Boyne Island and Tannum Sands Shoreline Erosion Management Plan (SEMP)

August 2022

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Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for **Gladstone Regional Council** under the contract titled **'127-22 Boyne Island and Tannum Sands Shoreline Erosion Management Plan (SEMP)'**.

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Executive Summary

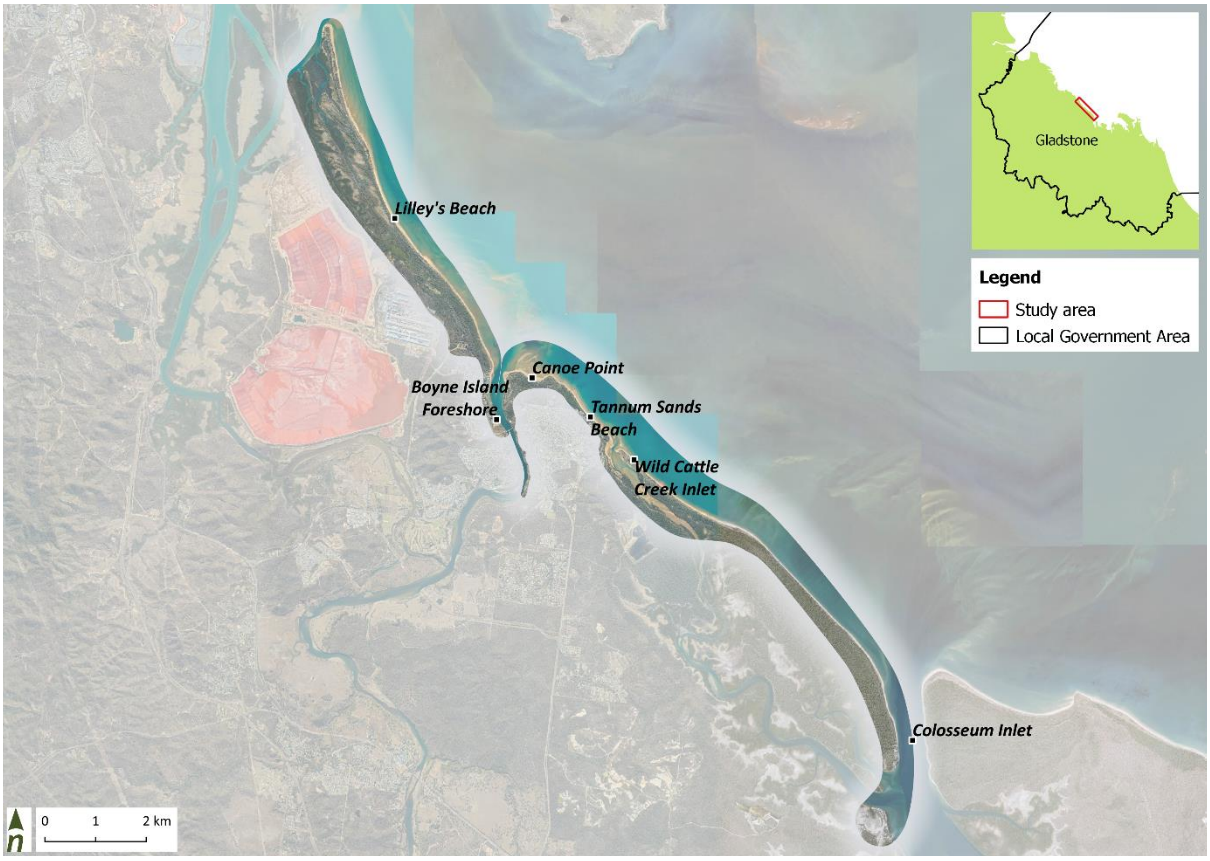
Located in the Gladstone region, Boyne Island and Tannum Sands are situated south of Gladstone. Boyne Island is bounded by a tributary of South Trees Inlet in the north and the Boyne River to the south. The island is separated from the mainland by a series of narrow channels branching from the Boyne River and a dense vegetated buffer. The Boyne Island aluminium smelter is Australia's largest, and the grounds are approximately 2 km behind the beach occupying more than 1 km^2 of the island's area. The land between the road access and the beach remains in a natural state.

Tannum Sands is located east of the Boyne River and has a wide sandy main beach along the east coast and a sandy beach with low rock flats towards the north at Canoe Point. Riverine flows from the Boyne River and Wild Cattle Creek have a role in sediment supply, water quality and sustaining coastal and estuarine habitats and influence the formation of sandy plains along sections of this coast.

Boyne Island and Tannum Sands hold significant environmental, cultural and economic value to the Gladstone region, including Traditional Owners, the communities that reside there and visitors. Boyne Island and Tannum Sands coastal zones are naturally dynamic and complex places that are highly valued by the community. The Boyne Island and Tannum Sands community wishes to enjoy and maintain the natural and unique character of this coastal region. The dynamic nature of the coastal environment means some local foreshores are experiencing shoreline recession at a rate that is threatening the natural environment and infrastructure.

The Boyne Island and Tannum Sands Shoreline Erosion Management Plan (BITS SEMP) provides Gladstone Regional Council (Council) with a framework to proactively plan for the erosion management of their coastline while enabling natural coastal processes to be maintained. The SEMP study area focuses on the foreshore area from Lilley's Beach in the north to the southern community south of Bangalee.

This SEMP has considered recommendations from *Our Coast Our Future* and incorporated public and stakeholder values provided through community drop-in sessions and surveys (between 31st May 2022 to 26th June 2022). This SEMP has incorporated public and stakeholder feedback and comments on the draft SEMP between 15th July 2022 to 31st July 2022.



The SEMP study area

Objectives of the Shoreline Erosion Management Plan

A SEMP addresses the following management goals:

- Provide direction for the management of key parts of the coastline in the immediate to short-term (up to 20 years) planning horizon
- Investigate and address the underlying causes of shoreline erosion and future impacts
- Enable efficient use of Council resources in alignment with community values.

A SEMP is informed by a strong technical understanding of the coastal processes and the values and knowledge of the stakeholders and community. This is aligned with an appreciation of the means, opportunities, and resources of the Council to deliver management actions.

A range of shoreline management options have been considered to mitigate the erosion threat on the local foreshore areas. However, preferred options vary depending on site context and stakeholder preferences. The appropriate options to mitigate erosion threats at specific locations depend on the nature and level of threat as well as the consequences if they are disregarded. Erosion threats that require prioritisation are typically those resulting in immediate risks to public infrastructure and loss of beach amenities in public spaces.

Coastal processes

Boyne Island and Tannum Sands are exposed to the Coral Sea from the north to the northeast, with prevailing wind climate typically dominant from the east. Wind speed is typically below 15 m/s, with southeast winds making up the largest portion of strong winds. Rodds Peninsula and Middle Island partially shelter Tannum Sands and Colosseum Inlet from south easterly and southerly. The wave climate of the region consists of fetch-limited waves generated by winds and swells generated offshore that propagate over the Great Barrier Reef. The region is also protected to an extent by northerly swells by Facing Island and the Great Barrier Reef. Hence, waves exceeding $H_s \approx 0.5$ m are predominantly incoming from the east-northeast to east directions, while smaller waves are coming from the north direction as fetches are quite limited from this directionality.

The sand transport in and around Boyne Island and Tannum Sands is mostly driven by wind and tide, contributing to the generation of longshore currents near the beach as well as waves breaking at an angle to the shore, which mobilises sand along the coast. Longshore sediment transport is distributed across the surf zone, and it is mainly in the wave break area where the bed shear stresses are the greatest.

Location	Estimated longshore sediment transport (m^3/year)
Boyne Island	8,000 to 32,000 (north)
Tannum Sands	30,000 to 36,500 (north)

There is a dominant northerly sediment transport with little reverse (southerly) transport, which is limited due to the infrequent northerly waves. These results are intended to provide an indicative assessment and are likely to be somewhat conservative in nature. It should be noted that these rates of transport are due to wave-driven processes on open coast beaches only. No consideration has been given at these locations to current-driven transport due to tidal or riverine flow

Key coastal issues/ erosion threats

When considering appropriate erosion management options along the Boyne Island and Tannum Sands shoreline, the shoreline has been divided into 12 coastal segments.

Coastal segment	Shoreline condition
Lilley's Beach	Localised erosion has occurred along this beach section. Evidence of erosion scarps of up to 0.5 m, loss of mature trees and some exposed root systems of mature trees. There are distinctive patches with loss of vegetation, especially around the formal and informal campsites behind the foredunes. The recession along this section of Lilley's Beach is not uniform and driving vehicles on the beach and over the dunes is a contributing factor to the increasing erosion issue.

Lilley's Beach entrance	The informal access tracks cutting across the sand dune have resulted in vegetation damage. Increased recreational use of the area and loss of vegetation may also be contributing to the accelerated shoreline variability.
Island Esplanade foreshore	This area is moderately stable due to the construction of the unapproved seawall. Public infrastructure and private properties are located in close proximity to the active beach system, with residential properties within 5 to 10m of the high tide mark. Immediately north and south of the Geotextile Sand Containers (GSC) seawall, there are scour holes at both termination points.
Turtle Way	Sections of Turtle Way lack well-established vegetation and are variably eroded with localised scour pockets, particularly along sections with no additional buffers provided by mangrove communities. There have been recent efforts to place loose rocks and concrete debris informally on the riverbank to provide protection. Increased recreational use and uncontrolled access are exacerbating eroded scarps.
Canoe Point	This area is moderately stable and controlled by rocky outcrops. It is sheltered from wave energy as waves dissipate when refracting around the rocky outcrops and into the sheltered beach.
Oaks Road foreshore	This section is an open sandy beach with potential erosion and shoreline recession vulnerability. Residential development is established along the majority of The Oaks Road foreshore, with a setback from the beach in the order of 30 – 40 m with dunal vegetation at most locations. There is a stormwater outlet on the southern end.
Tannum Sands Surf Life Saving Club (SLSC)	This section is an open sandy beach with potential erosion and shoreline recession vulnerability. The wide foreshore has a wide vegetated buffer of approximately 40 m, but erosion threat may increase with sea level rise and an increase in storm activity.
Millenium Esplanade	Major erosion has occurred in this section and led to the loss of frontal dunes. There has been a recent recovery effort to nourish the eroded foreshore in 2017, which was supplemented with revegetation to stabilise the foreshore. There are two stormwater outlets along the Millenium Esplanade foreshore.
Wild Cattle Creek boat ramp	Immediately north of the boat ramp, there is a scour hole under the abutment of the boat ramp. Loosely placed concrete and debris have been used to protect the eroded sections of the abutment by providing scour protection. Directly south of the boat ramp, localised erosion has occurred immediately south of the boat ramp, and the edge of the car park is undermined. It is important to note this is a State-owned boat ramp.
Wild Cattle Island foreshore	This section is an open sandy beach with erosion and shoreline recession vulnerability. Localised erosion has occurred in sections of this beach and led to the loss of frontal dunes. There is evidence of fallen trees and some exposed root systems of mature trees from ongoing erosion. There are no assets directly behind the frontal dunes, and the vegetation buffer is extensive.
Bangalee	There is no immediate coastal erosion threat to the Bangalee foreshore, but it may become threatened by the changing climate in the future.
Southern community	This community is vulnerable to sea level rise, which will inundate the low-lying areas. Any future erosion protection works for the shoreline should consider ways to mitigate sea level rise and storm tide hazards. It is important to note that the land parcel on the southern community is leased from the Queensland Government

The overall intent of actions associated with the 12 coastal segments of the SEMP is to develop viable erosion management strategies that integrate across the entire Boyne Island and Tannum Sands shoreline to maximise social, economic, cultural and environmental benefits for the community.

Recommended shoreline erosion management options

Potential management opportunities have been identified at each site, including coastal hazard protection and access improvements. Proposed options aim to address the increasing frequency of coastal erosion events relative to the present day whilst maintaining the natural environment and minimising the economic cost to the community.

Options development has also considered community values and perspectives and their potential influence over management initiatives or works. All potential management options have undergone a qualitative Multi-Criteria Assessment (MCA) to identify a preferred option at each site for consideration before moving to design, further assessment and implementation. The assessment criteria and weightings were developed with Council to shape key considerations in assessing the proposed management options.

Criteria included accessibility, adaptability, cultural heritage, protection, environment, approvals, safety, cost and visual amenity. After reviewing the coastal processes, opportunities, risks and values at each site, various potential coastal management options were defined, and a preferred option was selected following a structured appraisal process. The recommended management options and the respective indicative costs are summarised in Table 1.

Table 1. Recommended erosion management options and preliminary cost estimates for the coastal segments

Coastal segment	Recommended management option	Estimated cost
Lilley's Beach	Active vegetation management and 4WD access management.	$70,000
Lilley's Beach entrance	Maintain status quo	$50,000
Island Esplanade foreshore	Full removal of the structure and replace with revetment*	$1.4M*
Turtle Way	Maintain and monitor (protection of infrastructure where required)	$1.6M
Canoe Point	Maintain and monitor	$40,000
Oaks Road foreshore	Active monitoring, revegetation and stormwater management	$51,000
Tannum Sands Surf Life Saving Club (SLSC)	Maintain status quo	$51,000
Millenium Esplanade	Stormwater management	$2.0 M
Wild Cattle Creek boat ramp	Monitor and assess plus replenish with gravel	$150,000
Wild Cattle Island foreshore	Maintain status quo	N/A
Bangalee	Maintain and monitor	N/A
Southern community	Inform of coastal hazard risks	N/A

*Subject to additional assessment of options through Council's Investment Decision Framework

Implementation plan

The scheduling of the various tasks associated with the implementation of the recommended strategy is as follows in Table 2.

1. **Immediate** (recommend implementation within 1 to 2 years)
2. **Medium-term** (recommend implementation within next 2 – 4 years)
3. **Future** (recommend implementation within 5 – 10 years)

Table 2. Actions summary

Location	Recommended action	Timing	Description
Lilley's Beach	4WD traffic management plan	1	Develop a 4WD traffic management plan for Lilley's Beach. Consultant support (if applicable).
	Revegetation and management/ Access management	1	Establish a 20 m revegetation buffer zone landward of HAT by revegetating with native species. Access management as a part of revegetation and management works.
	Monitoring and evaluation	2	Undertake an audit of the access tracks on a yearly basis to determine whether illegal access tracks are being established.
	HOLD POINT Review of SEMP actions for Lilley's Beach.	2	**Review of SEMP actions and effectiveness within 2 - 4 years.**
	Tier 2 action (if applicable and triggered by the effectiveness of SEMP actions for Lilley's Beach.	3	Restrict 4WD access on Lilley's Beach if: • permit conditions are not adhered to • 4WD access is exacerbating erosion and impacting vulnerable species and ecosystems.
Lilley's Beach entrance	Easement agreement	1	Liaise directly with Boyne Smelter Limited to negotiate an easement agreement for the Lilley's Beach entrance foreshore area.
	Revegetation and management/ Access management	1	Revegetate with native species. Access management as a part of revegetation and management works.
	HOLD POINT Review of SEMP actions for Lilley's Beach.	2	**Review of SEMP actions and effectiveness within 2 - 4 years.**
	Tier 2 action (if applicable and triggered by the effectiveness of SEMP actions for Lilley's Beach.	3	Restrict 4WD access on Lilley's Beach if: • permit conditions are not adhered to • 4WD access is exacerbating erosion and impacting vulnerable species and ecosystems.
Island Esplanade foreshore	Internal options assessment	1	Recommended options to be assessed by Council's Investment Decision Framework.
	Design and approvals for revetment	1	Design and approvals pending the outcome of the internal options assessment. Consultant support (if applicable).
	Construction of revetment	3	Construction of preferred revetment option.
Turtle Way	Monitoring – visual/photo	1	Annual and event-based review of impacts and changes.
	Design and approvals for riprap	1	Consultant support (if applicable). Design and approvals for riprap.
	Installation of riprap	3	Installation of riprap to protect stormwater and sewerage assets.
Canoe Point	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.
	Monitoring – visual/photo, 'CoastSnap' monitoring station	1	Establishment of monitoring points (photo and depth markers) for monthly beach profile monitoring.
	Revegetation and management/ Access management	2	Revegetate with native species. Access management as a part of revegetation and management works.
	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.

Location	Recommended action	Timing	Description
The Oaks Road foreshore	Monitoring – visual/photo, 'CoastSnap' monitoring station	1	Establishment of monitoring points (photo and depth markers) for monthly beach profile monitoring.
	Revegetation and management/ Access management	2	Revegetate with native species. Access management as a part of revegetation and management works.
	Stormwater management plan	2	Develop a stormwater management plan/procedure to manage the stormwater outlet at The Oaks Road. Consultant support (if applicable).
Tannum Sands SLSC	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.
	Monitoring – visual/photo, 'CoastSnap' monitoring station	1	Establishment of monitoring points (photo and depth markers) for monthly beach profile monitoring.
	Revegetation and management/ Access management	2	Revegetate with native species. Access management as a part of revegetation and management works.
Millenium Esplanade	Stormwater management	1	Design and approvals for a stormwater improvement area. Consultant support (if applicable).
	Revegetation and management/ Access management	1	Revegetate with native species. Access management as a part of revegetation and management works.
	Construction of stormwater management area	3	Construction of the designed and approved stormwater management option, in accordance with design and approvals.
Wild Cattle Creek boat ramp	Maintain boat ramp	1	Monitor and assess the condition of the boat ramp. If an upgrade is required, liaise directly with the State Government.
	Gravel replenishment	1	Undertake gravel replenish design to determine size, scale and extent of works to maintain undermined carpark area.
	Monitoring – access	2	Annual and event-based review of the accessibility of the turn-off to access Wild Cattle Island.
Wild Cattle Island foreshore	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.
	Monitoring – access	2	Annual and event-based review of the vehicle accessibility on the beach and liaise directly with National Parks.
Bangalee	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.
	Monitoring – access	2	Annual and event-based review of the vehicle accessibility on the beach and liaise directly with National Parks.
Southern community	Consult with State Government	1	Consult with State Government and inform permit holders of future coastal hazard risks.

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1 Introduction

1.1 Purpose of a Shoreline Erosion Management Plan

Coastal zones are naturally dynamic and complex places that are highly valued by the community. Ongoing interactions occur between waves, winds, tides, rivers and the natural environment. Coastal erosion is a natural process that shapes and reshapes coastlines over long timeframes. However, erosion processes may become problematic when interacting with communities and built infrastructure. The Queensland Government states that 'Developed areas impacted by erosion require balanced management to protect infrastructure and preserve coastal values and amenity' (DES 2018).

The Boyne Island and Tannum Sands Shoreline Erosion Management Plan (BITS SEMP) provides Gladstone Regional Council (Council) with a framework to proactively plan for the erosion management of their coastline while ensuring natural coastal processes are maintained. A SEMP is informed by a strong technical understanding of the coastal processes and the values and knowledge of Traditional Owners, stakeholders and the broader community. This is aligned with an appreciation of the means, opportunities, and resources of the Council to deliver management actions. In addressing this goal, SEMPs provide direction for the management of key parts of the coastline in the immediate to short-term (up to 20 years) planning horizon and enable efficient use of Council resources in alignment with community values. The recommendations and consultation outcomes from the previous BITS SEMP (Ecosure 2014) have been reviewed and considered.

Two other SEMPs have recently been completed within the Council region at Turkey Beach and Agnes Water.

1.2 SEMP context

This SEMP has been commissioned by Council to assist with the proactive management of the Boyne Island and Tannum Sands shoreline. Council has been supported in the SEMP development process by Alluvium Consulting (Alluvium) in partnership with Natural Capital Economics (NCE) and Jeremy Benn Pacific (JBP). The SEMP study area focuses on the foreshore area from Lilley's Beach in the north to Colosseum Inlet in the south, as shown in Figure 1.

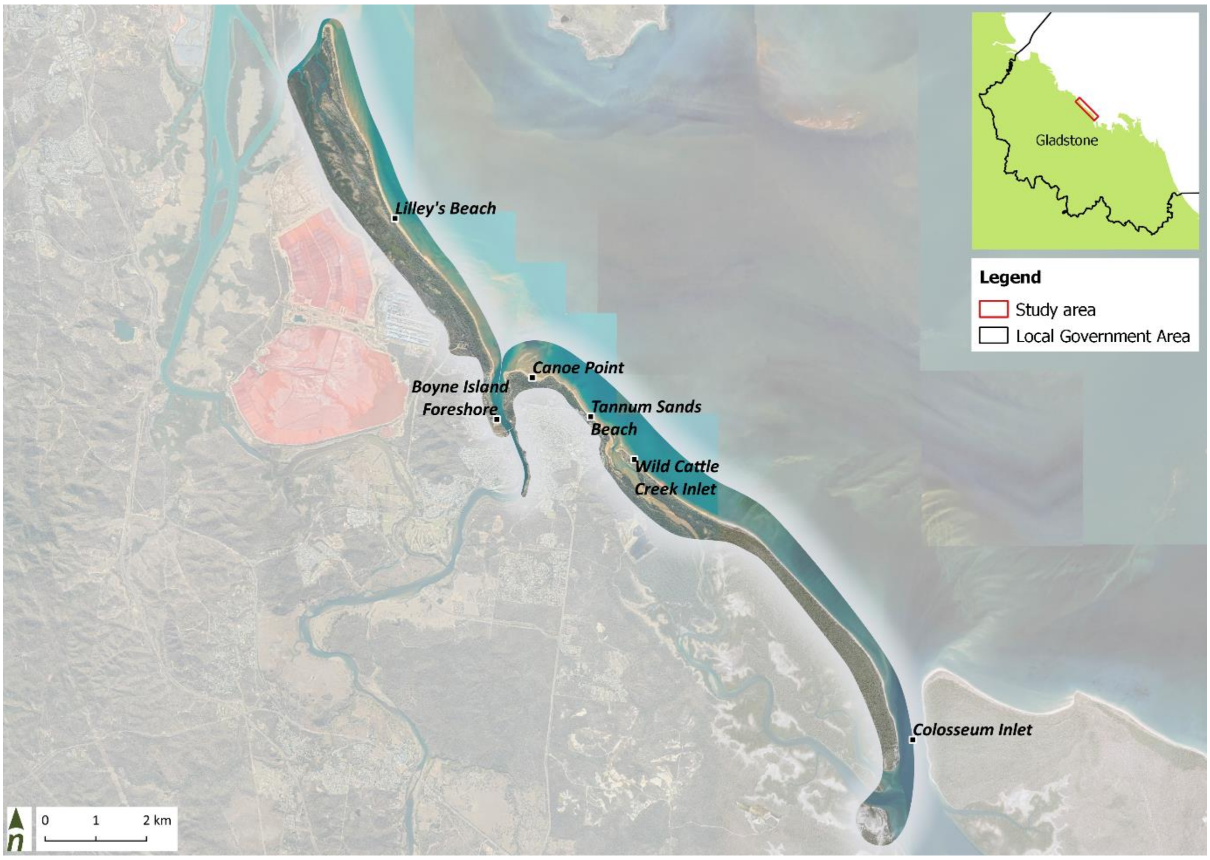

Figure 1. *Area of interest for the Boyne Island and Tannum Sands SEMP in the Gladstone Regional Council LGA.*

This Boyne Island and Tannum Sands SEMP is informed by:

- A technical understanding of coastal processes
- Understanding of local coastal values and the experience of stakeholders and community
- An appreciation of the means, opportunities, and resources of Council to deliver management actions, as well as policy and legislative context relevant to implementation.

Council has also completed a Coastal Hazard Adaptation Strategy (CHAS) for the Gladstone coastline (GRC 2021). This adaptation planning work was completed in 2021 and focuses on long-term planning to 2100. The CHAS's tailored adaptation framework for Boyne Island and Tannum Sands includes:

- Enhance community adaptive capacity to coastal hazards, including awareness of increasing coastal hazard exposure and risk (particularly inundation)
- Consult with State Government on permit to occupy arrangements, with consideration of future coastal hazard risks for relevant properties
- Update local disaster management planning
- Review and update Council asset management plans to incorporate upgrades and modifications in inundation prone areas and assets
- Review and update Council asset management plans to develop a transition response for Olunda Street/Island Esplanade carparks
- Continue and expand the dune protection and maintenance programs at Canoe Point and Tannum Beach
- Review and revise the existing SEMP with a focus on Boyne River mouth and Wild Cattle Creek, including minimising disturbance to sensitive areas.

The outcomes of this SEMP consider shorter-term strategies that align with Council's longer-term CHAS. The SEMP will therefore provide Council with a plan to address issues of immediate concern. A recommended action to be implemented from the CHAS is continuous monitoring of coastal erosion, as well as a SEMP for the remaining Boyne Island and Tannum Sands foreshore.

The preparation of the SEMP has been undertaken in line with the State Government guidelines, *Preparing a shoreline erosion management plan* (DES 2018). Consideration of the legislative context has also been included (Attachment A). The SEMP development has included consultation with the Council, State Government, and community stakeholders at relevant stages of the process. This SEMP has incorporated public and stakeholder values provided through workshops and surveys (between 31st May 2022 to 26th June 2022).

1.3 Plan structure

This SEMP draws on a range of technical studies, engagement activities, and a strategic options assessment, which have informed and shaped the Plan. The SEMP structure is shown in Table 3.

Table 3. SEMP structure

Section	Content	Relevant Attachments
Section 2: Boyne Island and Tannum Sands context	• Landscape setting • Geomorphic content	- Attachment A – Legislative context
Section 3: Coastal values	• Environmental, social, economic • Engagement activities	
Section 4: Coastal processes	• Coastal processes • Erosion prone area • Trends in shoreline change • Present-day shoreline • Trajectory of change and management focus	- Attachment B – CHAS context - Attachment C – Boyne Island and Tannum Sands coastal processes review
Section 5: Shoreline erosion management options	• Generic option considerations • Options assessment appraisal	
Section 6: Assessment of shoreline erosion management options	• Management options	

	• Recommended options	
Section 7: SEMP implementation plan	• Implementation plan • Policy context and approvals	

2 Boyne Island and Tannum Sands context

This section of the SEMP provides a summary of the landscape setting and geomorphic context for Boyne Island and Tannum Sands. It considers the natural processes that shape the landscape, trends in shoreline changes over the years, the current shoreline condition, and the likely trajectory of change. The coastal processes study focuses on the foreshore areas from Lilley's Beach to Colosseum Inlet, as shown in Figure 1.

2.1 Landscape setting

Boyne Island

Boyne Island (Figure 2) is bounded by a tributary of South Tree Inlet in the north and the Boyne River to the south. The island is separated from the mainland by a series of narrow channels branching from the Boyne River and a thick vegetated buffer. The Boyne Island aluminium smelter is Australia's largest, and the grounds are approximately 2 km behind the beach occupying more than 1 km^2 of the island's area. The land between the road access and the beach remains in a natural state.

Lilley's Beach, a sensitive foreshore area on Boyne Island's east coast with tidal flats and seagrass meadows, is a popular spot for camping and 4WD access. The beach faces east to northeast as it meanders between two creeks. The high tide beach averages 30 m in width with a moderate gradient. The beach is also fronted by 200 – 300 m wide, ridged sand flats to the northern end, with approximately 150 m wide bar along the middle and up to 1 km wide tidal shoals of the Boyne River mouth on the southern end. Residential and infrastructure development is established close to Boyne River.

Tannum Sands

Tannum Sands (Figure 3), east of the Boyne River, has a wide sandy main beach along the east coast and a sandy beach with low rock flats towards the north at Canoe Point. Riverine flows from the Boyne River and Wild Cattle Creek have a role in sediment supply, water quality and sustaining coastal and estuarine habitats and influence the formation of sandy plains along sections of this coast.

Wild Cattle Island is low-lying with a series of ridged sand flats. The island consists of a series of beach ridges in the centre, with 1 to 2 km long recurved spits to either end. The sand ridges are covered in dense casuarina that are valued for recreation, including camping and fishing. The island is a National Park and has mangroves, turtle nesting beaches and fish habitat areas. There is limited vehicle access to the island, and the only settlement is on the southern end of Wild Cattle Island.

Figure 2. *Study sites in Boyne Island and surrounding area.*

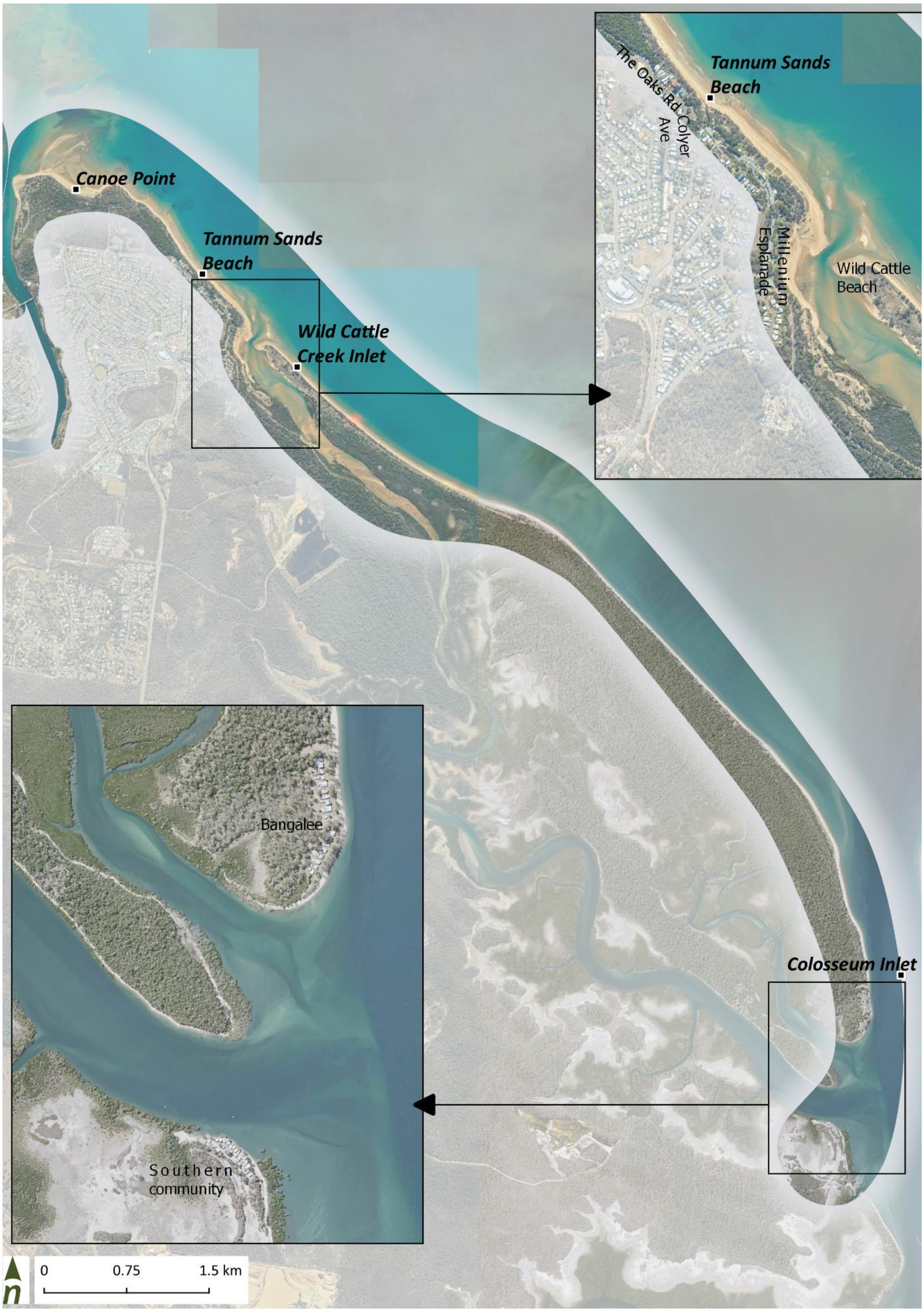

Figure 3. *Study sites in Tannum Sands and surrounding area.*

3 Coastal values

Boyne Island and Tannum Sands hold significant environmental, cultural and economic value to the Gladstone region, including Traditional Owners, the communities that reside there as well as visitors. This section provides a summary of key values to protect and consider in the management of shoreline erosion processes.

Council has undertaken a range of ongoing engagement and consultation activities in the development of the SEMP. The purpose of this engagement was to develop a shared appreciation of coastal values, aspirations, and concerns to inform management options (including preferences) for the Boyne Island and Tannum Sands coastline. There was also prior broader engagement on the coastal zone as part of the region wide CHAS – *Our Coast Our Future*. This section provides a summary of key values to protect and consider in the management of shoreline erosion processes.

3.1 Environmental values

Tannum Sands (from south of Canoe Point to Wild Cattle Island) is located within the Great Barrier Reef Marine Park, however, north of Canoe Point and Boyne Island do not fall under this marine management area. The study site contains a number of vegetation and wildlife habitats that are of State and National significance (Figure 4). Wild Cattle Creek Inlet and Colosseum Inlet contain fish habitat areas. As such, the waters in these areas have specific management requirements due to their high value for fisheries. The shoreline and dune areas, particularly along Lilley's Beach, Canoe Point and Wild Cattle Creek Inlet, contain essential vegetation habitats and threatened and migratory species. The dugong protection area 'B' covers offshore of Boyne Island and Tannum Sands, Wild Cattle Creek and Colosseum Inlet. There are also small areas of wetlands of high ecological significance.

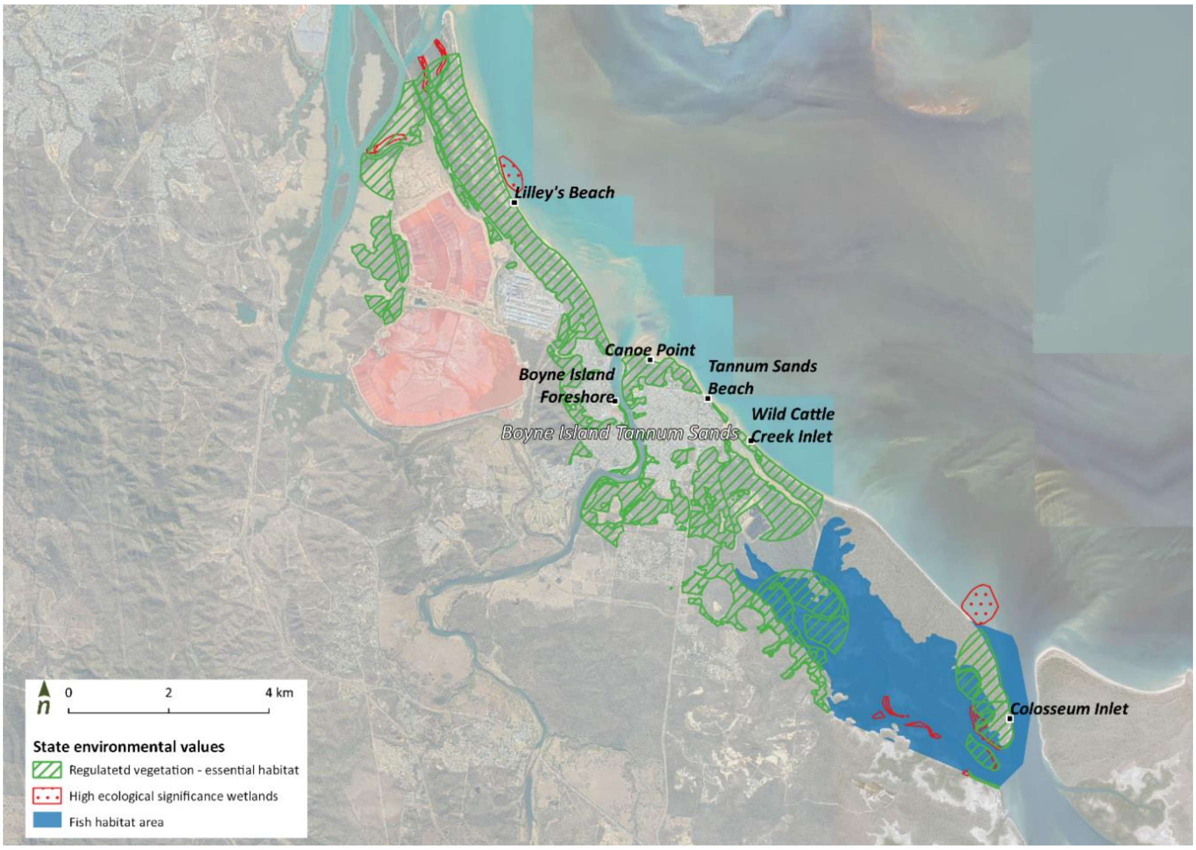

Figure 4. *State mapped environmental values for the Boyne Island and Tannum Sands SEMP study site.*

3.2 Cultural values

The Bailai, Gooreng Gooreng, Gurang and Taribelang Bunda People are the Traditional Owners within the Gladstone Region. The coastal area of the Gladstone Region, including the shorelines at Canoe Point, Wild Cattle Inlet and Colosseum Inlet hold significant value to the Traditional Owners. Indigenous cultural identity is intrinsically linked to the condition of the natural components of the region (GBRMPA 2019).

3.3 Social values

Social values can represent the things people find important or meaningful that make up the Boyne Island and Tannum Sands identity, lifestyle and social fabric. The natural coastal environments here are used by residents and visitors for many activities, including swimming, fishing, boating and camping. These environments also provide important spiritual and passive recreation opportunities. The Boyne Island and Tannum Sands shoreline is a place for people to meet with friends and family, have picnics, play, and explore. Residents have identified that protecting and preserving the natural environment is important to them.

3.4 Economic values

The major economic drivers of the Gladstone Region are mining and manufacturing (REMPLAN 2022). The largest aluminium smelter in Australia is located at Boyne Island and employs 1,300 people. This facility provides significant employment opportunities, including manufacturing in the carbon plant, aluminium production and casting for export (RioTinto 2021). Boyne Island and Tannum Sands have become a satellite town for residents-employed in major manufacturing industries and coal export facilities located in nearby Gladstone.

There is also high tourism value in the region. Fishing is a common pastime in the Gladstone Region and the shorelines are a popular location for fishing. Australia's largest fishing competition is held annually at Boyne Island (Gladstone Region 2021). The Boyne Tannum Hookup draws thousands of visitors from around Australia (Boyne Tannum Hook Up 2021). Other beaches are also popular shore fishing spots. There are also campgrounds at Lilley's Beach, caravan parks at Boyne Island and Discovery Park at Millenium Esplanade. Access to Lilley's Beach is via 4WD, which is another popular pastime. At Tannum Sands there is a surf beach and surf lifesaving club.

3.5 Engagement activities and feedback

Our Coast. Our Future. Strategic Plan (CHAS)

As part of the *Our Coast Our Future* Strategic Plan, key stakeholder groups and the Gladstone region communities were extensively engaged through numerous in-person and virtual events and activities through 2020 and 2021. Feedback from this engagement highlighted the importance of the coastal environment to the residents of the region. This includes access to the beaches and waterways for boating, camping and fishing.

Boyne Island and Tannum Sands SEMP

Community drop-in sessions

Two activities were undertaken at the community drop-in sessions. The first activity focused on the objective of developing a shared understanding of coastal values, goals and aspirations of Traditional Owners, community and other stakeholders. The second activity focused on discussing potential management options. This was achieved via an online values and concerns survey, an in-person workshop with Traditional Owners, as well as two community drop-in sessions.

Survey

The survey was hosted on the Gladstone Regional Council community engagement website, https://conversations.gladstone.qld.gov.au/bits-shoreline-erosion-management-plan, from 31st May 2022 to 26th June 2022. This survey was advertised through Council's website and social media platforms, Gladstone Today, EcoFest and Mount Larcom Show. A total of nine surveys were completed (refer to Attachment 4).

Draft SEMP feedback

The draft SEMP was open for comment from 15th July 2022 to 31st July 2022 on the Gladstone Regional Council community engagement website, https://conversations.gladstone.qld.gov.au/bits-shoreline-erosion-management-plan. This survey was advertised through Council's website, social media platforms and previous community drop-in sessions. This SEMP has incorporated public and stakeholder feedback and comments on the draft SEMP.

4 Coastal processes

This section provides details regarding the natural processes that are shaping the Boyne Island and Tannum Sands foreshore. The coastal environment responds continually to the changing influences of waves, tides, ocean currents, winds and the supply of littoral sediments. The sections below summarise the coastal processes with a further detailed assessment of the Boyne Island and Tannum Sands coastal processes presented in Attachment C.

4.1 Astronomical tides

The Gladstone tides are semi-diurnal, with the dominant tidal planes specified in Table 4. Tidal plane information has been taken from the Queensland Tide Tables (2021) for South Trees Island at Gladstone (PSM 2168), as shown in Table 4. The tidal amplitude is approximately 1.48 m during neap tides, 3.11 m during spring tides and a maximum range of 4.63 m.

Table 4. Tidal planes at South Trees

Tidal plane	2021 (m, LAT)	2021 (m, AHD)
Highest Astronomical Tide (HAT)	4.63	2.42
Mean High Water Spring (MHWS)	3.80	1.59
Mean High Water Neap (MHWN)	2.99	0.78
Mean Sea Level (MSL)	2.20	-0.01
Mean Low Water Neap (MLWN)	1.51	-0.70
Mean Low Water Spring (MLWS)	0.69	-1.52
PSM3853	7.728	5.52
Australian Height Datum (AHD)	2.21	0.00
Lowest Astronomical Tide	0	-2.21

4.2 Storm tides

Storm tide can lead to inundation and erosion of the coastal zone. Storm tide is the ultimate water level, combining the astronomical tide with storm surge. Storm surge is a rise in sea level above the expected tide to produce still water level (SWL) driven by a combination of low pressure on the water surface and extreme winds. The continuous wave breaking action, including wave runup on the shoreline and wave set up due to breaking waves, subsequently create a locally higher mean water level (MWL) at the shore. The primary water level components of a storm tide event are illustrated in Figure 5.

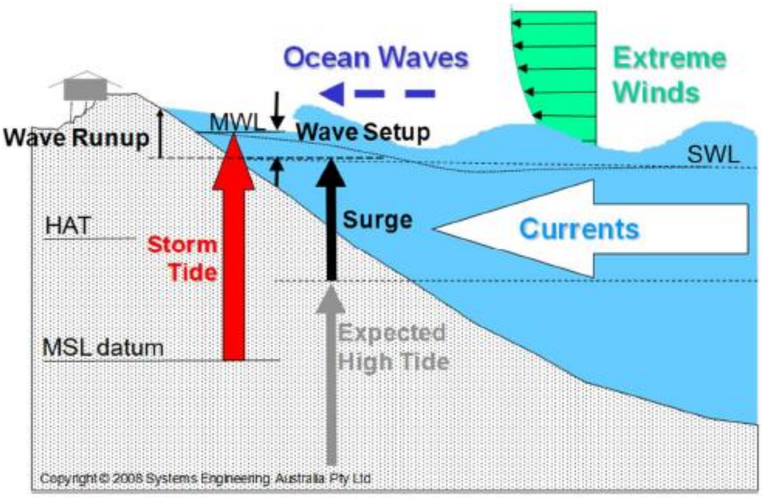

Figure 5. *Comparison between water levels under normal conditions (expected high tide) and storm event conditions. Elevated water level during storm events is known as storm tide and can cause significant damage to low-lying coastal assets (GHD 2015).*

The storm tides reported by the Gladstone Storm Tide Study and Erosion Prone Area Assessment and the Gladstone's *Our Coast Our Future* (CHAS) have been used in the preparation of this SEMP and are summarised in Table 6 for the present-day climate scenario. These levels included the effects of the breaking wave setup component.

Table 5. Present-day storm tide levels with wave setup and runup (m AHD)

Probability of storm event

	10 % AEP	1 % AEP	0.2 % AEP
Boyne Island	3.2	3.9	4.3
Tannum Sands	3.8	4.5	4.8

4.3 Wind climate

Boyne Island and Tannum Sands are exposed to the Coral Sea from the north to the northeast with prevailing wind climate typically dominant from the east. The wind climate of the region is assessed based on the closest and more representative Gladstone Radar AWS, located approximately 15 km northwest of Tannum Sands.

The wind rose presented in Figure 6 generally shows a dominance of easterly and secondary north easterly and south easterly winds. Analysis of 10-min average wind speed data shows dominant easterly wind, with a tendency for higher wind speeds in the summer months. Easterly winds are more dominant in the summer months, with winds becoming more southerly from May to August. Wind speed is typically below 15 m/s, with southeast winds making up the largest portion of strong winds. Rodds Peninsula and Middle Island partially shelter Tannum Sands and Colosseum Inlet from south easterly and southerly. However, it is possible for extreme winds to occur from any direction at Gladstone due to the potential for cyclone activity.

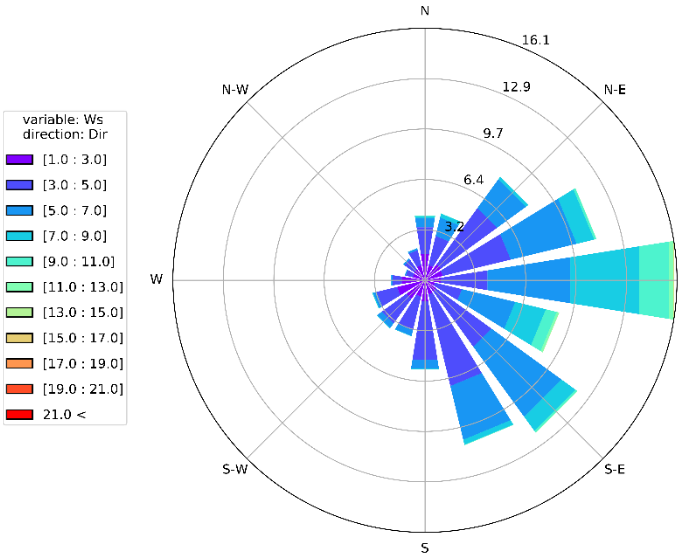

Figure 6. *Wind roses Gladstone Radar AWS showing wind direction and speed from 1957 to present day*

4.4 Wave climate

Boyne Island and Tannum Sands are located between Facing Island and Rodds Peninsula, and are sheltered from the prevailing southerly swell. A review of regional wave data sources, including the Gladstone Waverider buoy (WRB) and European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5, and the development of a SWAN numerical wave model has been completed for this SEMP study (Attachment C).

