consider potential impacts to intertidal habitats.

Vegetation

The *Stotts Island Nature Reserve Plan of Management* (2001) manages weeds of the reserve. Continuation of weed management is important to minimise impacts on intertidal vegetation, prioritising SLR migration pathways particularly after flood events that may introduce weeds into overwash zones. Weeds that impact on mangrove migration are detailed in IMVS: *Weed Management Guide.*

Disturbances to intertidal vegetation should be minimised, for example by using environmental best management practices including avoiding impacts on the canopy vegetation when clearing floodgated drainage outlets at Stotts Channel to allow mangrove growth and migration without trimming.

People and Planning

The public (Crown) land of Rawson Island is zoned DM. A measure to protect or enhance biodiversity values could include rezoning these coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands, and Coastal Saltmarsh to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations*

Report (2015). These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

The Tweed River Estuary CMP proposes a Stotts Island Conservation Zone, extending from the Tweed Broadwater to the upstream end of Stotts Channel. This recommendation is complementary to the recommendations of the IMVS. To facilitate public awareness and education about the ecological and cultural values of mangrove and saltmarsh habitats while managing public access, boardwalks or self-guided canoe trails could be used in this area. This action is consistent with the Tweed River Estuary CMP *Fundamental Management Action B4: Provide additional nature-based educational opportunities including signage and information at the proposed Stotts Island Conservation Zone* (TSC 2022).

Management actions to support the resilience of intertidal vegetation at Hotspot 19 will require landowner engagement and cooperation. Hydrological assessments (see Hydrology) may identify blue carbon opportunities at sites south of Stotts Island as the suitability for agriculture will continue to decline over time. DPIRD investigations at Duck Creek found gross margin for grazing a low coastal floodplain paddock will fall from $1,223 / ha / year in 2020 to $173 / ha / year in 2050 (McGrath 2023). There are significant advantages to undertaking a blue carbon project on an island as the project would have limited to no impact on neighbours and be a land use more resilient to sea level rise and flooding.

For example, low-lying land to the south of Stotts Island and riparian areas along Stotts Creek near cleared private RU1 zoned may be at risk of future mangrove incursion. This low-lying area was identified as a potential blue carbon opportunity for landowners in the NSW Blue Carbon Strategy. Undertaking blue carbon projects in this area would be best achieved by a partnership of landholders to incorporate all areas that face the prospect of future inundation. In areas where the primary land use is agricultural, rezoning may also occur at the request of the landowner, or if it is consistent with a negotiated development outcome.

Hotspot 20: Rous River, North Tumbulgum

Hotspot 20 is in an agricultural landscape on the Rous River with significant legacy drainage infrastructure and existing areas of mangroves (Figure 62).

Most of the intertidal vegetation and hotspot areas occur in areas zoned Deferred Matter (DM) or Natural Waterways (W1), including an embayment off the Rous River channel, a semi-enclosed lagoon, and the Rous River channel near its confluence with the Tweed River. To the north, a part of the hotspot is zoned Private Recreation (RE1).

TECs (listed under the BC Act) that may be present near hotspot areas include Lowland Rainforest and Swamp Sclerophyll Forest.

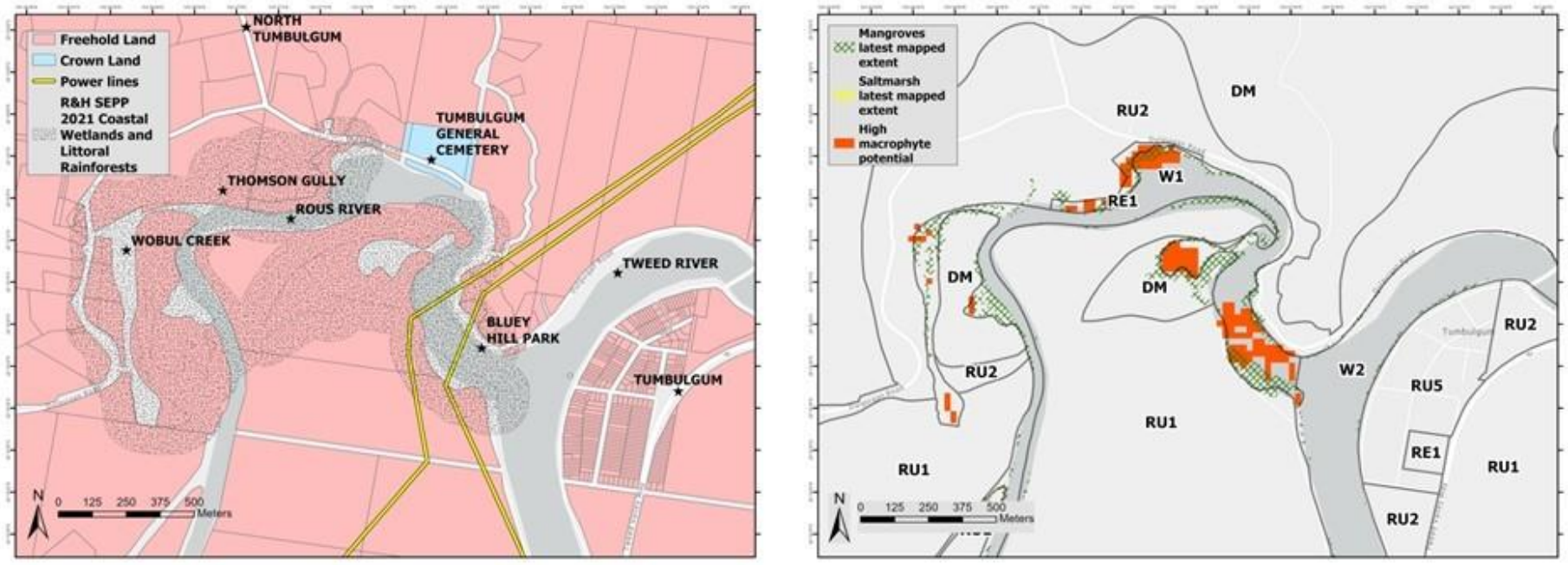
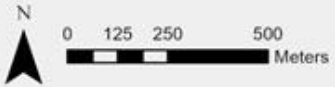


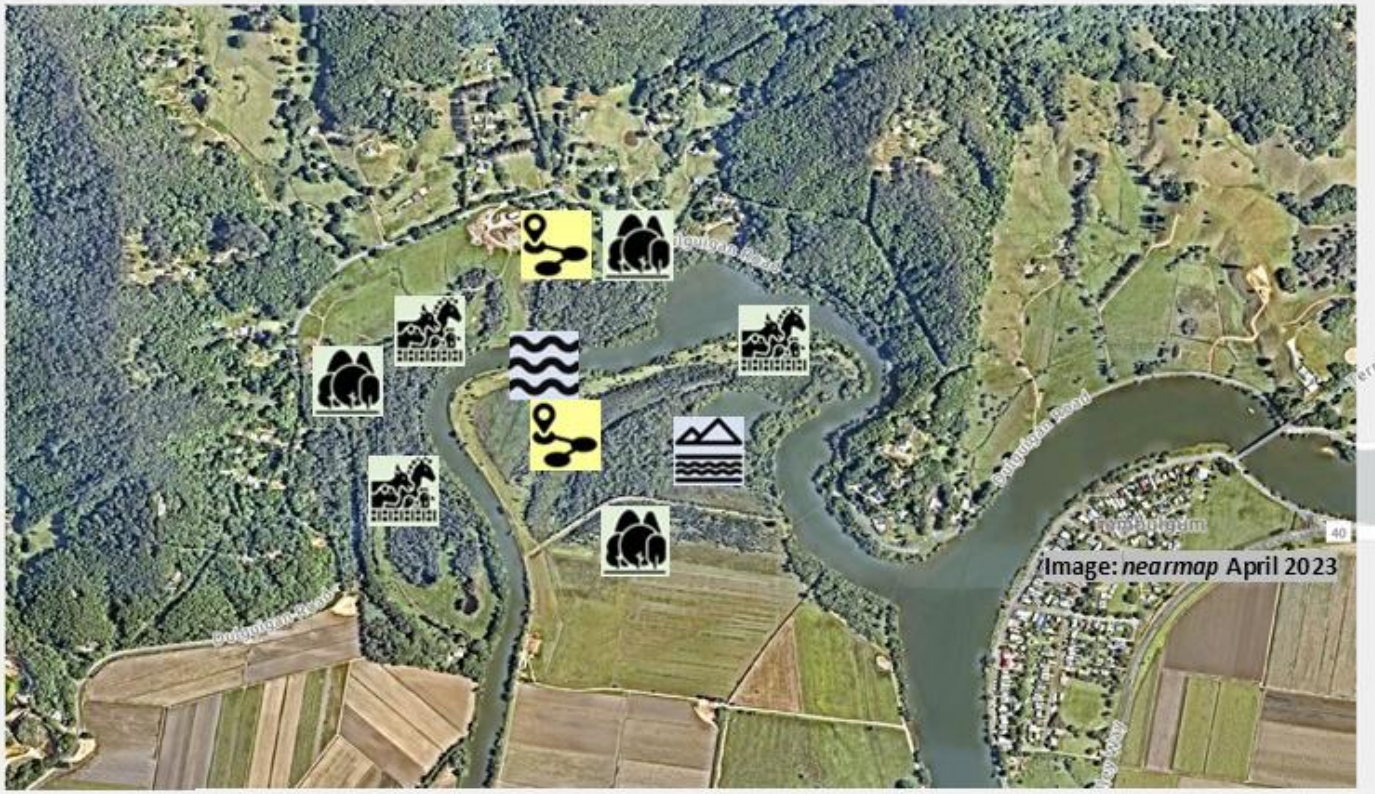
Figure 62 Tweed Hotspot 20: Rous River, North Tumbulgum. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 20:

Rous River, North Tumbulgum





Hydrological assessment to determine options to reinstate more natural floodplain hydrology and tidal connectivity with levee and drainage infrastructure and management modifications on the right bank of the Rous River.