The Gladstone WRB dataset includes significant wave height (Hs) and peak wave period (Tp), with no wave directionality between 1979 to 1983 and with directionality from 2009 onwards. Hence, the ERA5 global re-analysis data (significant wave height (Hs), peak wave period (Tp), and mean wave direction (θm)) was utilised to fill data gaps in the WRB dataset. The ERA5 data was reviewed and cross-referenced against the available WRB data to ensure no discrepancies between the two datasets. The distribution of the assimilated significant wave height and directionality is presented in Figure 7.

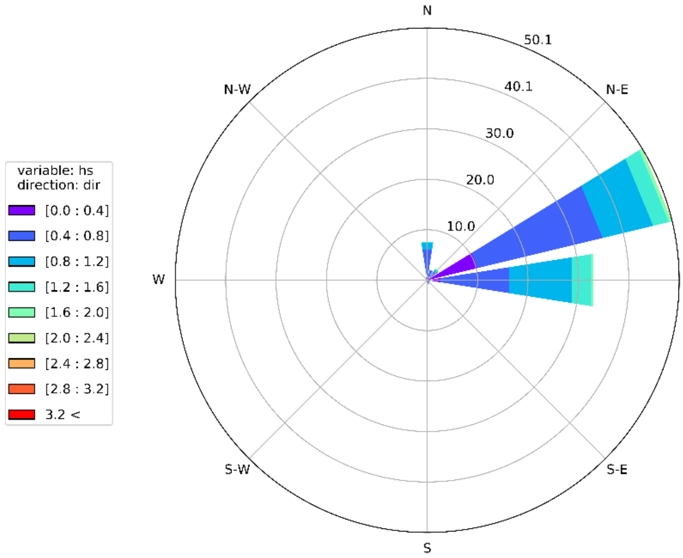

Figure 7. *Wave rose from 1979 to 1983 and 2009 to 2021 – offshore wave height recorded at the Gladstone wave buoy.*

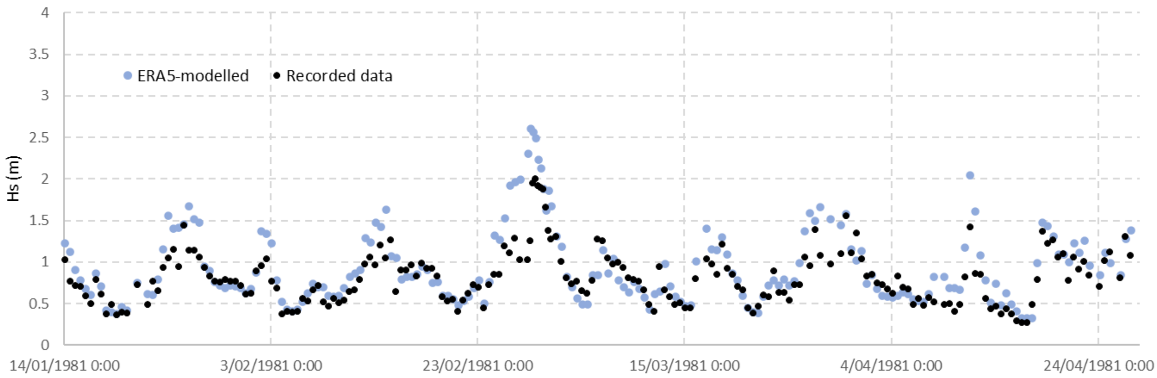

Figure 8. *Comparison of WRB recorded (black) and ERA5-modelled (light blue) wave height data.*

The wave climate of the region consists of fetch-limited waves generated by winds and swells generated offshore that propagate over the Great Barrier Reef. Boyne Island and Tannum Sands are situated in the middle portion of the Gladstone coastline, and are somewhat protected from southeast swells by Rodds Peninsula. The region is also protected to an extent by northerly swells by Facing Island and the Great Barrier Reef.

Nearshore wave conditions have been modelled at five locations along the Boyne Island and Tannum Sands coastline, and the distribution of significant wave height and direction are presented in Figure 9 and Figure 10. At Lilley's Beach north, the results show a trend toward smaller easterly conditions due to protection provided by Facing Island. At Lilley's Beach south, this trend shifts to slightly larger and more northerly waves. Tannum Sands Beach experienced the largest wave heights due to exposure to the largest fetch from this directionality. This effect is reduced at Wild Cattle Beach north and south locations due to the presence of nearshore tidal flats directly in front of Wild Cattle Beach.

Table 6. Nearshore wave conditions

Sites	Av. Hs (m)	Max Hs (m)	Av. Tp (s)	Max Tp (s)	Av. Dir (°N)
Lilley's Beach north (LB_1)	0.19	0.36	5.81	15.58	88.83
Lilley's Beach south (LB2)	0.36	0.64	5.77	15.58	62.51
Tannum Sands beach (TS_1)	0.71	1.2	5.78	15.56	61.69
Wild Cattle Island north (WC_1)	0.56	1.06	5.78	15.58	38.3
Wild Cattle Island south (WC_2)	0.47	0.93	5.86	15.57	57.05

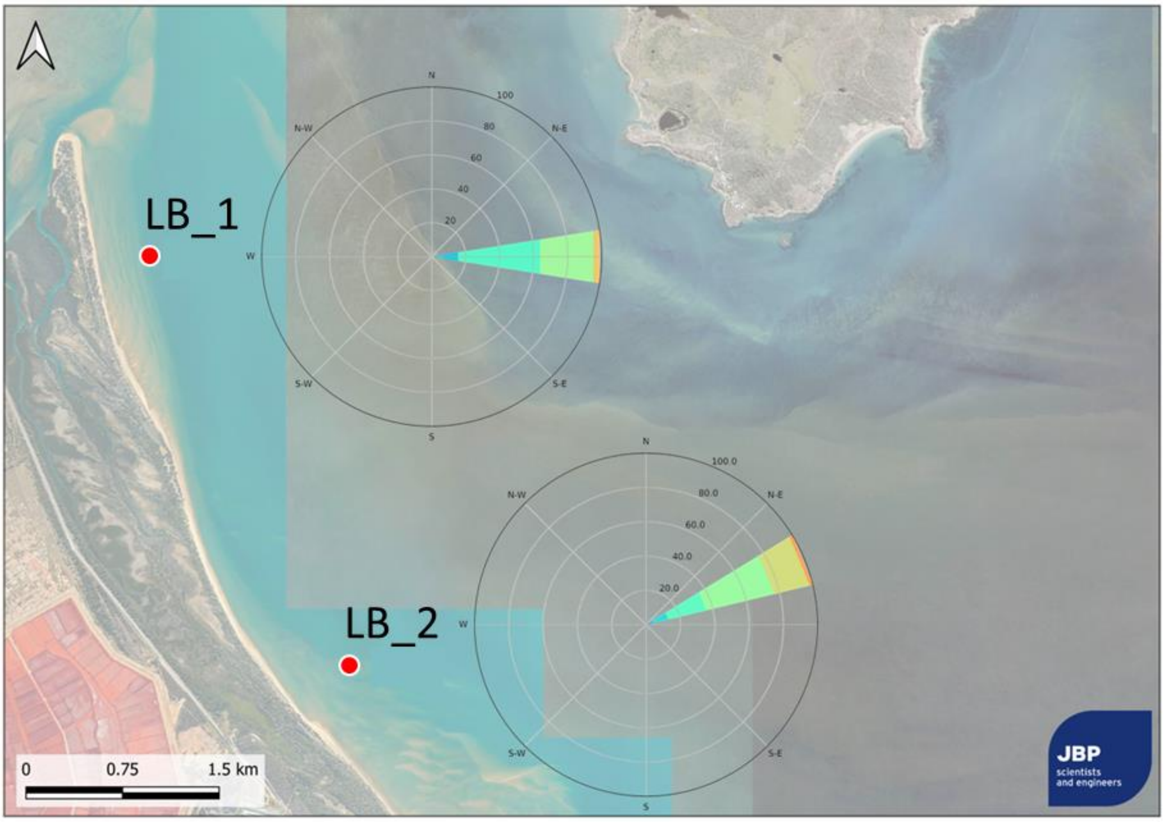

Figure 9. *Nearshore wave conditions at Lilley's Beach north (LB_1) and Lilley's Beach south (LB_2).*

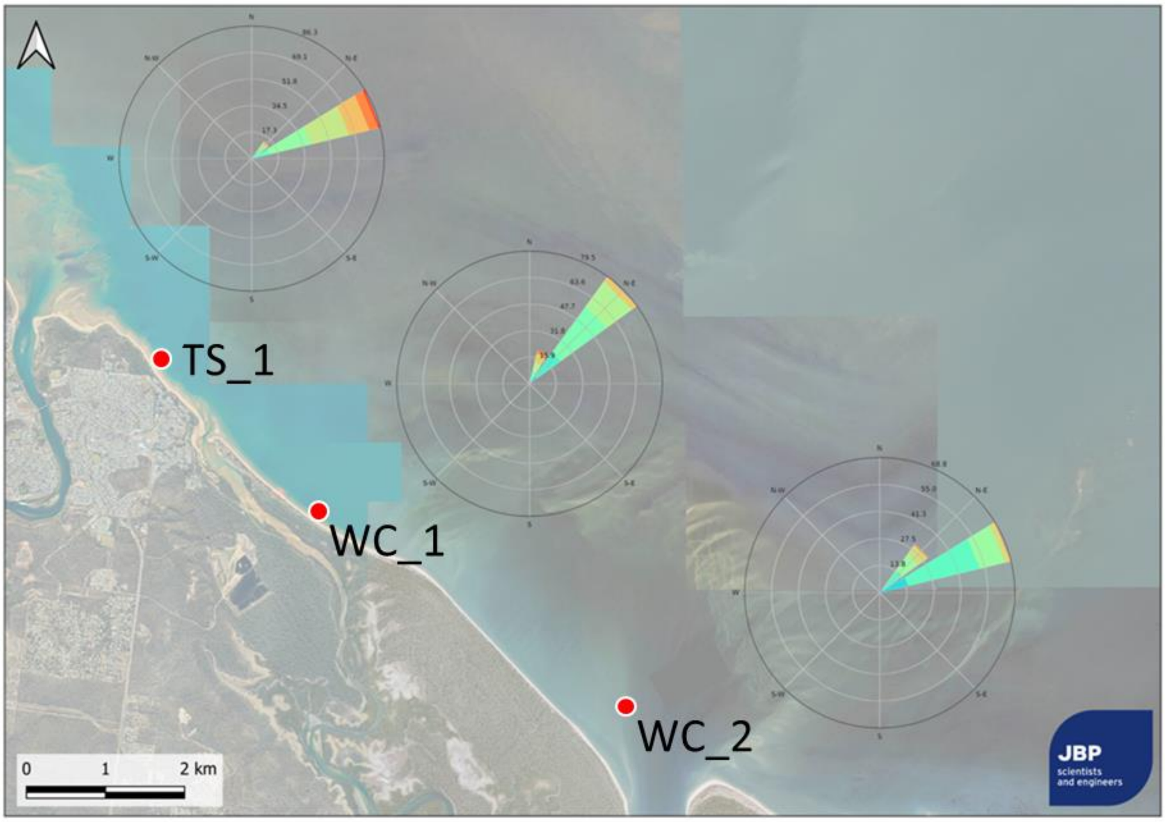

Figure 10. *Nearshore wave conditions at Tannum Beach (TS_1), Wild Cattle Island north (WC_1) and Wild Cattle Island south (WC_2).*

4.5 Nearshore currents

The sand transport in and around the Boyne Island and Tannum Sands foreshore is mostly driven by combined wave and current action in the surf zone. The modelled tidal currents for flood and ebb tides are presented in Figure 11 and Figure 12, respectively. The circulation during the peak ebb flow is the reverse of the flood tide, and the neap tide current are significantly weaker (up to a factor of 2) in comparison to the spring flood tide (Herzfeld, et al. 2004).

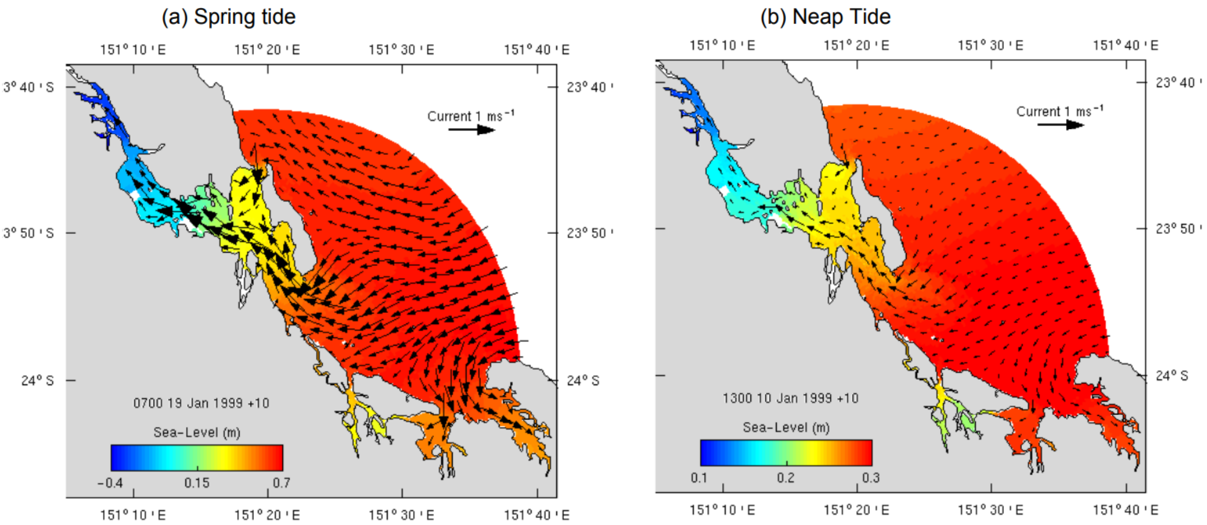

Figure 11. *Depth-averaged tidal currents at flood tide* (Herzfeld, et al. 2004).

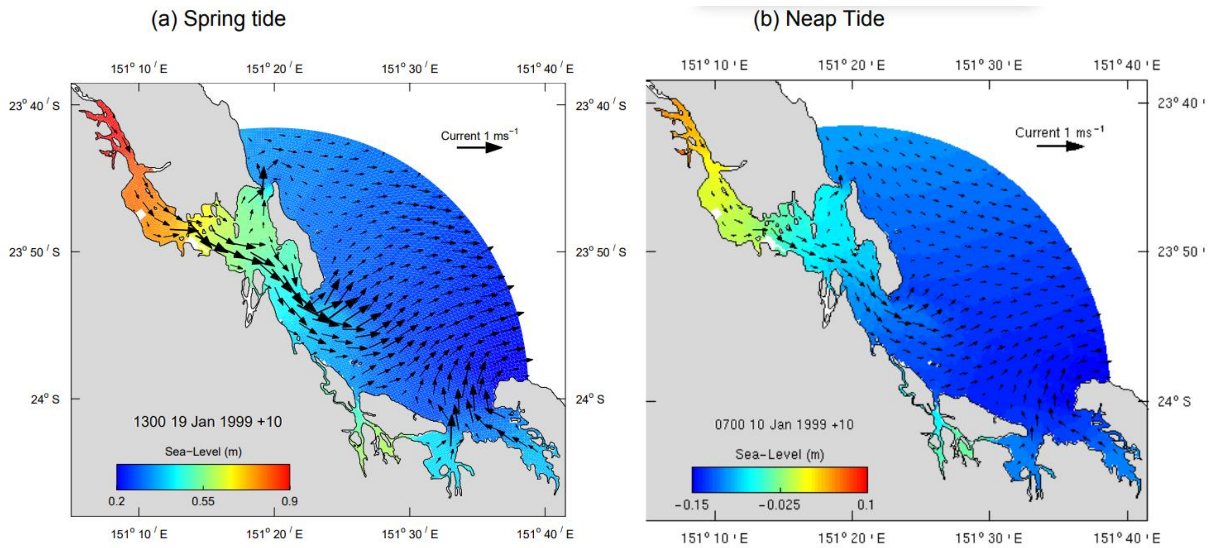

Figure 12. *Depth-averaged tidal currents at ebb tide* (Herzfeld, et al. 2004).

4.6 Sediment transport

Statistical data analysis and model outputs provided an improved understanding of offshore wave, nearshore wave and storm tide conditions. Outputs (noted in Attachment C) have been used to inform an appreciation of sediment transport rates along the Boyne Island and Tannum Sands coastline (Figure 13) and present-day erosion potential at the beach compartments (Table 8).

Longshore sediment transport (LST) between Boyne Island and Tannum Sands is predominantly from wind and tide contributing to the generation of longshore currents near the beach as well as waves breaking at an angle to the shore, which mobilises sand along the coast. Longshore sediment transport is distributed across the surf zone, and it is mainly in the wave break area as the bed shear stresses are the greatest.

Wave conditions were simulated through the SWAN wave model and coupled with the JBEM beach evolution model (refer to Attachment C) to estimate the potential longshore sediment transport at the respective locations. Wave effects on longshore transport are complex and variable due to the irregularity of storm occurrences and the effects of coastal features (rocky outcrops) present along the Tannum Sands shoreline.

While considering the coastal processes from south to north, the estimated longshore sediment transport rates are summarised below:

- The most northerly point (Lilley's Beach north) is expected to have a significantly lower rate of wave-driven transport due to the sheltering offered by Facing Island, in addition to the sheltering provided to all five points by the Capricorn Group of Islands offshore in the Great Barrier Reef (GBR). The calculated LST rate is 8,000 m^3/year towards the north.

- Rates of LST are higher for Tannum Sands and Wild Cattle Island. This is due to the shoreline orientation of these beaches with respect to the dominant easterly wave direction. The calculated LST rates are 36,000 m^3/year at Tannum Beach, 30,000 m^3/year and 34,000 m^3/year at Wild Cattle Beach north and Wild Cattle Beach south, respectively.

These longshore transport rates align with recent studies completed for Agnes Water and Seventeen Seventy (Alluvium & JBP, 2020), located approximately 60 km to the south of Tannum Sands. This study notes a maximum potential sediment transport rate for the beach at Seventeen Seventy is 34,000 m^3.

These trends suggest a dominant northerly sediment transport and indicate little reverse (southerly) transport, which is limited due to the infrequent northerly waves. These results are intended to provide an indicative assessment and are likely to be somewhat conservative in nature. It should be noted that these rates of transport are due to wave-driven processes on open coast beaches only. No consideration has been given at these locations to current-driven transport due to tidal or riverine flow.

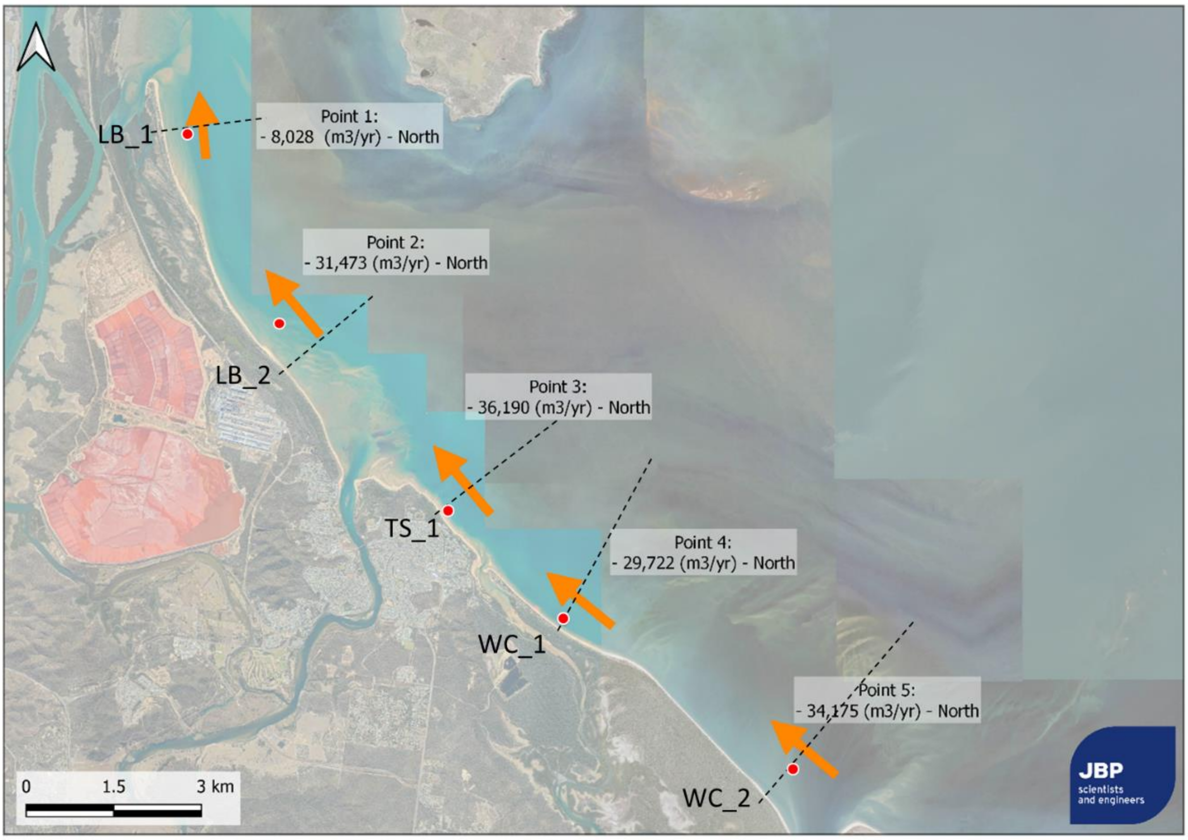

Figure 13. *Estimated longshore sediment transport rates along the Boyne Island and Tannum Sands coastline (m^3 per year).*

4.7 Erosion prone area

2100 State tidal and erosion prone area

The Queensland State Government defines Erosion Prone Areas (EPA) for the Queensland Coastline. The EPAs indicate areas that may be prone to coastal erosion processes by 2100. This includes open coast erosion and tidal inundation due to sea-level rise, based on a storm event with a 1 % AEP (annual exceedance probability). The EPA extent for Boyne Island and Tannum Sands includes areas likely to be exposed to open coast erosion (sandy beach erodible area) by 2100 (Figure 14). Erosion in the tidal area is represented by the mapping of the Highest Astronomical Tide (HAT) plus 0.8 m sea-level rise and a HAT plus 40 m (horizontal) erosion zone.

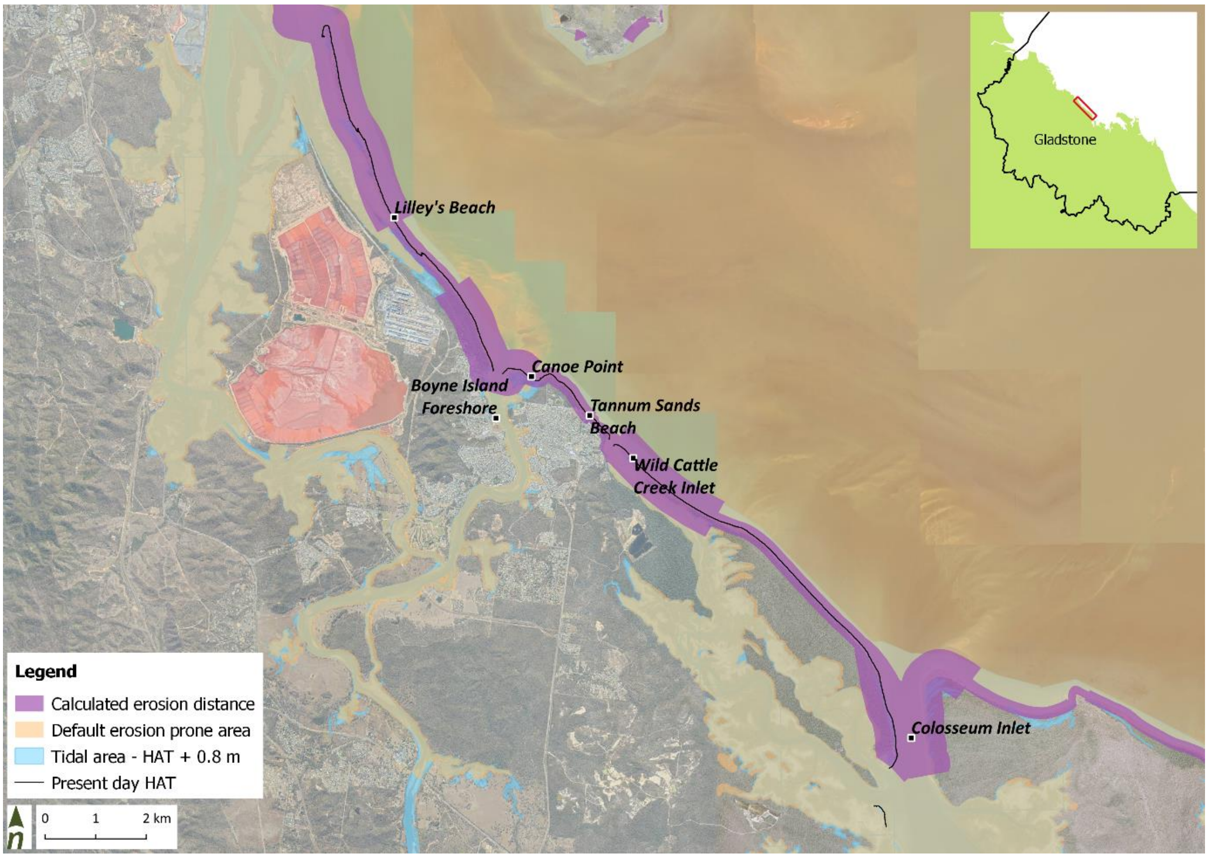

Figure 14. *State 2100 Erosion Prone Area.*

Longer-term adaptation options were included in the *Our Coast Our Future* (CHAS) developed by Council in 2021. For the SEMP process, the EPA assists in highlighting areas that may be increasingly prone to the emerging coastal hazards from present-day to 2100. The State defined 2100 erosion prone area widths summarised in Table 7 include the rate of long-term erosion, short-term erosion from design storm event, erosion due to sea level rise, 40 % safety factor and dune scarping.

Table 7. Erosion prone area

Site	*State open coast erosion calculated component width (m)*
Lilley's Beach north	150
Lilley's Beach south	400
Tannum Beach	145
Wild Cattle Beach north	400
Wild Cattle Beach south	150

Present day

Boyne Island and Tannum Sands are experiencing coastal erosion under present-day conditions. For this SEMP study, additional modelling has been completed to estimate the present-day erosion volume (storm bite) and width for 1 % AEP storm event for Boyne Island and Tannum Sands.

Modelling of the open coast component of the erosion prone area has been undertaken using the JBP Erosion Prone Area (JEPA) tool (refer to Attachment C for approach and results). The outcome of the modelling provides an indication of potential present-day erosion volume (from dunes) and erosion width (measured landward from HAT) for a 1 % AEP event (Table 8). The present-day 1 % AEP erosion widths at Boyne Island and Tannum Sands are summarised in Table 8.

Table 8. Present-day potential erodible widths (m) under 1 % Annual Exceedance Probabilities (AEP)

Site	*Potential erosion width from HAT (m) for present-day 1 % AEP*
Lilley's Beach north	4
Lilley's Beach south	15
Tannum Beach	9
Wild Cattle Beach north	14
Wild Cattle Beach south	15

The erosion widths assume a fully erodible sandy profile, however, the section between Canoe Point and Tannum Beach are dominated by rocky outcrops. Therefore, the actual erosion width may be limited by this rocky substrate material and less prone to erosion. There is no immediate present day potential erosion threat to any land-based assets and not considered an immediate issue of concern.

4.8 Trends in shoreline change

The shoreline along Boyne Island and Tannum Sands is subjected to variability with sediment transport under the influences of the prevailing coastal processes. A preliminary assessment of the shoreline movements has been undertaken with the use of historical coastlines using Digital Earth Australia (DEA).

The DEA coastlines application uses a large database of aerial imagery and tidal models to map the mean annual shoreline position for 32 years from 1988 to 2020 across the Australian coast and islands. Satellite images from Landsat are paired with coincident tide levels to approximate the location of the shoreline. This enables the analysis of coastal rates of change (accretion or recession), with data being regularly updated as it is acquired and allowing an overview of broad trends to be identified.

Macro changes

The broader Boyne Island and Tannum Sands shoreline has been relatively stable over recent decades. In the north of the study area, Lilley's Beach is a sensitive natural foreshore area on Boyne Island's east coast, fronted with tidal flats of 200 – 300 m wide. The beach faces east to northeast and averages 30 m in width with a moderate gradient. Shoreline fluctuations are apparent along the foreshore, experiencing sections of erosion and accretion. Erosion along this shoreline is observed around sections of the convex shoreline and accretion at the leeward side. This is likely a result of high wave energy concentrating on coastal protrusions (convex shoreline configuration), leading directly to increased erosion as compared to adjacent low energy concave shoreline configuration. This is combined with prevailing south-easterly longshore transport, creating a sand "slug" gradually moving from south to north. Lilley's Beach has had little accretion and recession over the last 32 years (1988 to 2020). Disturbance, including increased recreational use and uncontrolled 4WD access tracks, have been observed along Lilley's Beach. These 4WD access tracks cutting across the dune have damaged terrestrial vegetation.

South of Lilley's Beach is the Boyne Island foreshore, and it is located on the northern side of the Boyne River mouth. Since the establishment of residential properties along Island Esplanade in the 1960s, the overall Boyne River mouth shoreline has been relatively stable until 2013. The shoreline was significantly impacted during Tropical Cyclone (TC) Oswald in combination with the peak releases from Awoonga Dam in 2013. This event was represented in a model (refer to Attachment C) and the results are presented in Figure 15. The post-flood event map shows significant straightening of the channel due to the rapidly flowing water, with erosion on both riverbanks. The 2.0 m AHD contour line has been used as an approximation for the dune crest at the mouth of the channel. The erosion between 16 m to 50 m in front of the Island Esplanade properties was observed, and a large volume of sediment from the eastern bank is removed and deposited offshore. These results are supported by historical aerial imagery (Figure 16), where there were minimal shoreline changes from 2007 to 2012, but it was impacted significantly after TC Oswald. Figure 15 also shows a cross-section of the Boyne River mouth before and after the modelled flood event and the eroded bank on the western bank.

The unapproved construction of the GSC seawall along Island Esplanade foreshore in 2015 has stabilised the shoreline in recent years. However, this seawall may have resulted in the end-wall effect, which scours the toe of the wall and causes a gradual loss of beach in front of the seawall. The seawall may also have exacerbated erosion immediately north of the residential properties, directly in front of the car park. Loosely placed rocks have been placed along the eroded section to provide scour protection. Adjacent beaches to the north and south of Island Esplanade foreshore are accreting, and terrestrial vegetation are also prograding, which typically indicates the shoreline is recovering and rebuilding. However, being in an estuarine environment, the mouth of Boyne River is expected to be dynamic.

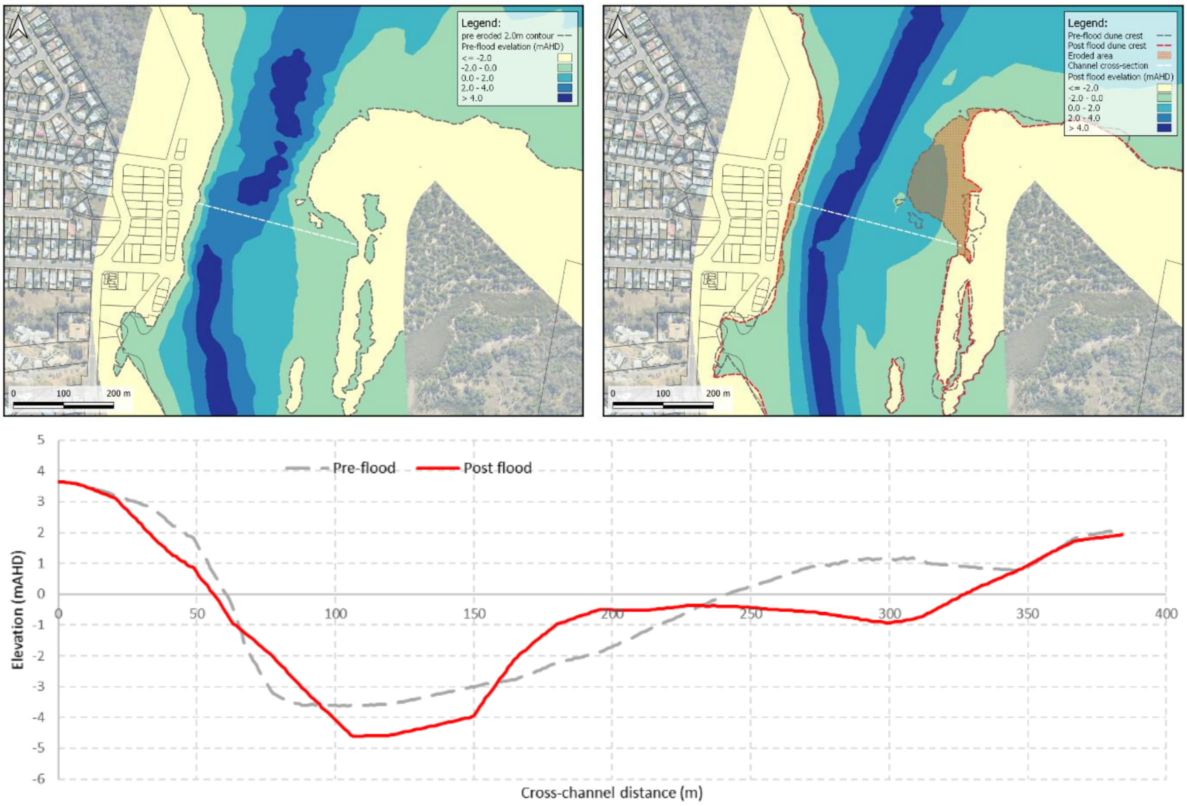

Figure 15. *(Left) Boyne River mouth pre-flood dune crest at 2.0m AHD. (Right) Boyne River post-flood dune crest at 2.0m AHD and eroded areas. (Bottom) Pre- and post-flood cross section at Boyne River mouth.*

Figure 16. *Historical aerial imagery for Island Esplanade with indicative 2007 to 2021 vegetation line.*

The shoreline from Canoe Point to Tannum Sands Beach has been relatively stable over the recent decades with little recession and accretion (Figure 17). The comparative shoreline position and net shoreline movement (NSM) have been presented in Figure 17. Canoe Point and Tannum Sands Beach have been maintaining a stable net shoreline position in the last 31 years, with accretion and recession rates ranging between -1 to +1 m/year at most locations.

Wild Cattle Creek Inlet shoreline is highly variable, being in an estuarine environment. Based on 20 years of inlet flow paths, the inlet is not in a closed state but has been stable. This is expected as the inlet is tidally fed from the north as well as the southern entrance at Colosseum Inlet. The inlet is almost recreating an intermittently open and closed lake or lagoon (ICOLL) but with tidal forcing and the channel mouth is being maintained primarily by upstream freshwater flows. Detailed assessment of Wild Cattle Creek inlet is presented in Attachment C.

Wild Cattle Beach faces east to northeast similar to Lilley's Beach. As such, the erosion and accretion trend along this stretch of coastline is also similar. Erosion is observed around the section of the convex shoreline further south towards Bangalee and accretion on the leeward side. This section of the shoreline has been gradually receding in the last 31 years, and there is evidence of long-term recession, with fallen mature trees on the beach and exposure of the root systems of mature trees. The net shoreline movement measurements indicate that the beach has receded up to 50 m. Anecdotal report from a Bangalee resident confirmed this measurement.

The Bangalee shoreline has been relatively stable over the recent decades with little recession and accretion (Figure 17).

Historical shoreline movements

Measurements of the mean annual shoreline positions relative to a "baseline" have been adopted to provide a reliable assessment of shoreline movements. The Digital Earth Australia (DEA) Coastlines application was used to identify finer-scale historical shoreline changes and trends between 1988 to 2021 and supported by measurements of vegetation lines, where necessary. Key observations include (refer to Figure 17):

Full extent end point rate:

- The magnitude and rate of shoreline change vary spatially along the Boyne Island and Tannum Sands coastline between sections of the coast dominated by erosion and other accretion.
- The rate of open coast shoreline movement at Lilley's Beach ranges between -2.54 to +2.68 m/year.
- The highest rate of shoreline movements occurred at Boyne River mouth and Wild Cattle Creek Inlet. Estuary environments are expected to be dynamic and sensitive to episodic floods and tidal regime.
- In general, the Boyne Island and Tannum Sands shoreline is relatively stable, except for some localised recession at various sections.

Net shoreline movement:

- Between 1988 and 2020, the magnitude of shoreline movement has varied spatially across the coastline.
- The magnitude of shoreline change has ranged from -95 m to 102 m.
- The greatest amount of shoreline recession/erosion has occurred on the southern end of Lilley's Beach and the southern end of Wild Cattle Beach, with up to -95 m and -76 m of recession, respectively.
- The areas which have experienced the most accretion/growth have occurred directly north of the localised recessed sections along both Lilley's Beach and Wild Cattle Beach.
- The Island Esplanade shoreline was stable until 2012 and significantly impacted by TC Oswald. The construction of the GSC seawall resulted in the stabilisation of the foreshore in front Lot 104 to Lot 108, and Lot 112 only.

End point rate and net shoreline movement measurements indicate that recession is most evident on the southern end of both Lilley's Beach and Wild Cattle Beach. The recession at Lilley's Beach has been gradual since 1988, but it is the most evident in 2009 and post-2013. The measurements confirmed that while there is localised erosion, the shoreline is also accreting at other locations. Hence, the accretion and recession rates are about 2.5 m/year at all locations, except Island Esplanade foreshore.

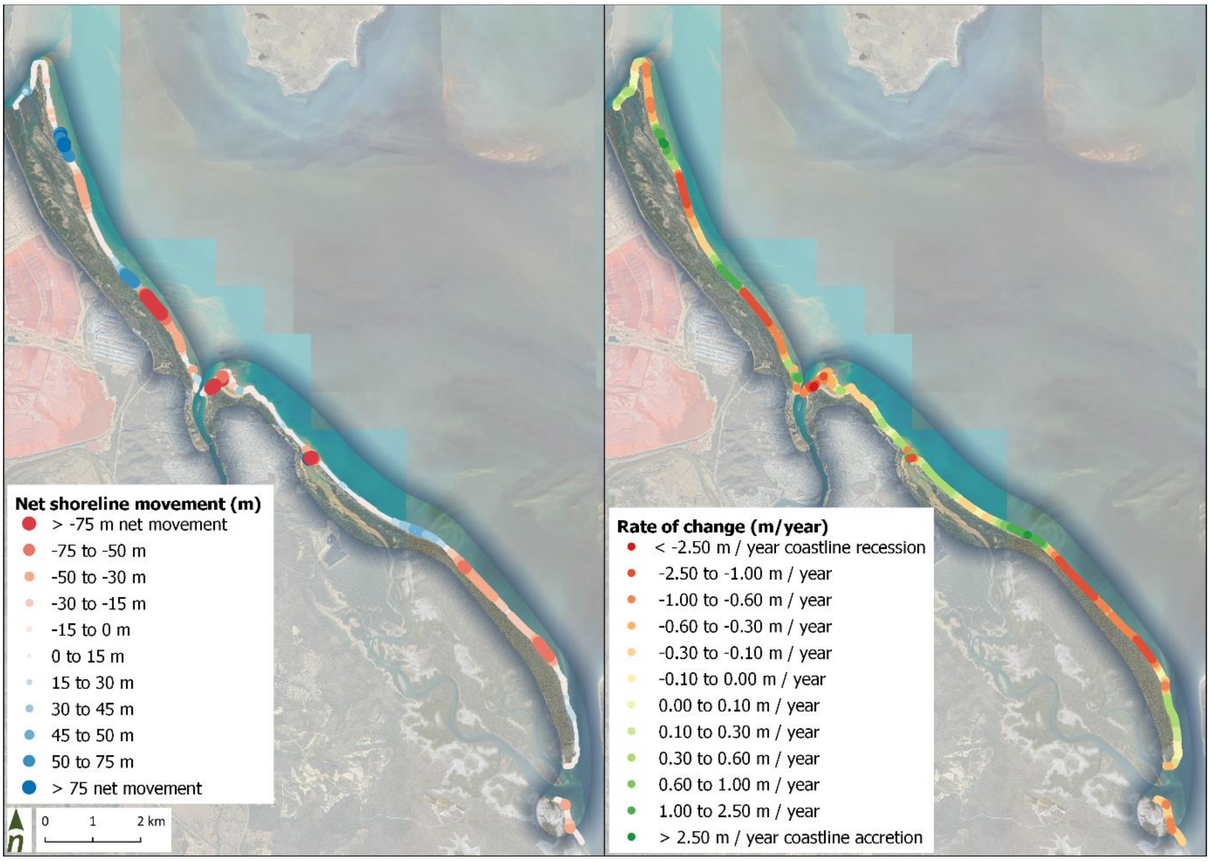

Figure 17. *(Left) Net shoreline movement (m) and (right) annual rate of change (m/year) from 1988 to 2021– seaward accretion (+ve change) or landward recession (-ve changed).*

4.9 Trajectory of change and management focus

The prevailing coastal processes will continue to drive erosion events along the Boyne Island and Tannum Sands shoreline over the coming decades. With a changing climate and projected sea level rise, the area prone to erosion and tidal inundation as well as the magnitude of erosion as a result of storm events is expected to increase.

Assets and infrastructure at Island Esplanade, Turtle Way, The Oaks Road, Tannum Beach, Millenium Esplanade, Wild Cattle Boat Ramp and Bangalee are positioned such that erosion has already impacted these areas. Erosion will continue to have adverse impacts on shoreline amenity, recreation and other social and economic values locally and for the region.

When considering appropriate erosion management options along the Boyne Island and Tannum Sands shoreline, it is evident that the shoreline can be considered in 12 coastal segments:

1. Lilley's Beach
2. Lilley's Beach entrance
3. Island Esplanade foreshore
4. Turtle Way
5. Canoe Point
6. Oaks Road foreshore
7. Tannum Sands Surf Life Saving Club (SLSC)
8. Millenium Esplanade
9. Wild Cattle Creek Boat Ramp
10. Wild Cattle Island foreshore
11. Bangalee
12. Southern communities

The overall intent of actions associated with the 12 coastal segments of the SEMP is to develop viable erosion management strategies that integrate across the entire Boyne Island and Tannum Sands shoreline to maximise social, cultural, economic and environmental benefits for the community. Section 5 provides a range of shoreline erosion management options, and Section 6 discusses the 12 defined coastal segments in detail.

Mouth of Boyne River

5 Shoreline erosion management options

5.1 Overview generic option considerations

When preparing the SEMP, a range of shoreline management options have been considered to mitigate the erosion threat on the local foreshore areas. However, preferred options vary depending on site context and stakeholder preferences. The appropriate options to mitigate erosion threats at specific locations depend on the nature and level of threat as well as the consequences if they are disregarded. Erosion threats that require prioritisation are typically when they result in immediate risks to public infrastructure and loss of beach amenities in public spaces.

Management options can generally be identified as two strategic approaches: "soft" (non-structural) options and "hard" (structural) options.

Soft erosion management options

"Soft" (non-structural) options are solutions to restore and/or preserve the natural character, behaviour and values of the existing coastal system. These management options allow the shoreline to adapt naturally to prevailing coastal processes. "Soft" options typically include options listed in Table 9.

Table 9. Generic "soft" erosion management options

OPTIONS	*DESCRIPTIONS*
Do nothing	Allows prevailing coastal processes to take their natural course without threats to community or assets where foreshore land is undeveloped or there are assets of only limited value.
Maintain status quo	Allows the local coastal processes to take their natural course while actively monitoring and managing a stable or low-risk foreshore.
Avoid development	Implement planning and management controls to avoid development in erosion and flood-prone areas. This would also preserve the amenity, ecosystem and character of the foreshore.
Planned retreat	Remove any development under threat and allow the beach and dune system to behave naturally. Planning retreat must consider the ownership of the land and the responsibility of any structure removal.
Beach nourishment	Large-scale placement of sand directly along the coastal segment either by earthmoving equipment or by sand dumping to increase the volume of sand on the beach. Sand can be nourished utilising an external sand source (e.g., river mouth or offshore deposits). Sand can be shaped to provide a dune system that is stabilised with fencing and vegetation.
Beach scraping	Move sand from lower levels of the cross-shore beach profile up onto the beach slope or into the dune system. Provides an increased buffer of sand at the back of the beach to improve resilience against storm events.
Revegetation	Native coastal vegetation can be sourced and planted to provide stability to a newly established sand dune. This can be through direct seeding or planting established vegetation to diffuse wind and wave action and allow for sand retention. Revegetation species are dependent on the coastal environment, level of protection and salinity.

Hard erosion management options

"Hard" (structural) options involve engineering works to mitigate the threat of coastal erosion by altering natural processes or creating a barrier to maintain the existing shoreline. "Hard" options typically include options listed in Table 10.

Table 10. Generic "hard" erosion management options

Revetments and seawalls

Typically made of rock, concrete, geo-fabric bags or wood, seawalls provide an artificial barrier to erosive processes and protect the coastal assets behind them. A seawall also has a limited ability to dissipate energy and generally results in an accelerated scour of sand from the base of the wall.

Less formal revetments can also be implemented through the placement of rock or geo-bags.

Buried seawall

Similar to an exposed seawall, except they are buried and generally require extensive excavation. It acts as the last line of defence structure.

As they are buried, they allow the natural beach cycle to occur in most cases, except extreme events, maintaining a more natural beach most of the time.

Groyne

Built perpendicular to the coast, groynes can be constructed from a variety of materials, including rock, geo-bags, concrete or wood. Groynes assist with sand retention in areas prone to longshore drift. Sediment is captured on the updrift side, while erosion generally occurs on the downdrift side.

Groynes can be formally engineered with excavation or less formally constructed. They can vary in length, dependent on the sediment transport environment at the site and the level of protection required. In some cases, groynes can also be oriented to provide a barrier to wave energy.

Offshore breakwater

An offshore structure that is not connected to the beach. Offshore breakwaters function by sheltering the shoreline in its lee side by providing a "wave shadow". Reducing the wave energy landward of the breakwater helps to minimise waves from moving sand along the shoreline.

Offshore submerged reef

Similar to a breakwater, an artificial reef also reduces the wave energy impacting the beach. Artificial reefs often have greater habitat value and encourage marine life to establish, mimicking natural reef systems.

Considering the variability of local coastal processes along the Boyne Island and Tannum Sands shoreline, foreshore amenity and recreational values, the most appropriate shoreline management options may vary from site to site. Likely, combinations of options or "hybrid" management strategy, including both "soft "and "hard" options might be appropriate for any particular location.

5.2 Other consideration

Other options have been considered based on the preference expressed by the community during the community workshops.

Artificial breakthrough at Wild Cattle Creek inlet	Some members of the community expressed interest in considering an artificial breakthrough at the Wild Cattle Creek Inlet, to create a safe swimming environment at Millenium Esplanade.
Restrict Lilley's Beach as off-limits to 4WDs	Some members of the community expressed a preference to close off Lilley's Beach for 4WDs to protect flora and fauna habitat.

5.3 Weightings

The pairwise matrix (presented in Figure 18) was prepared in consultation with Council, and it generates a series of weightings for each criterion (see Table 11). It involves comparing and prioritising each of the selected criteria against each other sequentially. The pairwise ranking provides decision-makers with oversight into the relative degree of importance of each criterion with respect to each other.

We assessed the sensitivity of the MCA final output scores by adjusting the assessment criteria scores as detailed in Attachment 5. Sensitivity testing with various scenarios such as equal weightings, swapping protection and accessibility weightings, and swapping value (cost) and environmental weightings had demonstrated little sensitivity on the options rankings. As such, the criteria weightings are unchanged and have been adopted.

Criteria		Accessibility	Adaptability	Cultural heritage	Protection	Environmental	Approvals	Safety	Value (cost)	Visual and recreational	Total	Weighting (%)	Rank
		a	b	c	d	e	f	g	h	i			
Accessibility	1	1	0	1	0	0	0	0	0	1	3	3.6%	9
Adaptability	2	2	1	2	1	0	1	0	0	1	8	9.6%	7
Cultural heritage	3	1	0	1	2	1	1	0	1	2	9	10.8%	5
Protection	4	2	1	1	1	2	1	1	1	0	10	12.0%	3
Environmental	5	2	2	1	0	1	1	1	2	1	11	13.3%	2
Approvals	6	2	1	1	1	1	1	0	0	0	7	8.4%	8
Safety	7	2	2	2	1	2	2	1	2	2	16	19.3%	1
Value (Cost)	8	2	2	1	1	0	2	0	1	0	9	10.8%	5
Visual and recreational amenity	9	1	1	0	2	1	2	0	2	1	10	12.0%	3

Figure 18. *Pairwise matrix weightings.*

5.4 Options assessment approach

There is a range of management options that can be considered to help manage and enhance coastal and foreshore areas, in line with Council's desired outcomes. The MCA approach is adopted to assess all the potential coastal management options across the 11 sites. The MCA evaluates the management options by assessing each option against a defined set of decision criteria that represent the range of values and interests at each site. The degree to which the option achieves the above criteria is scored out of 5 according to Table 11, and each criterion is weighted based on priorities for specific sites. The decision criteria are as follows:

Table 11. MCA assessment criteria scoring

Criteria	1	2	3	4	5
Accessibility *Ability to increase usage and access the foreshore or surrounding areas, including by people with disability and reduced mobility.*	Significant reduction of usage and access to foreshore.	May restrict foreshore usage and access – more difficult to walk along foreshore.	No change to foreshore usage and access.	Moderate increase in usage and access to foreshore.	Increase usage and access to foreshore. Fully DDA compliant.
Adaptability *Longevity of the solution, in relation to potential future sea level rise.*	No ability to be adapted for future needs.	Very difficult to be adapted for future needs.	Limited adaptability to future needs.	Can be adaptable to future needs, with some challenges.	Readily adaptable to future needs.
Cultural heritage *Conservation of cultural heritage values.*	Unacceptable ground disturbance. Likely to disturb culturally significant items or areas.	Disturbance and excavation of large footprint beyond existing footprint. Likely to disturb cultural heritage if present at site.	Disturbance and excavation beyond the existing footprint. Likely to disturb cultural items if directly in location of works.	Disturbance or excavation within existing footprint. Unlikely to disturb any cultural significant items even if present at site.	Minimal disturbance or excavation of ground. No new ground disturbance.
Protection *Design life and level of protection to foreshore and assets.*	Limited to no risk reduction.	Minimal protection – moderate risk reduction.	No change in level of protection.	Moderate increase in mitigating risk (5 % AEP or greater event tolerable).	Effective in mitigating the risk (1 % AEP or greater event tolerable).
Environmental *Impact on coastal processes regime, environmental and marine values.*	Significant adverse impact on natural processes, environmental and marine values.	Notable adverse impact on natural processes, environmental and marine values.	No adverse impact on natural processes, environmental and marine values.	Minimal adverse impact on natural processes, enhance environmental and marine values.	No impact on natural processes, enhance environmental and marine values.
Approvals *Levels of approvals and permits required, and the likelihood obtaining approvals.*	Significant approvals risk – against development codes and guidelines.	Moderate approval risks – not in clear alignment with codes or guidelines.	Approvals required – in accordance with planning policy or legislative requirements.	Readily approved – consistent with current planning policy or legislative requirements.	Readily approved – limited approvals required – exempt works or accepted development.
Safety *Risks to public safety.*	Potentially intolerable risks (high to extreme risks).	Moderate, but tolerable risks (injury/first aid).	No impact on safety.	Moderate positive impact on safety.	Significant positive impact on safety.
Value (cost) *Whole of life costs, including capital costs and ongoing maintenance requirements.*	Estimated cost is higher than $4.5M.	Estimated cost is between $2.5M to $4.5M.	Estimated cost is between $1.5M to $2.5M	Estimated cost is between $500k to $1.5M	Estimated cost is less than $500k.
Visual amenity *Conservation of the existing vistas and recreational activities.*	Significant reduction to visual amenity and recreational use of the foreshore.	Moderate reduction to visual amenity and recreational use of the foreshore.	No impact on visual amenity and recreational use of the foreshore.	Moderate improvement to visual amenity and use of the foreshore.	Significantly improve to visual amenity and use of the foreshore.

6 Assessment of shoreline erosion management options

The overall intent of actions associated with the four individual coastal segments of this SEMP is to manage erosion in a way to maximise social, economic and environmental benefits for the community. Twelve coastal segments are defined for this SEMP (Figure 18):

1. Lilley's Beach
2. Lilley's Beach entrance
3. Island Esplanade foreshore
4. Turtle Way
5. Canoe Point
6. The Oaks Road foreshore
7. Tannum Sands Surf Life Saving Club (SLSC)
8. Millenium Esplanade
9. Wild Cattle Creek Boat Ramp
10. Wild Cattle Island foreshore
11. Bangalee
12. Southern communities

General principles for management that apply to all sites include:

- Minimise disturbance to dunes and vegetation, including limiting access points across dunes and along the dune toe, supported by education.
- Enhance dune vegetation – which assists in retaining sand and assisting dunes to accrete/build up.
- Boost additional dune care actions, including protective fencing and revegetation of dunes, to enhance natural dune building processes between storm events.

In addition to these principles, some additional actions may be required at each site, as noted in the following sections. Section 6.1 to 6.12 assess a range of options for each of the 12 coastal segments.

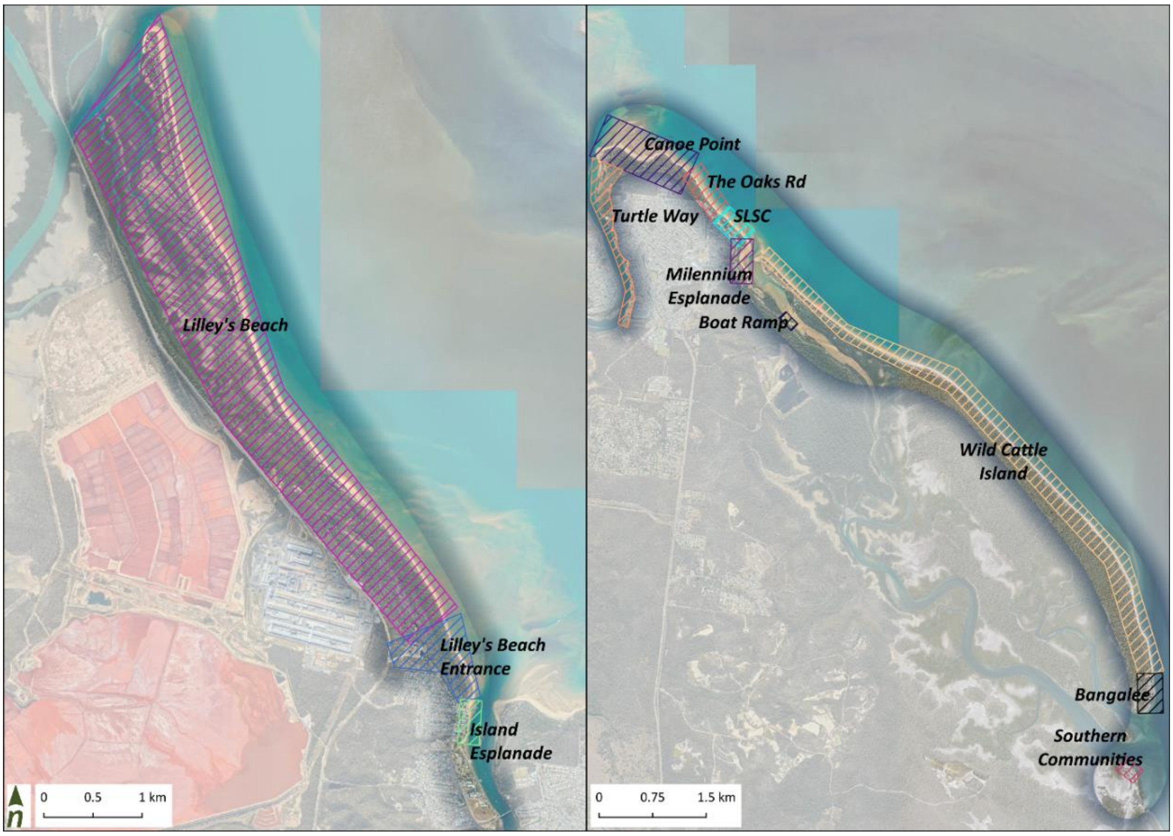

Figure 19. *Management segments of Boyne Island and Tannum Sands SEMP.*

6.1 Lilley's Beach

Present day shoreline condition and key coastal issues

Lilley's Beach is an open sandy beach with potential erosion and shoreline recession vulnerability. Disturbance, including beach driving, informal access tracks and informal campsites, have been observed along Lilley's Beach. Localised erosion has occurred along this beach section. Evidence of erosion scarps of up to 0.5 m, loss of mature trees and some exposed root systems of mature trees. There are distinctive patches with loss of vegetation, especially around the formal campsites (Lot 4 SP144771 under Subordinate Local Law No. 4, Schedule 6) and informal campsites behind the foredunes. The recession along this section of Lilley's Beach is not uniform and driving vehicles on the beach and over the dunes is a contributing factor to the increasing erosion issue. The vegetation buffer along this section between the beach and Handley Dr ranges from 400 m to 600 m.

Increased erosion occurs from 4WD-ing on soft sand above the intertidal zone, whereas driving on the hard-packed sand between the HAT and low tide marks reduces the likelihood of erosion. The informal access tracks cutting across the dune have resulted in vegetation damage. Increased recreational use of the area and loss of vegetation may also be contributing to the accelerated shoreline variability.

Additionally, there is anecdotal evidence of illegal camping in other areas along the foreshore, which may also result in further vegetation clearing, and habitat loss and fragmentation. Vehicle, pedestrian and other access along the foreshore within potential sensitive and vulnerable habitats, including turtle nesting areas and seagrass meadows.

The following management options are considered for Lilley's Beach:

1. Maintain status quo
2. Vegetation management and education plus traffic management plan

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 12 provides an overview of the scores for each option against the weighted assessment criteria for Lilley's Beach.

Table 12. Criteria weighting and scores (unweighted and weighted) for Lilley's Beach options

		Unweighted		Weighted	
Criteria	**Criteria weighting**	**Option 1**	**Option 2**	**Option 1**	**Option 2**
Accessibility	3.6%	2	2	0.07	0.07
Adaptability	9.6%	1	4	0.10	0.39
Cultural heritage	10.8%	2	5	0.22	0.54
Protection	12.0%	1	2	0.12	0.24
Environmental	13.3%	3	5	0.40	0.66
Approvals	8.4%	5	4	0.42	0.34
Safety	19.3%	2	5	0.39	0.96
Value (Cost)	10.8%	5	5	0.54	0.54
Visual amenity	12.0%	2	5	0.24	0.60
Total	100%			2.49	4.35
Rank				2	1

The weighted score is the criteria weighting multiplied by the unweighted score. For example, 3.6% x 2 = 0.07. The maximum possible total weighted score for any option is 5.

Option 1 – Maintain status quo
Continue to monitor and maintain Lilley's Beach as per current management activities.

This does not resolve the current erosion problems for Lilley's Beach, especially sections where disturbance, including beach driving and informal access cutting across the dune have resulted in vegetation damage and localised beach erosion.

The sections of Lilley's Beach may continue to have a slow sand loss to the north – the rate of loss may be exacerbated by changing climate.

Table 13 provides scores for Option 1 against the assessment criteria.

Figure 20. *Existing conditions at Lilley's Beach.*

Table 13. Lilley's Beach – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	2	Increase disturbance to the foreshore as 4WD access continues to damage vegetation and cause erosion in new areas with unknown cultural significance.
Protection	1	Require monitoring and maintenance. Provides no protection and improvement to the foreshore.
Environmental	3	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	There would be no additional cost.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Vegetation management and education plus traffic management plan
Protect and enhance dune systems with appropriate vegetation communities, including rehabilitation of a corridor of appropriate coastal vegetation along with the dune systems.

This option will require community engagement on the appropriate vegetation communities, their geomorphic and ecological value, and strategies to manage other values, including access points and other amenity values of the foreshore. Active vegetation management should be supplemented with beach access control and protective fencing to stabilise the dune system.

Council should develop a traffic management plan for Lilley's Beach to improve beach driving safety. Education around the conditions of the 4WD permits to be undertaken, including information about following rules/conditions results in less disturbance to the environment. Council should actively monitor compliance with the permits.

If these rules/conditions are not followed, Council may need to consider restricting or stopping 4WD access on Lilley's Beach.

Table 14 provides scores for Option 2 against the assessment criteria.

Figure 21. *Lilley's Beach – Option 2 – Active vegetation management and dune stabilisation.*

Table 14. Lilley's Beach – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce to minimise pedestrian foot traffic and damage to the plants.
Adaptability	4	Long-term site resilience would be improved by vegetation establishment and reduction in vehicle, pedestrian and other access along the foreshore.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Erosion may still occur during storm events. If multiple events hit in succession, protection may be limited.
Environmental	5	Surrounding environmental values would be enhanced. Reducing access points along the foreshore will be important to enhance the protection and recovery of vegetation.
Approvals	4	Where works are limited to minor structures such as signage that have an insignificant impact on coastal management and is reversible or expendable and involve: • interfering with quarry material, as defined under the Coastal Act, on State coastal land above high-water mark; and/or • removing or interfering with coastal dunes on land, other than State coastal land, that is in an erosion prone area The works are likely to comprise excluded work and will not comprise assessable development under Schedule 10, Part 17, S.28(b) of the *Planning Regulation 2017*.
Safety	5	The overall site safety increases as pedestrian foot traffic would be minimised.
Value (Cost)	5	**Capital cost = $68,000** Whole of life cost of approximately $77,000, including:

		• Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	5	Improve foreshore width and natural foreshore aesthetic.

Recommended option

Option 2 – Active vegetation management and 4WD access management. *Protect and enhance dune systems with appropriate vegetation communities, including rehabilitation of a corridor of appropriate coastal vegetation along with the dune systems.*

Description

This SEMP identifies active vegetation management as the recommended option at Lilley's Beach and 4WD access management is highly encouraged to improve and protect the significant environmental value and recreational use of Lilley's Beach. The desired outcome from this recommendation is to reduce erosion and the impact to vulnerable species and ecosystems. The impacts of 4WD use on the beach could be mitigated by limiting use to the hard sand only and within a certain width of the beach.

Establish zones of management along the Lilley's Beach foreshore, especially vulnerable sections that are receding, to create up to a 20 m buffer zone landward of HAT to stabilise the dune and prevent erosion by revegetating with native species.

Council to develop a 4WD traffic management plan by formalising and maintain defined access tracks, as well as appropriately sign at camp site entrances. The impacts of 4WD use on the beach could be mitigated by limiting use to the hard sand only and within a certain width of the beach. Enforce 4WD driving to Lilley's Beach users with approved permits under the permit conditions. Council/Local Laws Officers to undertake random beach patrols as part of enforcement to issue warnings (or fines). Information to be provided directly to permit holders to communicate when there are active nesting sites to avoid. Council to undertake an audit of the access points on a yearly basis to determine whether illegal access tracks are being established.

Council should enforce illegal clearing local laws to prevent further establishment of unauthorised and informal access tracks. Review 4WD use on Lilley's Beach following an assessment of two years of beach monitoring data to determine the impact of vehicle use on the sensitive flora and faunal habitats. Additionally, Council should provide community education material regarding the limitations placed on Council to remove debris along the foreshore and beach which sits within the Great Barrier Reef Marine Park Zone.

Tier 2 action – Restrict 4WD access on Lilley's Beach (if applicable)

Alternatively, restricting or stopping 4WD access on Lilley's Beach should be considered if permit conditions are not adhered to, and continued 4WD access is exacerbating erosion and impacting on vulnerable species and ecosystems.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 15.

Table 15. Lilley's Beach – recommended option 2 (Active vegetation management and 4WD access management) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$20,000
Revegetation, fencing, access management	$18,124
Labour and minor items	$1,359
SUBTOTAL	**$39,483**
Allow 70 % budget contingency[1]	$27,638
TOTAL	**$67,121**

[1] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.2 Lilley's Beach entrance

Present day shoreline condition and key coastal issues

The informal access tracks cutting across the sand dune have resulted in vegetation damage. Increased recreational use of the area and loss of vegetation may also be contributing to the accelerated shoreline variability.

There has been significant unapproved clearing to provide an access track through the vegetation in the foreshore zone. Access to Lilley's Beach is currently through the Boyne Smelter Limited (BSL) gazetted freehold land, which was an informal and non-binding agreement between Council and BSL.

The following management options are considered for Lilley's Beach entrance:

1. Maintain status quo
2. Relocate and formalise entrance
3. Restrict 4WD access to Lilley's Beach and create an off-limits area

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 16 provides an overview of the scores for each option against the weighted assessment criteria for Lilley's Beach entrance.

Table 16. Criteria weighting and scores for Lilley's Beach entrance options

Criteria	Criteria weighting	Option 1	Option 2	Option 3
Accessibility	3.6%	0.11	0.14	0.07
Adaptability	9.6%	0.10	0.10	0.19
Cultural heritage	10.8%	0.54	0.22	0.54
Protection	12.0%	0.24	0.36	0.48
Environmental	13.3%	0.66	0.27	0.66
Approvals	8.4%	0.34	0.25	0.34
Safety	19.3%	0.39	0.77	0.77
Value (Cost)	10.8%	0.54	0.54	0.54
Visual amenity	12.0%	0.36	0.48	0.48
Total	100%	3.28	3.13	4.08
Rank		2	3	1

Option 1 – Maintain status quo
Continue to maintain 4WD access through freehold land. It does not resolve the current issues of beach driving in prohibited areas and over sand dunes, particularly at high tide, and encroachment onto the Boyne Island Sewage Treatment Plant and Boyne Smelter owned freehold lands. This option is not recommended as it has the potential to exacerbate shoreline recession, increase foredune slope and further loss of vegetation and fauna habitat. Table 17 provides scores for Option 1 against the assessment criteria.

Table 17. Lilley's Beach entrance – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	3	Retain access to Lilley's Beach.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Require monitoring and maintenance. Provides no protection and improvement to the foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	4	Where works are limited to minor structures such as signage, board and chain access treatments or inclusion of bollards to limit vehicle movements and all structures have an insignificant impact on coastal management and is reversible or expendable and involve: • interfering with quarry material, as defined under the *Coastal Protection and Management Act 1995*, on State coastal land above high-water mark; and/or • removing or interfering with coastal dunes on land, other than State coastal land, that is in an erosion prone area The works are likely to comprise excluded work and will not comprise assessable development under Schedule 10, Part 17, S.28(b) of the *Planning Regulation 2017*. Council should formally negotiate with Boyne Smelter Limited on an easement agreement to allow permitted 4WDs on the foreshore area.
Safety	2	The overall site safety decreases as the track continues to deteriorate without any additional maintenance.
Value (Cost)	5	There would be no additional cost, only a budget to maintain existing Council assets.
Visual amenity	3	The visual amenity of the entrance is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Relocate and formalise entrance
Relocate existing access track and formalise new access track onto reserve land. This option would involve restricting access using rocks or bollards to denote the current designated path and provide a barrier to allow vegetation to establish itself again. There is currently an informal access track 240 m south of the existing access track that is within a reserve land. This informal access track should be formalised and maintained as the designated track to Lilley's Beach with wooden sleepers and chains if necessary. This will allow users to 'stick to the track', protecting the dunes without the need for fencing. Council should monitor the access point with a regulated access system. This option should be supplemented with standardised signage at the land and beach entrances to provide safe, designated access to the beach, and educate and build understanding with regard to foreshore protection. Table 18 provides scores for Option 2 against the assessment criteria.

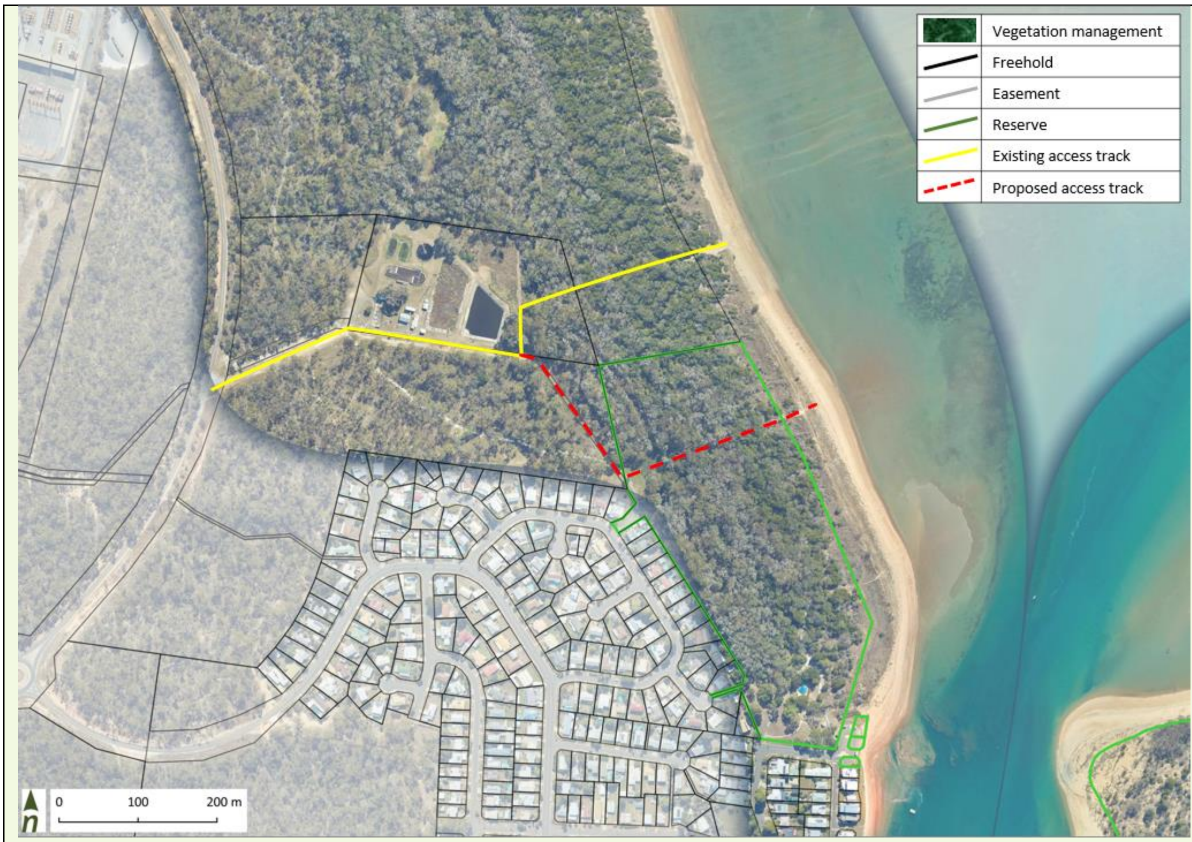

Figure 22. *Lilley's Beach entrance – Option 2 – Relocate and formalise entrance*

Table 18. Lilley's Beach entrance – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore would be formalised, providing safe access.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	2	Minimal disturbance or excavation to the ground beyond existing informal access track. However, it is considered as high risk works.
Protection	3	Require monitoring and maintenance. Provides improvement to foreshore but no protection to coastal processes.
Environmental	2	No adverse impacts on natural processes. Replacing the existing access track will cause disturbance to the existing flora and fauna. The works are located within a high risk area for protected plants. Any clearing within this area that does not qualify for an exemption will require a protected plants survey to be progressed in accordance with the State's Flora Survey Guidelines prior to any clearing commencing, and an exempt notification lodged with the Department where no conservation significant plant species are located within the clearing extent or 100m buffer to the proposed clearing area.
Approvals	3	Where works are limited to minor structures such as signage, wooden sleepers and chain access treatments or inclusion of bollards to limit vehicle movements and all structures have an insignificant impact on coastal management and is reversible or expendable and involve: • interfering with quarry material, as defined under the Coastal Act, on State coastal land above high-water mark; and/or • removing or interfering with coastal dunes on land, other than State coastal land, that is in an erosion prone area The works are likely to comprise excluded work and will not comprise assessable development under Schedule 10, Part 17, S.28(b) of the Planning Regulation 2017. The land is also shown as supporting Category B "least concern" remnant vegetation. Clearing for a new road is consistent with the definition of routine

		management which is exempt development if occurring in trust land where carried out by the trustee and is consistent with achieving the purpose of the trust under Schedule 21, Part 2 Section 6(c)(vi). Lot 63 on CTN1787 is also listed on the Queensland Heritage Register (Site No. 601811) as William Wyndhams gravesite and remnant orchard trees. Consideration may be given to whether the Department of Environment and Science will support a request for an exemption certificate for the works or whether a material change of use will be required to upgrade the access track.
Safety	4	Access track would be formalised, improving overall safety.
Value (Cost)	5	Capital cost = $ 49,000 Whole of life cost of approximately $55,000, including: • ~500 m of formalised access track • Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	4	The visual amenity of the foreshore is likely to improve.

Option 3 – Restrict 4WD access onto Lilley's Beach and create an off-limits area

Restrict 4WD access to Lilley's Beach and create an off-limits area for 4WDs and designated camping areas.

This option would involve restricting 4WD access using rocks or bollards to denote all formal and informal tracks and provide a barrier to allow vegetation to establish itself again. Fencing and signs should be installed at the access points at the beach to note that it is a 4WD prohibited area. Pedestrian access should be retained. Council Officers to undertake random beach patrols as part of enforcement.

Table 19 provides scores for Option 3 against the assessment criteria.

Figure 23. *Lilley's Beach entrance – Option 3 – Restrict 4WD access onto Lilley's Beach and create an off-limits area*

Table 19. Lilley's Beach entrance – Option 3 criteria scores

Criteria	Score	Comment
Accessibility	2	Significant reduction of usage and access to foreshore by 4WDs. Foreshore access would be restricted to pedestrian foot traffic.
Adaptability	2	Erosion may still occur during storm events. Long-term site resilience would be improved by vegetation establishment.
Cultural heritage	5	No disturbance or excavation of land.
Protection	4	Provides additional buffer protection to mitigate coastal risks.
Environmental	5	Surrounding environmental values will be improved significantly. Provide safe nesting areas for turtles.
Approvals	4	Where works are limited to minor structures such as signage or inclusion of bollards to limit vehicle movements and all structures have an insignificant impact on coastal management and is reversible or expendable and involve: • interfering with quarry material, as defined under the Coastal Act, on State coastal land above high-water mark; and/or • removing or interfering with coastal dunes on land, other than State coastal land, that is in an erosion prone area The works are likely to comprise excluded work and will not comprise assessable development under Schedule 10, Part 17, S.28(b) of the *Planning Regulation 2017*. Additional approvals required to change local laws and undertake associated community consultation.
Safety	4	Provide good recreational area with minimal safety risks.
Value (Cost)	5	Low short-term cost for revegetation and low ongoing maintenance cost.
Visual amenity	4	Provide improvement to visual amenity and reduce the foreshore usage as access will be limited.

Recommended option

Option 1 – Maintain status quo
Option 3 – Restrict 4WD access onto Lilley's Beach and create an off-limits area

Continue to maintain 4WD access through freehold land in the short-term. This option must be supported by a formal easement agreement between Council and BSL.

Description

Although Option 3 (restricting 4WD access onto Lilley's Beach) is most beneficial to the coastal system and the environment, Lilley's Beach is also a popular recreational area for 4WDing and camping. It is likely that new informal and unapproved access tracks will be created as a result of restricting 4WD access, which may be more detrimental than managing the current access tracks and use.

This SEMP has identified Option 1 – Maintain status quo as the recommended option. In order to continue this option, a formal easement agreement is required. This option involves Council to liaise directly with Boyne Smelter Limited (BSL) to negotiate on an easement agreement.

Council should maintain the formal access track and provide a barrier to allow vegetation to establish itself again. Pedestrian access should be retained. Council Officers to undertake random beach patrols as part of enforcement. This option should be supplemented with standardised signage at the land and beach entrances to provide safe, designated access to the beach, and educate and build understanding with regard to foreshore protection.

Tier 2 action – Restrict 4WD access onto Lilley's Beach and create an off-limits area (if applicable)

Alternatively, restricting or stopping 4WD access on Lilley's Beach should be considered if:

- easement agreement cannot be negotiated with BSL to formalise access point, or
- permit conditions are not adhered to, exacerbating erosion and impacting vegetation.

Cost estimates
The detailed cost estimates associated with the recommended option are presented in Table 20.

Table 20. Lilley's Beach entrance – recommended option 1 (Maintain status quo) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$20,000
Access track	$2,380
Revegetation, fencing, access management	$5,365
Labour and minor items	$581
SUBTOTAL	**$28,326**
Allow 70 % budget contingency[2]	$19,828
TOTAL	**$48,154**

Lilleu's Beach

[2] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.3 Island Esplanade foreshore

Present day shoreline condition and key coastal issues

Public infrastructure and private properties are located in close proximity to the active beach system, with residential properties within 5 to 10m of the high tide mark.

The GSC seawall was constructed in 2015 and additional concrete edging was added to the crest of the wall. Construction of the seawall was undertaken by private residents; this wall was not constructed by Council. Based on visual inspection of the seawall, the GSCs are largely intact, but the seawall is in poor condition with minimal remaining useful life. Some of the GSCs are partially deflated, potentially a combination of gravity and slow "creep" from the internal migration of sand. There are cracks throughout the concrete edging, likely due to the dynamic movements of the GSC seawall.

Immediately north and south of the GSC seawall, there are scour holes at both termination points – between Lot 104 and the Olunda Street carpark and Lot 109 and Lot 10. This is likely due to increased turbulence during periods of elevated water levels caused by the presence of the seawall. Loosely placed rocks and debris have been used to protect the eroded sections by providing scour protection.

There are four carpark areas within the foreshore area along Island Esplanade, including the Olunda Street carpark. There are also stormwater and sewer infrastructure in proximity to the foreshore area. Any potential options will need to consider the carparks and long-term planning of the stormwater and sewerage infrastructure.


GSC seawall – looking south


GSC seawall – southern end


Olunda Street – localised scour


In front of Lot 104 – localised scour

The following management options are considered for Island Esplanade foreshore:

1. Maintain status quo
2. Full removal of the structure and replace with new geotextile sand container revetment
3. Full removal of the structure and replace with rock revetment
4. Full removal of the structure and replace with AquaRock bag revetment
5. Retain existing seawall and remediate using submerged AquaRock bags nearshore

Note: Options 2 to 5 will not be possible for residents to undertake without Council's involvement due to the tenure of the land adjoining the foreshore. A potential secondary seawall could extend further south to protect the properties south of the decommissioned boat ramp.

Council recognises the future threat to private properties, critical services and community facilities from erosion of the Island Esplanade foreshore and that private property owners have limited capacity to individually implement an effective, approved management option. Further engagement with impacted property owners will be undertaken before a management option is selected.

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 21 provides an overview of the scores for each option against the weighted assessment criteria for Island Esplanade foreshore.

Table 21. Criteria weighting and scores for Island Esplanade foreshore options

Criteria	**Criteria weighting**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Accessibility	3.6%	0.07	0.14	0.11	0.14	0.11
Adaptability	9.6%	0.10	0.48	0.48	0.48	0.48
Cultural heritage	10.8%	0.54	0.43	0.43	0.54	0.43
Protection	12.0%	0.24	0.60	0.60	0.60	0.24
Environmental	13.3%	0.66	0.40	0.40	0.40	0.27
Approvals	8.4%	0.17	0.17	0.17	0.17	0.17
Safety	19.3%	0.39	0.77	0.77	0.77	0.39
Value (Cost)	10.8%	0.54	0.11	0.11	0.33	0.22
Visual amenity	12.0%	0.24	0.36	0.36	0.36	0.36
Total	100%	2.95	3.47	3.43	3.80	2.66
Rank		4	2	3	1	5

Option 1 – Maintain status quo

Continue to maintain and assess the seawall, stormwater outlet and adjacent car parks and infrastructure as required.

This option does not provide any additional protection to mitigate erosion, scour and overtopping for Island Esplanade foreshore. The majority of the Island Esplanade foreshore is somewhat protected by the existing geotextile sand containers (GSC) seawall to avoid extensive erosion impacts on the foreshore and residential areas. However, sections of the foreshore and adjacent residential areas are already being impacted by adverse effects from the seawall. This section of Island Esplanade may continue to be under erosion and inundation threats episodically and may be exacerbated by any future sea level rise.

Table 22 provides scores for Option 1 against the assessment criteria.

Figure 24. *Existing conditions at Lilley's Beach entrance.*

Table 22. Island Esplanade foreshore – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce as the seawall continues to deteriorate.
Adaptability	1	Existing seawall and assets may require repair or replacement after large storm events. Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.

Protection	2	Requires continuous maintenance and repair works. Provides no additional protection to mitigate coastal risks. Assets, adjacent public land and infrastructure at high risk of storm and tidal inundation.
Environmental	5	Surrounding environmental values are unchanged and undisturbed. Reducing access points in front of the Olunda Street carpark will be important to enhance the protection and recovery of vegetation.
Approvals	2	Maintenance of an existing approved structure may be undertaken in accordance with the *Code for accepted development For tidal works, or work completely or partly in a Coastal Management District*. From the available information, the existing works do not appear to benefit from an existing approval, and the works are therefore likely to be unlawful. Accordingly, a development permit for prescribed tidal works and disturbing quarry material on State coastal land above high-water mark will be required. Landowner's consent would be required prior to the application being made. It is possible that no impact to marine plants will occur where no saltwater couch or other marine plants are present in proximity to the proposed alignment. A response to State Code 7 and State Code 8 will be required for the tidal works, and a response to State Code 11 will also be required where the works impact on marine plants.
Safety	2	The overall site safety decreases as the existing seawall continues to deteriorate.
Value (Cost)	5	There would be no additional cost, only budget to maintain foreshore and Council assets.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Full removal of the structure and replace with geotextile sand containers

Full removal of the existing seawall and replace with engineering-designed geotextile sand containers (GSC), combined with vegetation management, formalised beach access and stormwater integration.

A new seawall using GSC's is proposed to span across the Island Esplanade foreshore and Olunda Street carpark. A geotextile layer would be installed along the base and wrapped around the back of the revetment to prevent washout from beneath and behind the structure. The required depth of the revetment to prevent the structure from becoming undermined would need to be confirmed. Beach and foreshore access would need to be incorporated over the revetment.

Maintenance would likely be required as the structure is exposed to waves and current. The useful life of GSCs can be up to 17 years if they are well protected, but it reduces to approximately ten years if they are exposed to the weather and coastal processes.

Table 23 provides scores for Option 2 against the assessment criteria.

Figure 25. *Island Esplanade foreshore – Option 2 – Concept plan and illustration of GSC seawall.*

Table 23. Island Esplanade foreshore – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access points would be improved, providing safe access.
Adaptability	5	The crest could be raised to adapt to the future climate if required.
Cultural heritage	4	Minimal disturbance or excavation to the ground beyond existing footprint.
Protection	5	Excellent protection for assets behind the seawall. However, the area in front of the wall is subject to natural erosion. The ends of the seawall will need to be tied into the existing ground to avoid adverse erosion.
Environmental	3	No adverse impacts on natural processes. Replacing the existing seawall would cause disturbance to the existing flora and fauna.
Approvals	2	Works would be subject to an operational works development application (prescribed tidal works), with referral required to the State Assessment Referral Agency for tidal works and potentially impacts to marine plants. Landowner's consent would be required prior to the application being made. It is possible that no impact to marine plants will occur where no saltwater couch or other marine plants are present in proximity to the proposed alignment. A response to State

		Code 7 and State Code 8 will be required for the tidal works, and a response to State Code 11 will also be required where the works impact on marine plants.
Safety	4	Access points would be formalised, improving overall safety.
Value (Cost)	1	**Capital cost = $3.1M** Whole of life cost of approximately $4.9M, including: • ~ 270 m geotextile sandbags seawall replacement. Optional additional ~80 m seawall to the south. • Stormwater outlets upgrade • Design, approvals, site setup and environmental management • Revegetation, landscaping, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	3	Will change the natural aesthetics of the coastline. No more appealing than existing amenity

Option 3 – Full removal of the structure and replace with rock revetment

Full removal of the existing seawall and replace with engineering-designed rock revetment, combined with vegetation management, formalised beach access and stormwater integration.

Revetments can be used to protect critical assets from coastal hazards. These structures are typically in the form of a seawall that provides a barrier between the ocean and adjacent coastal land. This option would involve excavation of the existing wall, installing geofabric and a multilayer revetment. The revetment would be constructed with a crest level similar to the current crest level. The crest could be raised in future stages if required to adapt to increasing sea levels. A geotextile layer would be installed along the base and wrapped up at the back of the revetment to prevent washout from beneath and behind the structure. This structure must be appropriately engineered and to ensure the design (size, height, grade, layers, filters and material) meets the required standards to provide sufficient protection from the local wave climate

This option would require an access path and stormwater outlet to be incorporated. It is important to note that the seawall may be buried on the northern section in front of the Olunda Street carpark, and the southern end of the seawall would need to be tied into the decommissioned boat ramp.

Table 24 provides scores for Option 3 against the assessment criteria.

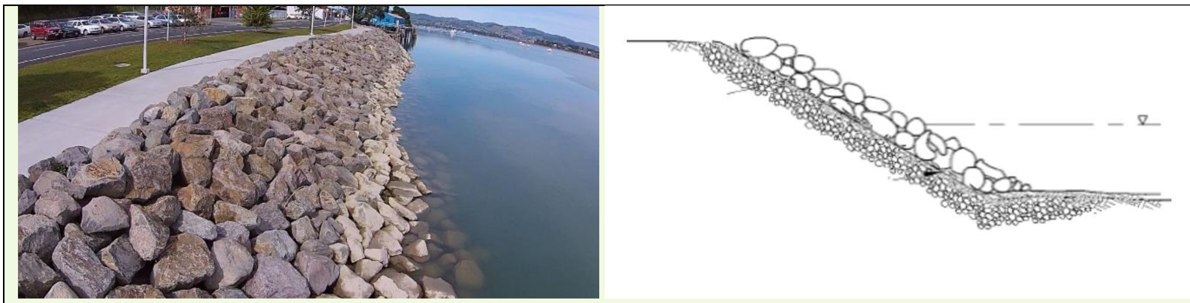

Figure 26. *Island Esplanade foreshore – Option 3 – Concept plan of rock armour revetment replacement. Illustration (bottom right) adapted from USACE Coastal Engineering Manual.*

Table 24. Island Esplanade foreshore – Option 3 criteria scores

Criteria	Score	Comment
Accessibility	3	Access points may be reduced but would be formalised, providing safe access.
Adaptability	5	The crest could be raised to adapt to the future climate if required.
Cultural heritage	4	Minimal disturbance or excavation to the ground beyond existing footprint.
Protection	5	Excellent protection for assets behind the seawall. However, the area in front of the wall is subject to natural erosion. The ends of the seawall will need to be tied into the existing ground to avoid adverse erosion.
Environmental	3	No adverse impacts on natural processes. Replacing the existing seawall would cause disturbance to the existing flora and fauna.
Approvals	2	Works would be subject to an operational works development application for (prescribed tidal works), with referral required to the State Assessment Referral Agency for tidal works and potentially impacts to marine plants. Landowner's consent would be required prior to the application being made. It is possible that no impact to marine plants will occur where no saltwater couch or other marine plants are present in proximity to the proposed alignment. A response to State Code 7 and State Code 8 will be required for the tidal works, and a response to State Code 11 will also be required where the works impact on marine plants.
Safety	4	Access points would be formalised, improving overall safety.
Value (Cost)	1	Capital cost = $4.0M Whole of life cost of approximately $4.6M, including: • ~ 270 m rock revetment replacement. Optional additional ~80 m seawall to the south • Stormwater outlets upgrade • Design, approvals, site setup and environmental management • Revegetation, landscaping, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	3	Will change the natural aesthetics of the coastline. No more appealing than existing amenity

Option 4 – Full removal of the structure and replace with AquaRock bag revetment

Full removal of the existing seawall and replace with engineering designed AquaRock bag revetment, combined with vegetation management, formalised beach access and stormwater integration.

Similar to Option 2 and Option 3, this option would involve excavation of the existing wall and placing multi-layers of AquaRock bags. The AquaRock bags are flexible and can be installed on uneven surfaces or slopes. The bags are made of recycled materials and are typically filled with rocks. The useful life of AquaRock bags can exceed 25 years, depending on the site conditions.

The AquaRock bags are quick and easy to fill on or off-site and can be installed in a shorter timeframe than conventional revetment walls. A crane will be required to lift the bags and place them on site. This structure must be appropriately engineered to ensure the design (size, heigh, grade and layers) meets the required standards to provide sufficient protection from the local wave climate. This option would require an access path and stormwater outlet to be incorporated.

Table 25 provides scores for Option 4 against the assessment criteria.

Figure 27. *Island Esplanade foreshore – Option 4 – Concept plan of AquaRock bag revetment replacement. Photo (bottom right) sourced from Gabion Cages and Baskets*[3].

Table 25. Island Esplanade foreshore – Option 4 criteria scores

Criteria	Score	Comment
Accessibility	4	Access points would be improved, providing safe access.
Adaptability	5	The crest could be raised to adapt to the future climate if required.
Cultural heritage	5	AquaRock bags can placed directly on uneven surfaces. Minimal disturbance or excavation to the ground beyond existing footprint.
Protection	5	Excellent protection for assets behind the seawall. However, the area in front of the wall is subject to natural erosion. The ends of the seawall will need to be tied into the existing ground to avoid adverse erosion.
Environmental	3	No adverse impacts on natural processes. Replacing the existing seawall would cause disturbance to the existing flora and fauna.
Approvals	2	Works would be subject to an operational works development application (prescribed tidal works), with referral required to the State Assessment Referral

[3] https://www.gabioncages.com.au/

		Agency for tidal works and potentially impacts to marine plants. Landowner's consent would be required prior to the application being made. It is possible that no impact to marine plants will occur where no saltwater couch or other marine plants are present in proximity to the proposed alignment. A response to State Code 7 and State Code 8 will be required for the tidal works, and a response to State Code 11 will also be required where the works impact on marine plants.
Safety	4	Access points would be formalised, improving overall safety.
Value (Cost)	3	Capital cost = $1.5M Whole of life cost of approximately $2.0M, including: • ~ 270 m AquaRock bags revetment replacement. Optional additional ~80 m seawall to the south. • Stormwater outlets upgrade • Design, approvals, site setup and environmental management • Revegetation, landscaping, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	3	Will change the natural aesthetics of the coastline No more appealing than existing

Option 5 – Retain existing seawall and remediate using submerged AquaRock Bags nearshore

Retain existing GSC seawall and remediate using submerged rock-filled AquaRock Bags to reduce wave impacts on the foreshore.

This option would involve an offshore structure to withstand the incident wave climate and forms a tombolo or salient to provide a sheltering environment to stabilise the shoreline. The structure is to have a crest level of approximately at Mean High Water Spring (MHWS) to reduce wave overtopping.

The offshore structure is proposed to be filled with rocks using AquaRock Bags. Should this option progress being concept design, a detailed assessment of wave climate would need to inform refinement of the layout and stability of the structure.

Ongoing maintenance would be likely to be required for the existing GSC seawall as it is exposed.

Table 24 provides scores for Option 4 against the assessment criteria.