Investigate the legacy drainage network on the right bank of the Rous River to determine impacts on hydrology and identify options to reduce the extent of drainage and facilitate overland tidal flows.

Create fenced vegetation buffers above the level of the highest astronomic tide and riparian zones along the left and right banks of the Rous River, Thomson Gully and Wobul Creek.

Manage feral herbivores and priority weeds targeting supratidal areas along identified SLR migration pathways including the left and right banks of the Rous River and Wobul Creek.

Provide SLR migration pathways at Wobul Creek, Thomson Gully and the right bank of the Rous River. Protect, manage and restore biodiversity values by rezoning existing estuarine vegetation and SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.

Hydrology

A historical expansion of mangroves into the embayment to the north of Hotspot 20 is evident from historical imagery (Figure 63A) and is likely to continue into the future. Salt water incursion inland of the embayment is causing dieback of adjacent terrestrial habitats and is likely to impact Lowland Rainforest in the future (Figure 63, inset). Dynamic changes to vegetation types such as this are expected as part of an ongoing response to SLR. As identified in the NSW Scientific Committee final determination for the TEC 'Swamp Sclerophyll Forest, changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

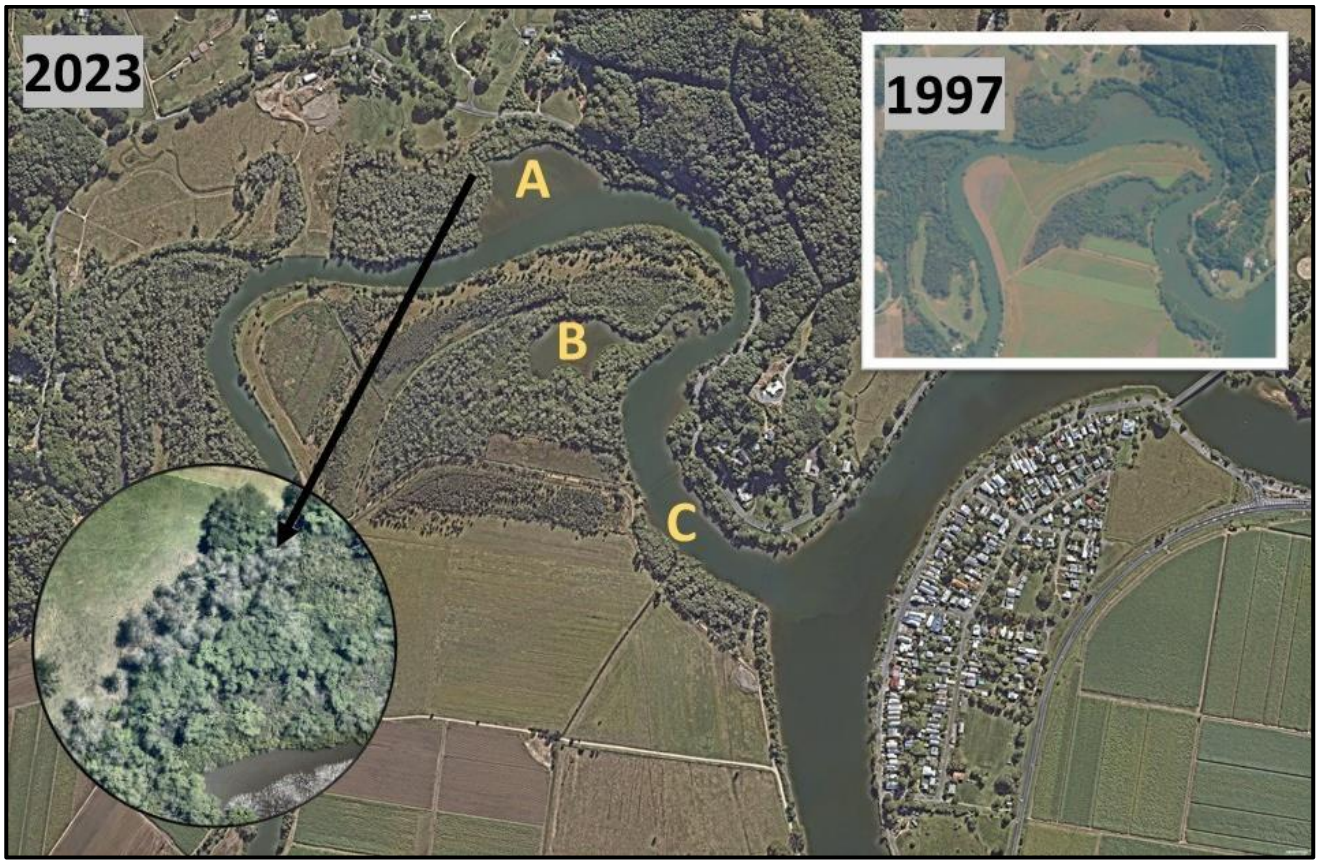


Figure 63 Rous River, North Tumbulgum including land use changes over time. A, embayment in the north. B, semi-enclosed lagoon. C, Rous River channel near confluence with the Tweed River. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

Legacy drainage infrastructure, including drains and potentially levees, is impacting mangrove habitats near the semi-enclosed lagoon on the right bank of the Rous River (Figure 63B). To the south, mangroves are expanding along drainage ditches and to the north connectivity to adjacent habitats is truncated. A hydrological investigation of legacy drainage structures is recommended for this site to identify actions that could reinstate a more natural hydrology such as reinstating overland flows, infilling or reshaping drains and raising groundwater levels. This may mitigate artificially accelerated mangrove expansion and provide viable SLR migration pathways for both intertidal vegetation and adjacent upslope habitats while protecting adjacent land uses.

Management recommendations for the management of acid sulphate soil and blackwater generation at farmland adjacent to parts of Hotspot 20 (e.g., near Figure 63B and 63C) (see Tucker et al. 2023) are consistent with the recommended actions that may support the long-term resilience of intertidal vegetation at this site. They include improving tidal flushing by reviewing pumping regimes, modifying or removing drains and drainage infrastructure to reinstate natural tidal hydrology and raise groundwater levels. It is also

recommended to continue controlled tidal flushing through floodgate Structure 205 (which is located near intertidal habitats at Figure 63C).

Vegetation

The Rous River Hotspot is dominated by an agricultural landscape, and management of impacts is necessary to improve the resilience of intertidal vegetation to ongoing stressors. Actions can include minimising disturbances to riparian or intertidal vegetation through creating fenced native vegetation buffers around intertidal vegetation and waterways (particularly where this is adjacent to agricultural land). Sites could include the left and right banks of the Rous River, Thomson Gully and Wobul Creek. Concurrent management of feral herbivores and weeds is important to minimise impacts on intertidal vegetation, prioritising SLR migration pathways. Weeds that impact on saltmarsh and mangrove migration are detailed in IMVS: *Weed Management Guide.* These actions will largely need to be undertaken on an ongoing basis with the co-operation of landowners.

People and Planning

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP, existing riparian and estuarine vegetation and wetlands to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. For example, rezoning of the RE1 area landward of the embayment in the north of this site (Figure 63A), incorporating areas of Swamp Oak Floodplain Forest and Lowland Rainforest, and rezoning the DM areas along Wobul Creek and Thomson Gully, may provide protections to these viable migration pathways.

These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values. The recommended actions for Hotspot 20 are also consistent with the Tweed River Estuary CMP, which identifies this area as a high priority to facilitate migration of estuarine vegetation with SLR.

Investigations undertaken as part of the *Tweed River Floodplain Prioritisation Study* (Tucker et al. 2023) show most of the floodgate outlets in this hotspot have increasingly compromised functionality with drain invert levels and adjacent estuarine tidal levels combining to effectively limit drainage to between 50 – 95% of the time for most structures and for less than 50% of the time for others. The aerial photographic record indicates that several paddocks have shifted from cropping during the 1990s to grazing and are now dominated by wetland vegetation in some of the lowest paddocks. More information can be found in the MEMS Coastal floodplain prioritisation studies.

Hydrological assessments (see Hydrology) may identify blue carbon opportunities at sites in this hotspot as the suitability for agriculture will continue to decline over time. For example, the previously sugarcane farmland adjacent to the semi-enclosed lagoon (Figure 63B) in this area is slowly reverting to more natural bushland and may provide the landowner an opportunity as an offset area or to generate blue carbon. DPIRD investigations at Duck Creek found gross margin for grazing a low coastal floodplain paddock will fall from $1,223 / ha / year in 2020 to $173 / ha / year in 2050 (McGrath 2023). Stakeholder engagement will be crucial, but in the long-term low-lying agricultural land in this area may transition to intertidal wetlands.

Hotspot 21: Noble Lake

Hotspot 21 is a uniquely anthropogenically generated site in the Tweed River estuary study area, being centred on a former sand extraction pit. It is an interesting case study for innovative thinking about ecosystem adaptation in a changing environment.