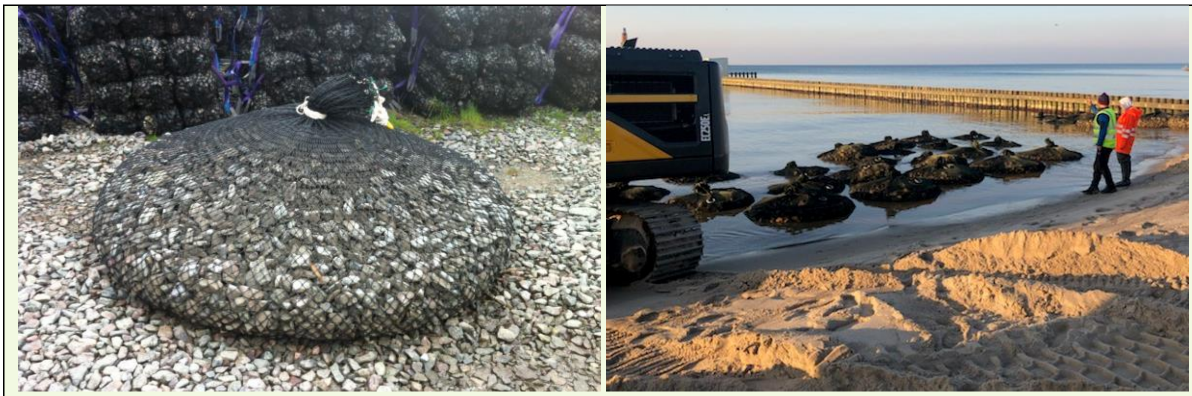

Figure 28. *Island Esplanade foreshore – Option 5 – Concept plan of AquaRock Bags structure alignment. (Bottom) Photos sourced from Gabion Cages and Baskets.*

Table 26. Island Esplanade foreshore – Option 5 criteria scores

Criteria	Score	Comment
Accessibility	3	Access to foreshore remain unchanged.
Adaptability	5	The crest could be raised to adapt to the future climate if required.
Cultural heritage	4	Minimal disturbance or excavation to the ground. AquaRock Bags would be placed on the ground.
Protection	2	Provide protection for assets in ambient conditions. No additional protection during storm events.
Environmental	2	The offshore structure would cause disturbance to the existing environment and create potential adverse impacts. This option provides potential fish habitat benefits.
Approvals	2	Works would be subject to an operational works development application (prescribed tidal works), with referral required to the State Assessment Referral Agency for tidal works and potentially impacts to marine plants. Landowner's consent would be required prior to the application being made. It is possible that no impact to marine plants will occur where no saltwater couch or other marine plants are present in proximity to the proposed alignment. A response to State Code 7 and State Code 8 will be required for the tidal works, and a response to State Code 11 will also be required where the works impact on marine plants.
Safety	2	No change to safety on the foreshore. The offshore structure may create marine safety issues.
Value (Cost)	2	Capital cost = $2.1M Whole of life cost of approximately $3.1M, including: • ~ 170 m AquaRock Bags offshore structure • Design, approvals, site setup and environmental management • Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	3	Will change the natural aesthetics of the coastline. Will not be visible at high tide.

Recommended option

Council recognises the future threat to private properties, critical services and community facilities from erosion of the Island Esplanade foreshore and that private property owners have limited capacity to individually implement an effective, approved management option. Additional consideration by Council is required before a definitive management option can be selected to address this issue. The proposed options will be assessed by Council's Investment Decision Framework to identify a feasible option that considers the gazetted road reserve, council land and assets, private property and community use. This will also consider all costs and funding options for construction and maintenance of the proposed solutions, including varying proportions of Council, private or alternative investment. Further engagement with impacted property owners will be undertaken before a management option is selected.

Management options to be considered:

Option 4 – Full removal of the structure and replace with AquaRock bag revetment

Option 2 – Full removal of the structure and replace with new geotextile sand container revetment

Option 3 – Full removal of the structure and replace with rock revetment

Full removal of the existing seawall and replace with an engineering designed revetment, combined with vegetation management, formalised beach access and stormwater integration.

Description

This SEMP identifies that the recommended option for the Island Esplanade foreshore is removing the existing structure and replacing with an engineering designed and approved revetment. The protection of the residential properties and public assets located within the Island Esplanade foreshore are key drivers of this outcome.

The options involve removing the existing GSC structure and installing an engineering designed revetment spanning across the proposed alignment. There is an opportunity to extend the seawall further south if necessary to protect the residential properties south of the decommissioned boat ramp. When the preferred option progresses beyond concept design, the southern section should be reassessed during approvals and detailed design to determine if a revetment is necessary. The revetment should follow as close as practicable to the alignment of the existing structure. A geotextile layer should be installed along the base and wrapped around the back of the revetment to prevent washout from beneath and behind the structure.

In order to be effective, the revetment should extend to a suitable foundation depth to prevent undermining of the structure. The confirmation of materials, specifications and levels is subject to a detailed design and should meet the requirements of the *QLD Prescribed Tidal Works Code* as part of the *Coastal Protection & Management Regulation 2017*. Several access points should be provided through the structure for pedestrian access to the beach.

Cost estimates

The detailed cost estimates associated with the highest scoring option – Option 4 (Full removal of the structure and replace with AquaRock bag revetment) are presented in Table 27.

Table 27. Island Esplanade foreshore – option 4 (Full removal of the structure and replace with AquaRock bag revetment) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$65,000
AquaRock Bags structure	$613,760
Revegetation, access management	$12,232
Labour and minor items	$59,768
SUBTOTAL	**$750,760**
Allow 70 % budget contingency[4]	$613,670
TOTAL	**$1,364,430**

Island Esplanade

[4] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.4 Turtle Way

Present day shoreline condition and key coastal issues

Tuttle Way is approximately 1.5 km along Boyne River from Canoe Point to Ibis Park, connecting local primary and high schools, shopping centres and community facilities. Along Turtle Way, unique sculptures, interpretive signage and amenities are installed.

Sections of Turtle Way lack well-established vegetation and are variably eroded with localised scour pockets, particularly along sections with no additional buffers provided by mangroves communities. There have been recent efforts to place loose rocks and concrete debris informally on the riverbank to provide protection. Increased recreational use and uncontrolled access are exacerbating eroded scarps.

Turtle Way is currently acting as the last line of defence for more than 15 sewer points and approximately 1 km of reticulation pipe located directly landward of the path. Turtle Way will require adaptation works if it is expected to provide long-term protection to the path and assets behind it.

The following management options are considered for Turtle Way:

1. Do nothing
2. Maintain and monitor (protect infrastructure where required)

The options assessment approach, including the descriptions of assessment criteria and weightings, are outlined in Sections 5.4 and 5.3. Table 28 provides an overview of the scores for each option against the weighted assessment criteria for Turtle Way.

Table 28. Criteria weighting and scores for Turtle Way options

Criteria	Criteria weighting	Option 1	Option 2
Accessibility	3.6%	0.14	0.14
Adaptability	9.6%	0.10	0.10
Cultural heritage	10.8%	0.54	0.54
Protection	12.0%	0.24	0.48
Environmental	13.3%	0.66	0.66
Approvals	8.4%	0.42	0.34
Safety	19.3%	0.39	0.77
Value (Cost)	10.8%	0.33	0.22
Visual amenity	12.0%	0.24	0.24
Total	100%	3.06	3.49
Rank		2	1

Option 1 – Do nothing
Do nothing and allow natural processes to take their course. This option does not resolve the current erosion and scour issues along Turtle Way and land-based assets near the path. Table 29 provides scores for Option 1 against the assessment criteria.

Figure 29. *Existing conditions at Turtle Way.*

Table 29. Turtle Way – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Require monitoring and maintenance. Provides no protection and improvement to foreshore or sewer infrastructure.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	3	There would be no additional cost. Potential loss of sewer infrastructure.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Maintain and monitor (protection of infrastructure where required)
Maintain Turtle Way and protect stormwater outlets and adjacent public land and infrastructure as required. Approximately 350 m of Turtle Way has been identified as a priority to protect the shared path and sewerage infrastructure. With the narrow section of the riparian zone between the riverbank and Turtle Way, additional protection along sections that are especially vulnerable is recommended. It is recommended to place riprap (various-sized) rocks on the bank of Turtle Way. Riprap should consist of durable, angular run-of-quarry rock placed over a bedding layer of angular gravels over geotextile. Riprap must be appropriately keyed in to withstand the velocities of runoff or discharge landward side. Vegetation management and reducing access points should be undertaken to stabilise the bank. A priority for this option is to consider long-term planning for sewerage infrastructure (sewer points and reticulation pipes) as sections of Turtle Way may continue to be under threat of episodic erosion and inundation and may be exacerbated by any future sea level rise. Table 30 provides scores for Option 2 against the assessment criteria.

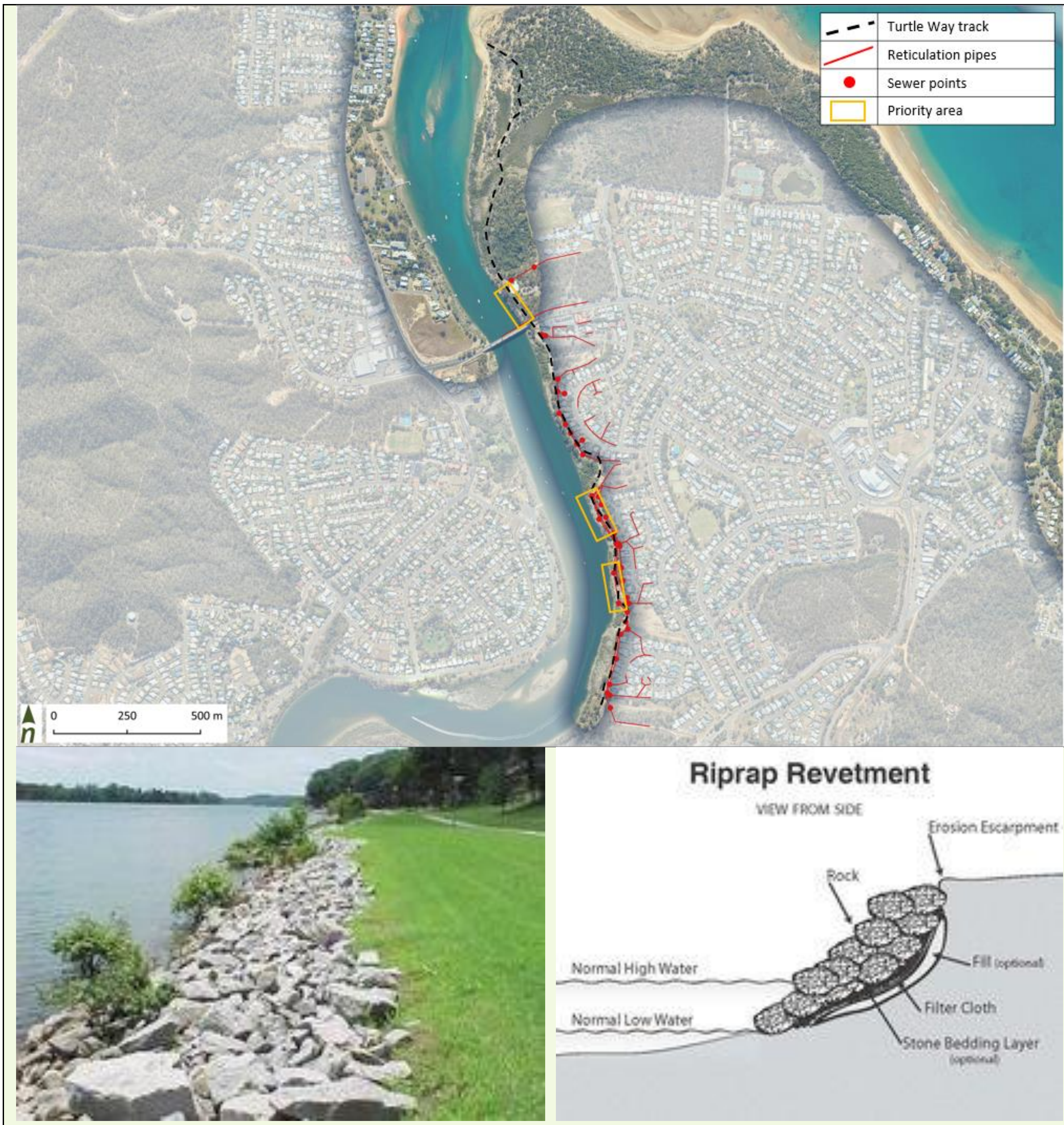

Figure 30. *Turtle Way – Options 2 – Maintain and monitor (protect infrastructure where required)*

Table 30. Turtle Way – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access the foreshore will improve.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	4	Require monitoring and maintenance. Provides additional protection and improvement to foreshore, stormwater outlets and sewer infrastructure.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	4	If works are limited to specific priority areas for the purpose of protecting sewer or stormwater infrastructure potentially at risk the works can be undertaken without the need for a development approval under the *Code for Accepted Development for tidal works, for work completely or partly in a coastal management district* and the *Accepted Development requirements for operational work that is the removal, destruction or damage of marine plants.* However, should Council wish to implement works for the total length of 350 m of priority area immediately, it will be considered beyond what is permitted under the Accepted Development codes. An operational works development application

		for prescribed tidal works with referral is required to the State Assessment Referral Agency for tidal works.
Safety	4	The overall site safety increases when the foreshore is maintained, and mangroves start to expand.
Value (Cost)	2	Capital cost = $1.6M Whole of life cost of approximately $2.6M, including: • ~ 350 m of riprap repairs • Revegetation, managing access and signage • Ongoing maintenance costs and contingency The cost to protect Turtle Way seems high but it avoids replacing sewerage infrastructure, which would be even more expensive to replace.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Recommended option

Option 2 – Maintain and monitor (protection of infrastructure where required)
Maintain Turtle Way and protect stormwater outlets and adjacent public land and infrastructure as required.

Description

The recommended option is to maintain and monitor the existing Turtle Way path to better understand localised erosion drivers. This would provide essential information for future decisions about management at this site. If stormwater and sewerage infrastructure are at immediate erosion risk, they should be protected with rock riprap. The value of infrastructure and open space located along Turtle Way are key drivers of this outcome.

This option would involve reprofiling localised sections of Turtle Way with riprap. The riprap profiles should follow close to the gradient of the existing profile. This option would require further consideration of the following:

- Riprap sizing and grading
- Riverbank slope

Riprap should consist of durable, angular rock placed over a bedding layer of angular gravels over geotextile. Riprap must be appropriately keyed in to withstand the velocities of runoff or discharge. Where possible, vegetation should be supplemented to provide further stability and additional protection buffer. Maintenance may be required to ensure the riprap structures remain stable after large rainfall events.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 27.

Table 31. Turtle Way – recommended option 2 (Maintain and monitor) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup	$20,000
Riprap repairs	$833,120
Revegetation, access management	$4,013
Labour and minor items	$62,785
SUBTOTAL	**$919,918**
Allow 70 % budget contingency[5]	$643,942
TOTAL	**$1,563,860**

[5] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.5 Canoe Point

Present day shoreline condition and key coastal issues

At present, Canoe Point is sheltered from wave energy as waves dissipate when refracting around the rocky outcrops and into the sheltered beach. This area is moderately stable and controlled by rocky outcrops.

There do not appear to be any erosion issues in this section under present day conditions. The threat to Canoe Point may increase with sea level rise and an increase in storm activity.

The following management options are considered for Canoe Point:

1. Do nothing
2. Maintain and monitor

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 32 provides an overview of the scores for each option against the weighted assessment criteria for Canoe Point.

Table 32. Criteria weighting and scores for Canoe Point options

Criteria	Criteria weighting	Option 1	Option 2
Accessibility	3.6%	0.14	0.14
Adaptability	9.6%	0.10	0.10
Cultural heritage	10.8%	0.54	0.54
Protection	12.0%	0.12	0.24
Environmental	13.3%	0.66	0.66
Approvals	8.4%	0.42	0.42
Safety	19.3%	0.39	0.39
Value (Cost)	10.8%	0.54	0.54
Visual amenity	12.0%	0.24	0.24
Total	100%	3.16	3.28
Rank		2	1

Option 1 – Do nothing
Do nothing and allow natural processes to take their natural course. This option does not resolve any potential current or future erosion issues where existing assets are already located within foreshore areas prone to erosion. Table 33 provides scores for Option 1 against the assessment criteria.

Table 33. Canoe Point – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	1	Require monitoring and maintenance. Provides no protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	There would be no additional cost.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Maintain and monitor
Maintain and monitor the Canoe Point foreshore and land-based assets as required. There is no immediate coastal erosion threat to the Canoe Point foreshore, but it may become threatened by the changing climate in the future. Sea level rise may inundate low-lying areas and cause the shoreline to shift landward. Council to continue to undertake foreshore revegetation, control of invasive weeds and manage high-value remnant coastal littoral rainforest. Other active monitoring actions are suggested to determine long-term trends. Monitoring actions could include regular drone capture of the shoreline position and citizen science contributions by establishing a “CoastSnap” monitoring station. Photo posts with a defined outlook/viewpoint can be installed to capture photos from the same perspective each time. Formal or informal versions of this system can be established at this section of the coast. Periodic aerial imagery and drone surveys of the beach can help to better support the correlation between erosion cause and effect. The drone surveys can also provide elevation data that can be analysed to quantify changes in the beach profile over time (i.e., dune width, slope, toe position, berm height). This would provide essential information for future decisions on coastal management at this site. Table 34 provides scores for Option 2 against the assessment criteria.

Table 34. Canoe Point – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Require monitoring and maintenance. Provides no protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.

Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	Minor maintenance cost to maintain foreshore.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Recommended option

Option 2 – Maintain and monitor

Maintain and monitor the Canoe Point foreshore and land-based assets as required.

Description

This SEMP identifies that the recommended option for Canoe Point is to continue to maintain and actively monitor the foreshore area. There is no immediate coastal erosion threat to the Canoe Point foreshore, but it may become threatened by the changing climate in the future.

This option would involve Council continuing to undertake foreshore revegetation, biosecurity control of invasive weeds and manage high-value remnant coastal littoral rainforest.

Monitoring actions are suggested to determine the long-term trend of behaviours. Monitoring actions could include regular drone capture of the shoreline position and citizen science contributions by establishing a "CoastSnap" monitoring station. Photo posts with a defined outlook/viewpoint can be installed to capture photos from the same perspective each time. Formal or informal versions of this system can be established at this section of the coast.

Periodic aerial imagery and drone surveys of the beach can help to better support the correlation between erosion cause and effect. The drone surveys can also provide elevation data that can be analysed to quantify changes in the beach profile over time (i.e., dune width, slope, toe position, berm height). This would provide essential information for future decisions on coastal management at this site. By ensuring continuous improvement in management outcomes, management options must be reviewed and reassessed at this stage.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 38.

Table 35. Canoe Point – recommended option 2 (Maintain and monitor) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$10,000
Revegetation, access management	$10,000
Labour and minor items	$750
SUBTOTAL	**$20,750**
Allow 70 % budget contingency[6]	$14,525
TOTAL	**$35,275**

[6] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.6 The Oaks Road foreshore

Present day shoreline condition and key coastal issues

The Oaks Road foreshore is an open sandy beach with potential erosion and shoreline recession vulnerability. No localised erosion or erosion scarps have been observed. Residential development is established along the majority of The Oaks Road foreshore, with a setback from the beach in order of 30 – 40 m with dunal vegetation at most locations. This setback facilitates an adequate buffer zone for well-established coastal vegetation, which assists with building and storing sand on the upper beach. The threat to The Oak Road foreshore may increase with sea level rise and an increase in storm activity.

On the southern end of The Oaks Road foreshore is a stormwater outlet flowing along the beach, creating an Intermittently Closed and Open Lakes and Lagoons (ICOLL). Any potential options will need to consider the outlet and ongoing stormwater management.

The following management options are considered for The Oaks Road foreshore:

1. Maintain status quo
2. Active monitoring, revegetation, and stormwater management
3. Buried seawall

If the stormwater outlet develops adverse environmental and safety impacts, Council should establish an ICOLL/stormwater management procedure to ensure regular flushing of the outlet and avoid water quality issues.

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 36 provides an overview of the scores for each option against the weighted assessment criteria for The Oaks Road foreshore.

Table 36. Criteria weighting and scores for The Oaks Road foreshore options

Criteria	Criteria weighting	Option 1	Option 2	Option 3
Accessibility	3.6%	0.14	0.14	0.14
Adaptability	9.6%	0.10	0.10	0.10
Cultural heritage	10.8%	0.54	0.54	0.54
Protection	12.0%	0.24	0.48	0.48
Environmental	13.3%	0.40	0.66	0.66
Approvals	8.4%	0.42	0.42	0.25
Safety	19.3%	0.58	0.77	0.39
Value (Cost)	10.8%	0.54	0.54	0.11
Visual amenity	12.0%	0.24	0.48	0.24
Total	100%	3.20	4.14	2.92
Rank		2	1	3

Option 1 – Maintain status quo
Continue to maintain and monitor The Oaks Road foreshore. This option does not resolve any potential current or future erosion issues where existing assets are already located within foreshore areas prone to erosion. Council should continue to maintain the stormwater outlet discharging on the back of beach. Table 37 provides scores for Option 1 against the assessment criteria.

Table 37. The Oaks Road foreshore – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Require monitoring and maintenance. Provides no protection and improvement to foreshore.
Environmental	3	May have adverse environmental impacts if stormwater outlet does not to flush regularly.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	3	No change to overall safety.
Value (Cost)	5	There would be no additional cost, only budget to maintain foreshore.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Active monitoring, revegetation and stormwater management
Continue to assess and monitor the foreshore, in combination with revegetation and stormwater management. This option involves ongoing monitoring, including regular drone capture of the shoreline position and citizen science contributions by establishing a "CoastSnap" station. Active monitoring can better support the correlation of erosion cause and effect. This option does not resolve any potential current or future erosion issues where existing assets are already located within foreshore areas prone to erosion. Table 38 provides scores for Option 2 against the assessment criteria.

Table 38. The Oaks Road foreshore – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will improve.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	4	Provides additional protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are likely to improve with revegetation and stormwater management.
Approvals	5	No approvals appear to be required where no specific development actions are proposed.
Safety	4	The overall site safety will improve.
Value (Cost)	5	Minimal cost to maintain foreshore, including monitoring, revegetation and stormwater management.
Visual amenity	4	The visual amenity of the foreshore is likely to improve with revegetation and stormwater management.

Option 3 – Buried seawall
A buried rock or geotextile sand container seawall along The Oaks Road foreshore directly in front of residential properties. This buried seawall would act as a last line of defence to prevent shoreline recession. Council could consider supporting residents to deliver the whole seawall for The Oaks Road foreshore, rather than at an individual property level, as there would be improved results from delivering one project. As the seawall primarily protects private properties, Council does not need to support residents but could consider ways to support residents as a way to achieve better outcomes. Council could consider an approach whereby they could work with residents to determine an agreed alignment and gain approval for the typical design that residents could use at a later date to protect their own properties. The cost of the seawall would be the responsibility of the residents. However, it would be more cost-effective for residents if one application was submitted and the seawall was constructed as a whole. With a setback from the beach in order of 30 – 40 m with dunal vegetation at most locations and a calculated 1% AEP erosion width of 9 m, it is unlikely a seawall would need to be considered within the current planning period of this SEMP. Table 39 provides scores for Option 1 against the assessment criteria.

Figure 31. *The Oaks Road – Option 3 – Buried seawall*

Table 39. The Oaks Road foreshore – Option 3 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	4	Remains buried. Act as a last line of defence.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	3	Works would be subject to an operational works development application (prescribed tidal works) for new coastal protection works, with referral required to the State Assessment Referral Agency for tidal works. Impacts to marine plants is less likely at this location. Landowner's consent would be required prior to the

		application being made. A response to State Code 7 and State Code 8 will be required for the tidal works. Works appear to be located outside of the marine park as they are situated above HAT. The land is also shown as supporting Category B and Category C vegetation under the *Vegetation Management Act 1999*. Clearing of woody vegetation may require approval where an exemption for clearing within esplanade or on unallocated State land under Schedule 21 of the *Planning Regulation 2017* cannot be relied upon and where clearing is deemed necessary.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	1	Capital cost = $2.6M – 2.9M* Whole of life cost of approximately $3.4M – 4.6M, including: • ~ 160 m of buried seawall in front of residential properties • Design, approvals, site setup and environmental management • Revegetation, landscaping, managing access and signage • Ongoing maintenance costs and contingency
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

* Estimated cost for seawall is the responsibility of property owners. The seawall only protects private properties.

Recommended option

Option 2 – Active monitoring, revegetation and stormwater management

Continue to assess and monitor the foreshore, in combination with revegetation and stormwater management.

With a setback from the beach of 30 - 40 m at most locations and a calculated 1 % AEP erosion width of 9 m, a seawall is unlikely to be required within the current planning period of this SEMP. A seawall may need to be considered if a large erosion event significantly reduces the vegetation buffer.

Description

This SEMP identifies that the recommended option for The Oaks Road foreshore consists of active monitoring, revegetation and stormwater management.

This option involves ongoing monitoring, including regular drone capture of the shoreline position and citizen science contributions by establishing a "CoastSnap" station. Photo posts with a defined outlook/viewpoint can be installed to capture photos from the same perspective each time. Formal or informal versions of this system can be established at this section of the coast.

Periodic aerial imagery and drone surveys of the beach can help to better support the correlation between erosion cause and effect. The drone surveys can also provide elevation data that can be analysed to quantify changes in the beach profile over time (i.e., dune width, slope, toe position, berm height). This would provide essential information for future decisions on coastal management at this site.

If the stormwater outlet develops adverse environmental and safety impacts, Council should establish an ICOLL/stormwater management procedure to ensure regular flushing of the outlet and avoid water quality issues.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 38.

Table 40. The Oaks Road foreshore – recommended option 2 (Active monitoring, revegetation and stormwater management) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$20,000
Revegetation, access management	$20,000
SUBTOTAL	**$30,000**
Allow 70 % budget contingency [7]	$21,000
TOTAL	**$51,000**

[7] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.7 Tannum Sands Surf Life Saving Club (Tannum Sands Beach)

Present day shoreline condition and key coastal issues

The Surf Life Saving Club (SLSC) is located towards the southern end of Tannum Sands Beach with adjacent walking paths, picnic and BBQ areas, and carpark area. There is a retaining wall directly in front providing protection with designated access to the beach. The wide foreshore has a wide vegetated buffer of approximately 40 m, but erosion threat may increase with sea level rise and an increase in storm activity.

The following management options are considered for Tannum Sands SLSC:

1. Maintain status quo
2. Buried seawall

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 41 provides an overview of the scores for each option against the weighted assessment criteria for Tannum Sands SLSC.

Table 41. Criteria weighting and scores for Tannum Sands SLSC options

Criteria	Criteria weighting	Option 1	Option 2
Accessibility	3.6%	0.14	0.14
Adaptability	9.6%	0.10	0.10
Cultural heritage	10.8%	0.54	0.54
Protection	12.0%	0.24	0.60
Environmental	13.3%	0.66	0.66
Approvals	8.4%	0.42	0.25
Safety	19.3%	0.39	0.39
Value (Cost)	10.8%	0.54	0.11
Visual amenity	12.0%	0.24	0.24
Total	100%	3.28	3.04
Rank		1	2

Option 1 – Maintain status quo
Continue to actively monitor and maintain the Tannum Sands SLSC foreshore and access points. There is an existing retaining wall in front of the SLSC, and it provides a level of protection for the key asset within this beach compartment. The sand within this beach compartment is largely controlled by the rocky outcrop to the north, which acts like a groyne. However, during large events, sand may be lost from the system – the rate of loss may be exacerbated by any future sea-level rise. Table 42 provides scores for Option 1 against the assessment criteria.

Table 42. Tannum Sands SLSC – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Require monitoring and maintenance. Provides no protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	There would be no additional cost, only budget to maintain foreshore.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Buried seawall
Install new buried seawall in front of the existing small retaining seawall to act as the last line of defence structure in front of the SLSC. This option is only proposed on sections of Tannum Sands that have existing development or environmental and social values that are at risk of damage or loss to erosion processes in the planning period. The buried seawall would be built in front of the existing seawall alignment or similar. The existing retaining seawall currently offers little protection to the SLSC from storm events to a degree, and erosion may be exacerbated by any future sea level rise. This option would have no impact on visual amenity as the whole seawall is expected to be buried, and it would only become visible in response to a significant series of smaller events or storm conditions. This option is less likely to result in a loss of beach. This wall could be either rock or GSC. Table 43 provides scores for Option 2 against the assessment criteria.

Figure 32. *Tannum Sands SLSC – Options 2 – Buried seawall*

Table 43. Tannum Sands SLSC – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	5	Provides substantial protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	3	Works would be subject to an operational works Development Application for (prescribed tidal works) for new coastal protection works, with referral required to the State Assessment Referral Agency for tidal works. Impacts to marine plants is not likely at this location. Landowner's consent would be required prior to the application being made. A response to State Code 7 and State Code 8 will be required for the tidal works. Works appear to be located within the marine park which is mapped as extending up to and above the dunal vegetation in front of the surf club. Confirmation as to whether the marine park extents are outside of the footprint would be subject to further investigation during design development, but where this applies, a marine parks permit would be required for the works. The land is also shown as supporting Category B vegetation under the *Vegetation Management Act 1999*. No clearing of woody vegetation appears to be present in this location. Exemptions may exist for clearing within an esplanade under Schedule 21 of the *Planning Regulation 2017*. Where no exemptions exist and clearing of woody vegetation is required, approval for clearing remnant vegetation may also be necessary including a response to State Code 16.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	1	**Capital cost = $3.4.6M - $3.5M** Whole of life cost of approximately $4.3M - $4.9M, including:

		• ~ 215 m of buried seawall in front of SLSC and public assets • Design, approvals, site setup and environmental management • Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Recommended option

Option 1 – Maintain status quo

Continue to actively monitor and maintain the Tannum Sands SLSC foreshore and access points.

With a setback from the beach of 30 – 40 m at most locations and a calculated 1 % AEP erosion width of 9 m, a seawall is unlikely to be required within the current planning period of this SEMP. A seawall may need to be considered if a large erosion event significantly reduces the vegetation buffer.

Description

This SEMP identifies that the recommended option for Tannum Sands SLSC is to maintain status quo to continue to maintain the SLSC foreshore, as required. There is no immediate coastal erosion threat to the Tannum Sands SLSC foreshore, but it may become threatened by the changing climate in the future.

To improve the knowledge of potential localised erosion threats, active monitoring should be prioritised by undertaking monitoring actions could include regular drone capture of the shoreline position and citizen science contributions by establishing a "CoastSnap" monitoring station. Photo posts with a defined outlook/viewpoint can be installed to capture photos from the same perspective each time. Formal or informal versions of this system can be established at this section of the coast.

Periodic aerial imagery and drone surveys of the beach can help to better support the correlation between erosion cause and effect. The drone surveys can also provide elevation data that can be analysed to quantify changes in the beach profile over time (i.e., dune width, slope, toe position, berm height). This would provide essential information for future decisions on coastal management at this site.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 44.

Table 44. Tannum Sands SLSC – recommended option 1 (Maintain status quo) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$20,000
Revegetation, access management	$20,000
SUBTOTAL	**$30,000**
Allow 70 % budget contingency[8]	$21,000
TOTAL	**$51,000**

[8] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.8 Millenium Esplanade

Present day shoreline condition and key coastal issues

Millenium Esplanade is located at the mouth of Wild Cattle Inlet. Major erosion has occurred in this section and led to the loss of frontal dunes. There has been a recent recovery effort to nourish the eroded foreshore in 2017, which was supplemented with revegetation to stabilise the foreshore. Approximately 9,000 m^3 of sand was sourced from the mouth of Wild Cattle Inlet and relocated to the Millenium Esplanade foreshore along a 10 m corridor at the top of the beach. From anecdotal observation, this section of the shoreline is dynamic but has been accreting since the nourishment campaign.

There are two stormwater outlets along the Millenium Esplanade foreshore. One is located on the northern end, which runs off along the foreshore towards the access point in the middle of the beach and the second outlet is located on the southern end and runs off directly into Wild Cattle Creek. Any potential options will need to consider the outlets and ongoing stormwater management.

The following management options are considered for Millenium Esplanade:

1. Maintain status quo
2. Stormwater management
3. Artificial breakthrough

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 45 provides an overview of the scores for each option against the weighted assessment criteria for Millenium Esplanade.

Table 45. Criteria weighting and scores for Millenium Esplanade options

Criteria	Criteria weighting	Option 1	Option 2	Option 3
Accessibility	3.6%	0.07	0.14	0.07
Adaptability	9.6%	0.10	0.39	0.19
Cultural heritage	10.8%	0.54	0.33	0.22
Protection	12.0%	0.24	0.48	0.24
Environmental	13.3%	0.66	0.66	0.13
Approvals	8.4%	0.42	0.34	0.08
Safety	19.3%	0.39	0.77	0.77
Value (Cost)	10.8%	0.54	0.33	0.11
Visual amenity	12.0%	0.24	0.60	0.36
Total	100%	3.20	4.04	2.18
Rank		2	1	3

Option 1 – Maintain status quo
Do nothing new and continue to assess and maintain the foreshore, assets and stormwater outlets as required. This option does not provide any additional protection to mitigate erosion and local scour, however, there are no immediate erosion concerns at Millenium Esplanade. Existing assets and infrastructure are located within foreshore areas prone to future erosion. This section of Millenium Esplanade is expected to be dynamic but may continue to be under erosion threat episodically and may be exacerbated by any future sea level rise. Table 46 provides scores for Option 1 against the assessment criteria.

Table 46. Millenium Esplanade – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Repair works may be required after large rainfall events. Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Requires continuous monitoring and maintenance. Provides no protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed. Revegetation will be important to stabilise the foredune and enhance protection.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety may decrease as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	Low short-term cost for revegetation program and low ongoing maintenance cost to maintain foreshore.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Stormwater management
Create a stormwater improvement area, including revegetation, access controls and installation of educational signs. The existing stormwater outlet discharges directly onto the beach from the back of the Millenium Esplanade foreshore, which can cause local scour and make the beach compartment more vulnerable and exacerbate beach erosion in its vicinity. As such, improvements to stormwater runoff and discharge should be considered. This option proposes a stormwater improvement area to capture runoff, similar to a bioretention basin. The proposed improvement area must be appropriately designed to meet the required standards. This option also enhances site aesthetics. Table 47 provides scores for Option 2 against the assessment criteria.

Figure 33. *Millenium Esplanade – Options 2 – Stormwater management.*

Table 47. Millenium Esplanade – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access on the beach will improve significantly.
Adaptability	4	Somewhat adaptable to future climate.
Cultural heritage	3	Moderate disturbance and excavation of footprint beyond existing footprint.
Protection	4	Beach is still subject to natural erosion, but local scour would be reduced.
Environmental	5	Surrounding environmental values would be improved from stormwater improvement area.
Approvals	4	Part B2 of the *Code for accepted development for tidal works or work completely or partly in a Coastal Management District* includes alterations to a stormwater outlet, indicating the works may be able to be progressed as accepted development. Impacts to marine plants does not appear likely at this location. Landowner's consent would be required prior to the application being made. A response to State Code 7 and State Code 8 will be required for the tidal works. Works appear to be located within the marine park. Confirmation as to the extent the works encroaches into the marine park will be subject to further investigation

		during design development, but where this applies, a marine parks permit would be required for the works.
Safety	4	The overall site safety will improve significantly.
Value (Cost)	3	**Capital cost = $2.0M** Whole of life cost of approximately $2.6M, including: • Stormwater improvement area • Design, approvals, site setup and environmental management • Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	5	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 3 – Artificial breakthrough

The community expressed an interest in creating an artificial breakthrough on the northern end of Wild Cattle Island to maintain and provide area swimming at Millenium Esplanade.

This option requires relocating the mouth of Wild Cattle Creek by approximately 650 m to the south. This option may have adverse effects on local coastal processes, and potential environmental and water quality impacts must be considered.

Table 48 provides scores for Option 3 against the assessment criteria.

Figure 34. *Millenium Esplanade – Option 3 – Artificial breakthrough*

Table 48. Millenium Esplanade – Option 3 criteria scores

Criteria	Score	Comment
Accessibility	2	May improve the Millenium Esplanade foreshore but may cause significant adverse impacts.
Adaptability	2	Erosion may still occur during storm events. Long-term resilience of this option is unknown.
Cultural heritage	2	Disturbance and excavation of large footprint beyond existing footprint.

Protection	2	Beach is still subject to natural erosion. If multiple events hit in succession, protection may be limited.
Environmental	1	May have significant impacts on coastal processes and would require removing vegetation from a National Park.
Approvals	1	The works will be subject to an operational works Development Application for prescribed tidal works, with referral required to the State Assessment Referral Agency for tidal works, works in a coastal management district and impacts to marine plants. Landowner's consent would be required prior to the application being made. A response to State Code 7, State Code 8 and State Code 11 will be required. In addition, it is likely the works will be construed as dredging, which comprises ERA16 under Schedule 2 of the *Environmental Protection Regulation 2019*. A response to State code 22 including an assessment of impacts to environmental elements and preparation of a dredge management plan will be required. Works appear to be located within the marine park and a marine parks permit would be required for the works. Additional approvals may relate to the clearing of mapped remnant vegetation, requiring a response top State Code 16.
Safety	4	Provide a more stable recreational area with minimal safety risks.
Value (Cost)	1	Capital cost = $5.4M Whole of life cost of approximately $9.1M, including: • ~ 15 m^2 removal of vegetation • Excavation of approx. 5m deep • Design, approvals, site setup and environmental management • Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	3	Provide moderate improvement to visual amenity.

Recommended option

Option 2 – Stormwater management *Create a stormwater improvement area, including revegetation, access controls and installation of educational signs.*

Description

This SEMP identifies stormwater management as the recommended option at Millenium Esplanade to reduce local scour and improve dune stability and health.

This option involves creating a stormwater improvement area to manage runoff to improve stormwater runoff and discharge, similar to a bioretention basin. The initial construction would involve removing the existing stormwater outlet and rehabilitate the area. Access management and educational signs should be incorporated into the design.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 49.

Table 49. Millenium Esplanade – recommended option 2 (Stormwater management) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$65,000
Stormwater management area and revegetation	$1,014,322
Access management	$1,542
Labour and minor items	$79,565
SUBTOTAL	**$1,160,429**
Allow 70 % budget contingency[9]	$812,300
TOTAL	**$1,972,729**

Wild Cattle Inlet

[9] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.9 Wild Cattle Creek Boat Ramp

Present day shoreline condition and key coastal issues

Immediately north of the boat ramp, there is a scour hole under the abutment of the boat ramp. Loosely placed concrete and debris have been used to protect the eroded sections of the abutment by providing scour protection. There's an erosion scarp of ~5 m along the pocket beach immediately north of the boat ramp.

Directly south of the boat ramp, localised erosion has occurred immediately south of the boat ramp, and the edge of the car park is undermined. This section is currently threatening the car park, and temporary safety fencing has been installed for safety reasons.

There is also an informal turn-off through the mangroves and onto Wild Cattle Creek to access Wild Cattle Beach and Bangalee. It is known that residents from Bangalee cross the creek during low tide to access the mainland and vice versa. All options should consider the future accessibility of the creek crossing to Wild Cattle Island.

It is to note that this boat ramp is State-owned and managed by Council.


Boat ramp – looking north


Boat ramp – looking south

The following management options are considered for Wild Cattle Creek Boat Ramp:

1. Do nothing
2. Monitor and assess plus gravel replenishment
3. Planned retreat

No hard engineering solutions have been considered for this site. Any significant modification to this section may result in adverse impacts such as changing the channel alignment and exacerbating erosion.

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 50 provides an overview of the scores for each option against the weighted assessment criteria for Wild Cattle Creek Boat Ramp.

Table 50. Criteria weighting and scores for Wild Cattle Creek Boat Ramp options

Criteria	Criteria weighting	Option 1	Option 2	Option 3
Accessibility	3.6%	0.04	0.07	0.04
Adaptability	9.6%	0.10	0.10	0.29
Cultural heritage	10.8%	0.33	0.54	0.22
Protection	12.0%	0.12	0.12	0.24
Environmental	13.3%	0.27	0.53	0.27
Approvals	8.4%	0.42	0.34	0.34
Safety	19.3%	0.39	0.39	0.77
Value (Cost)	10.8%	0.54	0.54	0.54
Visual amenity	12.0%	0.24	0.36	0.24
Total	100%	2.43	2.99	2.94
Rank		3	1	2

Option 1 – Do nothing
Do nothing and allow natural processes to take their natural course. This option does not resolve any current or future erosion issues where existing assets are already located within foreshore areas prone to erosion. This is not considered as an acceptable option due to the edge of the carpark already being undermined and closed. If it is left as it is, it is likely that the carpark area will also eventually come under threat. In addition, the boat ramp is currently providing access to the informal turn-off to cross Wild Cattle Creek to access Wild Cattle Island. If the boat ramp gets undermined and becomes unsafe, it would threaten the future accessibility to Wild Cattle Island. Further consideration would be required for the future accessibility of the turn-off to access Wild Cattle Island. Table 51 provides scores for Option 1 against the assessment criteria.

Table 51. Wild Cattle Creek Boat Ramp – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	1	Boat ramp access will reduce if it continues to undermine.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	3	Disturbance to land due to ongoing erosion.
Protection	1	Provides no reduction in erosion and not adaptable to future conditions. Public assets are already damaged and at risk.
Environmental	2	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety decreases as the boat ramp and carpark continue to deteriorate and become unstable.
Value (Cost)	5	There would be no additional cost.
Visual amenity	2	The visual amenity of the boat ramp is likely to reduce as it continues to deteriorate.

Option 2 – Monitor and assess plus gravel replenishment
Assess and maintain the boat ramp and carpark area as required. Approximately 158 m of the foreshore are not protected by mangrove and vegetation communities and hence this section is the most affected by bank erosion during rainfall or high tide events. This section of the boat ramp may continue to be under erosion threat episodically and may be exacerbated by any future sea level rise. A priority for this option is to maintain the boat ramp and the edge of the carpark that is already being undermined. This option proposes general maintenance and restoration of the boat ramp to ensure safe access for users. This option would also include replenishing the eroded section of the carpark using coarse-grained sand or gravel to provide additional protection buffers. The coarse-grained sand or gravel should be placed on the section where the carpark is being undermined. This option will require further consideration of the sediment sizing and movement threshold. Where possible, mangroves should be established to provide further protection and stability. Maintenance may be required after larger storm events. This option will maintain future accessibility of the turn-off to access Wild Cattle Island. Table 52 provides scores for Option 2 against the assessment criteria.

Table 52. Wild Cattle Creek Boat Ramp – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the boat ramp will reduce if it continues to undermine.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	1	Provides no reduction in erosion and not adaptable to future conditions. Public assets are already damaged and at risk.

Environmental	4	Surrounding environmental values are unchanged and undisturbed.
Approvals	4	Maintenance of the approved boat ramp can occur under the Code for Accepted Development for tidal works or work completely or partly in a Coastal Management District as the ramp appears to be an approved structure. Works would be required to occur in accordance with the marine parks permit for the ramp. Subject to size, scale and extent of gravel replenishment. No approvals required for Council actions where works are undertaken in accordance with: • Code for Accepted Development for tidal works, or work completely or partly in a Coastal Management District for demolition of structures seaward of high-water mark • Accepted Development requirements for operational work that is the removal, destruction or damage of marine plants for fish habitat rehabilitation or restoration work that provides a net benefit to marine plant communities subject to an approved project plan
Safety	2	The overall site safety decreases as the boat ramp and carpark continue to deteriorate and become unstable.
Value (Cost)	5	Capital cost = $142,000 Whole of life cost of approximately $182,000, including: • Gravel replenishment • Design, approvals, site setup and environmental management • Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	3	The visual amenity of the boat ramp is likely to reduce as it continues to deteriorate.

Option 3 – Planned retreat

This option allows coastal processes to take their natural course with the intent of a planned retreat strategy by removing infrastructure from the erosion zone, designing infrastructure that can be removed before large storm events or allowing previously developed land to function as an erosion buffer.

The threatened foreshore along Wild Cattle Creek Boat Ramp encompasses public assets, and the long-term planned retreat strategy would require relocating these public assets to another location. These identified assets are:

- Boat ramp
- Carpark area
- Turn off to access Wild Cattle Island

This option will allow the mangrove communities adjacent to the existing boat ramp to gradually expand and re-establish.

However, the accessibility to Wild Cattle Island will be obliterated, and this option will not provide alternate land-based access for Bangalee residents.

Further consideration would be required for the future accessibility of the turn-off to access Wild Cattle Island.

Table 51 provides scores for Option 3 against the assessment criteria.

Table 53. Wild Cattle Creek Boat Ramp – Option 3 criteria scores

Criteria	Score	Comment
Accessibility	1	Significant restriction to the foreshore area in the initial phases of relocation. Restricted access to Wild Cattle Island.
Adaptability	3	Does not resolve any current erosion concerns and need to consider continue retreat.
Cultural heritage	2	Disturbance and excavation beyond the existing footprint for the new boat ramp location.
Protection	2	Requires relocation of potentially affected assets.
Environmental	2	May have moderate impacts on coastal processes and mangroves communities. If the depth of disturbance is dependent on the boat ramp design.
Approvals	4	No approvals required for Council actions where works are undertaken in accordance with: • Code for Accepted Development for tidal works, or work completely or partly in a Coastal Management District for demolition of structures seaward of high-water mark • Accepted Development requirements for operational work that is the removal, destruction or damage of marine plants for fish habitat rehabilitation or restoration work that provides a net benefit to marine plant communities subject to an approved project plan Works would be required to accord with the marine parks permit in place for the structure.
Safety	4	Overall safety would be improved.
Value (Cost)	5	**Capital cost = 421,000** Whole of life cost of approximately $421,000, including: • Cost of removal • Relocation and replacement of assets

		• Revegetation, managing access and signage • Ongoing maintenance costs • Contingency
Visual amenity	2	Old boat ramp will be decommissioned. New boat ramp at a new location.

Recommended option

Option 2 – Monitor and assess plus replenish with gravel

Monitor and assess the boat ramp and carpark area as required. Replenish localised eroded section with gravel.

Description

The recommended option for Wild Cattle Creek boat ramp is to assess and maintain the boat ramp, as required, and replenish the localised eroded section with gravel. By replenishing the eroded section with gravel, it can provide additional protection to erosion. It is to note that this boat ramp is State-owned and managed by Council.

A priority for this option is to monitor and assess the condition of the boat ramp. Council is to liaise directly with the State Government when the boat ramp requires general maintenance and restoration to ensure safe access for users.

This option would also include replenishing the edge of the carpark which is already being undermined using coarse-grained sand or gravel to provide an additional protection buffer. The coarse-grained sand or gravel should be placed on the section where the carpark is being undermined only. This option will require further consideration of the sediment sizing and movement threshold. Maintenance may be required after larger storm events.

Where possible, mangroves should be established to provide further protection and stability.

This option will have no impact to the accessibility of the turn-off to access Wild Cattle Island.

Cost estimates

The detailed cost estimates associated with the recommended option are presented in Table 54.

Table 54. Wild Cattle Creek boat ramp – recommended option 2 (Maintain and monitor plus replenish with gravel) cost estimates

Item	Estimate costs
Preliminaries – project design, approvals, site setup and environmental management	$20,000
River gravel filling and earthworks	$57,037
Revegetation, access management	$2,048
Labour and minor items	$4,431
SUBTOTAL	**$83,516**
Allow 70 % budget contingency[10]	$58,461
TOTAL	**$141,978**

[10] Budgets are for comparative purposes only and a suitable additional contingency should be applied if to be used for budgetary purposes. A high contingency has been applied due to high uncertainty around coastal and marine construction costs.

6.10 Wild Cattle Island foreshore

Present day shoreline condition and key coastal issues

Wild Cattle Island is an open sandy beach with erosion and shoreline recession vulnerability. Localised erosion has occurred in sections of this beach and led to the loss of frontal dunes. There is evidence of fallen trees and some exposed root systems of mature trees from ongoing erosion. There are no assets directly behind the frontal dunes, and the vegetation buffer is extensive. However, Wild Cattle Island is a protected National Park, and there is a State-owned tower located on the frontal dune and is visible from the beach. Anecdotally, the tower used to be tucked away far behind the dense vegetation, but the shoreline has receded significantly in the last 50 years.


The following management options are considered for Wild Cattle Island foreshore:

1. Do nothing
2. Maintain and monitor

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 55 provides an overview of the scores for each option against the weighted assessment criteria for Wild Cattle Island foreshore.

Table 55. Criteria weighting and scores for Wild Cattle Island foreshore options

Criteria	Criteria weighting	Option 1	Option 2
Accessibility	3.6%	0.07	0.07
Adaptability	9.6%	0.10	0.10
Cultural heritage	10.8%	0.54	0.54
Protection	12.0%	0.12	0.24
Environmental	13.3%	0.27	0.27
Approvals	8.4%	0.42	0.42
Safety	19.3%	0.19	0.39
Value (Cost)	10.8%	0.54	0.54
Visual amenity	12.0%	0.12	0.24
Total	100%	2.37	2.81
Rank		2	1

Option 1 – Do nothing
Do nothing and allow natural processes to take their course. This option does not resolve any potential current or future erosion issues. Further consideration would be required for future accessibility to Bangalee. Table 56 provides scores for Option 1 against the assessment criteria.

Table 56. Wild Cattle Island foreshore – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	1	Provides no protection and improvement to foreshore.
Environmental	2	Surrounding environmental values will start to reduce as shoreline continues to recede.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	1	The overall site safety decreases as the foreshore continues to deteriorate and resulting in more fallen trees.
Value (Cost)	5	There would be no additional cost.
Visual amenity	1	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Maintain and monitor
Continue to assess and maintain the foreshore and the State-owned tower. Similar to Option 1, this option does not provide any additional protection to mitigate erosion and scour for this site. This section of the beach is vulnerable to erosion and shoreline recession and will likely be exacerbated by the changing climate and any future sea level rise. Further consideration would be required for future accessibility to Bangalee. Table 56 provides scores for Option 2 against the assessment criteria.

Table 57. Wild Cattle Island foreshore – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Provides no protection and improvement to foreshore.
Environmental	2	Surrounding environmental values will start to reduce as shoreline continues to recede.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and resulting in more fallen trees.
Value (Cost)	5	Cost is primarily dependent on the frequency of monitoring and ad-hoc maintenance. Low ongoing costs.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Recommended option

Option 2 – Maintain status quo
Continue to assess and monitor the foreshore and the State-owned tower.

Description

The recommended option for the Wild Cattle Island foreshore is to maintain status quo to continue to monitor the foreshore, vehicle access and the State-owned tower, as required.

This option includes undertaking monitoring actions on a semi-regular basis and maintaining the foreshore on an ad-hoc basis. This would provide essential information for future decisions about coastal management at this site.

Council to liaise directly with National Parks to maintain vehicle access on the beach for Bangalee residents.

Cost estimates

No additional costs for recommended options.

Wild Cattle Island

6.11 Bangalee

Present day shoreline condition and key coastal issues

Bangalee is a small township on the southern tip of Wild Cattle Island and on the northern side of Colosseum Inlet. There is no immediate coastal erosion threat to the Bangalee foreshore, but it may become threatened by the changing climate in the future. Sea level rise will inundate low-lying areas, and elevated water level across Colosseum Inlet will also increase breaker waves. These impacts will be exacerbated without any coastal protection measures and eventually restrict vehicle access on Wild Cattle Island foreshore. Consequently, Bangalee may become secluded and only accessible by boat.

The following management options are considered for Bangalee:

1. Do nothing
2. Maintain and monitor

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 58 provides an overview of the scores for each option against the weighted assessment criteria for Bangalee.

Table 58. Criteria weighting and scores for Bangalee options

Criteria	**Criteria weighting**	**Option 1**	**Option 2**
Accessibility	3.6%	0.07	0.14
Adaptability	9.6%	0.10	0.10
Cultural heritage	10.8%	0.54	0.54
Protection	12.0%	0.12	0.24
Environmental	13.3%	0.53	0.53
Approvals	8.4%	0.42	0.42
Safety	19.3%	0.19	0.39
Value (Cost)	10.8%	0.54	0.54
Visual amenity	12.0%	0.24	0.24
Total	100%	2.76	3.14
Rank		2	1

Option 1 – Do nothing
Do nothing and allow natural processes to take their course. This option does not resolve any potential current or future erosion issues where existing residential developments are already located within foreshore areas prone to erosion. This residential area is currently not impacted by erosion or inundation. However, it may experience erosion and inundation threats as a consequence of changing climate. Table 59 provides scores for Option 1 against the assessment criteria.

Table 59. Bangalee – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	2	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	1	Provides no protection and improvement to foreshore.
Environmental	4	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific actions are proposed.
Safety	1	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	There would be no additional cost.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Maintain and monitor
Continue to assess and maintain the foreshore. Similar to Option 1, this option does not provide any additional protection to mitigate erosion for Bangalee. There is no immediate coastal erosion or inundation threat to the Bangalee foreshore, but it may become threatened in the future by the changing climate. Accessibility may also become impacted by future rising sea levels. This option involves active monitoring by Council, including drone capture of the shoreline position and periodic aerial imagery. This would provide essential information for future decisions on access management planning. Additionally, Council should prepare a disaster management plan or cyclone action management plan and continuously engage with residents to ensure that they are aware of their risk of being isolated during cyclonic events. Table 60 provides scores for Option 2 against the assessment criteria.

Table 60. Bangalee – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	4	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	2	Require monitoring and maintenance. Provides no protection and improvement to foreshore.
Environmental	4	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approvals appear to be required where no specific development actions are proposed.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and become unstable.
Value (Cost)	5	Budget to maintain foreshore.

Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Recommended option

Option 2 – Maintain and monitor
Continue to assess and maintain the foreshore.

Description

The recommended option for the Bangalee foreshore is to maintain status quo. There is no immediate coastal erosion threat to the Bangalee foreshore, but it may become threatened by the changing climate in the future. Accessibility may also become impacted by future rising sea levels.

This option involves active monitoring by Council, including drone capture of the shoreline position and periodic aerial imagery. This would provide essential information for future decisions on access management planning.

Additionally, Council should prepare a disaster management plan or cyclone action management plan and continuously engage with residents to ensure that they are aware of their risk of being isolated during cyclonic events.

Cost estimates

No additional costs for recommended options.

Bangalee

6.12 Southern community

Present day shoreline condition and key coastal issues

Approximately 25 - 30 informal shacks/humpies are built on the mainland side of Colosseum Inlet. Access to this area is restricted and only accessible by boat or via a private gated road from Tannum Sands Road. The land parcel on the mainland side of Colosseum Inlet is leased from the State Government.

From recent aerial imagery, ad-hoc erosion control structures of various designs and materials have been installed to assist in retaining sand. A number of revetment walls have also been constructed using materials such as rocks, tyres, wooden planks and concrete pylons.

The southern community is vulnerable to sea level rise, which will inundate the low-lying areas. Any future erosion protection works for the shoreline should consider ways to mitigate sea level rise and storm tide hazards. Alternatively, retreat and transition may need to be considered in the context of long-term coastal hazard adaptation.

The following management options are considered for the southern community:

1. Do nothing
2. Inform of coastal hazard risks

The options assessment approach, including the descriptions of assessment criteria and weightings, is outlined in Sections 5.4 and 5.3. Table 61 provides an overview of the scores for each option against the weighted assessment criteria for the southern community.

Table 61. Criteria weighting and scores for the southern community options

Criteria	Criteria weighting	Option 1	Option 2
Accessibility	3.6%	0.04	0.11
Adaptability	9.6%	0.10	0.10
Cultural heritage	10.8%	0.54	0.54
Protection	12.0%	0.12	0.12
Environmental	13.3%	0.66	0.40
Approvals	8.4%	0.42	0.42
Safety	19.3%	0.39	0.58
Value (Cost)	10.8%	0.54	0.54
Visual amenity	12.0%	0.24	0.36
Total	100%	3.05	3.17
Rank		2	1

Option 1 – Do nothing

Do nothing

This option does not resolve any potential current or future erosion and inundation issues where existing assets are already located within foreshore areas prone to erosion.

Council should closely monitor this site as the southern community is already threatened by erosion and inundation. These impacts will be exacerbated with the changing climate without any additional coastal protection measures and may pose a safety risk to the community.

Table 62 provides scores for Option 1 against the assessment criteria.

Table 62. Southern community – Option 1 criteria scores

Criteria	Score	Comment
Accessibility	1	Access to the foreshore will reduce as the foreshore continues to deteriorate.
Adaptability	1	Not adaptable to future conditions.
Cultural heritage	5	No disturbance or excavation of land.
Protection	1	Provides no protection and improvement to foreshore.
Environmental	5	Surrounding environmental values are unchanged and undisturbed.
Approvals	5	No approval requirements.
Safety	2	The overall site safety decreases as the foreshore continues to deteriorate and becomes more exposed to coastal processes.
Value (Cost)	5	There would be no additional cost.
Visual amenity	2	The visual amenity of the foreshore is likely to reduce as the foreshore continues to deteriorate.

Option 2 – Inform of coastal hazard risks

Inform the southern community of the risks from coastal inundation, erosion and expanding tidal inundation.

The southern community is established directly on the foreshore, which is currently threatened by erosion and inundation. These impacts are expected to exacerbate by the changing climate without any additional coastal protection measures and may pose a safety risk to the community.

As the dwellings in the southern community are located on State lease permit area and are not Council rate payers, Council does not have the direct contact details for these residents. Any direct contact with these residents would need to be through the State Government.

As such, Council should contact the State Government with a suggested letter to inform residents of their potential coastal hazard risks (as per the same information Council has provided to residents/rate payers within the coastal hazard areas of the LGA). Council should also notify the State about the community's hazard and safety risks and allow the State to make leasing terms decisions accordingly.

Table 62 provides scores for Option 2 against the assessment criteria.

Figure 35. *Southern community – Options 2 – Inform of coastal hazard risks.*

Table 63. Southern community – Option 2 criteria scores

Criteria	Score	Comment
Accessibility	3	No change to foreshore usage and access.
Adaptability	1	No ability to adapt to future climate.
Cultural heritage	5	No disturbance and excavation of land.
Protection	1	Not protected from coastal hazards.
Environmental	3	No additional environmental impacts.
Approvals	5	No approvals required for Council actions where no specific works are required from Council directly.
Safety	3	Potentially high risk during larger storm events, but residents will be aware of their risks.
Value (Cost)	5	No additional costs required.
Visual amenity	3	No impact on visual amenity.

Recommended option

Option 2 – Inform of coastal hazard risks

Inform the southern community of their risks from coastal inundation, erosion and expanding tidal inundation.

Description

The recommended option for the southern community is for Council to inform the southern community of their coastal hazard risks by informing the State Government.

In line with *Our Coast Our Future* action 2.1.4 – 'Consult with State Government on permit to occupy arrangements, with considerations of future coastal hazard risks' and supplemented with broader education and awareness in actions 1.2.2, 1.2.3, 3.1.3 and 3.1.4, Council should prepare coastal hazard information materials to inform the community of their potential coastal hazard risks and liaise with State Government representatives to issue this information to the permit holders. Council should also notify the State Government about the community's hazard and safety risks and allow them to make leasing terms decisions accordingly.

Cost estimates

No additional costs for recommended options.

7 SEMP implementation plan

The recommended management actions for this SEMP for implementation, monitoring and review are summarised in Table 64. Prioritisation of the management actions have been assigned as immediate, medium-term or future.

1 **Immediate** (recommend implementation within 1 to 2 years)

2 **Medium-term** (recommend implementation within next 2 – 4 years)

3 **Future** (recommend implementation within 5 – 10 years)

Table 64. Actions summary

Location	Recommended action	Timing	Description	Costs	Approvals
Lilley's Beach	4WD traffic management plan	1	Develop a 4WD traffic management plan for Lilley's Beach. Consultant support (if applicable).	$20,000	N/A
	Revegetation and management/ Access management	1	Establish a 20m revegetation buffer zone landward of HAT by revegetating with native species. Access management as a part of revegetation and management works.	$20,000	N/A
	Monitoring and evaluation	2	Undertake an audit of the access tracks on a yearly basis to determine whether illegal access tracks are being established.	Council (N/A)	N/A
	HOLD POINT **Review of SEMP actions for Lilley's Beach.**	2	**Review of SEMP actions and effectiveness within 2 - 4 years.**	Council (N/A)	N/A
	Tier 2 action (if applicable and triggered by the effectiveness of SEMP actions for Lilley's Beach.	3	Restrict 4WD access on Lilley's Beach if: • permit conditions are not adhered to • 4WD access is exacerbating erosion and impacting vulnerable species and ecosystems.	Council (N/A)	N/A
Lilley's Beach entrance	Easement agreement	1	Liaise directly with Boyne Smelter Limited to negotiate an easement agreement for the Lilley's Beach entrance foreshore area.	Council (N/A)	N/A
	Revegetation and management/ Access management	1	Revegetate with native species. Access management as a part of revegetation and management works.	$2,50	N/A
	HOLD POINT **Review of SEMP actions for Lilley's Beach.**	2	**Review of SEMP actions and effectiveness within 2 - 4 years.**	Council (N/A)	N/A
	Tier 2 action (if applicable and triggered by the effectiveness of SEMP actions for Lilley's Beach.	3	Restrict 4WD access on Lilley's Beach if: • permit conditions are not adhered to • 4WD access is exacerbating erosion and impacting vulnerable species and ecosystems.	Council (N/A)	N/A
Island Esplanade foreshore	Internal options assessment	1	Recommended options to be assessed by Council's Investment Decision Framework.	Council (N/A)	N/A
	Design and approvals for revetment	1	Design and approvals pending the outcome of the internal options assessment. Consultant support (if applicable).	$65,000 - design & approvals only	i. Tidal Works Approval, including owner's consent
	Construction of revetment	3	Construction of preferred revetment option.	Subject to option	ii.
Turtle Way	Monitoring – visual/photo	1	Annual and event-based review of impacts and changes.	Council (N/A)	N/A
	Design and approvals for riprap	1	Consultant support (if applicable). Design and approvals for riprap.	$20,000 to $65,000 – subject to extent of works	i. N/A – for priority areas only. ii. Tidal Works Approval, including owner's consent – for the full length of Turtle Way
	Installation of riprap	3	Installation of riprap to protect stormwater and sewerage assets.	$850,000	i. N/A – for priority areas only. ii. Tidal Works Approval, including owner's consent – for the full length of Turtle Way

Location	Recommended action	Timing	Description	Costs	Approvals
Canoe Point	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.	Council (N/A)	N/A
	Monitoring – visual/photo, 'CoastSnap' monitoring station	1	Establishment of monitoring points (photo and depth markers) for monthly beach profile monitoring.	Council (N/A)	N/A
	Revegetation and management/ Access management	2	Revegetate with native species. Access management as a part of revegetation and management works.	$10,000	N/A
The Oaks Road foreshore	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.	Council (N/A)	N/A
	Monitoring – visual/photo, 'CoastSnap' monitoring station	1	Establishment of monitoring points (photo and depth markers) for monthly beach profile monitoring.	Council (N/A)	N/A
	Revegetation and management/ Access management	2	Revegetate with native species. Access management as a part of revegetation and management works.	$10,000	N/A
	Stormwater management plan	2	Develop a stormwater management plan/procedure to manage the stormwater outlet at The Oaks Road. Consultant support (if applicable).	$10,000	N/A
Tannum Sands SLSC	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.	Council (N/A)	N/A
	Monitoring – visual/photo, 'CoastSnap' monitoring station	1	Establishment of monitoring points (photo and depth markers) for monthly beach profile monitoring.	Council (N/A)	N/A
	Revegetation and management/ Access management	2	Revegetate with native species. Access management as a part of revegetation and management works.	$10,000	N/A
Millenium Esplanade	Stormwater management	1	Design and approvals for a stormwater improvement area. Consultant support (if applicable).	$65,000 - design & approvals only	N/A
	Revegetation and management/ Access management	1	Revegetate with native species. Access management as a part of revegetation and management works.	$10,000	N/A
	Construction of stormwater management area	3	Construction of the designed and approved stormwater management option, in accordance with design and approvals.	$1M	Constructed in accordance with approvals
Wild Cattle Creek boat ramp	Maintain boat ramp	1	Monitor and assess the condition of the boat ramp. If an upgrade is required, liaise directly with the State Government.	Council (N/A)	N/A
	Gravel replenishment	1	Undertake gravel replenish design to determine size, scale and extent of works to maintain undermined carpark area.	$60,000	N/A
	Monitoring – access	2	Annual and event-based review of the accessibility of the turn-off to access Wild Cattle Island.	Council (N/A)	N/A
Wild Cattle Island foreshore	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.	Council (N/A)	N/A
	Monitoring – access	2	Annual and event-based review of the vehicle accessibility on the beach and liaise directly with National Parks.	Council (N/A)	N/A
Bangalee	Monitoring – site survey	1	Annual and event-based review of shoreline profile change.	Council (N/A)	N/A
	Monitoring – access	2	Annual and event-based review of the vehicle accessibility on the beach and liaise directly with National Parks.	Council (N/A)	N/A
Southern community	Consult with State Government	1	Consult with State Government and inform permit holders of future coastal hazard risks.	Council (N/A)	N/A

8 References

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Attachment 1. Legislative context

Legislative context

Coastal management in Queensland is bound by a raft of international, Commonwealth, State and local legislation. The legislation results in a complex structure of rights and responsibilities, particularly surrounding implementation of coastal works. This section provides a summary of the key legislative and planning requirements that may impact how coastal erosion is managed for Boyne Island and Tannum Sands and how the recommendations of this project are affected by those requirements.

Key legislation relevant to coastal planning within the Gladstone Regional Council LGA is outlined in Figure 36. Any proposed management options will need to comply with all relevant legislation. Any proposed management options will comply with all relevant legislation. Approvals processes that may be required for coastal management actions are noted below.

Federal

Great Barrier Reef Marine Park Act 1975
Provision for the long-term protection and conservation of the Great Barrier Reef region.

National Strategy for Ecologically Sustainable Development 1992
Ensures the conservation of ecosystems into the future through the use of an environmental resource.

Native Title Act 1993
Provides legal principles for the recognition of native title, including the processes involved with having this native title recognised.

Environment Protection and Biodiversity Conservation Act 1999
Serves to protect the environment, with particular attention to matters of national environmental significance.

State

Nature Conservation Act 1992
Ensures the conservation of nature while allowing the involvement of Indigenous people in the management of protected areas.

Fisheries Act 1994
Provides for ecologically sustainable use and conservation of fisheries and fish habitats.

Land Act 1994
Ensures that the land to which it applies is managed for the benefit of the people of Queensland.

Environment Protection Act 1994
Provides for the protection of the environment while allowing development that improves quality of life.

Coastal Protection and Management Act 1995
Provides for the protection, conservation, rehabilitation and management of the coastal zone.

Vegetation Management Act 1999
Regulates clearing of vegetation to conserve remnant vegetation and ensure that land clearing does not cause land degradation.

Aboriginal Cultural Heritage Act 2003
Provides the effective recognition, protection and conservation of Aboriginal Cultural Heritage.

Marine Parks Act 2004
Provides for the conservation of the marine environment.

Recreation Areas Management Act 2006
Regulates establishment, maintenance and use of recreational areas with regard to conservation, cultural and recreational values.

Local Government Act 2009
Outlines the responsibilities of Local Government, providing a system that is accountable, effective, efficient and sustainable.

Waste Reduction and Recycling Act 2011
Provides regulatory regime for management of litter and illegal dumping to minimise the impact of waste generation and disposal.

Planning Act 2016
Provides for the efficient, effective, transparent, integrated, coordinated and accountable system of land use planning and development in an ecologically sustainable manner.

Figure 36. *Summary of the legislation relevant to the SEMP. Yellow boxes represent land tenure, title and commercial use plans or Acts, blue boxes represent waterway and coastal plans or Acts, green boxes represent land, climate, environment and wildlife legislation or plans.*

Approval requirements

Native Title

There is one registered native title claim over the Boyne Island and Tannum Sands region for the Bailai, Gurang, Gooreng Gooreng, Taribelang Bunda People. First Nation Traditional Owners Native Title Claim Group will be notified as part of the Marine Park permit process for works which are likely to proceed in a manner that does not compromise the State's policy of non-extinguishment under Section 24KA of the *Native Title Act 1993*. Council would typically notify Native Title claimant separately to cover works outside the Marine Park (unless the specific tenure history at a site has extinguished native title claim).

Owner's consent

Any assessable development below mean high water springs (MHWS) requires evidence of owner consent to be provided. All coastal works within reserve tenured land or Unallocated State Land (USL) require the consent of the landowner to be provided for any development application to be considered to be properly made. The proposed works will extend below the level of MHWS and therefore require proof of owner's consent from the State Government for any application to be lodged. Landowner's consent is required to be obtained from the Department of Resources (DoR).

Fish Habitat Area

The *Fisheries Act 1994* protects fisheries resources and fish habitats in Queensland. There are two fish habitat areas in Tannum Sands which protect important juvenile prawn habitats and fish, including dugongs. These fish habitat areas cover area adjacent to Wild Cattle Island and slightly overlap with the Colosseum Inlet sides of the Wild Cattle Island and Bangalee management areas as shown in Figure 37. The dugong protection area 'B' covers offshore of Boyne Island and Tannum Sands, Wild Cattle Creek and Colosseum Inlet.

The southern portion of Wild Cattle Creek is a Management B declared fish habitat area. The boundary extends from approximately 3.16km from the mouth of the creek to Colosseum Inlet and encompasses the Wild Cattle Creek floodplains on both the mainland and Wild Cattle Island. Colosseum Inlet is a Management A declared fish habitat area and extends from the mouth of the river to Boyne Creek and Twelve Mile Creek. Management A fish habitat areas are under more strict management and must meet rigorous assessment criteria. As such, beach nourishment and the construction of some permanent public structures are not permitted in Management A areas.

A Resource Allocation Authority (RAA) is required for all works within a fish habitat area. The new works will require documentation to be provided demonstrating compliance with the Fisheries Operational Policy for a RAA to be provided for works within a fish habitat area. The RAA is to be provided to the State Assessment and Referral Agency during its assessment of the application for undertaking works within a fish habitat area. Compliance with State Code 12: Development in a declared fish habitat area under the State Development Assessment Provisions (SDAP) will be required to be demonstrated prior to an approval being issued.

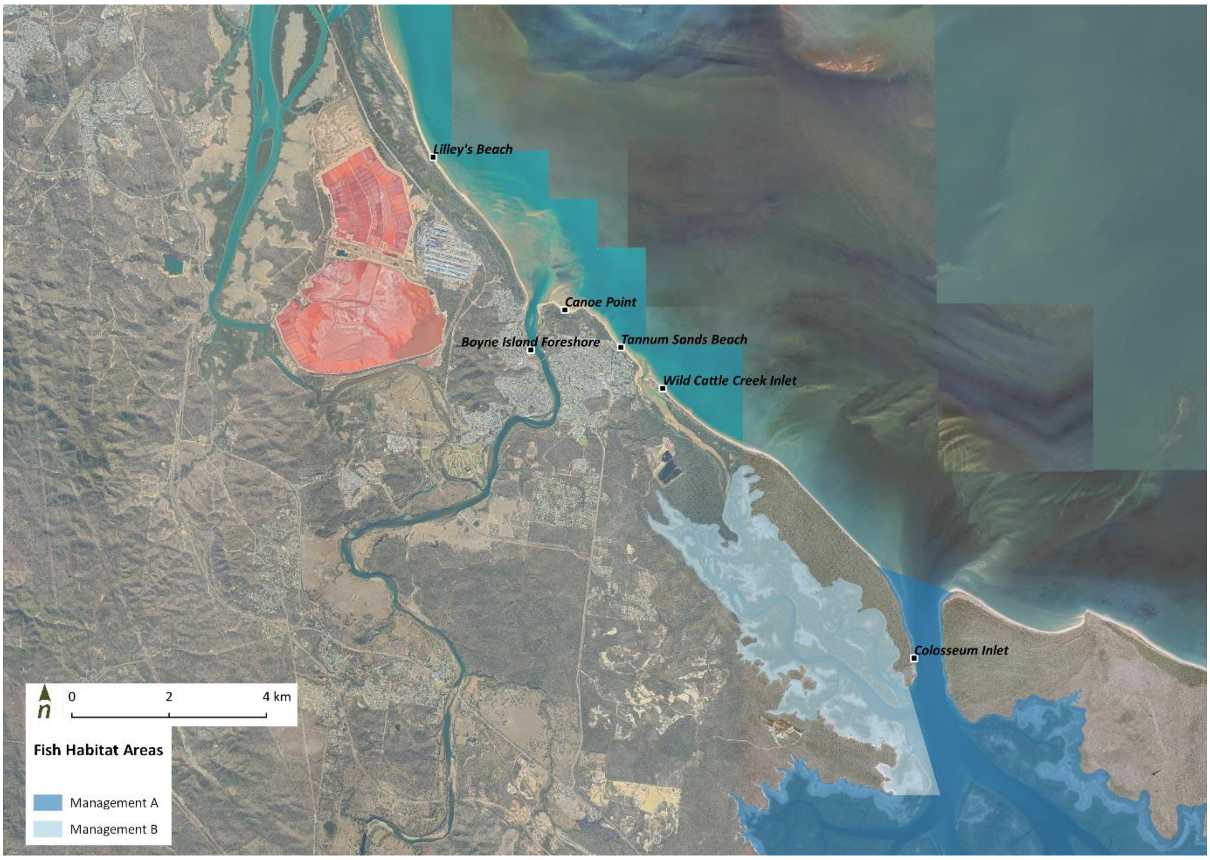

Figure 37. *Matters of State Environment Significance fish habitat areas within Boyne Island and Tannum Sands. Dark blue areas represent Management A fish habitat areas, and light blue areas represent Management B fish habitat areas.*

Marine Plants
The removal, damage or destruction of marine plants will require assessment against State Code 11: Removal, destruction or damage of marine plants under the SDAP. All works have been designed to avoid the removal, damage or destruction of marine plants where possible and the extent of impact will be required to be determined at the time any application is made for development approval.

Environmental Offsets
Environmental offsets may be imposed as a condition of development approval where the proposed works result in a significant residual impact to Matters of State Environmental Significance. A number of prescribed matters are likely to be present within proximity to Site 1 and Site 2, and conditions relating to offsets may apply where a significant residual impact is likely to occur on a Matter of State Environmental Significance.

Attachment 2. CHAS context

CHAS context

The work towards longer term Coastal Hazard Adaptation for Gladstone Regional Council has included identification of adaptation response and options for different localities. The following provides relevant extracts from Gladstone 'Our Coast Our Future' (CHAS).

Adaptation response

This adaptation framework defines the language for Council's adaptation response, and to screen adaptation options across different localities.

The tailored framework includes four adaptation responses – Avoid, Monitor, Mitigate, and Transition.

Adaptation response	Coastal hazard adaptation			
	Avoid	Monitor	Mitigate	Transition
	Avoid placing new development or assets in coastal hazard areas.	Monitor the risk of coastal hazards. Monitor until local trigger levels are reached to initiate mitigation.	Actively mitigate the risk of coastal hazards through a range of adaptation options. Mitigate until local trigger levels are reached to initiate transition.	A strategic decision to transition to an alternative land use in some areas. Mitigation may be part of the transition process.
Adaptation options		Monitoring and initiatives to enhance adaptive capacity	Full range of adaptation options	

Avoid

The general first principle is to avoid placing new development or assets in coastal hazard areas. The preference is to ensure land use in coastal hazard areas is one that is low risk for coastal hazard impacts, while also being a use that maximises economic, social, and environmental value to a region.

Any new development / infrastructure that is placed in coastal hazard areas will need to align with the State Planning Policy 2017 and the relevant approvals requirements and include necessary migration measures.

Monitor

In localities where the coastal hazard risk profile is low, Council will continue to monitor risk and undertake existing maintenance/asset management activities. If, over time, the risk profile is observed to increase (as indicated by local trigger levels), then the adaptation response may shift to mitigate.

Mitigate

In localities where coastal hazard risks have been identified, Council will actively manage the risk through implementing a range of adaptation options.

Mitigation will be tailored to each locality, incorporating site-specific processes, community, Traditional Owners input, Council's asset management and statutory planning considerations. If, over time, the risk profile is observed to increase (as indicated by local trigger levels), and mitigation becomes impractical (due to economic or other factors), then the adaptation response may shift to transition.

Transition

In some specific areas within a locality, if the coastal hazard risk profile is very high, and/or mitigation becomes impractical (due to economic or other factors), Council may make a strategic decision to transition to an alternative land use.

Transition is likely to be a gradual process over time, where mitigating hazards for a period is part of the transition process. However, in some cases, transition may also be a more rapid response in relation to a threshold trigger or event.

Adaptation pathway

This component of the framework defines the language for Council's adaptation options, applicable across different localities when a mitigate or transition adaption response is set and across different planning horizons (present day, 2060, 2100)

The adaptation response described above has been applied to Boyne Island and Tannum Sands (represented in reporting region 4) and more detailed descriptions of the options are provided in Table 65.

Table 65. Reporting region 4 adaptation pathway

	Present day	2060	2100
Adaptation response	Mitigate	Mitigate	Transition*
Adaptation actions			
1. Capacity building	As per region-wide actions, including:		
1.2 Knowledge sharing and collaborative partnerships	Enhance community adaptive capacity to coastal hazards, including awareness of increasing coastal hazard exposure and risk (particularly inundation) and ways to improve individual preparedness and adaptive capacity		
2. Planning updates	As per region-wide actions, including:		
2.1 Land use planning	Develop approach, including triggers, for a transition response for targeted areas of region in response to increasing long-term inundation exposure and risk. Includes low lying areas in Boyne Island, Wild Cattle Island, and smaller remote settlements in Reporting region 4.		Implement transition plan
	Consult with State Government to review and revise the approvals and conditions for future planning and development on Hummock Hill Island to avoid and mitigate potential risk.		
	Consult with State Government on opportunity to review and revise the approvals and conditions for permit to occupy arrangements for relevant properties.		Revise permit to occupy conditions to inform transition planning
2.2 Disaster management	Update local disaster management planning for this locality based on updated coastal hazard maps		
3. Modifying infrastructure	As per region-wide actions, including:		
3.1 Build resilience	Review and update asset management plan to incorporate upgrades to inundation prone sections and other relevant infrastructure. Includes Gladstone Benaraby Road, infrastructure along Boyne River, Boyne River Boat Ramp.		
	Promote resilient homes within the community		
3.2 Relocate infrastructure	Review and update asset management plan to and develop a transition response for Olunda Street carpark	Relocate infrastructure	
4. Coastal management and engineering	As per region-wide actions, including:		
4.1 Dune protection and maintenance	Continue and expand the dune protection and maintenance program at Canoe Point and Tannum Beach, Wild Cattle Creek using existing Wild Cattle Creek SEMP, including minimising disturbance to sensitive areas.		
4.3 Targeted investigations	Develop coincident flood models at Boyne River estuary to understand implications of the influence of riverine processes for inundation and erosion vulnerability for the Gladstone coast (potential link to ports, industry, and research partnerships)		
	Develop a Shoreline Erosion Management Plan (SEMP) – western bank of Boyne River mouth		
	Review and revise Shoreline Erosion Management Plan (SEMP) – Wild Cattle Creek		
4.4 Additional coastal hazard protection works	Consult with State Government on the implications of private/illegal coastal hazard protection structures, to review and revise approvals, and/or remove, modify, or formalise existing structures including along Boyne River.		
		Scope potential future works at Boyne River and Tannum Sands, in accordance with adaptation pathway planning, including concept options to manage increasing coastal hazards on Boyne River foreshore and Tannum Sands Main Beach.	

* A transition response may be appropriate for limited areas within the locality

Attachment 3. Boyne Island and Tannum Sands coastal processes review

Boyne Island and Tannum Sands Shoreline Erosion Management Plan

Coastal Processes Assessment

Final Report

August 2022

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
S3-P01 / June 2022	Draft Report	PW
A1-C01 / August 2022	Final	PW

Contract

This report describes work commissioned by Pam Wong, on behalf of Alluvium, by a letter dated 31/03/2022. Ben Cowling and Michael Thomson of JBP carried out this work.

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Director

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The conclusions and recommendations contained in this report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by JBP has not been independently verified by JBP, unless otherwise stated in the report.

The methodology adopted and the sources of information used by JBP in providing its services are outlined in this report. The work described in this report was undertaken between March 2022 and June 2022 and is based on the conditions encountered and the information available during this period of time. The scope of this report and the services are accordingly factually limited by these circumstances.

Any assessments of works or costs identified in this report are based upon the information available at the time, and where appropriate are subject to further investigations or information which may become available.

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Unless otherwise stated in this report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Where field investigations are carried out, these have been restricted to a level of detail required to meet the stated objectives of the services. The results of any measurements taken may vary spatially or with time and further confirmatory measurements should be made after any significant delay in issuing this report.

Acknowledgements

JBPacific acknowledges the traditional custodians of the lands and seas where we work. We pay our respects to Elders past, present, and emerging.

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Executive Summary

This report has been prepared by JBPacific (JBP) to support the Boyne Island and Tannum Sands Shoreline Erosion Management Plan (SEMP) in central Queensland. This report summarises the outcomes of a coastal process assessment which includes wind and wave investigations, wave modelling, hydrodynamic modelling, sediment modelling and historical coastline tracking. This information has been used to estimate erosion and sediment transport processes at Boyne Island and Tannum Sands.

Wind and wave assessment

Seasonal wind conditions have been assessed from recorded weather data at the Gladstone Radar Automatic Weather Station. This data shows prevailing easterly winds during summer months, trending toward south-easterly during winter.

Offshore and nearshore wave conditions have been assessed using a combined simulation and emulation approach. A 10,000-year dataset of potential offshore wave conditions has been generated from the Gladstone wave rider buoy. A sampled subset of 200 wave and storm tide conditions has been simulated in a numerical wave model, with results extracted in the nearshore. From these nearshore results, a machine learning emulator has been used to translate the full 10,000-year offshore dataset to the nearshore for use in sediment transport assessments.

Longshore Sediment Transport assessment

Potential rates of Longshore Sediment Transport (LST) have been estimated using the JBP Beach Evolution Model (JBEM). Wave conditions have been extracted from the emulated nearshore wave dataset and applied within JBEM as an event set spanning 10,000 years. The LST rate has been estimated at five key locations along the coast, with two reporting points located on Lilley's Beach, one at Tannum Sands beach and two on Wild Cattle Island. The LST modelling indicates a net northward transport across the southern four points in the order of 30,000 m^3/year and approximately 8,000 m^3/year for the more sheltered point at Lilley's Beach north.

Cross-shore erosion assessment

A probabilistic approach has been applied to assess extreme cross-shore erosion for open-coast beach segments at Lilley's Beach, Tannum Sands, and Wild Cattle Island. The 10,000-year offshore wave event set has been assessed withing the JBP Erosion Prone Area (JEPA) cross-shore toolkit. From the results of erosion modelling, a frequency analysis has been conducted on eroded widths for each location to determine a range of extreme erosion annual exceedance probabilities (AEP):

- Lilley's Beach north: 1% AEP erosion width = 4.3m
- Lilley's Beach south: 1% AEP erosion width = 15.2m
- Tannum Sands beach: 1% AEP erosion width = 9.3m
- Wild Cattle Island north: 1% AEP erosion width = 13.9m
- Wild Cattle Island south: 1% AEP erosion width = 15.4m

Hydrodynamic modelling assessment of Boyne River

An investigation has considered the causes of shoreline movement within the Boyne River inlet. The area has a degree of protection from the open coast, however has experienced well documented retreat during 2013, particularly after Tropical Cyclone (TC) Oswald. The potential for high catchment flows to cause estuarine erosion has been investigated using a numerical model.

Modelling using Delft3D was undertaken to understand the hydrodynamic and morphological processes occurring within the Boyne River inlet during a large flood event. This model has been developed as a decision support tool, to help understand how tides, upstream inflow, and sediment properties interact adjacent to Island Esplanade on Boyne Island. The model was established under the following conditions:

- An 18 day run period was simulated from 21/01/2013 to 06/02/2013 capturing the storm tide effects produced by TC Oswald and the peak of the dam releases over the spillway into Boyne River
- The model uses GBR30 bathymetry capturing bed levels at the study area and a combination of 1m and 5m LiDAR topography representing pre-flood inlet conditions
- The model includes discharge rates recorded at Awoonga Dam during the flood event. The upstream discharge boundary starts at 1694 m^3/s and peaks at 6972 m^3/s, coinciding with a time-varying tide signal at the downstream boundary.

The simulation results show a widening of the Boyne River inlet mouth on the east and west bank of the inlet during the extreme flood event. These results support the idea that the erosion experienced by property owners along Island Esplanade in 2013 can be attributed, at least partially, to the high flow conditions.

Historical coastline assessment

The remote sensing python-based toolkit CoastSat was used to supplement the Geoscience Australia Digital Earth Australia database. CoastSat was used to provide refined shoreline analysis at key erosion areas at Island Esplanade and Turtle Way, both within the Boyne River estuary.

Results of the shoreline analysis at Island Esplanade complement the hydrodynamic modelling assessment and identify significant shoreline recession from 2012 to 2013, following by a prograding trend from 2014 to present day. At Turtle Way, detailed shoreline analysis was inconclusive due to tree cover and lack of resolution in aerial imagery. However, it is suspected that the observed erosion in this area is due to combined tide and boat-wave waves as well as decreased mangrove coverage and anthropogenic interference (hard structures) along the river bank.

Additionally, the remote sensing python toolkit, InletTracker, was used to analyse the fluctuations at the Wild Cattle Creek inlet. Over the range of historical imagery included in this analysis, the inlet was not found to be in a closed state. This is expected to be due to the inlet being tidally fed from the north as well as the southern entrance at Colosseum Inlet. This assessment showed Wild Cattle Creek to be a fluctuating but stable open inlet.

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Abbreviations

ACDP............................. Acoustic Doppler Current Profile
AEP................................ Annual Exceedance Probability
AHD .... Australian Height Datum
AWS............................... Automatic Weather Station
BITS .... Boyne Island and Tannum Sands
BoM................................ Bureau of Meteorology
DEA................................ Digital Earth Australia
DEM .... Digital Elevation Model
DoC................................ Depth of Closure
EPA................................ Erosion Prone Area
GBR .... Great Barrier Reef
GRC .... Gladstone Regional Council
HAT................................ Highest Astronomical Tide
ICOLL............................. Intermittently Closed or Open Lake or Lagoon
LAT .... Lowest Astronomical Tide
LGA................................ Local Government Area
LiDAR............................. Light Detection and Ranging
LST .... Longshore Sediment Transport
MDA .... Maximum Dissimilarity Algorithm
MGA............................... Map Grid of Australia
MHWN .... Mean High Water Neap
MHWS............................ Mean High Water Spring
MLWN .... Mean Low Water Neap
MLWS .... Mean Low Water Spring
mNDWI .... modified Normalised Difference Water Index
MSL................................ Mean Sea Level
PD .... Present Day
PoT .... Peak over Threshold
PSM .... Permanent Service Mark
QLD................................ Queensland
SEMP............................. Shoreline Erosion Management Plan
STL .... Storm Tide Level
TC .... Tropical Cyclone
WGS .... World Geodetic System
WRB............................... Wave Rider Buoy

1 Introduction

JBPacific have been commissioned by Alluvium to conduct a coastal assessment supporting the Boyne Island and Tannum Sands (BITS) Shoreline Erosion Management Plan (SEMP). The SEMP is an essential tool for Gladstone Regional Council (GRC) to appropriately manage coastal erosion in the region ensuring coastal values, continuity of services and protection of assets are maintained. Identified by GRC are several key areas of concern around BITS, these include Lilley's Beach, Boyne Island Foreshore, Tannum Sands Beach, Canoe Point, Wild Cattle Inlet and Colosseum Inlet.

This report details the processes and methodology undertaken throughout the assessment. In addition to this introductory chapter, this report includes the following sections:

- **Section 2: Review of available data**
- **Section 3: Wind and wave assessment**
- **Section 4: Longshore sediment transport**
- **Section 5: Cross-shore erosion assessment**
- **Section 6: Hydrodynamic modelling of Boyne River**
- **Section 7: Historical coastline tracking**
- **Section 8: Summary**

Figure 1-1: The Boyne River inlet (JBP, March 2022)

Figure 1-2: Boyne Island and Tannum Sands location map

2 Review of available data

2.1 Background to coastal processes

Before undertaking any calculations or modelling of coastal and estuarine processes it is first important to understand the processes that are driving waves, currents and sediment transport within the area. This is a complicated process, affected by a number of wave, hydrodynamic and morphologic processes as shown in Figure 2-1. At present, there is no single numerical model capable of simulating each interaction, and a suite of statistical and numerical models is typically used to quantify impacts.

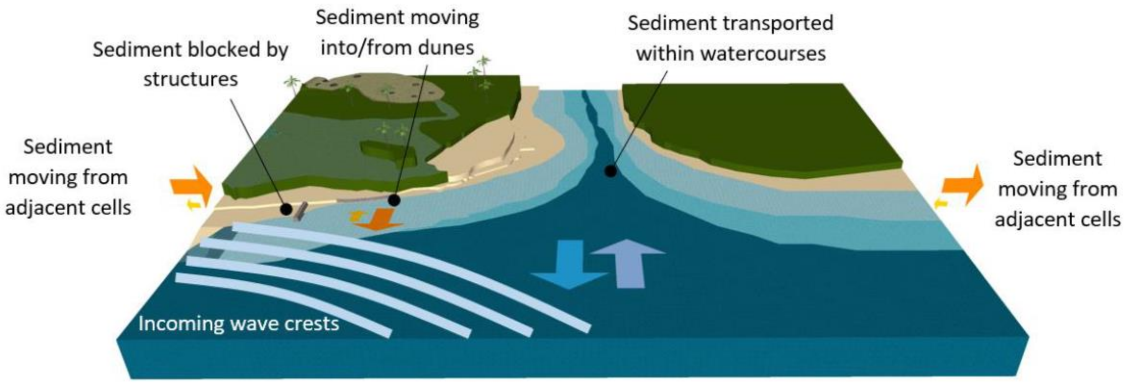


Figure 2-1: Main environmental controls for coasts and estuaries.

The way in which the different coastal processes interact will determine the tidal and wave conditions experienced at any location. As shown in Figure 2-1, these may include the following:

- Wind-driven waves: winds blowing across a water surface apply a shear stress which is converted to wave energy. The height (and energy) of a wave train is directly related to the speed of the blowing wind, the linear distance of water over which the wind is applied, and the duration that the wind blows for. Within estuaries, the distance and duration of wind stress, and hence the size of waves, is limited by the size of the estuary.
- Astronomical tide: this is the regular periodic variation in water levels due to the gravitational effects of the moon and sun, which can be predicted with generally very high accuracy at any point in time (past and present) if sufficient measurements are available. Tide levels can affect fetch distances in tidal areas, as well as the depth of water through which wind-driven waves can propagate
- Longshore sediment transport: when waves arrive at oblique angles to the coast, they cause sediment suspended in the water column to flow parallel to the coastline orientation. For much of the Gladstone region coastline, and for the east coast of Australia in general, this transport direction is toward the north, due to prevailing south to south-easterly waves.
- Cross-shore sediment transport: this process is the cyclical offshore and onshore movement of sediment across the beach profile. During storm conditions, sand is removed from the frontal dunes and deposited offshore. During seasonal calm periods, this lost material is gradually redeposited onshore by waves and wind.
- Sediment transport within the watercourse: this process is the transport of sand material in rivers and estuaries due to upstream flow and tidal currents. During flood events, large sediment deposits can be transported downstream to resettle within the estuary or be redistributed across the coast through longshore sediment transport. This process can be a primary source of sediment material for coastal beaches.

2.2 Available data

A range of datasets are available at a regional scale as well as specific to the study area. These provide information on wind, waves, tides, and local elevation.

2.2.1 Elevation data

Modelling of the BITS region has relied on a combination of datasets.

Topographic data has been sourced from:

- 1m LiDAR (2014): The coverage of this dataset is over the entire Gladstone region. This data set contains ground surface model in ASCII grid format derived from C3 LiDAR (Light Detection and Ranging) from an ALS50ii (Airborne Laser Scanner). This data is reliable to approximately the 0mAHD contour[1].
- 5m LiDAR: This dataset predates the 1m data and has been used to replicate the Boyne River estuary before the 2013 flood event. The 5m LiDAR Digital Elevation Model (DEM) has been sourced from more than 200 individual LiDAR surveys conducted between 2001 and 2015[2].

Bathymetric data has been sourced from:

- Offshore bathymetry data has been sourced from the Great Barrier Reef (GBR) 30m resolution DEM. This dataset is an amalgamation of many bathymetric surveys including multi- and single beam echo sounder as well as airborne lidar and chart data. Intertidal data within the GBR DEM is sourced from the Geoscience Australia Intertidal Extents Model (ITEM)[3]. This dataset has good resolution of offshore shipping channels and sand shoals near Boyne Island and Tannum Sands.

2.2.2 Height datums

All height data is relative to the Australian Height Datum (AHD), unless otherwise specified.

2.2.3 Tidal planes

Tidal plane information has been taken from the Queensland Tide Tables (2021) for South Trees Island at Gladstone (PSM 2168), as shown in Table 2-1.