The hotspot encompasses a low-lying area to the north of the constructed Noble Lake, and it has no mapped intertidal vegetation (Figure 64). Noble Lake is a freshwater habitat; and the farmland to the north may have substantial areas of the TECs (listed under the BC Act) including Swamp Sclerophyll Forest, Littoral Rainforest and Lowland Rainforest.

The area to the north of Noble Lake is zoned Deferred Matter (DM), along with a strip of land providing connectivity to the Tweed River. These DM areas encompass almost all of the hotspot areas.

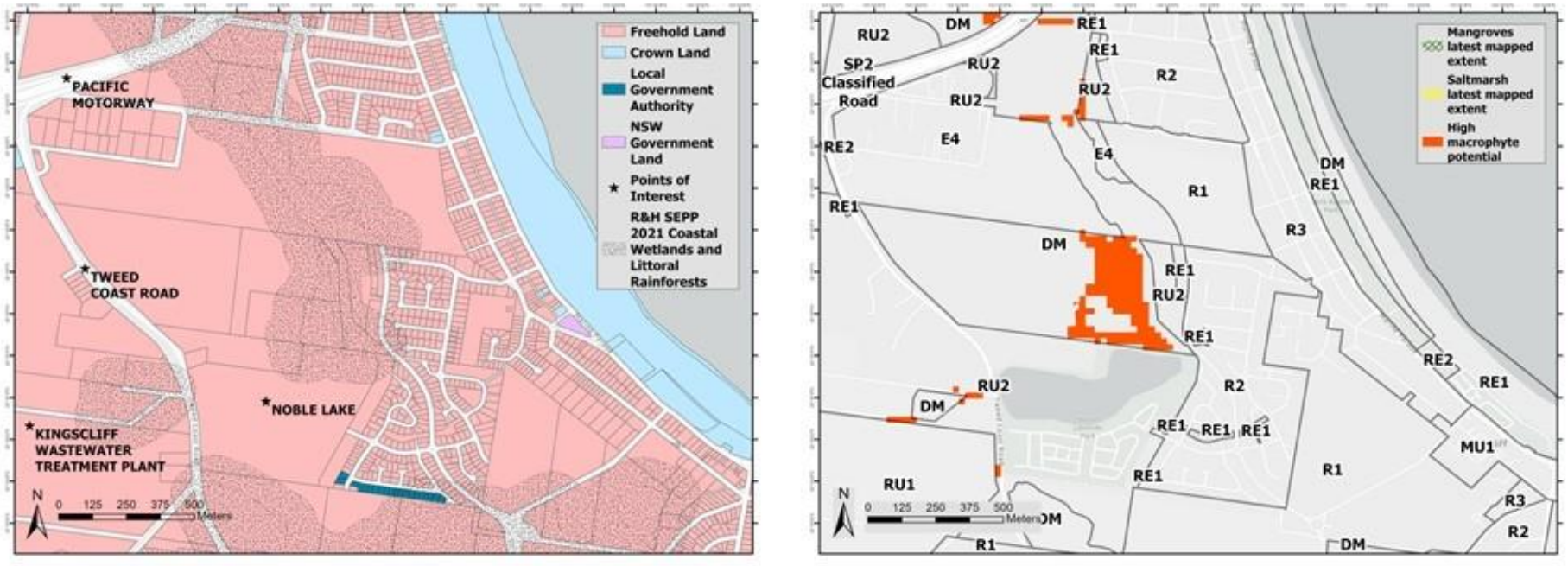


Figure 64 Tweed Hotspot 21: Noble Lake. Current tenures and mapped coastal wetlands and littoral rainforests (left), areas of high macrophyte potential, latest mapped extent of saltmarsh and mangroves and land zoning (right). Data sources: NSW Department of Planning, Housing and Infrastructure and NSW Department of Primary Industries and Regional Development.

Management Action Map

IMVS Tweed Hotspot 21:

Noble Lake

Hydrological assessment to determine options to reinstate more natural floodplain hydrology and possible tidal connectivity with levee and drainage infrastructure and management modifications including floodgate management.

Investigate options to raise groundwater levels and facilitate overland flows in floodplain areas north of Noble Lake and adjacent to the drainage channel with drainage modifications.

Provide a SLR migration pathway at the floodplain north of Noble Lake. Protect, manage and restore biodiversity values by rezoning SLR migration pathways to C2 or C3 zones. In areas where the primary land use is agricultural seek landowner agreement or ensure consistency with a negotiated development outcome.

Hydrology

The drainage infrastructure at Hotspot 21 reflects the quaternary paleochannels, revealing the original hydrological connectivity of the Noble Lake area with the Tweed River (Figure 65).

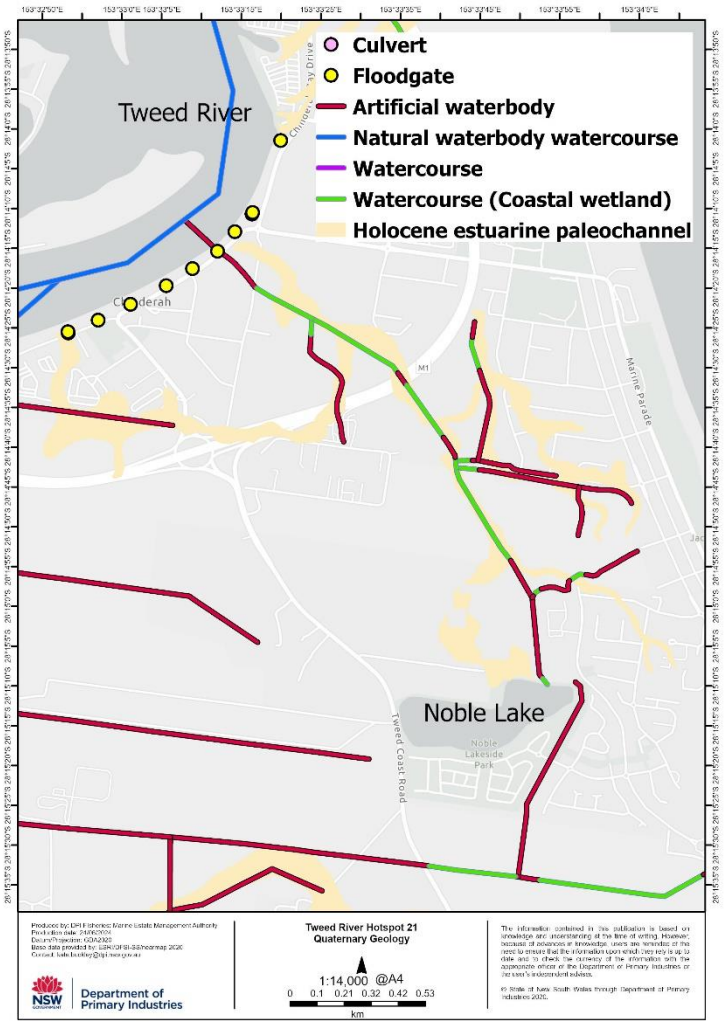


Figure 65 Quaternary geology and current drainage infrastructure in the Noble Lake area. Data sources: Drainage infrastructure: MEMS Coastal floodplain prioritisation studies. Quaternary geology: DIGS Geological Survey of NSW.

Although the area is relatively remote from the main waterway, the potential for connectivity to estuarine habitats through the Tweed River floodplain and farmland to the north is significant. Connectivity currently occurs via a drainage channel which travels through a very low-lying agricultural landscape. The floodgated drain is often manually opened to facilitate tidal flushing and mullet and other estuarine fish regularly occur in the channel.

Historical imagery (Figure 66) shows that the natural hydrology of the Noble Lake area was impacted substantially with clearing and drainage for agriculture, and more substantially when the site was mined for sand.

Management actions could facilitate a migration pathway for intertidal vegetation along the paleochannels with hydrological modifications including raising groundwater levels, allowing overland flows and supporting habitat connectivity via infrastructure modification and management. At the drain entrance (Figure 67 inset) sufficient vacant land is present within Infrastructure (SP2), Mixed Use (MU1) and Low Density Residential (R2) zoned areas to improve connectivity by widening the drain.

Figure 66 Noble Lake and surrounds including land use changes over time. A, Noble Lake. B, low-lying agricultural landscape. Images: *Nearmap* (base) and NSW Government Spatial Services (inset).

The footprint of the potential SLR migration pathway for intertidal vegetation is within the area identified as Ecologically Significant in the Tweed Shire Council's *Kingscliff Locality Plan*. Pursuing hydrological modifications may cause dynamic changes to TECs including Lowland Rainforest and Swamp Sclerophyll Forest habitats (Figure 66B). As identified in the NSW Scientific Committee final determinations for the TEC 'Swamp Sclerophyll Forest', changes to vegetation types should be monitored and managed appropriately with co-ordinated planning and management approaches to address and resolve priorities between management objectives (resilience of intertidal vegetation versus minimising possible direct impacts on threatened ecological communities). Further information can be found in the document IMVS: *Integrated landscape and seascape conservation*.

People and Planning

The tenures and land zoning to the north through which Hotspot 21 could connect to intertidal habitats is complex (Figure 67). Nevertheless, there is a unique opportunity to provide a significant intertidal SLR migration pathway with governance and policy tools at this hotspot.

Figure 67 Zoning and potential intertidal vegetation migration pathway at the Noble Lake. Images: *Nearmap* (inset). Data sources: NSW Department of Planning, Housing and Infrastructure (Environmental Planning Instrument - Land Zoning).

Although the multiple holdings within the area are privately owned, most of the potential connectivity and hotspot areas occur on land zoned as DM (Figure 67). The Tweed Shire Council's *Kingscliff Locality Plan* also identifies this drainage line as important for ecological connectivity and recommends that appropriate land use zoning be used to protect environmental values in this area.

A measure to protect or enhance biodiversity values could include rezoning coastal wetlands mapped in the R&H SEPP to C2 (Environmental Conservation) or C3 (Environmental Management) zones in accordance with the DPE *Northern Councils E Zone Review Final Recommendations Report* (2015). Where SLR migration pathways are identified outside these habitats, opportunities to rezone these areas to C2 or C3 should also be investigated. In areas where the primary land use is agricultural, this rezoning may occur at the request of the landowner, or if it is consistent with a negotiated development outcome. These actions may provide additional protections to potential SLR migration pathways and are consistent with the medium priority action in the Tweed River Estuary CMP (TSC 2022) to '*Review LEP zoning to incorporate areas for estuary vegetation migration*'. The rezoning stage is a key opportunity to set habitat, SLR migration and environmental buffers that can be managed to sustain and re-establish environmental values.

5. Conclusions

The identification of sites with high potential for saltmarsh and mangrove systems now and into the future alongside identification of priority threats and risks to ecosystem services and values forms a strong foundation for long term planning. The TARA (Fletcher and Fisk 2017) provides an opportunity to develop clear adaptive management strategies to safeguard ecosystem services and values provided by intertidal marine vegetation.

Without appropriate management actions to improve their resilience, saltmarsh and mangroves will continue to be heavily impacted by mechanical damage, pollution, climate change, modified hydrology, coastal squeeze and erosion. In addition, cumulative or synergistic stressors, temporal lags between activities and impacts, and spatial spill over of impacts from remote activities can exacerbate these impacts. The risk of reversing saltmarsh and mangrove ecosystem services to disservices strengthens the need to improve their resilience to priority threats and risks.

This document summarises multiple opportunities for appropriate management actions in the Tweed River estuary to improve intertidal vegetation resilience, using effective interventions that are targeted to local conditions. These management actions focus on ecosystem characteristics that build resilience in saltmarsh and mangroves, including natural tidal hydrology and connectivity, adequate sediment supplies, natural processes such as recruitment and nutrient cycling, and the ability to migrate in response to climate change. The IMVS may be incorporated into a co-ordinated catchment-scale management plan that includes existing coastal floodplain and infrastructure management.

These management actions form a portfolio of possible options based on site-specific conditions and available information at the time of writing. They can be delivered with suitable partnership and funding opportunities such as those identified in the IMVS: *Key approaches to mitigate risk and support adaptation.*

Where options identified in this IMVS are recognised in a certified Coastal Management Program the regulatory approval burden for the environmental protection works is reduced, although the need for detailed assessment remains. This will ensure that works are undertaken in ways that deliver the improved resilience of intertidal marine vegetation.

The IMVS are reliant on cooperative stewardship to address ongoing coastal management challenges in the jurisdictionally complex coastal zone. The evolution of wise floodplain management is challenging but necessary to allow the persist provision of ecosystem services and to prevent ongoing disservices (White et al. 2007).

More detailed information on each recommended strategy to improve the resilience of saltmarsh and mangroves habitats can be found in the document IMVS: *Key approaches to mitigate risk and support adaptation.* Ultimately, these documents will provide cohesive and meaningful management strategies that ensure that saltmarsh and mangroves in NSW continue to provide ecosystem services and their numerous economic, cultural and social benefits into the future.

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Appendix 1: Land Zoning Definitions.

Table 3 Land zones under the Tweed Local Environmental Plan 2014.

Zone	Definition
E1	Local Centre
E2	Commercial Centre
E3	Productivity Support
E4	General Industrial
MU1	Mixed Use
C1	National Parks and Nature Reserves
C2	Environmental Conservation
C3	Environmental Management
DM	Deferred Matter
R1	General Residential
R2	Low Density Residential
R3	Medium Density Residential
R5	Large Lot Residential
RE1	Public Recreation
RE2	Private Recreation
RU1	Primary Production
RU2	Rural Landscape
RU5	Village
SP1	Special Activities
SP2	Infrastructure
SP3	Tourist
W1	Natural Waterways
W2	Recreational Waterways
W3	Working Waterways
W4	Working Waterfront

Appendix 2: Key Threatening Processes.

Table 4 Key Threatening Processes that impact Mangrove and Saltmarsh Ecosystems in New South Wales.

Key Threatening Process	Legislation	Impacts on saltmarsh and mangroves	Directly or indirectly addressed under the IMVS
Predation, habitat degradation, competition and disease transmission by Feral Pigs, Sus scrofa Linnaeus 1758	BC Act 2016	Although not commonly cited in the Australian literature, Feral Pigs in both saltmarsh and mangrove habitats are known to be a major problem by trampling, rooting and wallowing in intertidal areas.	Directly addressed by actions to control feral animals in saltmarsh and mangrove habitats, buffers and migration pathways.
Invasion, establishment and spread of Lantana (*Lantana camara L. sens. Lat*)	BC Act 2016	Although not generally seen as a threat due to salinity intolerance, *Lantana* is often found on the fringes of saltmarsh and mangroves and may sometimes be found within these habitats. The Moreton Bay Ramsar Wetlands include areas of saltmarsh understory with a *Melaleuca* and *Casuarina* canopy. Weeds including Asparagus Fern, *Lantana*, and Pepper Trees have killed some areas of saltmarsh.	Directly addressed by actions to remove priority weeds from saltmarsh and mangrove habitats and migration pathways.
Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants	BC Act 2016	Bitou Bush, Pampas Grass, and *Lantana* are included in this category.	Directly addressed by actions to remove priority weeds from saltmarsh and mangrove habitats and migration pathways.
Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands	BC Act 2016	Causes direct impacts to mangrove and saltmarsh habitats by altering natural hydrology.	Directly addressed by actions to restore natural hydrology.
Invasion of native plant communities by bitou bush & boneseed	BC Act 2016	Coastal saltmarsh identifies that both Bitou Bush and Boneseed show a level of salt tolerance and are invasive weeds that have been found on brackish saltmarsh margins.	Directly addressed by actions to remove priority weeds from saltmarsh and mangrove habitats and migration pathways.
Invasion and establishment of exotic vines and scramblers	BC Act 2016	Invasion and establishment of exotic vines and scramblers impacts Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions.	Directly addressed by actions to remove priority weeds from saltmarsh and mangrove habitats and migration pathways.

Key Threatening Process	Legislation	Impacts on saltmarsh and mangroves	Directly or indirectly addressed under the IMVS
Invasion of native plant communities by exotic perennial grasses	BC Act 2016	Pampas Grass readily tolerates saline conditions, salt spray, drought and periodic inundation. Known to invade saltmarsh habitats and is an aggressive coloniser. Can form dense stands which prevent other plants from growing.	Directly addressed by actions to remove priority weeds from saltmarsh and mangrove habitats and migration pathways.
Clearing of native vegetation	BC Act 2016	Reduces extent of mangrove and saltmarsh habitats.	Directly addressed by actions to protect and restore existing areas of saltmarsh and mangrove habitats and migration pathways.
Human-caused Climate Change	BC Act 2016	Reduces resilience of mangrove and saltmarsh habitats with SLR and other cumulative or synergistic stressors.	Directly addressed by actions to provide migration pathways for saltmarsh and mangroves.
Ecological consequences of high frequency fires	BC Act 2016	Reduces resilience of mangrove and saltmarsh habitats by causing damage and dieback or mortality.	Indirectly addressed by actions to restore natural hydrology by increasing the hydro-period in coastal wetlands, making sites wetter and less vulnerable to fire.
Entanglement in, or ingestion of anthropogenic debris in marine and estuarine environments (by vertebrate species)	BC Act 2016	Reduces resilience of mangrove and saltmarsh habitats by contamination, smothering of habitat and impacts on flows and sedimentation.	Indirectly addressed by actions to remove accumulated dumped rubbish and flood debris from intertidal habitats.
Removal of dead wood and dead trees	BC Act 2016	The accumulation of natural debris encourages sediment accumulation and can facilitate the ability of mangrove and saltmarsh habitats to keep pace with SLR via vertical accretion.	Indirectly addressed by actions to encourage sediment accretion in intertidal habitats.
Novel biota and their impact on biodiversity	EPBC Act 1999	Includes vertebrate pests, invertebrate pests, terrestrial weeds, aquatic weeds and algae pests, marine pests and pathogens. The novel biota key threatening process encompasses those invasive taxa which are separately listed as KTPs under the EPBC Act, as well as other novel biota that are already established in Australia and species with the potential to become invasive in the future.	Directly addressed by actions to remove priority weeds and control feral animals in saltmarsh and mangrove habitats and migration pathways.
Land clearance	EPBC Act 1999	Reduces extent of mangrove and saltmarsh habitats.	Directly addressed by actions to protect and restore existing areas of saltmarsh and mangrove habitats and migration pathways.