Table 2-1: Tidal planes for Boyne Island and Tannum Sands, from South Trees

Tidal plane	2021 (mLAT)	2021 (mAHD)*
HAT	4.63	2.42
MHWS	3.80	1.59
MHWN	2.99	0.78
MSL	2.20	-0.01
MLWN	1.51	-0.70
MLWS	0.69	-1.52
PSM3853	7.728	5.52
AHD	2.21	0.00
LAT	0	-2.21

2.2.4 Available water level data

Recorded water level data has been sourced from the water level gauge at South Trees:

- South Trees Island storm tide gauge: ID 52026A, Oct. 1979 - present; (-23.8550, 151.3173)

Astronomical tide data is not available for this gauge, therefore the Utide python-based tool has been used to reconstruct the tidal series from the recorded data. Utide derives the principle tidal constituents from the recorded signal and hindcasts the astronomical series. The tool can also be

1 State of Queensland (Department of Resources) 2021: Queensland LiDAR Data - Gladstone 2014 Project

2 Geoscience Australia 2015. Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid. Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/89644

3 Beaman, R.J. 2017. High-resolution depth model for the Great Barrier Reef - 30 m. Geoscience Australia, Canberra. http://dx.doi.org/10.4225/25/5a207b36022d2

used to predict astronomical tides in the future[4]. Figure 2-2 shows the recorded and reconstructed astronomical signal for South Trees during Tropical Cyclone (TC) Oswald. The South Trees gauge recorded around 0.5m of surge during this event.

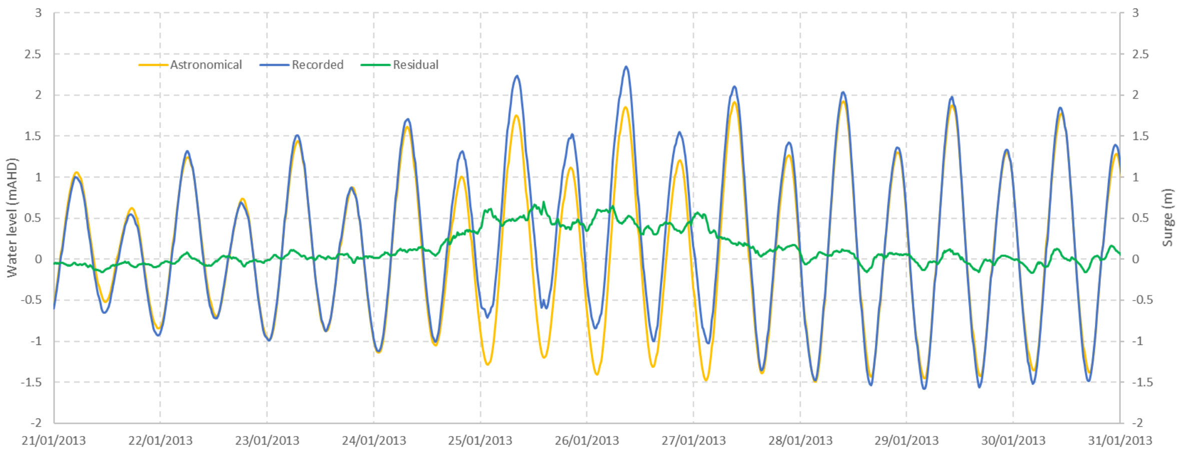


Figure 2-2: Water levels during TC Oswald

2.2.5 Available upstream water level data

This assessment has included hydrodynamic and morphodynamical modelling of the Boyne River for the 2013 flood event. Upstream water volume data has been sourced from the Bureau of Meteorology (BoM) for the Awoonga Dam recording station. This station is located at (-24.07, 151.31) and has storage volume data from January 1984 to present. The Awoonga Dam has a storage capacity of approximately 777,000 ML. After days of heavy rain associated with TC Oswald, on 27 January 2013 the dam reached a peak volume of 1,379,462 ML (representing 178% of the water storage level), the largest on record, and subsequently discharged at rates of up to 602,462 ML/day.

2.2.6 Available wind data

Wind data has been sourced from the Bureau of Meteorology (BoM) for Gladstone Radar Automatic Weather Station (AWS):

- Gladstone radar: ID 039123, Jan. 1957 - present; (-23.8553, 151.2628)

2.2.7 Available wave data

Wave data has been sourced from a combination of datasets:

- Recorded data at Gladstone Wave Rider Buoy (WRB): The Gladstone WRB is located at (-23.8984, 151.5081) around the 16m depth contour. Data is available for two periods: from 1979-1983, and from 2009-2021. Additional hindcast wave data has been used to supplement the recorded dataset
- ERA5 hindcast wave data: The ERA5 global hindcast model has been used to supplement the recorded wave data from the period of 1983 to 2009. The hindcast model provides hourly estimates from 1979 to present day for a range of atmospheric conditions and has a spatial resolution of 0.5° for wave extraction.

2.2.8 Event frequencies

This report has adopted the preferred terminology for event frequency description outlined in Book 1, Chapter 2.2.5 of Australian Rainfall and Runoff (ARR)[5]. Very frequent events, occurring at least once per year, are referred to by exceedances per year (EY). Frequent to very rare events are referred to by average exceedance probability (% AEP). For ease of reading, AEP events are also

4 Codiga, D.L., 2011. Unified Tidal Analysis and Prediction Using the UTide Matlab Functions. Technical Report 2011-01. Graduate School of Oceanography, University of Rhode Island, Narragansett, RI. 59pp.

5 Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), 2019

referred to by their respective average recurrence interval (ARI) in the first instance, however the ARI frequency terminology is being phased out by industry.

2.3 Previous investigations:

2.3.1 Gladstone Western Basin EIS - Numerical Modelling Studies - BMT WBM (2009):

This report was completed by BMT in 2009 to support the Gladstone Western Basin Strategic Dredging and Reclamation EIS. The study details numerical modelling of tidal hydrodynamics and flushing characteristics, turbid dredge plume dispersion, wave conditions and sedimentation processes. The extreme wave results from this study are available as a comparison for the new wave modelling required for this assessment, however the extent explored here is limited to within Gladstone Bay.

2.3.2 Boyne Island and Tannum Sands Shoreline Erosion Management Plan (SEMP) - Ecosure 2014

This report was the original SEMP completed for the Boyne Island and Tannum Sands region and commissioned by Gladstone Regional Council. Identified within this report are four key areas broadly categorised as Lilley's Beach, Boyne Island foreshore, Tannum Sands Beach, Wild Cattle Island and Colosseum Inlet. The assessment identified several locations where on-going coastal erosion is identified, with the report including management actions aimed at addressing these issues. Management actions include dune fencing, revegetation and dune stabilisation, monitoring, access restrictions, signage, permit systems, stormwater and permanent structure assessments, minor works, planned retreat and status quo.

2.3.3 Boyne Island and Tannum Sands Coastal Study - GHD 2015

This report was commissioned by Gladstone Regional Council to investigate on-going coastal erosion in the Boyne Island and Tannum Sands region. This involved site inspections, coastline tracking and the development of erosion mitigation options. Two sites were studied, including Island Esplanade on Boyne Island and Wild Cattle Creek inlet. Proposed mitigation options included no-action policies, maintenance shoreline nourishment, revegetation, and combinations of the above.

2.3.4 Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project EIS - Coastal Processes and Hydrodynamics - BMT 2019

Gladstone Ports Corporation Ltd sought to duplicate the existing Gatcombe and Golding Cutting bypass shipping channels to accommodate an anticipated growth in future shipping. This report covers a range of coastal process modelling including tidal hydrodynamics, extreme water levels, wave climate, sediment dynamics and coastal processes. This study provides a range of baseline information to compare with wave climate, extreme water levels and information on shoreline tracking for Boyne Island. Acoustic Doppler Current Profile (ADCP) wave recordings from BMT (2019) have been used to calibrate numerical wave modelling in the current study.

2.3.5 Gatcombe and Golding Cutting Channel Duplication Project - Environmental Impact Statement - Aurecon 2019

This environmental impact statement contains a chapter detailing coastal process and hydrodynamics for the Gladstone region. This includes a summary of the methodology, description of existing coastal processes, assessment of potential impacts of the project and mitigation measures and risks. Relevant to the current study is high level information on tides, water levels, wave climate and sediment dynamics through the shipping channel into the Port of Gladstone. Values are provided for reference for sediment budgets supplied by Calliope and Boyne rivers along with the approximate amount of dredged material removed from the shipping channels annually. Unfortunately, sediment supply budgets are not individually specified for Boyne River and can only be used as a guide for future investigations.

2.3.6 Agnes Water and Seventeen Seventy SEMP - Alluvium & JBP 2020

This project was commissioned by Gladstone Regional Council and was completed by Alluvium with technical inputs from JBPacific. This SEMP identified physical context, coastal values and subsequent management options and suitability for the region. Relevant information to the BITS SEMP includes:

- Sediment transport experienced at Seventeen seventy ranging from 11,000 m³ /year up to 34,000 m³ /year depending on beach orientation with reference to the dominant wave angle
- Trends in shoreline change with reference to dredging and sediment availability

3 Wind and wave assessment

3.1 Wind conditions analysis

Wind conditions have been sourced from the Gladstone Radar AWS, located approximately 15km northwest of Tannum Sands. Figure 3-1 shows a wind rose of data from this gauge from 1957 to present day. Figure 3-2 to Figure 3-4 shows analysis of wind speed and direction for this station. Analysis of 10-min average wind speed data shows dominate easterly wind, with a tendency for higher wind speeds in the summer months. Easterly winds are more dominant in the summer months, with winds becoming more southerly in May to August. However, it is possible for extreme winds to occur from any direction at Gladstone due to the potential for cyclone activity.

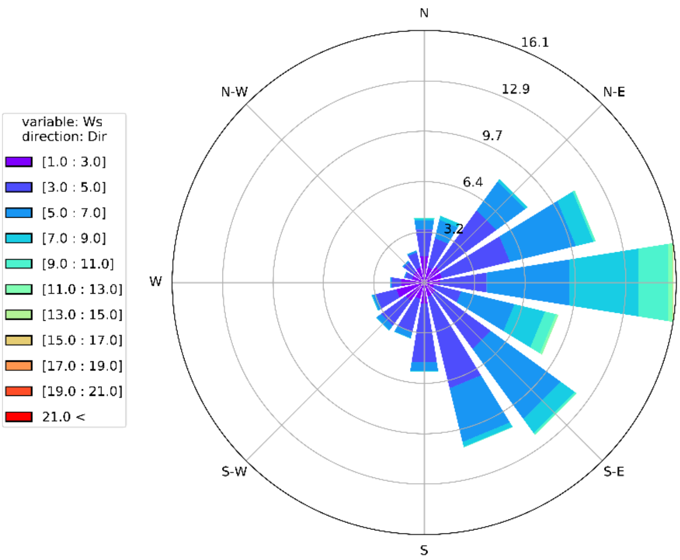


Figure 3-1: Gladstone radar wind rose (1957-2022)

Dir (°N) \ Ws (m/s)	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	>18
0-30	0.2%	0.8%	0.8%	0.6%	0.5%	0.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30-60	0.3%	1.4%	2.6%	2.9%	2.1%	0.8%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
60-90	0.3%	1.0%	2.3%	3.3%	3.6%	2.8%	1.7%	0.9%	0.4%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
90-120	0.4%	0.8%	1.2%	1.7%	2.6%	2.7%	2.5%	1.9%	1.3%	0.8%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
120-150	0.3%	0.8%	1.7%	3.5%	4.4%	2.6%	1.2%	0.4%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
150-180	0.3%	1.0%	2.6%	4.9%	2.9%	0.8%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
180-210	0.5%	1.1%	1.9%	1.6%	0.5%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
210-240	0.4%	1.5%	1.9%	1.1%	0.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
240-270	0.6%	1.7%	1.1%	0.4%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
270-300	0.5%	0.9%	0.4%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
300-330	0.3%	0.9%	0.7%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
330-360	0.3%	1.2%	1.0%	0.4%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
360-	0.2%	0.5%	0.4%	0.3%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Figure 3-2: Distribution of wind speed and direction for Gladstone Radar AWS

Ws (m/s)	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	>18
Jan	0.3%	0.7%	1.1%	1.5%	1.6%	1.2%	0.8%	0.5%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Feb	0.3%	0.7%	1.0%	1.4%	1.4%	1.0%	0.7%	0.5%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mar	0.3%	0.8%	1.2%	1.7%	1.7%	1.1%	0.8%	0.5%	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Apr	0.3%	0.9%	1.2%	1.8%	1.6%	1.0%	0.6%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
May	0.5%	1.3%	1.8%	2.0%	1.4%	0.7%	0.4%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
June	0.5%	1.4%	2.0%	1.8%	1.3%	0.6%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
July	0.5%	1.7%	2.2%	1.9%	1.2%	0.5%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aug	0.6%	1.7%	1.9%	1.9%	1.3%	0.6%	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sept	0.5%	1.5%	1.8%	1.8%	1.3%	0.7%	0.4%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oct	0.4%	1.2%	1.6%	1.8%	1.6%	0.9%	0.5%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Nov	0.3%	1.0%	1.4%	1.7%	1.7%	1.1%	0.6%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dec	0.3%	1.0%	1.4%	1.6%	1.6%	1.1%	0.7%	0.4%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Figure 3-3: Distribution of wind speed by month for Gladstone Radar AWS

	Dir (°N)												
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	360-
Jan	0.3%	0.9%	2.1%	1.9%	1.3%	0.8%	0.2%	0.1%	0.1%	0.1%	0.2%	0.3%	0.1%
Feb	0.2%	0.6%	1.4%	1.9%	1.5%	1.0%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%
Mar	0.2%	0.7%	1.4%	1.8%	1.9%	1.5%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%
Apr	0.1%	0.4%	1.1%	1.6%	1.8%	1.7%	0.5%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%
May	0.1%	0.4%	0.8%	1.3%	1.6%	1.5%	0.9%	0.8%	0.5%	0.1%	0.1%	0.1%	0.1%
June	0.1%	0.4%	0.7%	1.0%	1.4%	1.4%	1.0%	1.1%	0.7%	0.2%	0.1%	0.1%	0.1%
July	0.2%	0.6%	0.8%	1.0%	1.2%	1.2%	1.0%	1.2%	0.8%	0.3%	0.2%	0.1%	0.1%
Aug	0.3%	0.8%	1.1%	1.0%	1.1%	1.0%	0.8%	0.8%	0.6%	0.3%	0.3%	0.3%	0.1%
Sept	0.4%	1.2%	1.3%	1.0%	0.8%	0.8%	0.4%	0.4%	0.4%	0.3%	0.4%	0.5%	0.2%
Oct	0.6%	1.4%	1.8%	1.2%	0.9%	0.6%	0.2%	0.2%	0.3%	0.2%	0.3%	0.5%	0.4%
Nov	0.5%	1.5%	2.0%	1.2%	0.8%	0.6%	0.2%	0.2%	0.2%	0.2%	0.3%	0.4%	0.3%
Dec	0.5%	1.4%	2.0%	1.4%	1.0%	0.7%	0.2%	0.1%	0.1%	0.2%	0.2%	0.4%	0.2%

Figure 3-4: Distribution of wind direction by month for Gladstone Radar AWS

3.2 Wave conditions analysis

An analysis of wave conditions has been conducted for Gladstone. This data was used to assess exposure to coastal processes at key study sites in the area. Historic metocean records for Gladstone spans from the early 1980s to present day, representing approximately 40 years of real data. However, in order to adequately represent the full range of potential wave and water level conditions within the area, a much longer record is required. Therefore, a probabilistic approach has been used to establish a 10,000-year simulated dataset. This dataset represents the full range of potential wave and water level conditions at Gladstone. The following methodology has been used:

1. **Metocean data collation:** Historical wave and water level data is collated for Gladstone
2. **Data declustering:** The historical data series is declustered into discrete events
3. **Data simulation:** The declustered data is used to produce a 10,000-year simulated dataset
4. **Data sampling:** A subset of 200 discrete, representative events is sampled from the 10,000-year dataset
5. **Wave modelling:** The 200 representative events are applied as wave model boundary conditions
6. **Nearshore conditions:** Nearshore conditions are extracted at key coastal locations
7. **Nearshore wave emulation:** An emulator is used to translate the remaining 10,000-years of simulated wave data to the nearshore

The offshore and nearshore simulated wave conditions have been used in this study to assess various coastal processes as schematised in Figure 3-5.

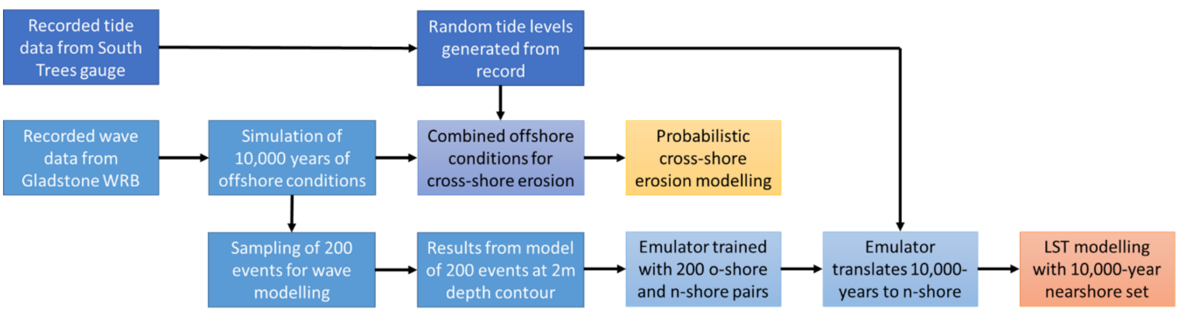


Figure 3-5: Schematisation of wave and water level data used in this assessment

3.3 Metocean data collation

Wave and water level data have been sourced from the Gladstone wave rider buoy and South Trees tide gauge, respectively, and combined to produce a complete set of water level and wave conditions from 1980 to 2021. Figure 3-6 shows a wave rose for the Gladstone buoy. This data is available for two periods: from 1979-1983, and from 2009-2021.

The ERA5 global hindcast model has been used to supplement the wave record for the period from 1983 to 2009. A comparison of the ERA5-modelled hindcast and recorded wave height is shown in Figure 3-7. Overall, the recorded and ERA5-modelled data agree well, with a tendency for the ERA5 set to overpredict more extreme wave events, resulting in a RMSE of 0.28m.

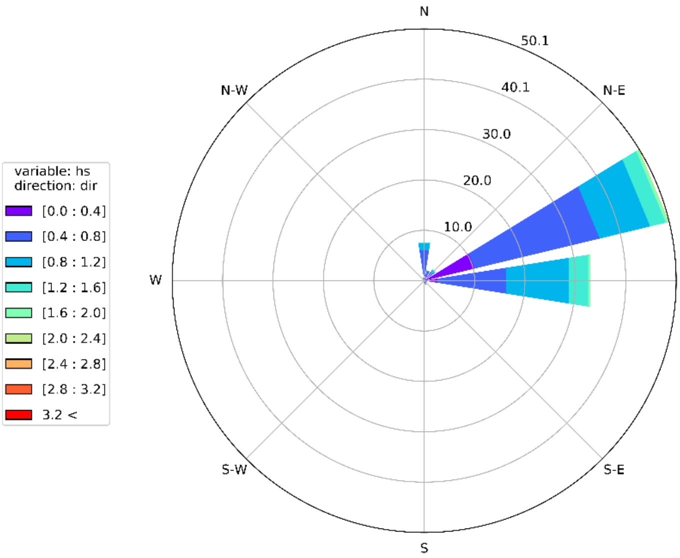


Figure 3-6: Wave rose for recorded data at Gladstone buoy.

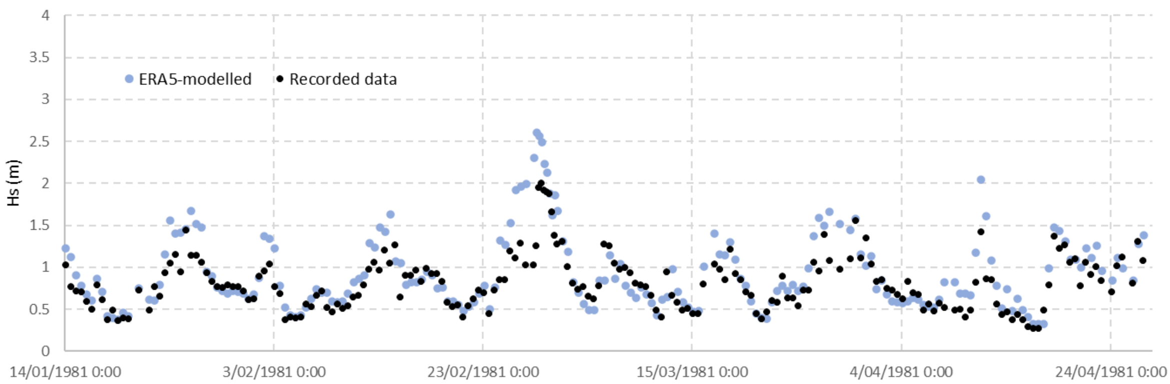


Figure 3-7: Comparison of recorded (black) and ERA5-modelled (light blue) wave height data

3.3.1 Data declustering

The historical dataset has been processed using peak analysis to isolate discrete weather events in the record. For the purposes of this study, a discrete weather event is defined as a peak in the wave height (Hs) record. The minimum duration for a weather event has been set to 2 days, with a minimum prominence of 0.2m (i.e. wave heights above 0.2m to their nearest neighbour in the time series). From the 40-year recorded data series, approximately 3200 weather events have been discretised. Figure 3-8 shows an example of declustered events of peak wave height and corresponding surge levels.

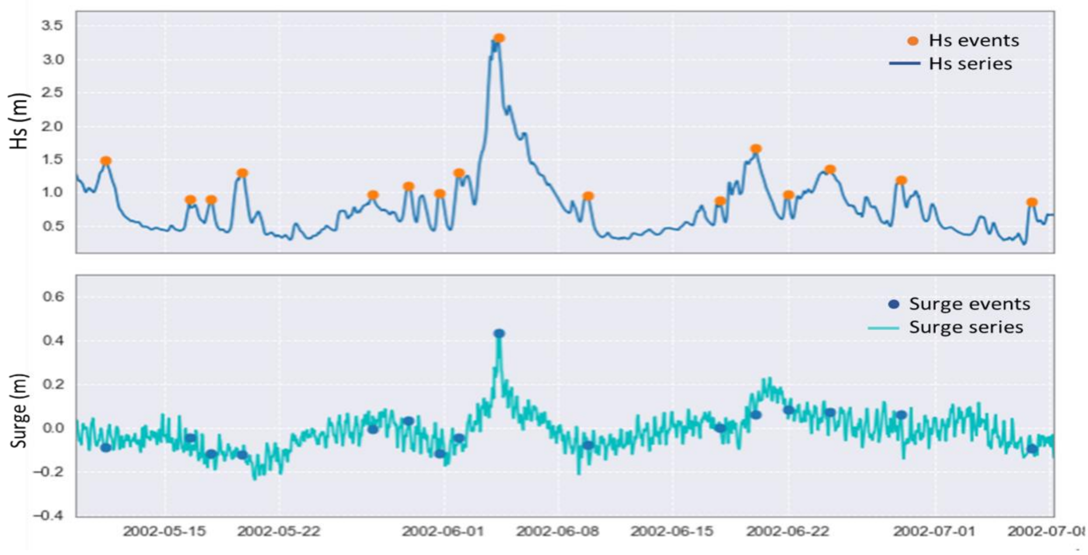


Figure 3-8: Declustering of discrete weather events in wave record (top), and corresponding surge record (bottom)

3.4 Data simulation

To fully represent the metocean conditions at Gladstone, a full range of potential wave and water level events is required. Conventionally, this would be accomplished by creating a set of conditions where all possible combinations for wave height, period, direction, and surge level are favoured equally. However, a more robust method has been used which relies on multivariate analysis to simulate the set of possible conditions. This method favours a more realistic distribution of wave and water levels conditions, as the characteristics of the historical data are used directly to simulate a much larger set of conditions.

First, the distribution of each of the declustered event parameters (Hs, Tp, Dir, and surge) is determined, as well as the correlation of each parameter to every other, as shown in Figure 3-9. This figure shows good correlation between Hs and residual surge, as well as Hs and Tp. Figure 3-9 also shows the largest wave conditions arriving from the east.

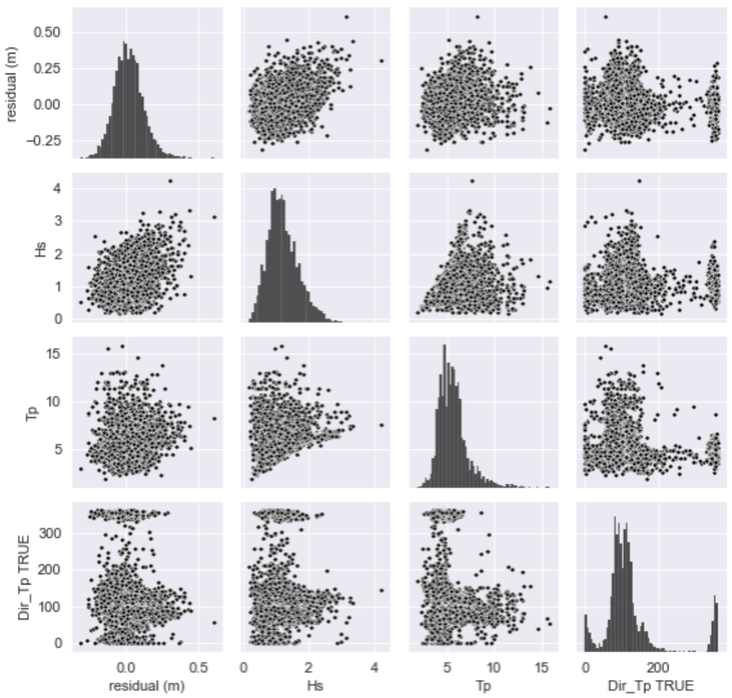


Figure 3-9: Pair plot of historical wave Hs, Tp, Dir, and residual surge events.

Next, a Gaussian copula method is applied to the data. This method fits a univariate distribution to each parameter and creates a set of 10,000 years' worth of simulated conditions. Figure 3-10 shows a comparison of historical events to the larger simulated set. Gaps in the simulated set are due to large solitary outliers in the historical marginal data.

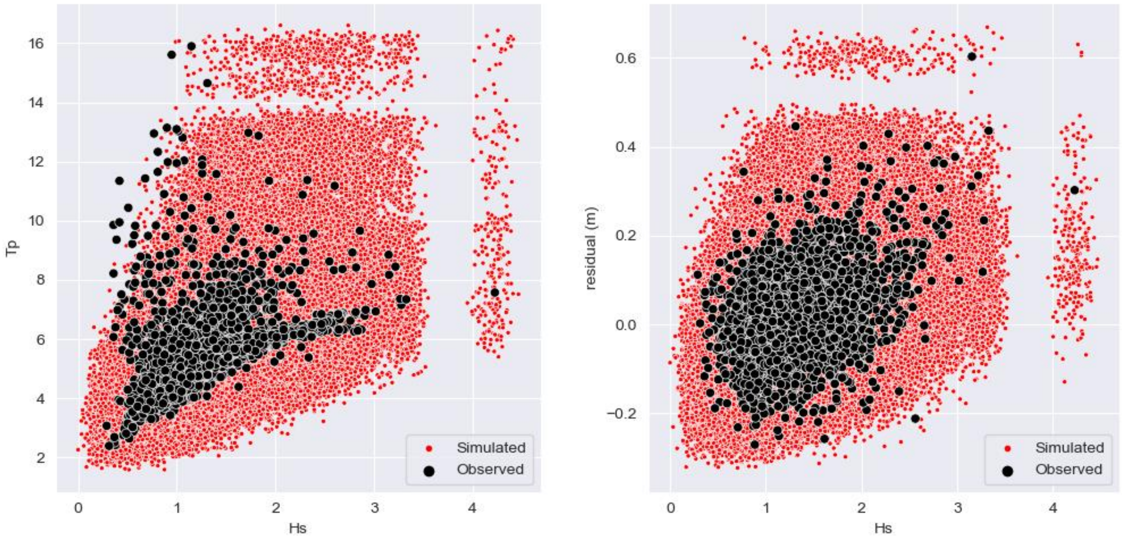


Figure 3-10: Historical and simulated offshore data showing Hs and Tp (left), and Hs and residual surge (right).

3.4.1 Data sampling

The large set of 10,000 years' worth of offshore data is required to be translated to the nearshore to assess sediment transport processes at key coastal locations. Numerical modelling will be used to simulate conditions in the nearshore, however it is not computationally efficient to model each event. Therefore, a subset of 200 events have been sampled from the large set to be used in numerical modelling. A Maximum Dissimilarity Algorithm (MDA) has been used for sampling. This method ensures that the full distribution and extremes of the larger dataset are retained in numerical modelling. The larger simulated dataset has been directionally limited to wave conditions from 0 to 100°N, as conditions outside of this range are not relevant to the study area. The MDA has been performed on this limited set. Figure 3-11 shows the sampled events and the larger dataset.

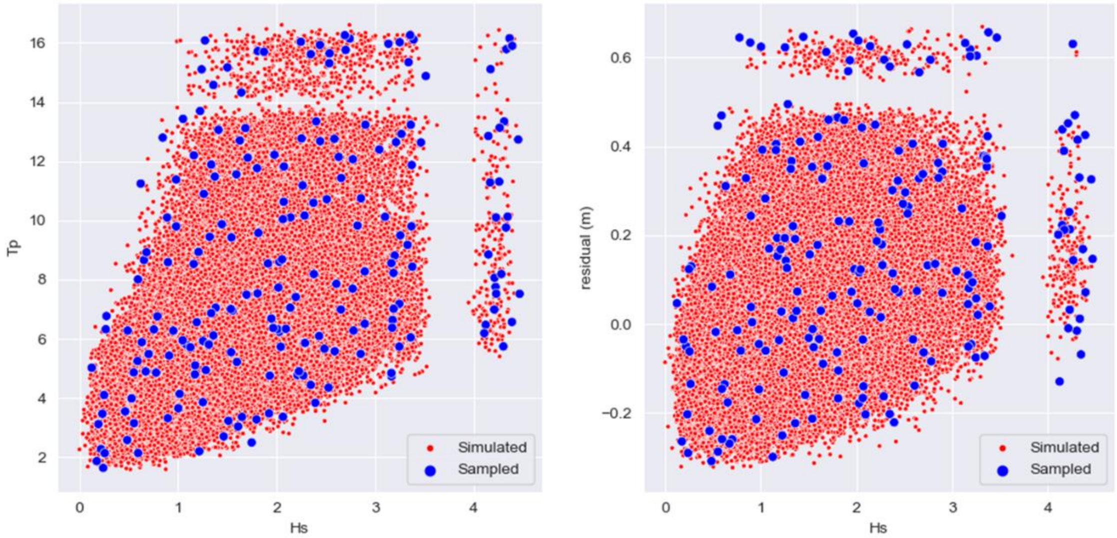


Figure 3-11: Simulated and MDA-sampled offshore data for Hs and Tp (left), and Hs and residual surge (right).

3.4.2 Tide and surge levels

Each of the 200 sampled events require an associated water level for numerical modelling. It is assumed that the duration of each event is greater than 6 hours, therefore a high tide level has been applied to each event. High tide levels have been randomly sampled from the astronomical tide record at South Trees. The modelled water level for each event is the combination of the residual and the random astronomical tide (i.e., tide + surge).

3.5 Wave Modelling

The 200 sampled events have been simulated in a numerical wave model to understand general nearshore wave conditions along the BITS coast. Wave modelling has been undertaken using the SWAN spectral wave model in Delft3D. SWAN is a third-generation wave model that simulates wave propagation in coastal and inland areas. It accounts for the following physics:

- Wind-wave interactions, which is the transfer of wind energy into wave energy, leading to the growth of waves.
- Shoaling, which is the build-up of energy as a wave enters shallow water, causing an increase in wave height.
- Refraction, which is the change in wave speed as waves propagate through areas of changing depth, causing a change in wave direction.
- Wave breaking, which is the destabilisation of a wave as it enters shallow water, causing broken waves with the characteristic whitewash or foam on the crest.
- Wave dissipation, which limits the size of waves through white-capping, bottom friction and depth-induced breaking.

3.5.1 Modelling domain

A spatially-varying grid has been used in the SWAN model wherein a high-resolution focus area is defined within the computational grid. The wave grid resolution ranges from 100m in the offshore to 12.5m at the key study areas. The spatially-varying approach allows for a high degree of model accuracy at areas of interest, whilst optimising computational runtimes.

The extent of the wave modelling grid has been designed to align with the offshore Gladstone WRB, at the 16mAHD depth contour, and extend within the channel inlets. The grid elevation is a combination of 5m LiDAR topography and 30m GBR bathymetry. Figure 3-12 shows the wave model domain.

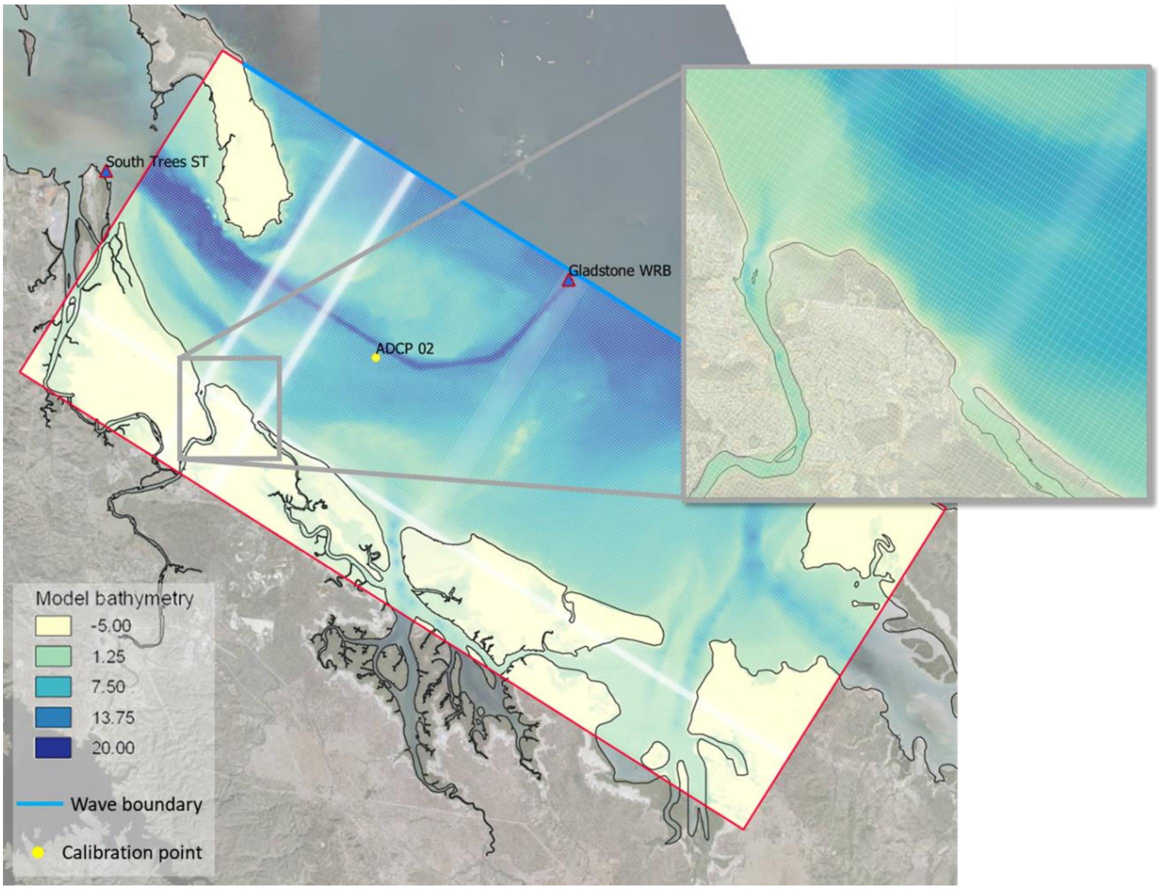


Figure 3-12: Wave model grid and bathymetry

3.5.2 Model calibration

The wave model has been calibrated against Acoustic Doppler Current Profile (ADCP) wave records published in BMT WBM (2019)[6]:

- Instrument name: ADCP 02
- Location: -23.9273, 151.428
- Depth at location: -10.3 mAHD
- Calibration period: 28/09/2014 to 26/10/2014

Wave conditions recorded at the Gladstone WRB for the calibration period have been modelled at 6-hour intervals, with model results extracted at the location of ADCP 02. Water levels in the model have been sourced from observed data at the South Trees gauge for the same period. Figure 3-13 shows ADCP-recorded data published in BMT WBM (2019) overlain with new modelled wave heights. Overall, the wave model agrees well with recorded wave conditions at ADCP 02 and has been used for design simulations.

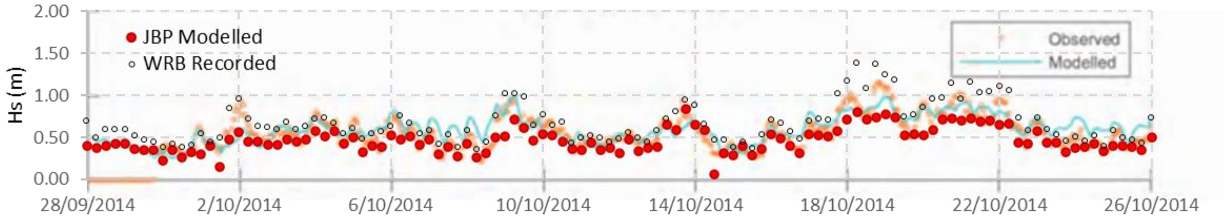


Figure 3-13: Comparison of observed (orange) and modelled (red) wave height at ADCP 02.

6 BMT WBM (2019), Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project EIS Coastal Processes and Hydrodynamics, available: https://eisdocs.dsdip.qld.gov.au/

3.6 Nearshore conditions

The calibrated model has been used to simulate the set of 200 sampled wave events. Nearshore results have been extracted at the 2m depth contour from Bangalee to South Trees at 500m spacing. Five key locations have been selected along the BITS foreshore based on recommended focus areas provided by GRC. These locations approximate the State Government (2015) coastal erosion prone area segments and are shown in Figure 3-14. These locations are:

- Lilley's Beach north (LB_1): (329922, 7357736), Coastal segment - GLR064
- Lilley's Beach south (LB_2): 331497, 7354530, Coastal segment - GLR063
- Tannum Sands beach (TS_1): 334384, 7351300, Coastal segment - GLR061
- Wild Cattle Island north (WC_1): 336364, 7349412, Coastal segment - GLR059
- Wild Cattle Island south (WC_2): 340241, 7346888, Coastal segment - GLR058

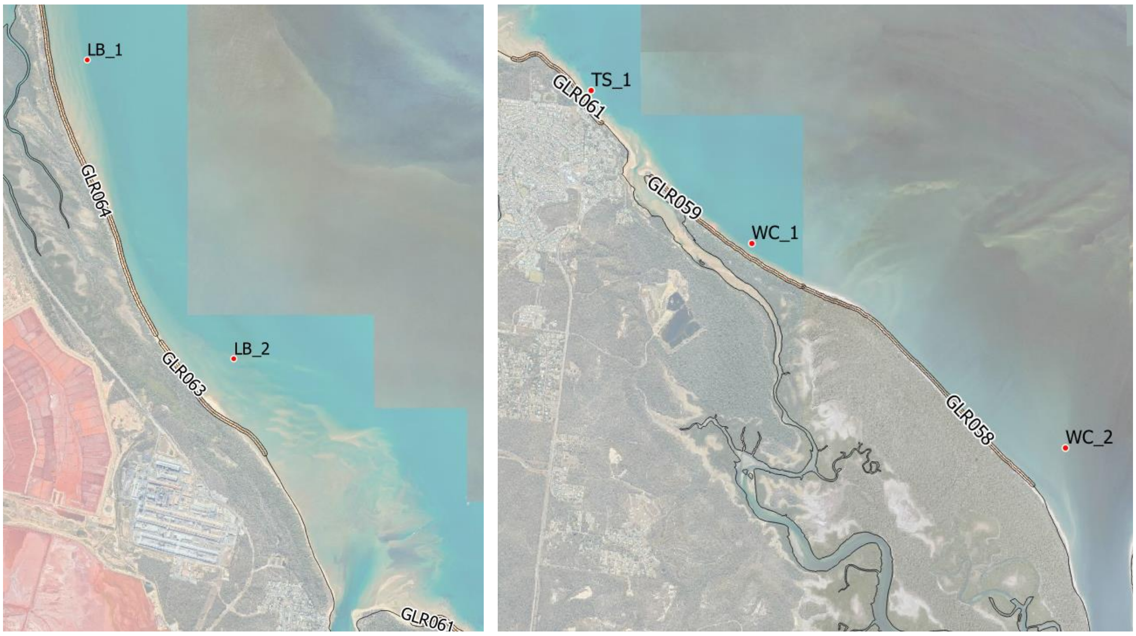


Figure 3-14: Key nearshore model output locations and State Government coastal segments

3.7 Nearshore wave emulation

For each location, nearshore results for the 200 modelled runs are paired with their respective offshore input conditions to be used to train a random forest regression (RFR) machine learning model. The RFR model uses the set of 200 offshore and nearshore pairs to generate a large number of cascading decision "trees" based on wave height, period, direction and water level. When new offshore data is applied to the RFR model, each tree makes a prediction of the nearshore conditions, the final prediction is the averaged values of all trees. The trained RFR model has been used to emulate the full set of 10,000 years of offshore conditions to the nearshore, with a prediction threshold of 90%.

3.7.1 Results of nearshore wave emulation

Figure 3-15 and Figure 3-16 show nearshore wave roses for the key coastal locations. Table 3-1 shows statistics for wave height, period, and direction for each location at the 2m depth contour. At Lilley's Beach north, these results show a trend toward smaller easterly conditions due to protection provided by Facing Island. At Lilley's Beach south this trend shifts to slightly larger and more northly waves. Tannum Sands beach experienced the largest waves of the key locations due to exposure to the largest nearshore conditions. This effect is lessened at the Wild Cattle Island north and south locations due to the presence of nearshore sand deposits originating from Colosseum inlet.

Table 3-1: Nearshore wave condition statistics

	Lilley's Beach north	Lilley's Beach south	Tannum Sands beach	Wild Cattle Island north	Wild Cattle Island south
Av. Hs (m)	0.19	0.36	0.71	0.56	0.47
Max Hs (m)	0.36	0.64	1.2	1.06	0.93
Av. Tp (s)	5.81	5.77	5.78	5.78	5.86
Max Tp (s)	15.58	15.58	15.56	15.58	15.57
Av. Dir (°N)	88.83	62.51	61.69	38.3	57.05

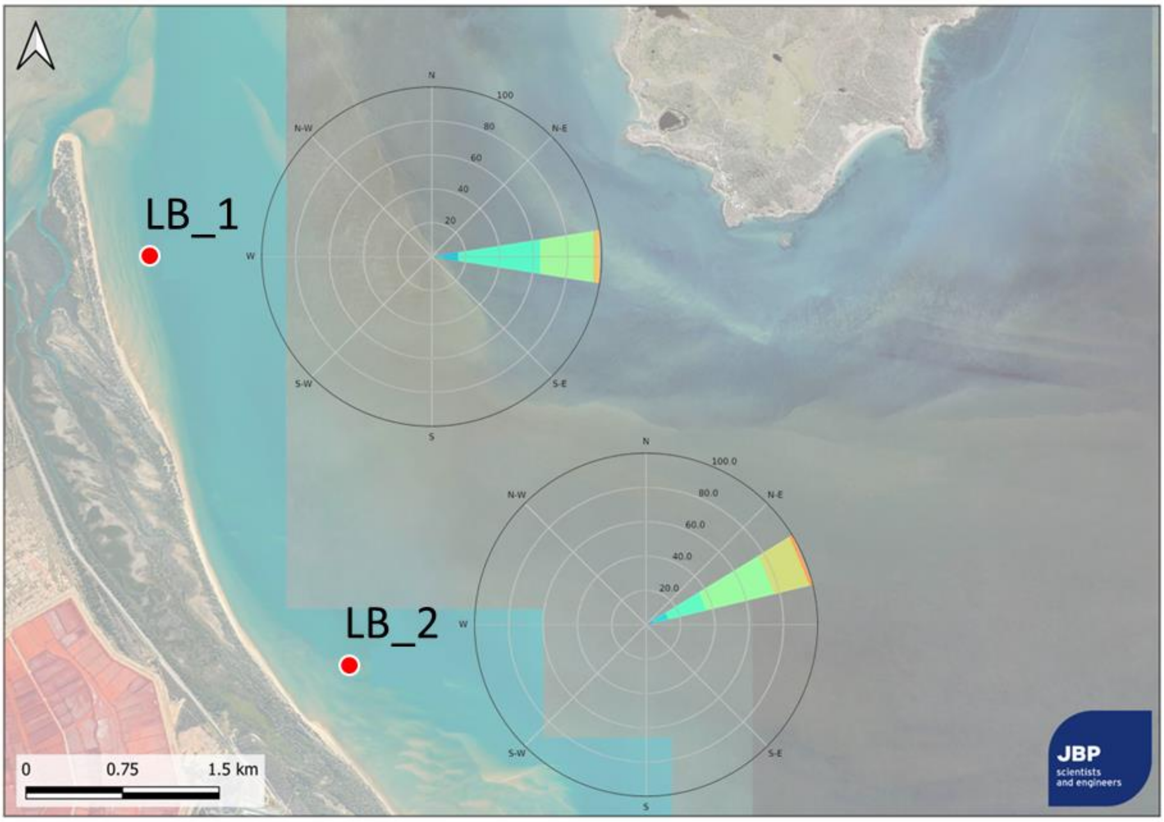


Figure 3-15: Nearshore wave rose for Lilley's Beach north and south

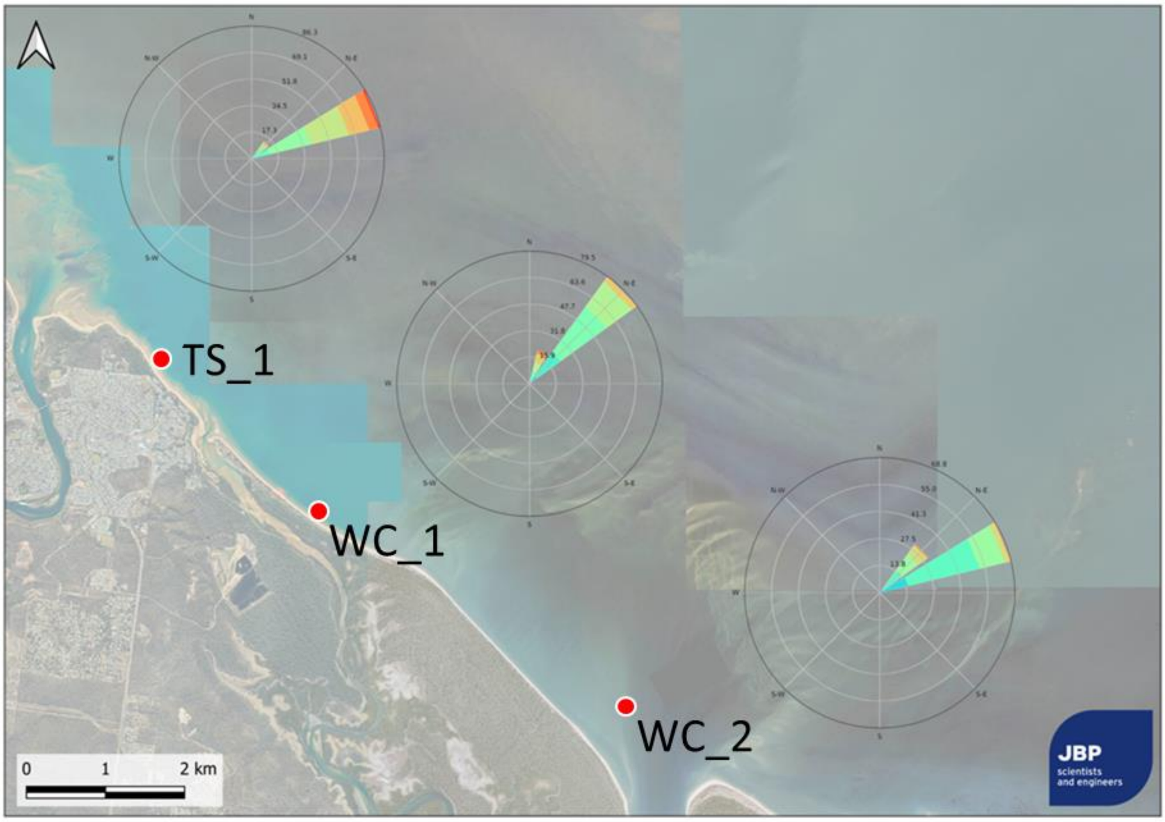


Figure 3-16: Nearshore wave rose for Tannum Sands and Wild Cattle Island north and south

4 Longshore sediment transport assessment

The results of the nearshore wave emulation have been used to inform potential rates of longshore sediment transport (LST). Nearshore wave modelling can be used to inform the potential LST rate for a beach compartment, however the actual rate of transport is generally limited by the availability of sand. Potential LST rates have been estimated with the JBP Beach Evolution Model (JBEM). The full set of nearshore emulated wave conditions discussed in Section 2 has been modelled in JBEM. Each nearshore wave result has been assigned an occurrence frequency based on the full set of 248,406 events representing 10,000 years of potential conditions. This results in each input condition representing an approximate 2-week period. From this interval, an annual potential LST rate can be determined.