Key Threatening Process	Legislation	Impacts on saltmarsh and mangroves	Directly or indirectly addressed under the IMVS
Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases	EPBC Act 1999	Reduces resilience of mangrove and saltmarsh habitats with SLR and other cumulative or synergistic stressors.	Directly addressed by actions to provide migration pathways for saltmarsh and mangroves.
Fire regimes that cause declines in biodiversity	EPBC Act 1999	Reduces resilience of mangrove and saltmarsh habitats by causing damage and dieback or mortality.	Indirectly addressed by actions to restore natural hydrology by increasing the hydro-period in coastal wetlands, making sites wetter and less vulnerable to fire.
Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris	EPBC Act 1999	Reduces resilience of mangrove and saltmarsh habitats by contamination, smothering of habitat and impacts on flows and sedimentation.	Indirectly addressed by actions to remove accumulated dumped rubbish and flood debris from intertidal habitats.
Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams	FM Act 1994	Causes impacts to mangrove and saltmarsh habitats by altering natural hydrology.	Directly addressed by actions to restore natural hydrology.
Degradation of native riparian vegetation along New South Wales water courses	FM Act 1994	Reduces resilience of mangrove and saltmarsh habitats by causing damage and dieback or mortality and reduces the ability of these ecosystems to provide ecosystem services such as water filtration, habitat provision and protection from coastal erosion.	Directly addressed by actions to protect and restore existing areas of saltmarsh and mangrove habitats and migration pathways.
Human-caused Climate Change	FM Act 1994	Reduces resilience of mangrove and saltmarsh habitats with SLR and other cumulative or synergistic stressors.	Directly addressed by actions to provide migration pathways for saltmarsh and mangroves.
Removal of large woody debris from New South Wales rivers and streams	FM Act 1994	The accumulation of natural debris encourages sediment accumulation and can facilitate the ability of mangrove and saltmarsh habitats to keep pace with SLR via vertical accretion.	Indirectly addressed by actions to encourage sediment accretion in saltmarsh and mangroves.

Appendix 3: Threatened Ecological Communities

Table 5 Threatened Ecological Communities that may be impacted by management of intertidal vegetation in the Tweed River estuary study area. Sources: NSW Scientific Committee - final determination (BC Act)[1]; Department of Climate Change, Energy, the Environment and Water SPRAT Species Profiles or Approved Conservation Advice (EPBC Act)[2].

Threatened Ecological Community	Status	Legislation	Threats relevant to management of intertidal vegetation	Potential for direct or indirect impacts from actions under the IMVS
Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered Ecological Community	BC Act 2016	Comprises intertidal vegetation and as such targeted by actions under the IMVS.	Direct impacts on saltmarsh are targeted with actions to restore natural hydrology and sediments, protect and restore existing habitats, and provision of migration pathways.
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered Ecological Community	BC Act 2016	Given the dynamic hydrological relationship between Freshwater Wetlands on Coastal Floodplains, Coastal Saltmarsh and other Endangered Ecological Communities on coastal floodplains, future management of water and tidal flows may result in the expansion of some communities at the expense of others. Proposals for the restoration of natural hydrological regimes and for the rehabilitation of acid sulfate soils may also result in changes to the distribution and composition of floodplain communities. Co-ordinated planning and management approaches across whole catchments will be required to address and resolve priorities between different management objectives[1].	Direct impacts may occur from actions to restore natural hydrology and sediments, protect and restore existing habitats, and provision of migration pathways as per the NSW Scientific Committee final determination.
Littoral Rainforest in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered Ecological Community	BC Act 2016	Threats include weed invasion; loss of canopy integrity from salt and wind damage as a result of clearing or damage to stand margins; fire, particularly fire incursion along boundaries; habitat fragmentation and loss of connectivity[1].	Indirect impacts may occur from actions to restore natural hydrology and sediments by reducing fire risk with increased moisture levels and protecting margins from disturbances. Provision of migration pathways may indirectly impact connectivity positively or negatively. Indirect impacts may occur by protection and restoration of intertidal habitats and migration pathways by protecting margins,

Threatened Ecological Community	Status	Legislation	Threats relevant to management of intertidal vegetation	Potential for direct or indirect impacts from actions under the IMVS
				reducing salt and wind damage and reducing priority weeds.
Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions	Endangered Ecological Community	BC Act 2016	May occur in conjunction with 'Lowland Rainforest on Floodplain of the NSW North Coast Bioregion' and 'Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions'. Threats include weed invasion; habitat fragmentation and loss of connectivity; high frequency fire; grazing by livestock; and potential impacts of anthropogenic climate change[1].	Indirect impacts may occur from actions to restore natural hydrology and sediments by reducing fire risk with increased moisture levels and protecting margins. Provision of migration pathways may impact connectivity positively or negativity. Protection and restoration of intertidal habitats and migration pathways may reduce priority weeds and grazing by livestock and provide resilience to SLR.
Lowland Rainforest on Floodplain in the New South Wales North Coast Bioregion	Endangered Ecological Community	BC Act 2016	Threats include clearing for agriculture; weed invasion; habitat fragmentation; fire; and grazing[1].	Indirect impacts may occur from actions to restore natural hydrology and sediments by reducing fire risk with increased moisture levels. Provision of migration pathways may impact connectivity positively or negativity. Protection and restoration of intertidal habitats and migration pathways may reduce priority weeds and grazing by livestock.
Subtropical Coastal Floodplain Forest of the New South Wales North Coast Bioregion	Endangered Ecological Community	BC Act 2016	Typically forms mosaics with other floodplain forest communities and treeless wetlands, often fringing treeless floodplain lagoons or wetlands with semi-permanent standing water. May adjoin or intergrade with **Swamp Sclerophyll Forest** on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions and **Swamp Oak Floodplain Forest** of the NSW North Coast, Sydney Basin and South East Corner bioregions and **Freshwater Wetlands** on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions. The boundaries between all of these communities are dynamic and may shift in response to changes in hydrological regimes, fire regimes or land management practices[1].	Direct impacts may occur from actions to restore natural hydrology and sedimentation, protect and restore existing habitats, and provision of migration pathways. As per the NSW Scientific Committee final determination this TEC may intergrade with other TECs that may change in distribution and composition as a response to future management of water and tidal flows.

Threatened Ecological Community	Status	Legislation	Threats relevant to management of intertidal vegetation	Potential for direct or indirect impacts from actions under the IMVS
			Large areas have been directly drained by construction of artificial channels or altered hydrologically by changed patterns of flooding and drainage following flood mitigation works, particularly the construction of drains, levees and floodgates. On the north coast of NSW, expansion of *Melaleuca quinquenervia* and *Casuarina glauca* has been attributed to artificial drainage and shortening of the hydroperiod[1].	
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered Ecological Community	BC Act 2016	Given the dynamic hydrological relationship between Swamp Oak Floodplain Forest, Coastal Saltmarsh and other Endangered Ecological Communities on coastal floodplains, future management of water and tidal flows may result in the expansion of some communities at the expense of others. Proposals for the restoration of natural hydrological regimes and for the rehabilitation of acid sulfate soils may also result in changes to the distribution and composition of floodplain communities. Co-ordinated planning and management approaches across whole catchments will be required to address and resolve priorities between different management objectives[1].	Direct impacts may occur from actions to improve the resilience of saltmarsh habitats and other floodplain communities as per the NSW Scientific Committee final determination.
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered Ecological Community	BC Act 2016	Given the dynamic hydrological relationship between Swamp Sclerophyll Forest on Coastal Floodplains, Coastal Saltmarsh and other Endangered Ecological Communities on coastal floodplains, future management of water and tidal flows may result in the expansion of some communities at the expense of others. Proposals for the restoration of natural hydrological regimes and for the rehabilitation of acid sulfate soils may also result in changes to the distribution and composition of floodplain communities. Co-ordinated planning and management approaches across whole catchments will be required to address and resolve priorities between different management objectives[1].	Direct impacts may occur from actions to improve the resilience of saltmarsh habitats and other floodplain communities as per the NSW Scientific Committee final determination.

Threatened Ecological Community	Status	Legislation	Threats relevant to management of intertidal vegetation	Potential for direct or indirect impacts from actions under the IMVS
River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered Ecological Community	BC Act 2016	Forms part of a complex of forested wetland and treeless wetland communities found throughout the coastal floodplains of NSW. May adjoin or intergrade with 'Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions', 'Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions' and 'Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions'. The boundaries between all of these communities are dynamic and may shift in response to changes in hydrological regimes, fire regimes or land management practices[1]. BC Act listed KTPs include 'Clearing of native vegetation', 'Alteration to the natural flow regimes of rivers, streams, floodplains and wetlands', 'Invasion of native plant communities by exotic perennial grasses', 'Predation, habitat destruction, competition and disease transmission by feral pigs', 'Anthropogenic climate change', 'High frequency fire' and 'Removal of dead wood and dead trees'[1.]	Direct impacts may occur from actions to restore natural hydrology and sedimentation, protect and restore existing habitats, and provision of migration pathways. As per the NSW Scientific Committee final determination this TEC may intergrade with other TECs that may change in distribution and composition as a response to future management of water and tidal flows.
Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community	Endangered Ecological Community	EPBC Act 1999	This ecological community is often found in association with other vegetation types such as coastal saltmarsh, mangroves, freshwater wetlands, littoral rainforests or swamp sclerophyll forests in a 'mosaic' of floodplain communities[2]. The boundaries of coastal ecological communities may change over time due to the dynamic nature of these systems[2].	Direct impacts may occur from actions to improve the resilience of mangrove and saltmarsh habitats as per the EPBC Act conservation advice.
Coastal Swamp Sclerophyll Forest of New South Wales and South East Queensland	Endangered Ecological Community	EPBC Act 1999	Threatened ecological communities that occur adjacent to or near to the Coastal Swamp Sclerophyll Forest include Subtropical and Temperate Coastal Saltmarsh[2].	Direct impacts may occur from actions to improve the resilience of saltmarsh or other intertidal habitats.

Threatened Ecological Community	Status	Legislation	Threats relevant to management of intertidal vegetation	Potential for direct or indirect impacts from actions under the IMVS
			EPBC listed KTPs include 'Land clearance', 'Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases', 'Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants', and 'Novel biota and their impact on biodiversity'[2].	Indirect impacts may occur from actions under IMVS that address listed KTPs.
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia	Critically Endangered Ecological Community	EPBC Act 1999	Threats include clearing of native vegetation, coastal development, visitor disturbance, weed invasion, animal grazing/browsing, fire and the effects of fragmentation. In addition, natural disturbances such as storms and cyclones, can impact the ecological community and are likely to increase in frequency and intensity with climate change. Management priorities include to manage any changes to hydrology which may result in increased run off or sediment or changes to the water table levels[2].	Indirect impacts may occur from actions to restore natural hydrology and sediments by reducing fire risk with increased moisture levels and protecting margins from natural disturbances. Provision of migration pathways may indirectly impact fragmentation positively or negatively. Indirect impacts may also occur by protection and restoration of intertidal habitats and migration pathways by protecting margins, reducing weeds and grazing.
Lowland Rainforest of Subtropical Australia	Critically Endangered Ecological Community	EPBC Act 1999	Intergrades with Littoral Rainforest in some coastal areas. Threats include land clearing; impacts associated with fragmentation of remnants; weeds and feral animals; high frequency fires; SLR; and grazing[2].	Indirect impacts may occur from actions to restore natural hydrology and sediments by reducing fire risk with increased moisture levels. Provision of migration pathways may impact connectivity positively or negativity. Protection and restoration of migration pathways may reduce priority weeds, feral animals, grazing by livestock and provide resilience to SLR.
Subtropical and Temperate Coastal Saltmarsh	Vulnerable Ecological Community	EPBC Act 1999	Comprises intertidal vegetation and as such targeted by actions under the IMVS.	Direct impacts on saltmarsh are targeted with actions to restore natural hydrology and sediments, protect and restore existing habitats, and provision of migration pathways.
Subtropical eucalypt floodplain forest and woodland of the New South Wales North Coast and South East Queensland bioregions	Endangered Ecological Community	EPBC Act 1999	In New South Wales, the majority of the ecological community is recognised 'Subtropical Coastal Floodplain Forest of the New South Wales North Coast Bioregion' TEC[2]. Typically forms 'mosaics' with other floodplain forest communities, lowland woodlands and treeless	Direct impacts may occur from actions to restore natural hydrology and sedimentation, protect and restore existing habitats, and provision of migration pathways. As per the NSW Scientific Committee final determination for 'Subtropical Coastal Floodplain Forest of the New South Wales North

Threatened Ecological Community	Status	Legislation	Threats relevant to management of intertidal vegetation	Potential for direct or indirect impacts from actions under the IMVS
			wetlands including 'Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions', 'Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions' and 'Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions'. The boundaries between all of these communities are dynamic and may shift in response to changes in hydrological regimes, fire regimes or land management practices[1,2]. EPBC listed KTPs include 'Land clearance', 'Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases', 'Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants', and 'Novel biota and their impact on biodiversity'[2].	Coast Bioregion', may intergrade with other TECs that may change in distribution and composition as a response to future management of water and tidal flows. Indirect impacts may also occur from actions under IMVS that address listed KTPs.

Appendix 4: Threatened Species

Table 6 Threatened species and populations that may be DIRECTLY impacted by management of intertidal vegetation in the Tweed River estuary study area.
Sources: Department of Climate Change, Energy, the Environment and Water SPRAT Species Profiles or Approved Conservation Advice (EPBC Act)[1]; NSW Office of Environment and Heritage Bionet Threatened Species Profiles or Final Determination (BC Act)[2]; NSW Fisheries Scientific Committee determination (FM Act)[3].

Threatened species	*Species name*	Status	Legislation	Threats relevant to management of intertidal vegetation
Alaskan Bar-tailed Godwit	*Limosa lapponica baueri*	Endangered	EPBC Act 1999	The loss of mudflats, wetlands, saltmarshes, sandflats, and beaches reduces the availability of resting and feeding habitat and may limit the individual's ability to build up energy stores required for successful migration and breeding[1].
Australian Fritillary	*Argynnis hyperbius inconstans*	Critically Endangered	EPBC Act 1999	Usually occurs around river estuaries or open, swampy coastal regions and drainage of coastal wetland habitat is a known threat[1].
Australian Painted Snipe	*Rostratula australis*	Endangered	EPBC Act 1999; BC Act 2016	Occurs in shallow freshwater (occasionally brackish) wetlands, both ephemeral and permanent, such as lakes, swamps, claypans, inundated or waterlogged grassland/saltmarsh, dams, rice crops, sewage farms and bore drains. The main identified threat is the loss and degradation of wetlands, through drainage and the diversion of water for agriculture and reservoirs. Priority actions include to manage any changes to hydrology that may result in changes to water table levels, run-off, salinity, algal blooms, sedimentation or pollution, and manage any disruptions to water flows[1].
Beach Stone-curlew	*Esacus magnirostris*	Critically Endangered	BC Act 2016	Inhabits coastal habitats including estuaries and the edges of or near mangroves[2].
Black Bittern	*Ixobrychus flavicollis*	Vulnerable	BC Act 2016	Inhabits terrestrial and estuarine wetlands, including mangroves[2].
Black Rock Cod	*Epinephelus daemelii*	Vulnerable	EPBC Act 1999; FM Act 1994	Modification of estuarine habitats is considered a potential threat to juvenile black cod[1].
Black-necked Stork	*Ephippiorhynchus asiaticus*	Endangered	BC Act 2016	Floodplain wetlands (swamps, billabongs, watercourses and dams) of the major coastal rivers are the key habitat in NSW for the Black-necked Stork. Secondary habitat includes minor floodplains, coastal sandplain wetlands and estuaries[2].
Black-tailed Godwit	*Limosa limosa*	Vulnerable	BC Act 2016	Primarily a coastal species, usually found in sheltered bays, estuaries and lagoons with large intertidal mudflats and/or sandflats. Threats include hydrological changes to impacting suitable habitat; mangrove incursion into saltmarsh habitat; habitat loss due to development; weed invasion of key habitat; habitat loss from erosion, climate change inundation and sea-level rise[2].
Blue-winged Parrot	*Neophema chrysostoma*	Vulnerable	EPBC Act 1999; BC Act 2016	Blue-winged parrots are vulnerable to any rise in sea level where they rely on coastal saltmarsh[1].
Broad-billed Sandpiper	*Limicola falcinellus*	Vulnerable	BC Act 2016	Inhabits sheltered parts of the coast such as estuarine sandflats and mudflats, harbours, embayments, lagoons, saltmarshes and reefs. Impacts from hydrological changes to

				estuaries and similar water bodies may modify or remove important areas of suitable habitat[2].
Brolga	*Grus rubicunda*	Vulnerable	BC Act 2016	Inhabits large open wetlands, grassy plains, coastal mudflats and irrigated croplands and, less frequently, mangrove-studded creeks and estuaries. Loss of wetland habitat through clearing and draining for flood mitigation and agriculture is a known threat[2].
Collared Kingfisher	*Todiramphus chloris*	Vulnerable	BC Act 2016	Virtually restricted to mangrove associations of estuaries, inlets, sheltered bays and islands, and the tidal flats and littoral zone bordering mangroves[2].
Curlew Sandpiper	*Calidris ferruginea*	Critically Endangered, Endangered	EPBC Act 1999 (Critically Endangered); BC Act 2016 (Endangered)	Feeding and roosting habitats includes intertidal sandflats, spits, and banks and less frequently, mudflats, estuaries, coastal lagoons, and bays often near beds of seagrass and sometimes near saltmarshes. Threats include habitat loss and disturbance including landfill or reclamation associated with developments; clearing saltmarsh; damage of wetland areas by rubbish dumping, storm water draining, and altered salinity from stormwater run-off. Habitats are shrinking due to a combination of restricted inflow of sediments from increasingly dammed rivers and SLR with barriers to habitat migration. Additionally, water regulation and diversion infrastructure along major tributaries has resulted in the reduction of water and sediment flows[1].
Eastern Coastal Free-tailed Bat	*Micronomus norfolkensis*	Vulnerable	BC Act 2016	Occurs in dry sclerophyll forest, woodland, swamp forests and mangrove forests east of the Great Dividing Range. Threats include loss of foraging habitat[2].
Eastern Osprey	*Pandion cristatus*	Vulnerable	BC Act 2016	Favours coastal areas, especially the mouths of large rivers, lagoons and lakes. Feed on fish over clear, open water. Threats include disturbances to water quality that increases turbidity in feeding areas (including degradation of riparian areas) and ingestion of fish containing discarded fishing tackle[2].
Fairy Tern	*Sternula nereis nereis*	Vulnerable	EPBC Act 1999	Inhabit coastal areas preferring sandy beaches but including estuarine wetlands. Main threats include increasing salinity in waters adjacent to colonies, which can reduce prey availability; irregular water management, which flood nests on sheltered beaches or allow access to breeding colonies by predators. Priority actions are to manage any changes to hydrology that may result in changes to tide levels, increase salinity or pollution[1].
False Water-rat	*Xeromys myoides*	Vulnerable	EPBC Act 1999	May nest in saltmarsh habitats[1].
Far Eastern Curlew	*Numenius madagascariensis*	Critically Endangered	EPBC Act 1999	Often forages near mangroves, on salt flats or saltmarsh, around rockpools, amongst rubble on coral reefs, and on ocean beaches near the tideline. Roost on sandy spits and islets and amongst coastal vegetation, including low saltmarsh or mangroves. Threats include habitat loss from development pressures, invasion of mudflats and coastal saltmarshes by mangroves and cordgrass, downstream effects of large dams on sediments and hydrology, and SLR[1].
Great Knot	*Calidris tenuirostris*	Vulnerable	EPBC Act 1999; BC Act 2016	Feed along the water's edge of intertidal mudflats and sand flats; typically roosts along sheltered coastal habitats such as inlets, bays, harbours, estuaries, and lagoons. Threats include wetland loss and degradation including landfill or reclamation associated