The rate of potential LST has been estimated using the modified Kamphuis (2013) bulk sediment equation (Mil-Homens et al., 2013[7]). This approach builds on the commonly used CERC[8] formulae and includes the effects of particle size, slope, and wave period, and includes additional reanalysis of the original Kamphuis (1991) equation[9]. The rate of sediment transport (Q) in m^3/hr is calculated by:

$$Q_k = 7.3\, H_{sb}^2\; T_p^{1.5}\; m_b^{0.75}\; D_{50}^{-0.25}\; \sin(2\alpha_b)^{0.6}$$

Where, H_{sb} is the significant wave height in the breaker zone, T_p is the peak period, m_b is the slope in the breaker zone, D_{50} is the sediment particle diameter, and α_b is the angle of wave incidence at breaking. Conventionally, a positive rate of transport is defined as flowing left to right from the perspective of someone standing on the shore, looking out to sea. On the east coast of Australia, therefore, negative rates of LST indicate flow direction from south to north.

4.1 Results of LST modelling

A sediment grain size of 0.25 mm has been used based on field collections of sand samples during the April site visit and analysed using the Geoscience Australia field measuring tool (Appendix B). The potential LST rate for each location point is shown in Table 4-1, with trends shown in Figure 4-1. There results demonstrate that:

- The most northerly point (Lilley's Beach north) is expected to have a significantly lower rate of wave-driven transport due to the sheltering offered by Facing Island, in addition to the sheltering provided to all five points by the Capricorn Group of Islands offshore in the Great Barrier Reef (GBR)
- Rates of LST are higher for Tannum Sands and Wild Cattle Island, this is due to the orientation of theses beaches with respect to the dominant easterly wave direction

These rates of transport align with recent studies completed for Agnes Water and Seventeen Seventy (Alluvium & JBP, 2020), located approximately 60 km to the south of Tannum Sands. This study notes a maximum potential sediment transport rate for the beach at Seventeen Seventy is 34,000 m^3. It should be noted that these rates of transport are due to wave-driven processes on open coast beaches only. No consideration has been given at these locations to current-driven transport due to tidal or riverine flow.

Table 4-1: Potential LST Rate (see Figure 4-1 for output locations map)

Location	Coordinates (x, y) MGA 56	Net potential annual LST (m^3/yr)
Lilley's Beach north	(329922, 7357736)	- 8,028 (North)
Lilley's Beach south	(331497, 7354530)	- 31,473 (North)
Tannum Sands beach	(334384, 7351300)	- 36,190 (North)
Wild Cattle Island north	(336364, 7349412)	- 29,722 (North)
Wild Cattle Island south	(340241, 7346888)	- 34,175 (North)

7 Mil-Homens, J., Ranasinghe, R., Van Thiel de Vries, J.S.M. and Stive, M.J.F., 2013 . Re-evaluation and improvement of three commonly used bulk longshore sediment transport formulas. Coastal Engineering 75, 29 39

8 USACE, 1984, Shore Protection Manual, CO. Eng. Res. Centre, US Army Corps of Engineers, Vicksburg, MS, USA

9 Kamphuis, J.W. 1991. Alongshore sediment transport rate. Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 117, 624-640

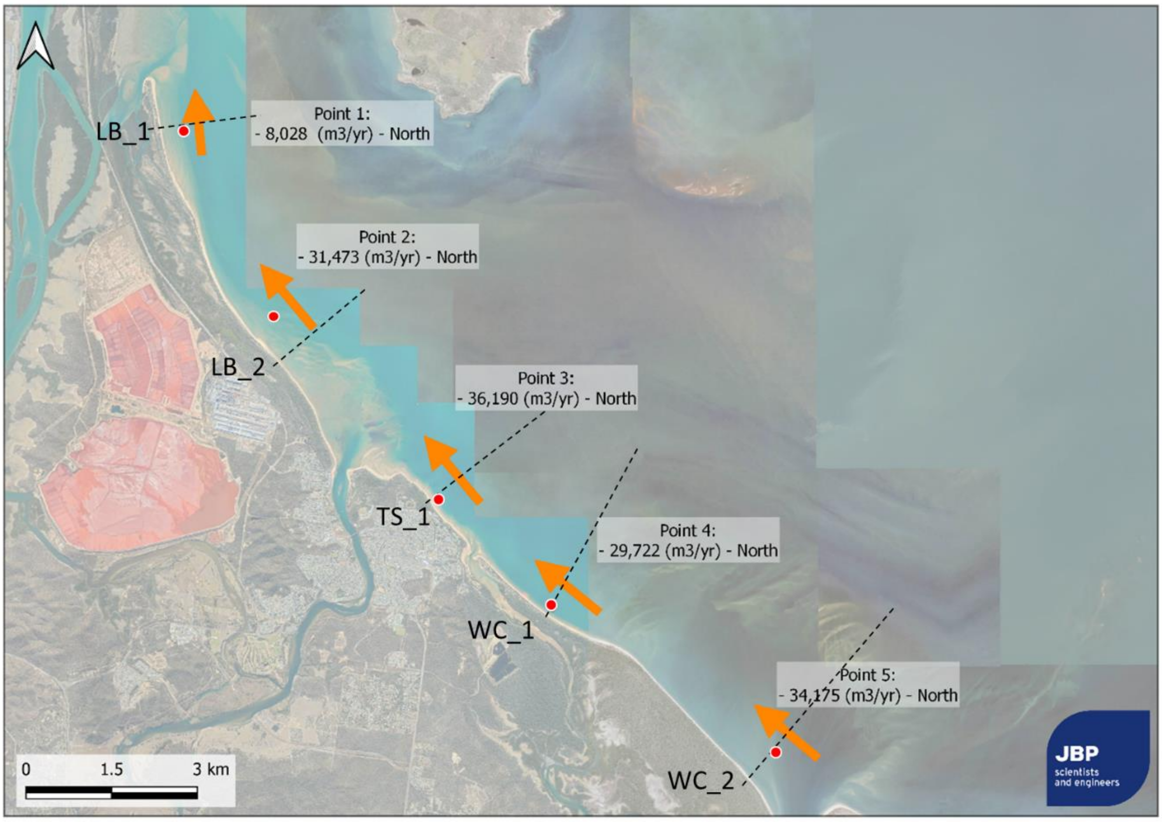


Figure 4-1: Potential annual longshore sediment transport rates and direction for the BITS coast, cross-shore profiles shown as dashed lines

5 Probabilistic cross-shore erosion assessment

An assessment of short-term cross-shore erosion has been conducted for key coastal locations at Wild Cattle Island, Tannum Sand beach, and Lilley's beach. Short-term erosion is attributed to surge and waves during large storm events. Sediment is eroded from the frontal dune and deposited in the nearshore as a bar. Gradually this sediment is shifted back across the beach profile by calmer conditions. Cross-shore profiles have been developed at the five locations of LST modelling described above.

Calculation of short-term cross-shore erosion has been undertaken using the JEPA (JBP Erosion Prone Area) toolkit. The JEPA toolkit estimates the post storm equilibrium profile for a pre-defined beach transect based on the method developed by Vellinga (1982)[10].

$$\left(\frac{7.6}{H_{0s}}\right) y = 0.47 \left[\left(\frac{7.6}{H_{0s}}\right)^{1.28} \left(\frac{w}{0.0268}\right)^{0.56} x + 18 \right]^{0.5} - 2.00$$

Where, H_{0s} = significant 'deep water' wave height and w = fall velocity of sand. The JEPA tool produces a post-storm equilibrium profile by balancing eroded and deposited sediment volumes along a beach transect. It assumes an offshore saturated slope of 1:12.5 and an onshore eroded dune slope of 1:3 to account for dune slumping (D).

Figure 5-1 shows a sample output from the JEPA tool. The input parameters for this method include:

- An initial beach profile
- Water level
- Offshore wave conditions
- Sediment grain size (D50).

Initial beach profiles have been developed for five locations along the BITS coastline. Each profile has been derived from a combination of 2014 1m topographic LiDAR and 30m bathymetric survey. Cross-shore profiles are assumed to be representative of the individual coastal segments defined by QLD State Government (2015), as described in Section 3.6.

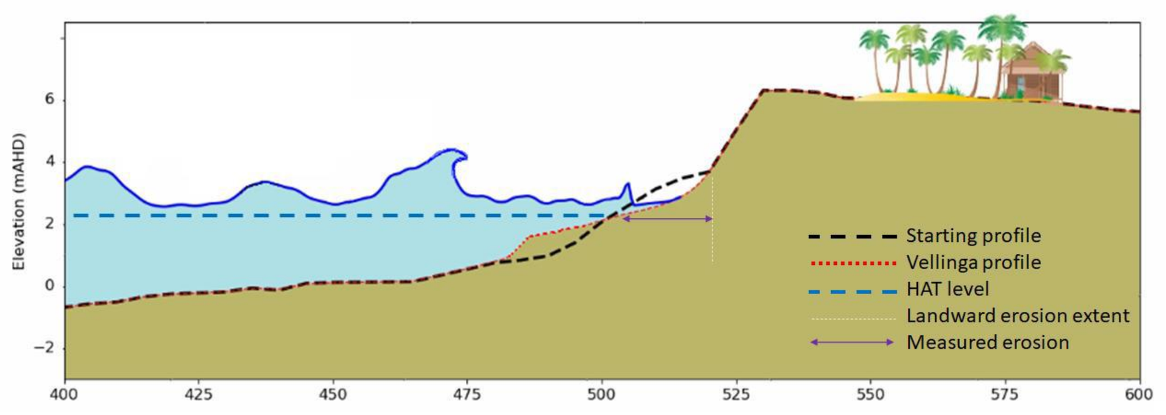


Figure 5-1: Schematic of JEPA short-term erosion modelling using Vellinga (1982).

5.1 Input conditions

Input conditions for cross-shore erosion modelling have been taken from the 10,000-year dataset of offshore wave and water conditions described in Section 3.4. This method allows for extreme cross-shore erosion to be determined probabilistically, based on Monte Carlo theory. Traditionally, extreme erosion is estimated by conducting extreme value analysis to determine AEPs for offshore wave and water level conditions, which are then used to estimate erosion of a coincident return period. The resulting erosion is therefore associated with the AEP of input conditions.

10 P. Vellinga (1982). "Beach and dune erosion during storm surges" Delft Hydraulics Laboratory

Contemporary measures, considered best-practice, now allow for the AEP of any erosion event to be determined directly from a statistical long-term dataset.

All input wave conditions are assumed to impact the input beach profile from a shore-normal direction, as per the Vellinga (1982) formulation. However, the directional spread of incoming wave directions has been limited for some locations to remove offshore waves that are not expected to impact a site. For example, input waves for the Lilley's Beach north location have been limited to east to south-easterly due to the expected protection from Facing Island.

Mean sediment grain size (Dn50) has been estimated based on sand samples obtained from the field. Sands sampled were collected from the intertidal zone and measured using the Geoscience Australia field measurement guide. From this assessment, a Dn50 of 0.25mm has been used for all cross-shore erosion models.

5.2 Results of cross-shore erosion modelling

Cross-shore erosion widths have been measured from HAT (2.42mAHD). Table 2-1 shows extreme erosion widths for a range of AEPs. Frequency plots for each location are attached in Appendix C. Eroded profiles for each location for a 1% AEP event are shown in Appendix D.

Of the five modelled profiles, the Lilley's Beach north location shows the least potential for extreme cross-shore erosion, due to protection from Facing Island and moderated wave climate. Erosion widths at the other locations are larger due to more exposure to a wider range of wave conditions. The Tannum Sands location experiences marginally less erosion due to larger available sand stores behind the frontal dune. The Wild Cattle Island locations experience the largest erosion due to their lack of protection from north-easterly waves.

These results agree with similar short-term erosion estimation conducted in JBP (2020) for coastal segments at Agnes Water, with the Agnes Water beach location expecting to experience somewhat larger short-term erosion due to deeper offshore bathymetry and reduced protection from south-easterly conditions. It should be noted that cross-shore erosion widths are dependent on the available elevation data for each profile, resulting in variation between similar locations. Furthermore, each coastal segment has been represented by a single profile, however in reality beach and dune topography can vary significantly across a single coastal segment.

Table 5-1: Extreme cross-shore erosion widths, measured from present day HAT

AEP	Lilley's Beach north (m)	Lilley's Beach south (m)	Tannum Sands beach (m)	Wild Cattle Island north (m)	Wild Cattle Island south (m)
10.00%	0.5	6.1	5.2	9.0	11.3
5.00%	2.0	7.9	6.3	10.6	12.5
1.00%	4.3	15.2	9.3	13.9	15.4
0.50%	7.7	15.6	10.6	14.7	16.5
0.20%	10.1	16.3	12.8	15.9	17.4
0.10%	10.9	16.6	13.6	16.7	18.5
0.05%	12.1	16.9	15.0	17.6	19.2
0.02%	13.0	17.6	16.0	18.8	20.3
0.01%	13.5	18.3	17.0	23.4	21.1

6 Hydrodynamic modelling assessment of Boyne River

Numerical tide, current and morphology modelling have been used to understand the hydrodynamic and morphological processes occurring within Boyne River during an extreme flood event. Whilst near to the coast, the inner shoreline is offered protection from the open coast. There is the potential for this area to be more effected by fluvial events than coastal events.

A hydrodynamic model has been developed as a decision support tool to help understand how the tidal propagation, upstream inflow, and sediment are interacting at the study site. The model has been used to understand changes to morphology at the mouth of the Boyne River following a large upstream flood that occurred in 2013. During this event, a large volume of sediment was removed from the east and west banks of the river inlet, including a significant vegetated area on the east bank, as shown in Figure 6-1. The event has been simulated using recorded discharge rates taken from Awoonga Dam during the spillway overtopping event that occurred after TC Oswald. The model does not cover all scenarios, e.g., extreme drought or conditions not captured from the dam release, however, is able to be used as a guide for future decisions.

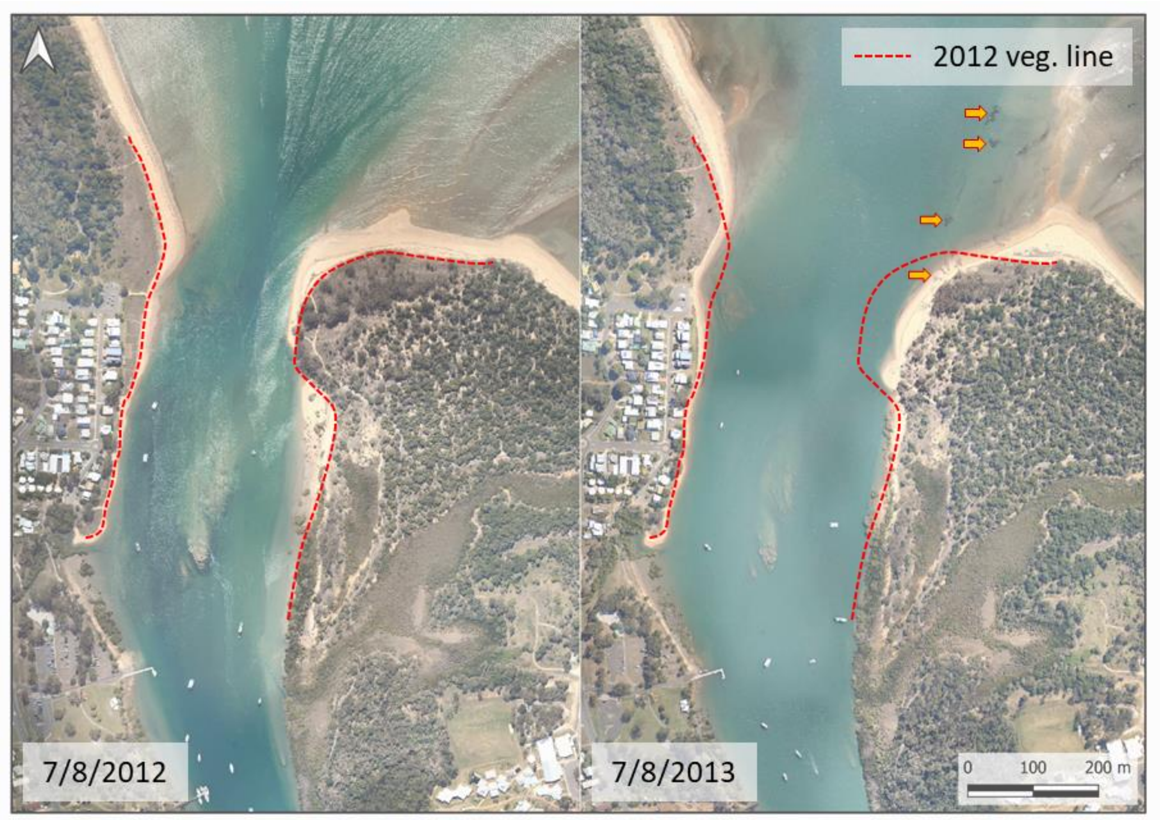


Figure 6-1: Changes to Boyne River inlet before (left) and after (right) the 2013 flood event, showing uprooted vegetation from the east bank (Nearmap, 2022).

6.1 Model development

Modelling has used Delft3D, an open-source hydrodynamic model[11] capable of estimating tides, extreme water levels, currents, salinity, and sediment transport conditions. As schematised in Figure 6-2, several modules of Delft3D can be used to support studies. For this tidal assessment the Delft3D-FLOW model was used to simulate hydrodynamics, operating over variable bed level, with a sediment regime implemented. The model is capable of simulating depth-averaged and pseudo-3D conditions. For this project all simulations were performed as depth-averaged in order to increase computational efficiency.

11 Website: http://oss.deltares.nl/web/delft3d/download

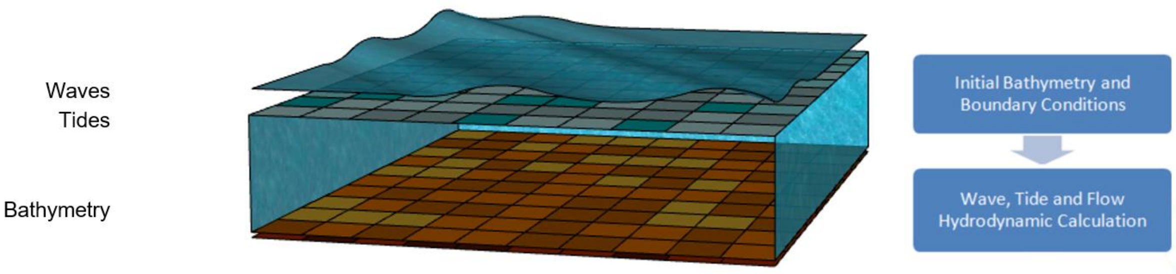


Figure 6-2: Potential Delft3D hydrodynamic, wave and sediment transport calculations

6.1.1 Model elevation data

Several existing elevation datasets have been used within this study. These include:

- Great Barrier Reef 30m (GBR30) LiDAR dataset
- Queensland Government 1m LiDAR Digital Elevation Model
- Geoscience Australia 5m LiDAR Digital Elevation Model

The bathymetry used for the lower estuary has been based on GBR30 data. However, upon inspection upstream of John Oxley Bridge the dataset did not accurately represent the bathymetry of Boyne River. Therefore, a synthetic bathymetric DEM has been generated for use in the model domain upstream of the river mouth. This was created as follows:

1. The bank outline extending from the downstream boundary to a point adjacent to the John Oxley Bridge was digitised in GIS utilising georeferenced aerial photography. The bank outline was then sampled using 5m DEM LiDAR at 5m intervals.
2. The main channel thalweg depth taken from the GBR30 dataset immediately downstream of the John Oxley Bridge was used as a reference point for the depth of the channel leading to the upstream boundary.
3. GIS processing was used to create a bathymetric surface from the bank edges to a central depth along the thalweg of the creek for utilisation in the hydrological modelling. The resulting DEM is synthetic and contains manufactured data. Whilst indicative of the likely bathymetry of Boyne River, and therefore suitable for evaluation of potential hydrological changes, it does not represent a full hydrographic survey of the domain extents and should not be relied upon for any other purpose than for this study.

6.1.2 Modelling Extent

The model extends approximately 18 km from the river mouth, between a convergence point downstream of Awoonga Dam and the 5m depth contour directly offshore from Boyne River mouth. This is coupled with a spatially varying width which reflects typical channel geometry. The model domain was digitised in QGIS using georeferenced imagery. The model uses two boundaries, a downstream time varying-tide signal and an upstream total-discharge.

The model was constructed using a curvilinear computational grid with a varying spatial resolution. This approach allows for large spacing between grid points in the centre of the upstream channel, where a detailed representation of the bathymetry is unnecessary, and more detailed information in the downstream study area. The grid resolution uses a longer grid oriented along the channel, with resolutions between 20m at the upstream boundary decreasing to a minimum of 5m at the river mouth.

Each elevation dataset was processed and merged over the computational grid. Once merged, the grid was inspected to ensure that the locations where datasets intersected did not contain abnormal changes in bathymetry, which could distort coastal processes. Any gaps in the bathymetry were smoothed and averaged with the adjacent grid cells.

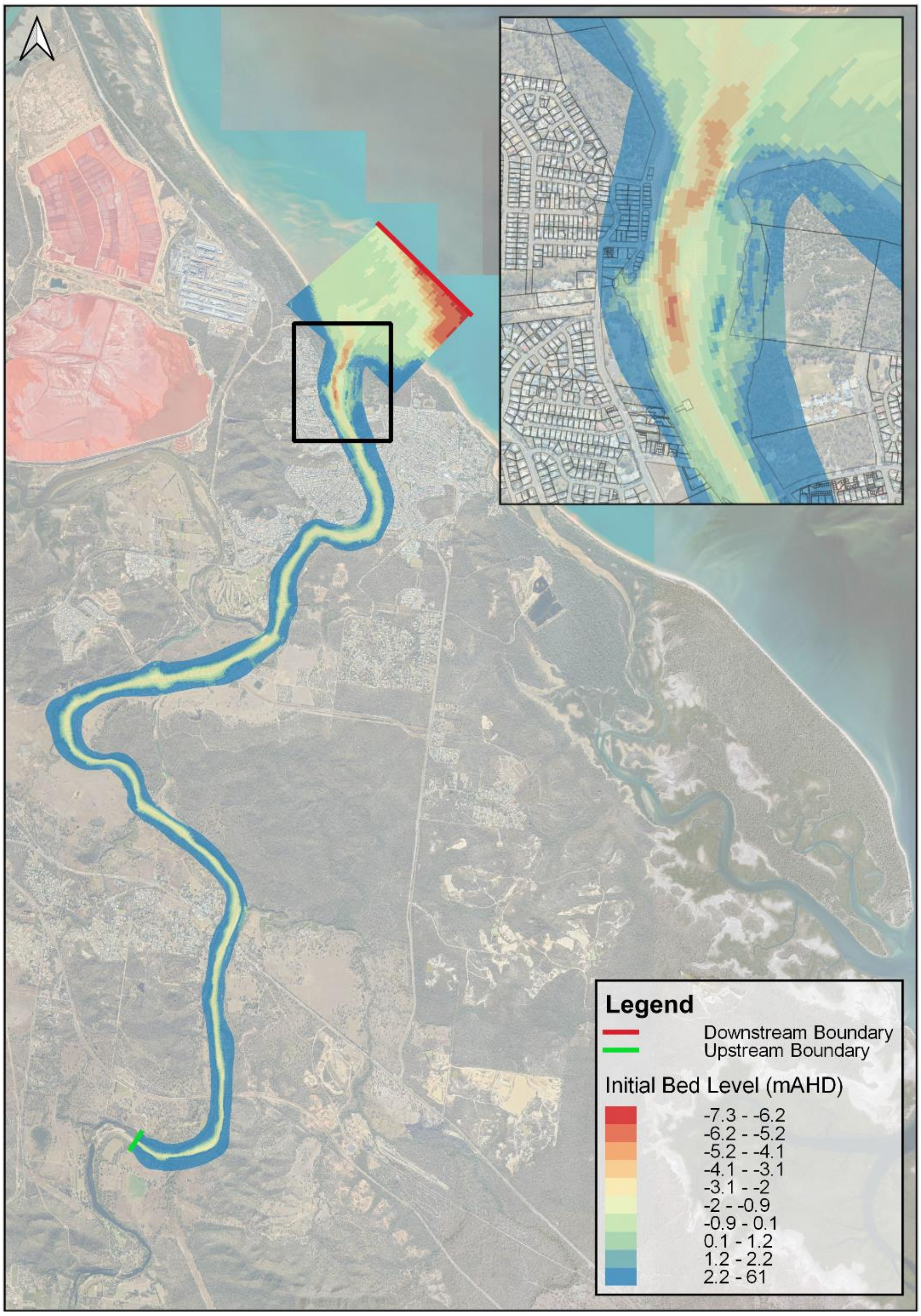


Figure 6-3: Delft3D FLOW model domain and bathymetry

6.1.3 Boundary Conditions

Two model boundaries have been applied at the downstream and upstream extents of the domain. The downstream water level boundary is a time-varying tide signal, based on recorded tidal data from the South Trees gauge.

The inflow applied to the upstream boundary has been taken from an analysis completed of the Awoonga Dam discharge rate over a 16-day period following TC Oswald in January 2013. The dam has a maximum capacity of 777,000 ML, and over this period reached a peak volume of up to 1,379,462 ML (178% of the water supply level) and subsequently discharged at rates of up to 602,462 ML/day. These discharge rates have been converted to m^3/s and applied to the upstream boundary during the design scenario. For the purposes of this assessment, it has been assumed that 100% of the excess volume at Awoonga dam flows into the model domain, though in reality it is expected that a portion of this volume would be dispersed upstream by flood plains and low-lying areas.

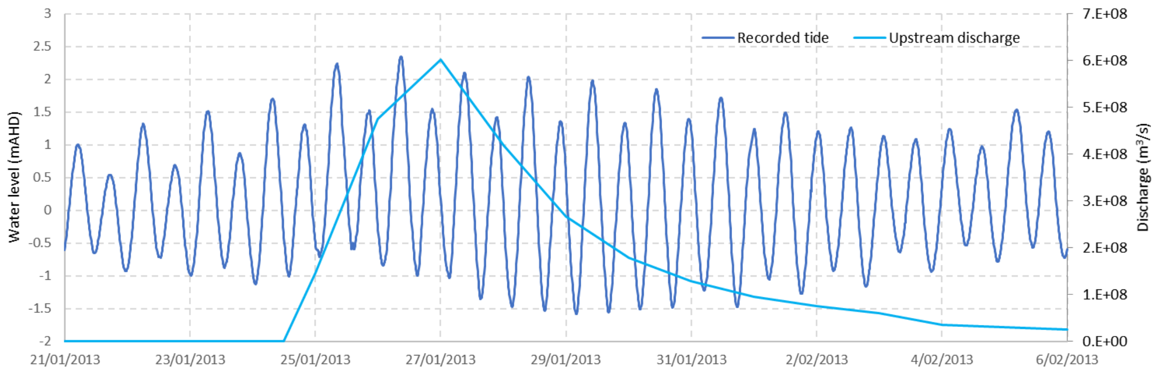


Figure 6-4: Delft3D model input conditions

6.1.4 Model validation

No monitoring sites are available on the Boyne River downstream of the dam, and consequently the model could not be calibrated against recoded water level or flow data. Instead, model validation was completed using river flood extent location points supplied by GRC for Boyne River following TC Oswald. As the bathymetry of the river upstream of John Oxley bridge has been created synthetically, the flood extent locations are not expected to match. Downstream of John Oxley Bridge however, the flood extent shows good agreement with the available data point and the 1m LiDAR dataset used to capture the ground elevation.

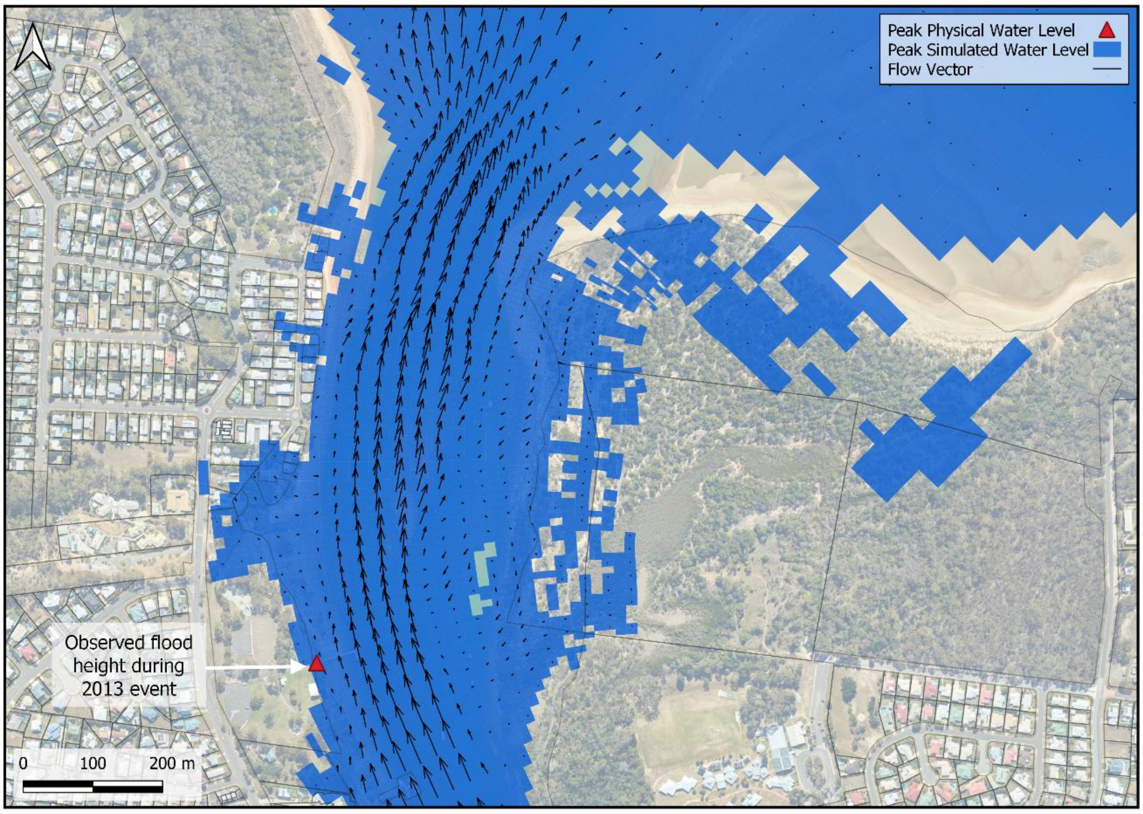


Figure 6-5: Peak flood extent of Delft3D model compared with peak flood markers supplied by GRC

6.1.5 Sediment transport formulation

The Delft3D morphological model uses the default Van Rijn (2007) formula which was determined to be sufficient for this application. A median sediment diameter grain size of 0.2 mm was uniformly applied across the model.

6.2 Scenario Testing

The model was tested under the following design scenario representing the flood and tide conditions following releases from Awoonga Dam:

- An 18 day run period was simulated from 21/01/2013 to 06/02/2013 capturing the storm tide effects produced by TC Oswald and the peak of the dam releases over the spillway into Boyne River
- The model uses GBR30 bathymetry capturing bed levels at the study area and a combination of 1m and 5m LiDAR topography representing pre-flood inlet conditions
- The model includes discharge rates recorded at Awoonga Dam during the flood event. The upstream discharge boundary starts at 1694 m^3/s and peaks at 6972 m^3/s, coinciding with a time-varying tide signal at the downstream boundary.

Figure 6-6 and Figure 6-7 shows the bed level at the beginning and end of the modelled 18-day simulation period. The post-event map in Figure 6-7 shows significant straightening of the channel due to the fast flowing water, with erosion on the both river banks. The 2.0mAHD contour line has been extracted from the model and used as an approximation for the dune crest at the mouth of the channel. An encroachment of the dune crest of up to 16m is observed in front of the Island Esplanade properties. On the eastern bank, a large volume of sediment is removed and deposited offshore. These results agree with aerial imagery before and after the event.

It should be noted that non-erodible rocky outcrops on the western bank have not been included in the model bathymetry, which may affect the realism of flow patterns at this location in the model. Figure 6-8 shows a cross-section of channel elevation before and after the modelled flood event, showing bank erosion adjacent to the west bank.

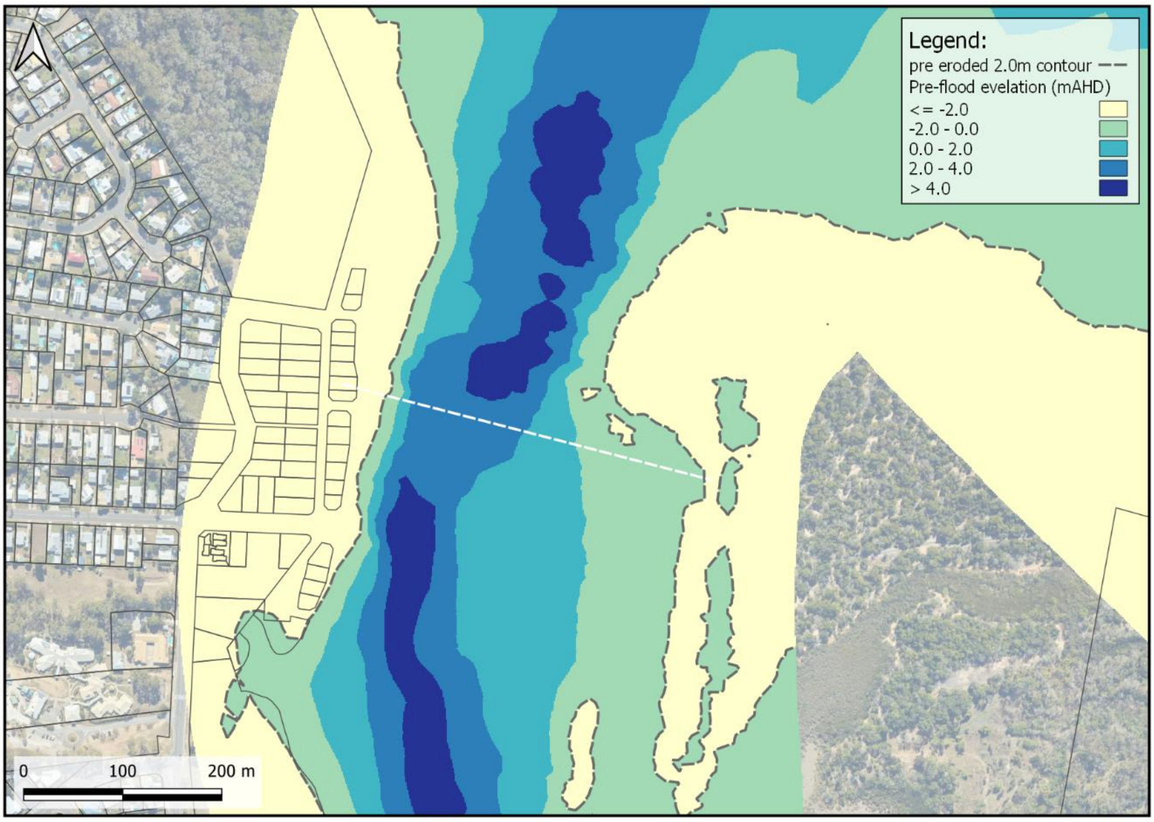


Figure 6-6: Boyne River mouth initial model elevation showing pre-flood dune crest (2.0mAHD)

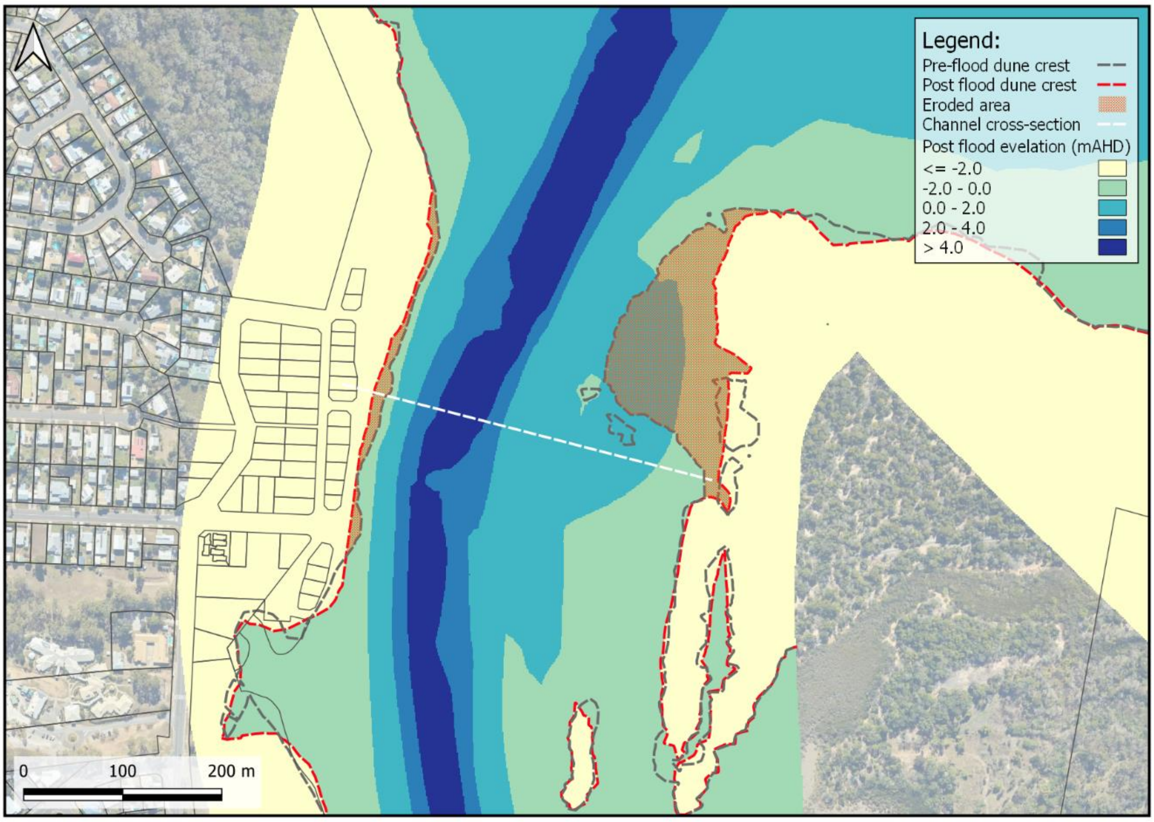


Figure 6-7: Boyne River mouth final model elevation, showing post-flood dune crest (2.0mAHD) and eroded areas.

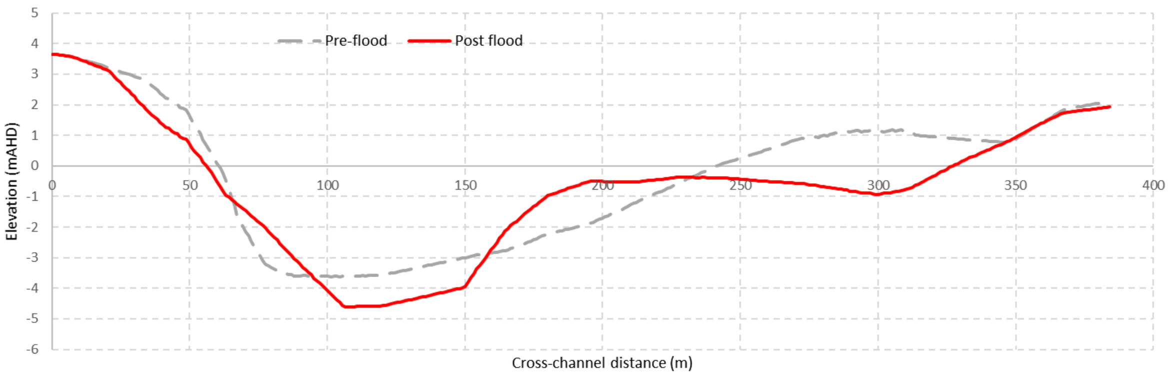


Figure 6-8: Boyne River mouth cross-section of pre-and post-flood elevation

6.3 Model limitations

The following limitations of hydrodynamic modelling have been identified:

- Modelling has been conducted for a single large historic flood event and does not consider changes in morphology during lesser flows including tide only.
- A uniform sediment grain size of 0.2mm has been assumed throughout the model to represent an aggregate of riverine and coastal sediment. Non-erodible rock layers have not been included in the model bathymetry
- The full discharge volume recorded at Awoonga dam from 21/01/2013 to 06/02/2013 has been applied to the upstream model boundary, approx. 6km downstream of the dam
- The model does not consider the effects of waves or future sea level rise at the study area

7 Historical coastline assessment

7.1 Detailed shoreline assessment

A detailed shoreline assessment has been conducted to supplement the publicly available Digital Earth Australia (DEA) analysis results shown in Appendix A, for locations at Boyne Island and Tannum Sands. The CoastSat shoreline analysis toolkit has been used to refine the shoreline mapping on key coastal and estuarine zones that are not available in the DEA dataset.

7.1.1 Site Information

Detailed shoreline mapping has been conducted for two sites:

- West bank of the Boyne River inlet at Island Esplanade
- Turtle Way cycle path, immediately upstream of the John Oxley Bridge on the east bank.

The Boyne River inlet is a site of interest due to erosion experienced by private landholders. Following the 2013 flood event, private landholders have implemented formal and informal protection structures along the foreshore, including a geotextile sand container (GSC) wall spanning approximately 100m. The Turtle Way cycle path shoreline is another site of interest due to observed shoreline recession, with localised slope failures noted during field assessment. These eroded areas are typified by a lack of shoreline protection in the form of mangrove cover or hard structures.

Figure 7-1: Field investigation of erosion at Island Esplanade (left) and Turtle Way cycle path (right)

7.1.2 CoastSat Toolkit

The CoastSat toolkit utilises satellite imagery to create a time-series of the shoreline position from historic satellite data over a 30-year period. Aerial data from Landsat and Sentinel-2 has been subjected to quality analysis to remove tearing, cloud cover, and detection errors, before being included in shoreline mapping. CoastSat pairs aerial imagery data with an inbuilt tidal model to determine tide levels for each image in the dataset.

Over the 30 years of historical data, specific shoreline positions have been selected from the CoastSat data to coincide with a MHWS water level ± 0.3m (i.e. ranging from 1.20mAHD to 1.75mAHD), with an emphasis on summer tides to allow a comparison of yearly shorelines.

7.1.3 Boyne River Inlet at Island Esplanade

Figure 7-2 shows the shoreline assessment results for Boyne River Inlet. Shorelines taken from 2012 and 2013 show a wider beach berm, especially prominent at the Island Esplanade. The 2013 shoreline is taken from the 15th of January, one week prior to TC Oswald. The 2014 shoreline is taken from 14th January, one year following TC Oswald. During this period recession is observed as the shoreline shifts landward and encroaches private land and the northern carpark. This matches aerial imagery over this period, and includes both TC Oswald and the January 2013 flood event. This analysis supports the results of morphological modelling which indicate the shoreline position at this location can be linked to fluvial events. Following 2014 there is a period of recovery that extends to 2021.