				with developments; clearing saltmarsh; damage of wetland areas by rubbish dumping, storm water draining, and altered salinity from stormwater run-off. Threats also include invasion of mudflats and coastal saltmarshes by mangroves and cordgrass, downstream effects of large dams on sediments and hydrology, and SLR[1].
Greater Sand Plover	*Charadrius leschenaultii*	Vulnerable	EPBC Act 1999; BC Act 2016	Feeding takes place within sheltered sandy, shelly, or muddy coastal areas, including large intertidal mudflats, sandbanks, saltmarshes, estuaries, tidal lagoons and dunes near the coast. Usually roost on sand-spits and banks on beaches or in tidal lagoons; occasionally on rocky points or in adjacent areas of saltmarsh or claypans. Threats include habitat loss and disturbance, a restricted inflow of sediments from increasingly dammed rivers and SLR with sea walls at many sites preventing suitable habitat migrating inland[1].
Grey-headed Flying-fox	*Pteropus poliocephalus*	Vulnerable	EPBC Act 1999; BC Act 2016	Congregate in large numbers at roosting sites (camps) that may be found in rainforest patches, Melaleuca stands, mangroves, riparian woodland or modified vegetation in urban areas. Threats include loss of roosting and foraging sites[2].
Lesser Sand Plover, Mongolian Plover	*Charadrius mongolus*	Endangered, Vulnerable	EPBC Act 1999 (Endangered); BC Act 2016 (Vulnerable)	Feeding areas include intertidal sandflats and mudflats in estuaries or beaches, shallow ponds in saltworks, and sandy or muddy river margins. Roosts near foraging areas. Impacts include losses of habitat through land clearing; habitat degradation from inundation, infilling, draining, changes in water quality, hydrology, pollution, changes to the water regime (including SLR) and invasive plants[1].
Little Tern	*Sternula albifrons*	Endangered	BC Act 2016	Almost exclusively coastal, preferring sheltered environments. Threats include loss or degradation of habitat (e.g., nesting areas and foraging areas) due to hydrological changes in estuaries[2].
Mangrove Honeyeater	*Lichenostomus fasciogularis*	Vulnerable	BC Act 2016	Inhabits mangroves and adjacent coastal vegetation[2].
Pied Oystercatcher	*Haematopus longirostris*	Endangered	BC Act 2016	Favours intertidal flats of inlets and bays, sandbanks, coastal or estuarine beaches and occasionally saltmarsh or grassy areas. Threats include loss or degradation of habitat due to hydrological changes in estuaries; pollution; and entanglement in or ingestion of marine debris[2].
Red Knot	*Calidris canutus*	Vulnerable	EPBC Act 1999	Mainly inhabits intertidal mudflats, sandflats, and sandy beaches of sheltered coasts, estuaries, bays, inlets, lagoons, and harbours. Occasionally seen on terrestrial saline wetlands near the coast and have been recorded on sewage ponds and saltworks. Threats include habitat loss and disturbance, a restricted inflow of sediments from increasingly dammed rivers and SLR with sea walls at many sites preventing suitable habitat migrating inland[1].
Red-flowered King of the Fairies	*Oberonia titania*	Endangered	BC Act 2016	Primarily occurs in littoral and subtropical rainforest and paperbark swamps but also occur in mangroves. Threats include loss of habitat through clearing, degradation and fragmentation of native vegetation; and potentially SLR, inundation and wind and salt incursions[2].

Sanderling	*Calidris alba*	Vulnerable	BC Act 2016	Often found in coastal areas on low beaches of firm sand, near reefs and inlets, along tidal mudflats and bare open coastal lagoons; individuals are rarely recorded in near-coastal wetlands. Hydrological changes to estuaries and waterbodies may modify or remove important areas of suitable habitat[2].
Sooty Oystercatcher	*Haematopus fuliginosus*	Vulnerable	BC Act 2016	Favours rocky headlands, rocky shelves, exposed reefs with rock pools, beaches and muddy estuaries. Threats include habitat destruction; hydrological changes to estuaries and other coastal wetlands[2].
Terek Sandpiper	*Xenus cinereus*	Vulnerable	BC Act 2016	Core habitat is mudbanks and sandbanks located near mangroves[2].
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Vulnerable	BC Act 2016	Threats to foraging resources from clearing, degradation or reclamation of saltmarsh, mangroves, sea grass and other riparian or shallow water vegetation. Increased mortality due to entanglement in discarded fishing gear[2].
Yellow-flowered King of the Fairies	*Oberonia complanata*	Endangered	BC Act 2016	Grows on trees and rocks in littoral rainforest, subtropical rainforest, dry rainforest, wet or dry eucalypt forests, dunes (including stabilised sands), stream-side areas, swampy forests and mangroves. Threats include loss of habitat through clearing, degradation and fragmentation of native vegetation[2].

Table 7 Threatened species and populations that may be INDIRECTLY impacted by management of intertidal vegetation in the Tweed River estuary study area.
Sources: Department of Climate Change, Energy, the Environment and Water SPRAT Species Profiles or Approved Conservation Advice (EPBC Act)[1]; NSW Office of Environment and Heritage Bionet Threatened Species Profiles or Final Determination (BC Act)[2]; NSW Fisheries Scientific Committee determination (FM Act)[3].

Common name	*Species name*	Status	Legislation	Threats relevant to management of intertidal vegetation
Australasian Bittern	*Botaurus poiciloptilus*	Endangered	EPBC Act 1999; BC Act 2016	Favours permanent freshwater wetlands. Primarily impacted by habitat loss from the diversion of water away from wetlands; drainage of swamps; and clearing for urban and agricultural development. Impacts may include elevated salinity levels from rising sea levels and a general decline in water quality. Frequent or intense burning of wetland areas may result in reduced nesting success[1].
Blue-billed Duck	*Oxyura australis*	Vulnerable	BC Act 2016	Prefers deep water in large permanent wetlands and swamps with dense aquatic vegetation. Threats include destruction or degradation of breeding habitat through drainage, flood mitigation works and ground water extraction; frequent burning; regulation of river flows and water harvesting schemes; and increased salinity[2].
Brown Fairy-chain Orchid	*Peristeranthus hillii*	Vulnerable	BC Act 2016	Restricted to coastal and near-coastal environments, particularly Littoral Rainforest and Lowland Rainforest on Floodplain. Threats include habitat destruction, weed invasion and inundation of low lying areas due to SLR[2].
Coast Euodia	*Melicope vitiflora*	Endangered	BC Act 2017	Grows in subtropical and littoral rainforest. Threats include fire, weeds, habitat fragmentation and inundation of coastal populations[2].
Coastal Petaltail	*Petalura litorea*	Endangered	BC Act 2016	A dragonfly that occupies a variety of permanent to semi-permanent coastal freshwater wetlands. Threats include loss or modification of natural swamps, wetlands and sedgelands through regulation of river flows, water harvesting schemes and changes in surface water flows and groundwater levels[2].
Comb-crested Jacana	*Irediparra gallinacea*	Vulnerable	BC Act 2016	Clearing and draining wetlands impacts core habitat of freshwater wetlands. Crucial actions to protect the species include encouraging landholders to enter land management agreements that promote the maintenance of natural hydrological flows in these and adjacent wetlands[2].
Common Blossom-bat	*Syconycteris australis*	Vulnerable	BC Act 2016	Core habitat is coastal forests including littoral rainforest, paperbark swamps, subtropical rainforest and wet sclerophyll forest. Threats include loss of habitat from climate change including inundation of lowland (wallum) habitat; coastal erosion; influx of saline water; and drying of littoral forests from temperature rise and increased drought[2].
Common Planigale	*Planigale maculata*	Vulnerable	BC Act 2016	Inhabits rainforest, eucalypt forest, heathland, marshland, grassland and rocky areas where there is surface cover, usually close to water. Threats include loss of habitat, changes to riparian areas and hydrology, and loss of ground cover vegetation and woody debris from too frequent fire and clearing[2].
Dugong	*Dugong dugon*	Endangered	BC Act 2016	Major concentrations occur in wide shallow protected bays, wide shallow mangrove channels and in the lee of large inshore islands. Threats include removal or pollution of seagrass habitats which in turn may be indirectly impacted by management of intertidal vegetation. Other impacts include collision with boats and entanglement in fishing gear[1].
Eastern Grass Owl	*Tyto longimembris*	Vulnerable	BC Act 2016	Found in tall grass, including grass tussocks, in swampy areas, grassy plains, swampy heath, and in cane grass or sedges on flood plains. Threatened by loss of suitable habitat, habitat disturbance and degradation and frequent burning[2].

Common name	*Species name*	Status	Legislation	Threats relevant to management of intertidal vegetation
Eastern Long-eared Bat	*Nyctophilus bifax*	Vulnerable	BC Act 2016	Threats include degradation of swamp, wet sclerophyll and rainforests habitats, alterations to moisture regimes, high frequency fires, edge effects, loss of connectivity and invasion of habitat by weeds, particularly by Bitou Bush on the coast[2].
Freckled Duck	*Stictonetta naevosa*	Vulnerable	BC Act 2016	Prefers permanent freshwater swamps and creeks. Threats include draining and clearing of wetland and swamp habitat; changes to natural river flows and flood patterns; degradation of habitat by grazing, trampling and too frequent or intense fires[2].
Greater Broad-nosed Bat	*Scoteanax rueppellii*	Vulnerable	BC Act 2016	Found mainly in the gullies and river systems that drain the Great Dividing Range, extending to the coast over much of its range. Threats include changes to water regimes that are likely to impact food resources, and the use of pesticides and herbicides near waterways[2].
Hairy Jointgrass	*Arthraxon hispidus*	Vulnerable	EPBC Act 1999; BC Act 2016	Usually found around in or on the edges of rainforest and in wet eucalypt forest, often in and around wetlands, drainage lines and groundwater seepages including in freshwater wetlands, Carex sedgelands and montane peat swamps. Sensitive to altered hydrology due to drainage or infilling from urban development, clearing, weed invasion, grazing and inappropriate fire regimes[2].
Leafless Tongue-orchid	*Cryptostylis hunteriana*	Vulnerable	EPBC Act 1999; BC Act 2016	Occurs mostly in coastal heathlands, margins of coastal swamps and sedgelands, coastal forest, dry woodland, and lowland forest. May be impacted by changes to water table and wetland drainage[1].
Lesser Swamp-orchid	*Phaius australis*	Endangered	EPBC Act 1999; BC Act 2016	Associated with coastal wet heath/sedgeland wetlands, swampy grassland or swampy forest. May be impacted by changes to water table and wetland drainage as clearing and fragmentation and drainage for development, agriculture and road works are identified threats[1].
Little Bent-winged Bat	*Miniopterus australis*	Vulnerable	BC Act 2016	Associated with moist eucalypt forest, rainforest, vine thicket, wet and dry sclerophyll forest, Melaleuca swamps, dense coastal forests and banksia scrub. Threats include changes to habitat.
Magpie Goose	*Anseranas semipalmata*	Vulnerable	BC Act 2016	Mainly found in shallow freshwater wetlands with dense growth of rushes or sedges. Threats include inappropriate hydrological regimes of wetland habitats through drainage of swamps, ponds, dams and other wetlands for agricultural and other human purposes[2].
Maundia triglochinoides	*Maundia triglochinoides*	Vulnerable	BC Act 2016	Grows in swamps, lagoons, dams, channels, creeks or shallow freshwater 30 - 60 cm deep on heavy clay, low nutrients. Threats include loss and fragmentation of habitat, changes in hydrology and water quality and weed invasion[2].
Mitchells Rainforest Snail	*Thersites mitchellae*	Critically Endangered, Endangered	EPBC Act 1999 (Critically Endangered); BC Act 2016 (Endangered)	Mostly found in remnant rainforest vegetation on the coastal plain. Threats include loss of coastal populations from SLR and climate change and damage to rainforest habitat from changes in hydrology[1].
Native Justicia	*Harnieria hygrophiloides*	Endangered	BC Act 2017	Grows in the understorey of littoral rainforest, dry rainforest and wet eucalypt forest, usually in well-drained areas. Threats include salt water incursion from SLR reducing suitable habitat for the species, high frequency fires, habitat loss and weed invasion[2].

Common name	*Species name*	Status	Legislation	Threats relevant to management of intertidal vegetation
Oxleyan Pygmy Perch	*Nannoperca oxleyana*	Endangered	EPBC Act 1999; FM Act 1994	Confined to freshwater systems draining through sandy coastal lowlands ('wallum') ecosystems. The emerging threat of climate change (fire, drought and water quality impacts) presents a risk to all subpopulations of the Oxleyan pygmy perch. Land clearing and associated impacts on the coastal drainage system are ongoing threats for subpopulations located outside of the conservation estate[1].
Pale-vented Bush-hen	*Amaurornis moluccana*	Vulnerable	BC Act 2016	Inhabits the margins of freshwater streams and natural or artificial wetlands, usually within or bordering rainforest, rainforest remnants or forests. Clearing, filling and draining of wetlands and alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands are threats[2].
Red Goshawk	*Erythrotriorchis radiatus*	Endangered	EPBC Act 1999; BC Act 2016	The degradation of rivers and wetlands from drainage and clearing may reduce prey availability, impacting foraging and breeding success within the core freshwater wetland habitats[2].
Red-backed Button-quail	*Turnix maculosus*	Vulnerable	BC Act 2016	In NSW, said to occur in grasslands, heath and crops. Said to prefer sites close to water, especially when breeding. Drainage of coastal wetlands and riparian grasslands for agriculture, particularly sugar cane farming, and urban development, reduces available breeding habitat[2].
Sand Spurge	*Chamaesyce psammogeton*	Endangered	BC Act 2016	Grows on fore-dunes, pebbly strandlines and exposed headlands, often with Spinifex and Prickly Couch. Threats include SLR, storm surge, coastal developments, invasive species and 4WD vehicle damage[2].
Scented Acronychia	*Acronychia littoralis*	Endangered	EPBC Act 1999; BC Act 2016	Associated with littoral rainforests. Susceptible to salt burn and sensitive to changes in hydrology[1].
Silverbush	*Sophora tomentosa*	Endangered	BC Act 2016	Occurs on coastal dunes, and threats include weeds, clearing and inundation of low-lying areas due to climate change[2].
Southern Myotis	*Myotis macropus*	Vulnerable	BC Act 2016	Generally, roost in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, wharves, bridges and in dense foliage. Forage over streams and pools catching insects and small fish. Threats include loss or disturbance of roosting sites, clearing adjacent to foraging areas and reduction in stream water quality affecting food resources[2].
Spider Orchid	*Dendrobium melaleucaphilum*	Endangered	BC Act 2016	Grows frequently on *Melaleuca styphelioides*, less commonly on rainforest trees or on rocks in coastal districts. Threats include wetland drainage, inappropriate fire regimes, weed invasion, grazing, changes to the natural hydrology of melaleuca wetlands[2].
Spiny Gardenia	*Randia moorei*	Endangered	EPBC Act 1999; BC Act 2017	Occurs in subtropical, riverine, littoral and dry rainforest. Threats include clearing and fragmentation of habitats, weeds, trampling from stock, fire, and salt water intrusion caused by SLR[2].
Stinking Cryptocarya	*Cryptocarya foetida*	Vulnerable	EPBC Act 1999; BC Act 2016	Found in littoral, warm temperate and subtropical rainforest, wet sclerophyll forest and Camphor laurel forest. Threats include habitat loss from climate change inundation, SLR, erosion and increased extreme storm events[1].
Swamp Foxglove	*Centranthera cochinchinensis*	Endangered	BC Act 2016	Uncommon in swampy areas and other moist sites. Threats include clearing, draining and degradation of swamp habitat; grazing; weeds; feral pigs; and disturbances[2].
Trailing Woodruff	*Asperula asthenes*	Vulnerable	EPBC Act 1999; BC Act 2017	Occurs in damp sites, often along riverbanks. Impacts may include weeds, clearing and grazing. Raising of the water table to reduce acid sulphate discharge as part of a habitat rehabilitation program could potentially be detrimental to the species[2].

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Wallum Froglet	*Crinia tinnula*	Vulnerable	BC Act 2016	Typically occur in sedgelands and wet heathlands. Threats include changes to hydrology of coastal wetlands as a result of a changing climate and/ or SLR, and reduction of water quality and modification to acidity in coastal wetlands[2].
Wallum Sedge Frog	*Litoria olongburensis*	Vulnerable	EPBC Act 1999; BC Act 2016	Found in coastal wallum swamps. Sensitive to changed hydrological regimes in ephemeral swamps that may limit reproductive success, facilitate establishment of predatory fish or impact water quality. Threats include reduction of water quantity and/or quality (including changes to pH) in coastal wetland habitat, climate change, and severe fires[2].
White Lace Flower	*Archidendron hendersonii*	Vulnerable	BC Act 2016	Occurs in riverine and lowland subtropical rainforest, littoral rainforest, coastal cypress pine forest and their ecotones. Threats include coastal locations likely to be exposed to saltwater intrusion, and increased intensity of storms/winds[2].
White-flowered Wax Plant	*Cynanchum elegans*	Endangered	EPBC Act 1999; BC Act 2017	Usually occurs on the edge of dry rainforest. Also associated with littoral rainforest; coastal scrub; Forest Red Gum and Spotted Gum open forest and woodland; and Bracelet Honeymyrtle scrub. Threats include clearing, weed invasion, environmental changes, hydrological disturbances, grazing, and climate change[2].
Whites Seahorse	*Hippocampus whitei*	Endangered	EPBC Act 1999; FM Act 1994	Favours shallow-water estuarine habitats, including sponge gardens, seagrass meadows and soft corals. Seagrass in turn may be indirectly impacted by management of intertidal vegetation. Loss of key habitats through anthropogenic effects would result in a negative effect on the species' abundance and distribution[2].