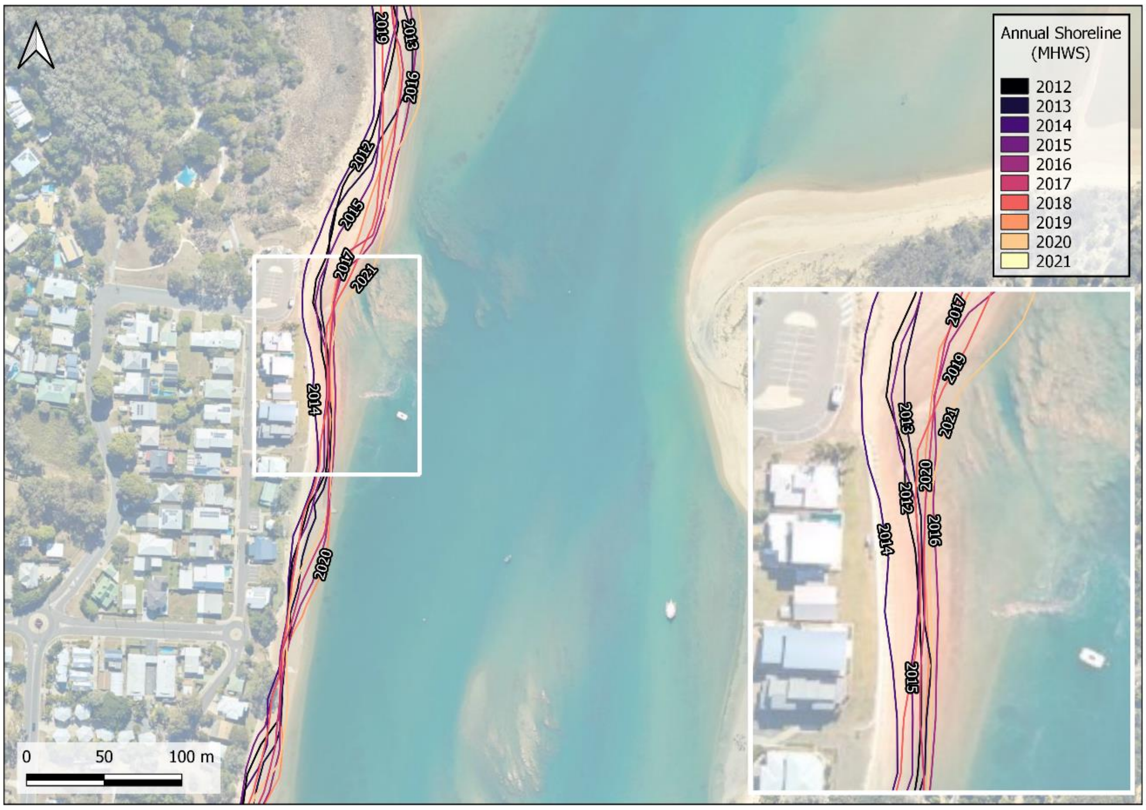


Figure 7-2: Shoreline positions at the Boyne River Inlet over a 10-year period.

Figure 7-3: Simplified shoreline positions at the Boyne River Inlet for 2012 (pre-flood event), 2014 (post-flood event) and 2021.

7.1.4 Turtle Way

The Turtle Way analysis shown in Figure 7-4 was inconclusive in accurately detecting the shoreline along the Boyne River. This is likely due to a lack of detectable sand and vegetation overgrowth appearing to affect the shoreline detection algorithm. Shoreline data is typically sourced from images captured at approximately 10:00 am local time, resulting in shadows the toolkit miscategorises as shoreline change.

Evident from site visits completed on 26th April 2022 are small pockets of localised erosion and the development of an erosion scarp along sections of the pathway. These features are not accurately captured in the CoastSat data, however it is suspected that ongoing erosion here is due to periodic high tides and boat wake waves, combined with a lack of marine vegetation and anthropogenic interference (hard structures) along the riverbank.

Figure 7-4: CoastSat analysis shoreline positions along the Turtle Way over a 9-year period

7.1.5 Limitations

The following limitations of detailed shoreline analysis have been identified:

- The Coastsat analysis toolkit is limited by the spatial resolution and light levels of the input satellite imagery data which can cause issues in identifying shorelines on narrow beach sections
- The toolkit assumes a uniform beach slope which can result in minor errors of shoreline placement with respect to tide level
- The shoreline slope along the GSC protection structure appears to be stable or accreting over the last ~5 years and was noted to have a consistent gradient along the frontage during site visits. The shoreline gradient prior to 2017 is not known.
- The typical satellite image collection time is approximately 10:00am which results in tide heights being out of alignment in successive images. As mentioned, analysed shorelines are representative of a MHWS, ranging from 1.20mAHD to 1.75mAHD.

7.2 Inlet tracking at Wild Cattle Creek

Historical aerial analysis has been conducted to track the flow path of the Wild Cattle Creek inlet and the northern end of Wild Cattle Island. This assessment was completed using the Google Earth Engine-enabled python-based toolkit InletTracker[12]. The InletTracker tool uses a novel least-cost pathfinding approach to trace inlets across and along the coastal berm from more than 20 years of historic Landsat and Sentinel satellite imagery. This information is used to determine the state of the inlet (open or closed) as well as its orientation over time, as schematised in Figure 7-5. This data has been incorporated to inform future planning and maintenance operations at the inlet.

12 Heimhuber, Valentin Et. Al. (2021), InletTracker: An open-source Python toolkit for historic and near real-time monitoring of coastal inlets from Landsat and Sentinel-2, available: 10.1002/essoar.10506493.1

7.2.1 Site Information

Wild cattle inlet is situated between the township of Tannum Sands and Wild Cattle Island. A section approximately 100m upstream of the inlet is used as an access track at low tide for residents of Bangalee, a small township located on the southeast coast of Wild Cattle Island. The inlet is known to be variable in form due to the sandy nature of both the inlet and surrounding coastal features, as well as the mesoscale tidal range and exposure to offshore waves. River currents in Wild Cattle Creek are primarily tidal, which dominate any freshwater inflows from the small upstream tributaries. Tides also extend into the creek from a southern entrance at Colosseum Inlet. A sand nourishment operation was completed on the western side of the inlet in approximately 2017 to mitigate erosion in front of Millennium Esplanade.

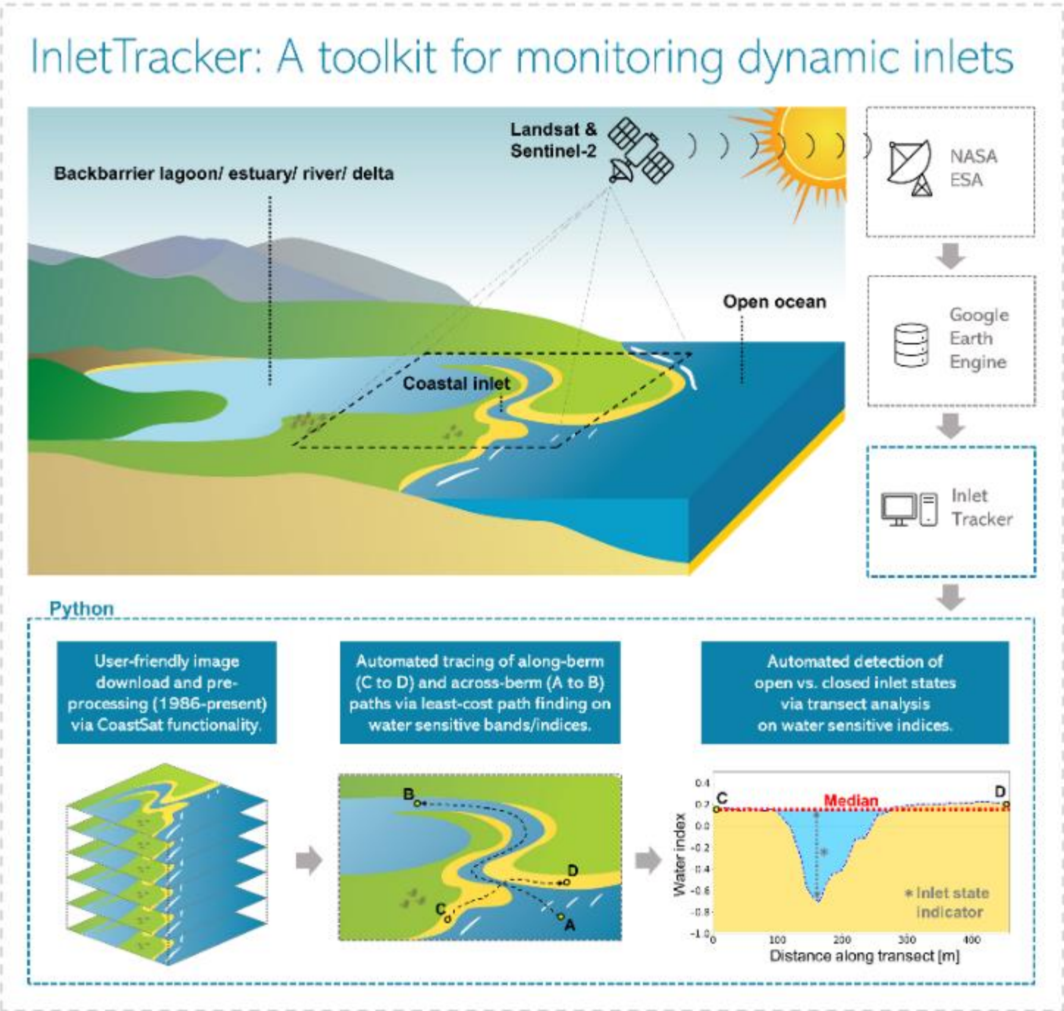


Figure 7-5: Conceptual diagram illustrating the architecture and key processing steps of InletTracker (Heimhuber, 2021)

7.2.2 Results of analysis

Figure 7-6 shows the variability of the outlet flow path at Wild Cattle Creek over several years. The image series highlights the pathfinding results for the Sentinel-2 satellite from 2016-2021. The image series illustrates the variation in water level, beach colour, channel alignment and wave conditions that are associated with this inlet. The C-D transect is the along-berm path while the A-B transect is the across-berm path, with the definition of the creek mouth indicated as the intersection of these transects. The modified Normalised Difference Water Index (mNDWI) band configuration was used to determine channel path alignment. This configuration of bands is recommended as it available in higher resolution to other indices and can detect variation of smaller inlets.

Figure 7-7 shows the results of inlet tracking across the entire 20-year study period. An inlet flow path for each year ranging from 2000 to 2021 is shown. Over the range of historical imagery included in this analysis, the inlet was not found to be in a closed state. This is expected to be due to the inlet being tidally fed from the north as well as the southern entrance at Colosseum Inlet. A typical intermittently open and closed lake or lagoon (ICOLL) lacks this tidal forcing, with the channel mouth being maintained primarily by upstream freshwater flows. Figure 7-7 shows a fluctuating but stable inlet over the 21-year study period.

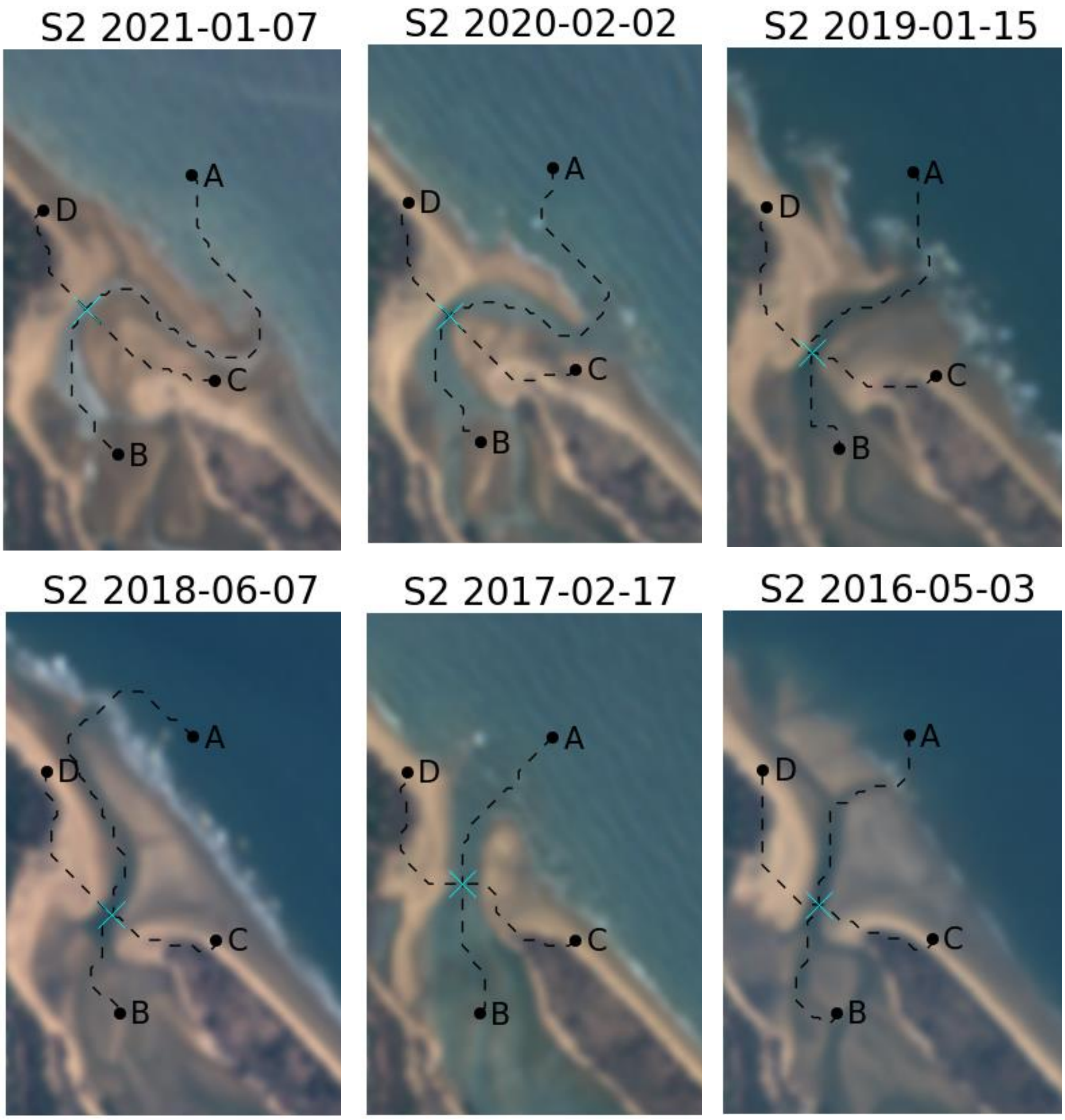


Figure 7-6: Inlet tracking for Wild Cattle Creek Inlet from the S2 mNDWI band over a five-year period.

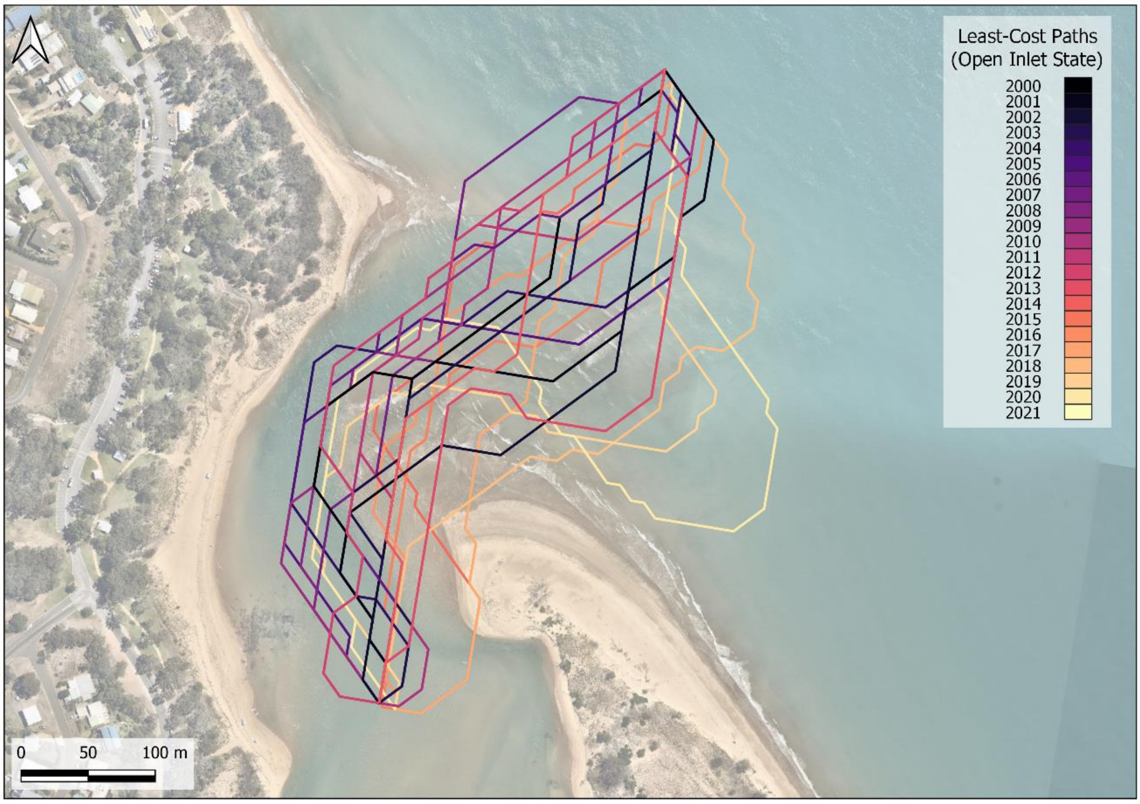


Figure 7-7: Least-cost pathfinding results for Wild Cattle Creek Inlet from the L5, L7, L8 and S2 NIR band spanning a 21-year period.

8 Summary

This study has assessed coastal processes at Boyne Island and Tannum Sands beaches including wind and wave investigations, wave modelling, hydrodynamic modelling, sediment modelling and historical coastline tracking. This data has been used to estimate erosion and sediment transport characteristics at key coastal locations.

8.1 Wind and wave assessment

Seasonal wind conditions have been assessed from recorded weather data at the Gladstone Radar AWS. This data shows a prevailing easterly wind during summer months, trending toward south-easterly during winter.

Offshore and nearshore wave conditions have been assessed using a combined simulation and emulation approach. A 10,000-year dataset of potential offshore wave conditions has been generated from the Gladstone wave rider buoy (WRB). A sampled subset of 200 wave and storm tide conditions has been applied in a numerical wave model, with results extracted in the nearshore. From these nearshore results, a machine learning emulator has been used to translate the full 10,000-year offshore set to the nearshore for use in longshore sediment transport assessment.

8.2 Longshore sediment transport (LST) assessment

Potential rates of longshore sediment transport (LST) have been estimated with the JBP Beach Evolution Model (JBEM). Wave conditions have been extracted from the emulated nearshore dataset and applied as a set of events over 10,000 years to JBEM. Each nearshore wave result has been assigned an occurrence frequency of approximately 2 weeks.

- LST has been estimated at five key locations along the coast, with two reporting points located on Lilley's Beach, one at Tannum Sands beach and two on Wild Cattle Island.
- Results of LST modelling suggest a net northerly transport across the southern four points in the order of 30,000 $m^{3/}$year and approximately 8,000 $m^{3/}$year for the more sheltered Lilley's Beach north point.

8.3 Cross-shore erosion assessment

A probabilistic approach has been applied to assess extreme cross-shore erosion for open-coast beach segments at Lilley's Beach, Tannum Sands, and Wild Cattle Island. The full range of 10,000-year offshore conditions has been assessed with the JEPA cross-shore erosion toolkit. From the results of erosion modelling, frequency analysis has been conducted on erosion widths for each location to determine a range of extreme erosion annual exceedance probabilities (AEP):

- Lilley's Beach north: 1% AEP erosion width = 4.3m
- Lilley's Beach south: 1% AEP erosion width = 15.2m
- Tannum Sands beach: 1% AEP erosion width = 9.3m
- Wild Cattle Island north: 1% AEP erosion width = 13.9m
- Wild Cattle Island south: 1% AEP erosion width = 15.4m

8.4 Hydrodynamic modelling assessment of Boyne River

Hydrodynamic numerical modelling was undertaken to understand the hydrodynamic and morphological processes occurring within the Boyne River inlet during a large flood event. This model has been developed as a decision support tool, to help understand how tides, upstream inflow, and sediment properties interact adjacent to Island Esplanade on Boyne Island. An upstream flood event has been modelled using discharge rates recorded at Awoonga Dam during the flood event following TC Oswald in January 2013.

The simulation results show a widening of the Boyne River inlet mouth on the east and west bank of the inlet during the extreme flood event. These results support the idea that the erosion experienced by property owners along Island Esplanade in 2013 can be attributed, at least partially, to the high flow conditions.

8.5 Historical coastline assessment

The remote sensing python toolkit, CoastSat, was used to supplement previous assessment of the DEA coastlines database. CoastSat was used to conducted detailed shoreline analysis at key erosion areas at Island Esplanade and Turtle Way, both within the Boyne River estuary.

Results of shoreline analysis at Island Esplanade complement the hydrodynamic modelling assessment and indicate significant shoreline recession from 2012 to 2013, following by a pro-grading trend from 2014 to present day. At Turtle Way, detailed shoreline analysis was unsuccessful due to tree cover and lack of resultion in aerial imagery. However, it is suspected that observed erosion in this area is due to combined tide and boat-wave waves as well as decreased mangrove coverage and anthropogenic interference (hard structures).

The remote sensing python toolkit, InletTracker, was used to analyse the historical flow path of the Wild Cattle Creek inlet. Over the range of historical imagery included in this analysis, the inlet was not found to be in a closed state. This is expected to be due to the inlet being tidally fed from the north as well as the southern entrance at Colosseum Inlet. This assessment showed Wild Cattle Creek to be a fluctuating but stable inlet.

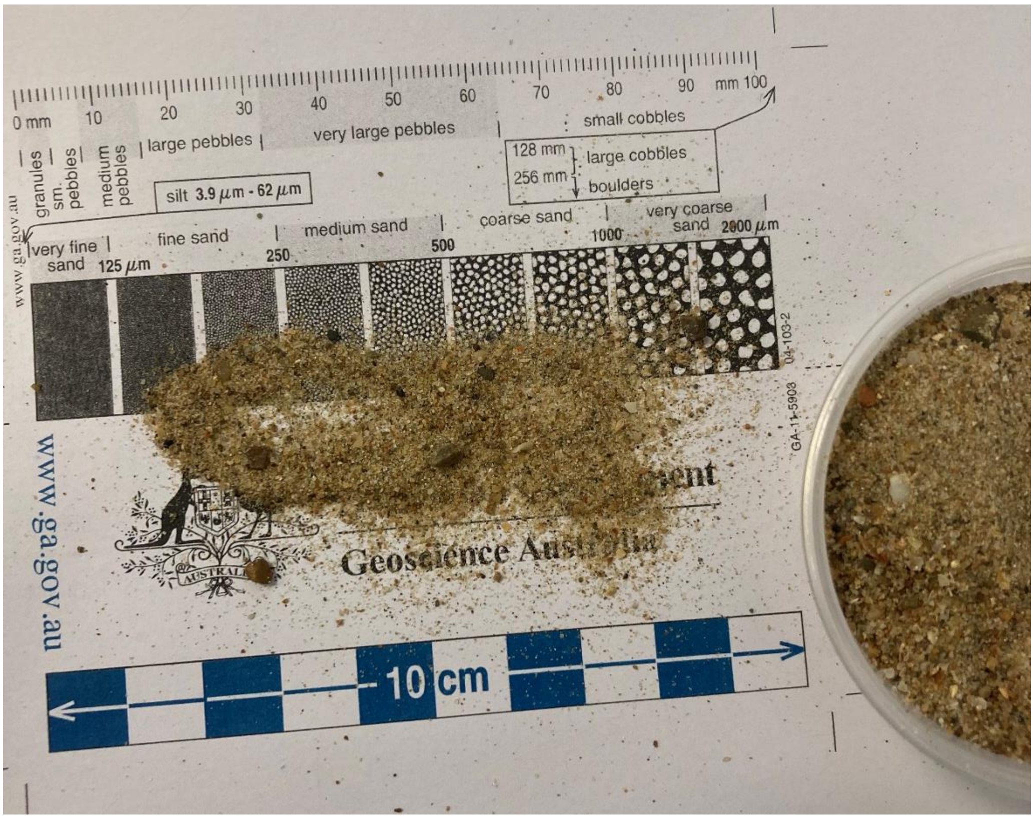
Appendices

A DEA Coastlines Assessment

Document supplied separately.

B Beach sand sampling

B.1 Lilley's Beach

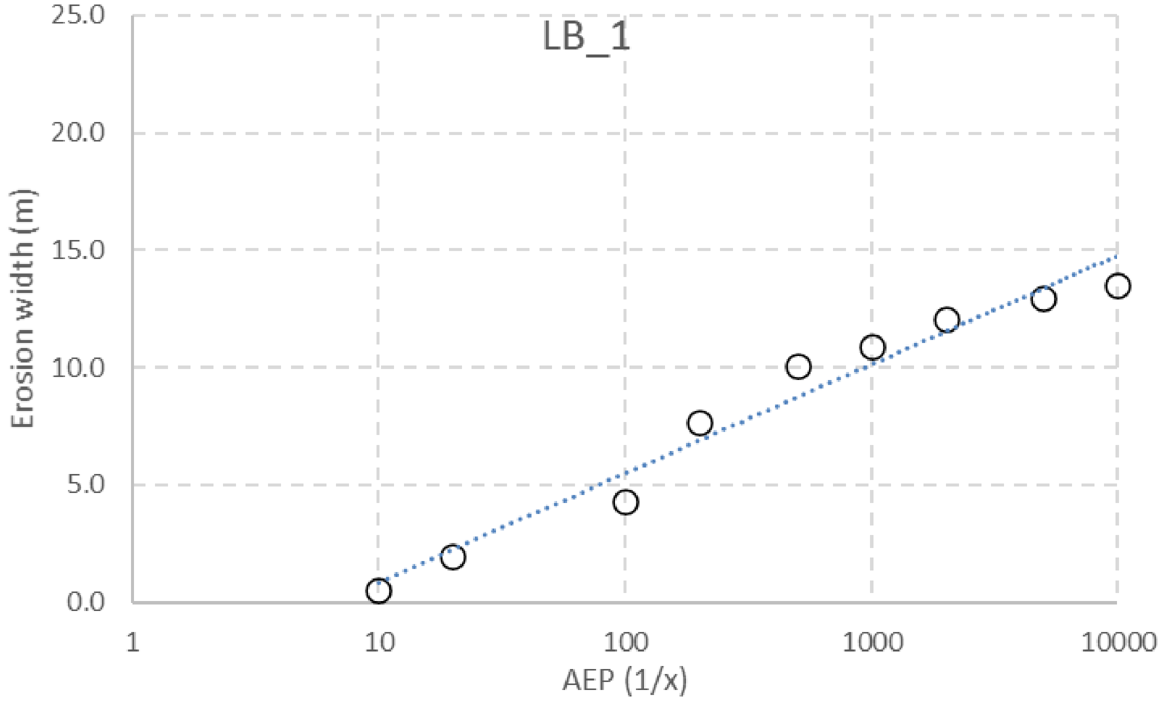


B.2 Boyne River inlet

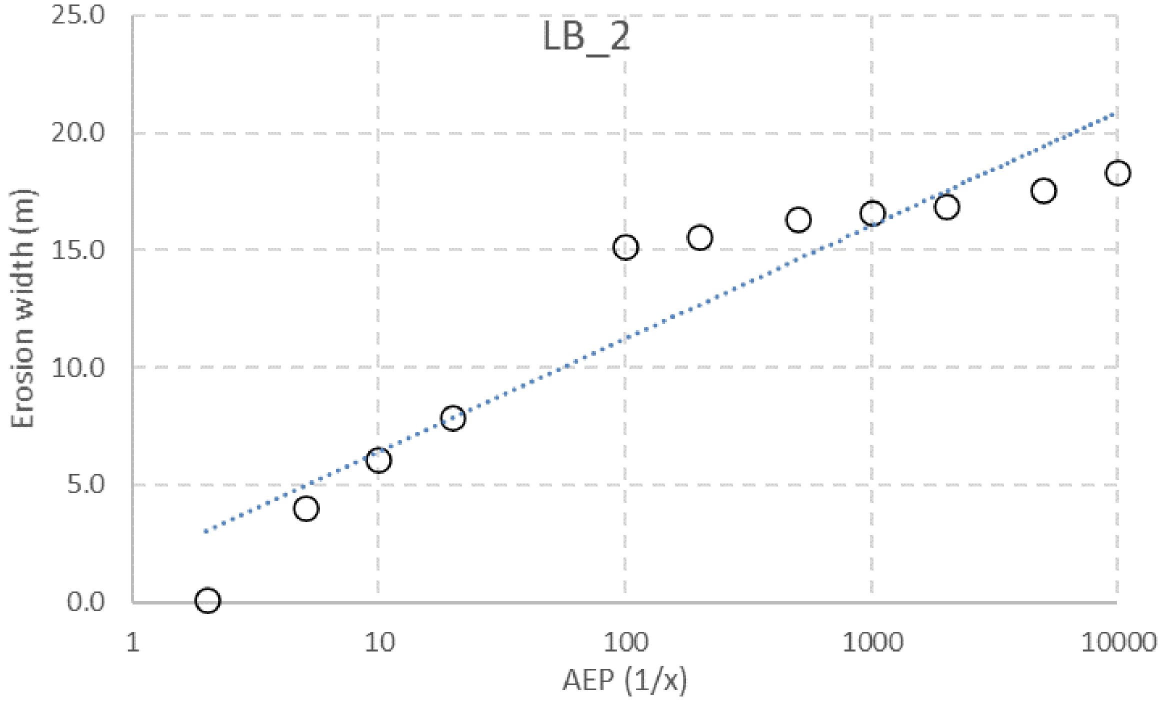
B.3 Wild Cattle Island

C Cross-shore erosion frequency diagrams

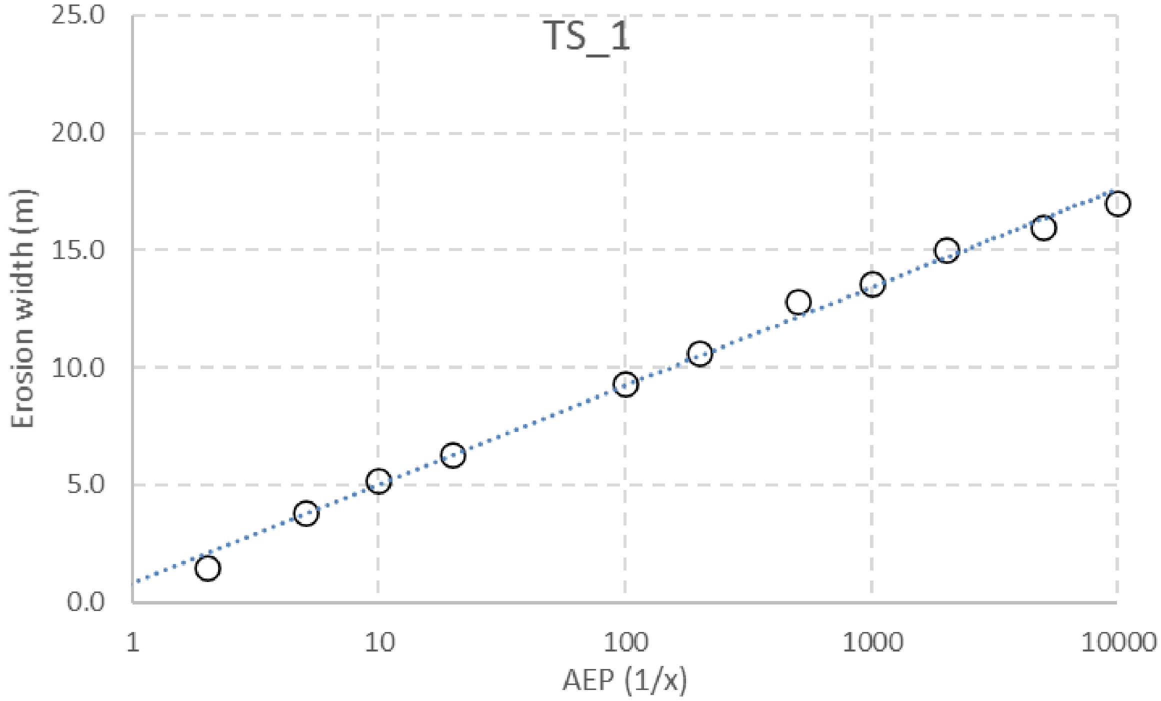
C.1 Lilley's Beach north (LB_1)



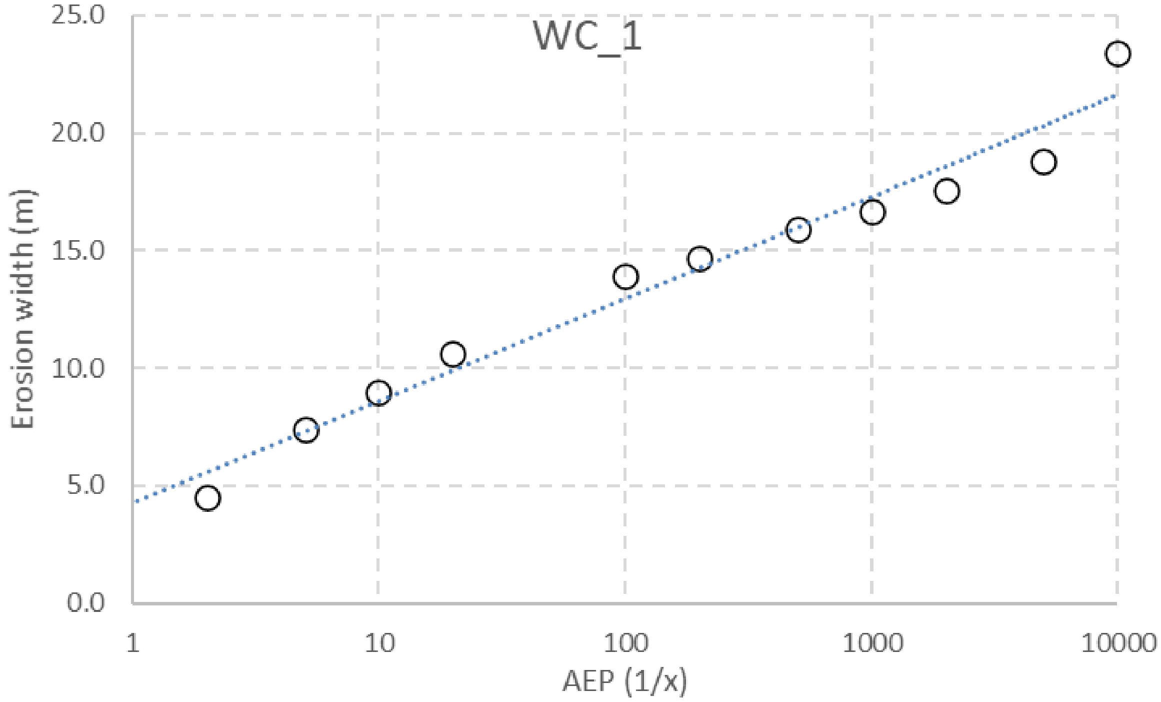
C.2 Lilley's Beach south (LB_2)



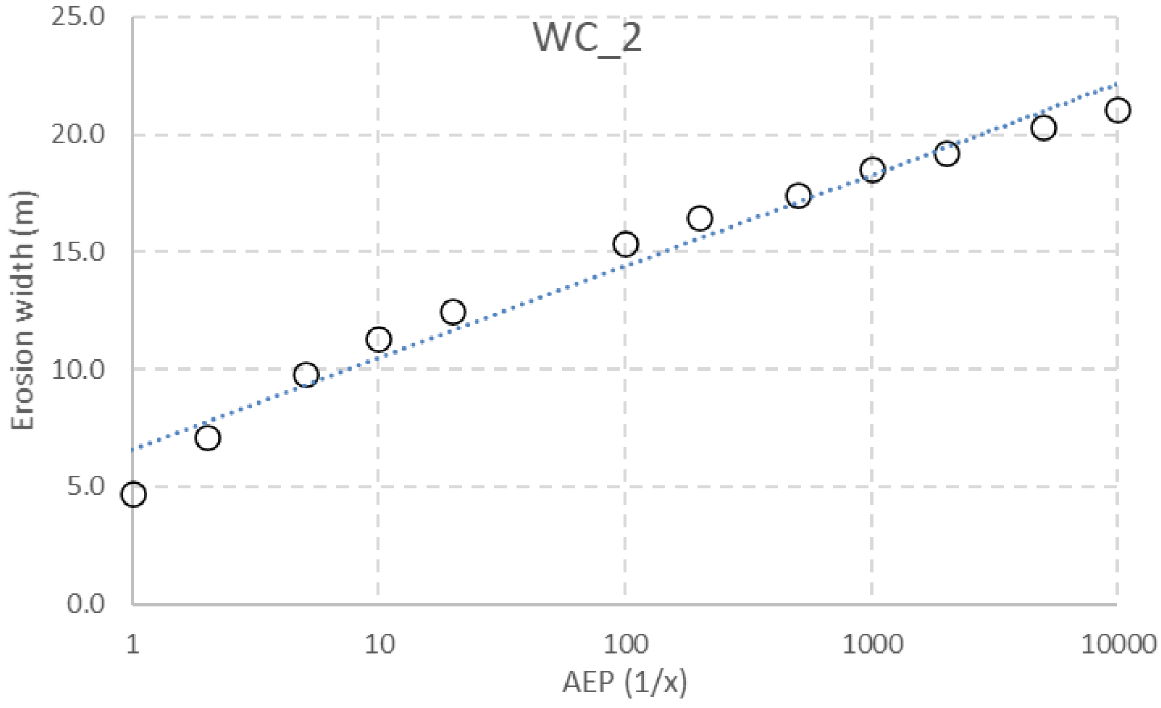
C.3 Tannum Sands beach (TS_1)



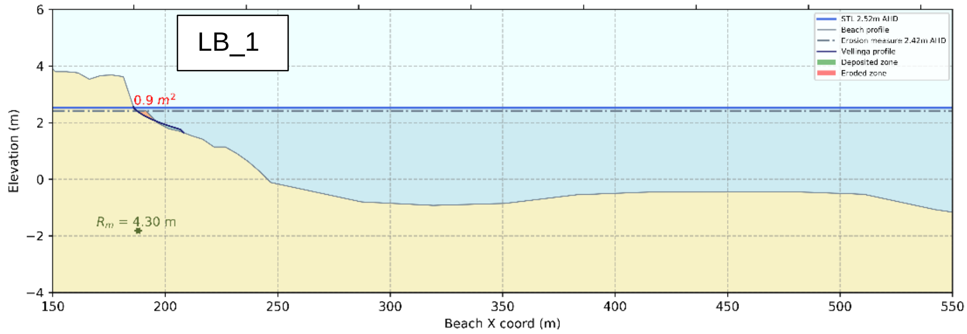
C.4 Wild Cattle Island north (WC_1)

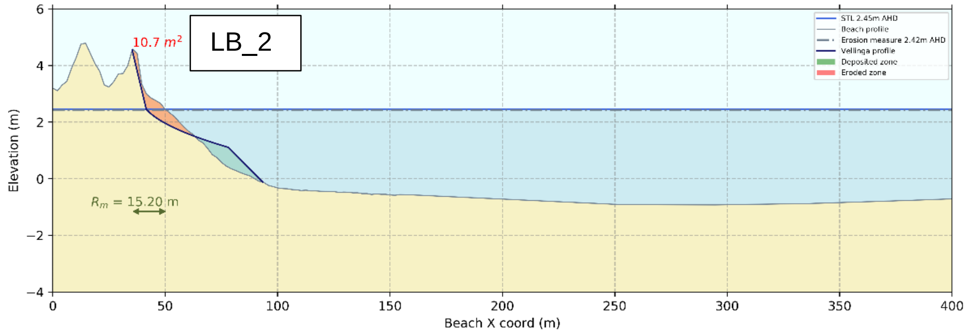


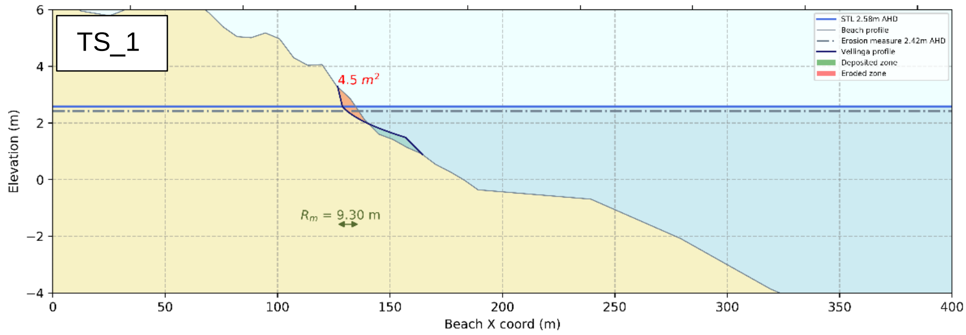
C.5 Wild Cattle Island south (WC_2)

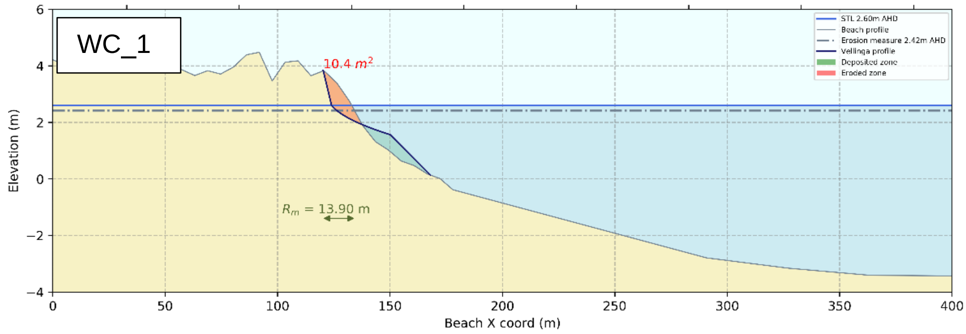


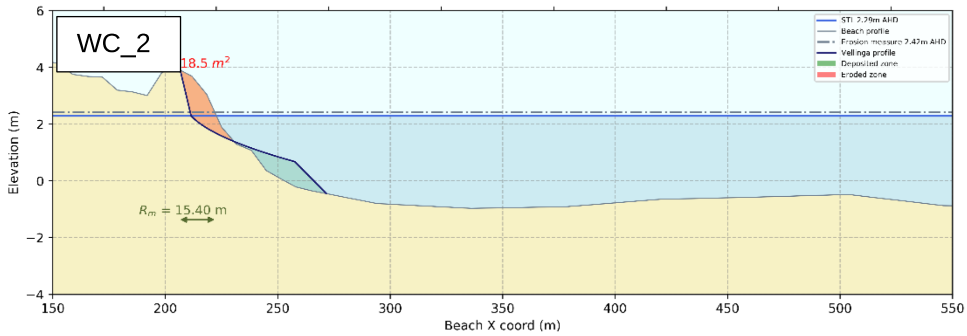
D 1% AEP cross-shore eroded profiles











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Attachment 4. Survey questions

Survey questions from 31st May 2022 to 26th June 2022

IMPORTANT & MEANINGFUL | COAST CHANGES & KEY EVENTS

Tell us: Why is the shoreline important and meaningful to you?

Tell us about why the shoreline is important and meaningful to you

CLOSED. The visioning activity has now concluded. **Click to see all the submitted ideas.**

13 June, 2022
says:
"The shoreline needs vegetation like Coastal Stand and Marram grass like in front of the lifesavers not sheoak trees that when eroded destroy"
👍 1 👎 0

13 June, 2022
says:
"I'm local for over sixty years. Boyne to Hummock Island leave it alone. Interfered with once and it's still a disaster. No more useles trees"
👍 1 👎 0

9 June, 2022
says:
"We are concerned about the abuse of our shoreline - Illegal driving on dunes, clearing of vegetation for "better views", beach modification."
👍 1 👎 0

9 June, 2022
says:
"The BITS shoreline is the most intact natural accessible shoreline in the Gladstone area. It is also regarded as the most scenic shoreline."
👍 1 👎 0

IMPORTANT & MEANINGFUL | **COAST CHANGES & KEY EVENTS**

Tell us: How the coast has changed overtime and are their key events that are linked?

Tell us about how the coast has changed over time and key events that you believe are linked to coastal changes.

CLOSED. The visioning activity has now concluded. **Click to see all the submitted ideas.**

9 June, 2022
says:
"We have observed continual natural movements of sand and the river estuaries during the 33year period of our residence. Floods do contribute"
👍 0 👎 0

3 June, 2022
says:
"This coast line changes minimally but also reverts back over time. My experience over apx 65 yrs has seen it cycle, so please take heed."
👍 1 👎 0

Attachment 5. MCA sensitivity testing

Sensitivity testing

We performed a sensitivity analysis on the criteria weighted scores. A sensitivity analysis is a check of how uncertainty in the output of a mathematical system can be divided and allocated to different sources of uncertainty in its inputs.

Table 66. Summary of sensitivity analysis for MCA

Criteria	Explanation	Result
No weighting	Weightings equalised.	No change on weighted MCA for all sites. All options retained the same rankings.
Protection/accessibility adjustment	Swapping the weightings of protection and accessibility, being the third highest and lowest ranked criteria respectively.	The changes on weighted MCA for all are insignificant. It generally increases the weightings for 'Do nothing' and 'Maintain status quo' options. However, all options retained the same rankings.
Value (cost)/environmental adjustment	Swapping the weightings of economic value and environmental. Giving a higher weighting to economic value, and lower weighting to environmental.	The changes on weighted MCA for all are insignificant. It generally decreases the weightings for engineering options as they are typically more expensive. However, all options retained the same rankings.