Phase 3 Identify Areas Exposed to Current and Future Coastal Hazards

Bundaberg Region Coastal Hazard Adaptation Strategy

Bundaberg Regional Council

Version	Doc type	Reviewed by	Approved by	Date issued
V01	Draft	Paul O'Brien	Jo Tinnion	23 July 2018
V02	Final	Jo Tinnion	Astrid Stuer	21 December 2018
V03	Final	Astrid Stuer	Jo Tinnion	29 January 2019
V04	Final	Astrid Stuer	Richard Sharp	02 April 2019

5057-03-R01

EXECUTIVE SUMMARY

The implications of climate change-induced sea level rise and the potential increase in tropical cyclone intensity for Queensland's coast are likely to lead to a progressive worsening of coastal hazards, including storm tide inundation and coastal erosion. The gap analysis undertaken during Phase 2 of the Bundaberg Region Coastal Hazard Adaptation Strategy (CHAS) in 2017, identified the need to better define the coastal hazards throughout the Bundaberg Region local government area, particularly regarding the implications of a range of future events. Furthermore, to be able to plan for a range of future climate predictions it was considered necessary to understand the impact on coastal hazards using a range of sea level rise increments up to the 0.8m predicted for the year 2100. The Phase 2 report also identified a number of key study locations which were considered in detail, namely Miara, Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach.

This report documents the technical assessments undertaken as part of Phase 3 of the Bundaberg Region CHAS, seeking to identify areas exposed to current and future coastal hazards. The analysis carried out includes the detailed assessment of various Annual Exceedance Probability (AEP) events, for a range of sea level rise scenarios, for both storm tide inundation and coastal erosion. This exploration of multiple storm tide inundation and erosion event scenarios over a range of planning horizons will significantly improve the risk assessment tasks to be subsequently undertaken in Phase 5 of the CHAS. Furthermore, by adopting a multiple outcome approach based on a range of scenarios, there will be more flexibility when defining adaptation options and implementation timeframes.

The Queensland Government dataset (GHD, 2014) has been used for the storm tide inundation mapping and has been adjusted to include predictions for sea level rise.

The erosion prone area assessment focused on the six key study locations mentioned above. No analysis was undertaken on the remainder of Council's coastal areas, instead the existing Queensland Government data for erosion prone areas was adopted for all other areas.

Storm tide Inundation mapping was undertaken for the 1% AEP storm tide event and for future climate scenario (+0.8m of sea level rise). The estimated storm tides have been mapped including the effects of wave setup.

Coastal hazard mapping illustrating areas identified as subject to storm tide inundation and coastal erosion hazard can be accessed via the mapping portal.

CONTENTS

5057-03-R01

5057-03-R01

APPENDICES

LIST OF FIGURES

5057-03-R01

LIST OF TABLES

1 INTRODUCTION

1.1 Background to coastal hazard adaptation planning

Over the last few years, the Queensland coast (and specifically the Bundaberg Region) has experienced disasters which have resulted in significant economic costs and societal impacts. In response, Bundaberg Regional Council has pro-actively developed a unique perspective on the concepts of, approaches to, and challenges involved in building resilience and undertaking activities to adapt to changing circumstances.

Relevantly, current projections for Queensland's coastline by 2100 indicate:

- A projected sea level rise of 0.8 m
- Tropical cyclones are projected to become less frequent but those tropical cyclones that do occur are expected to be more intense and may track further south.

The likely impacts associated with these changes mean that rising sea levels combined with storm tides are likely to cause accelerated erosion and increased risk of inundation. For settlements and infrastructure this is likely to result in damage to and loss of dwellings and infrastructure with community-wide impacts. For ecosystems, sea level rise may lead to loss of habitat, and salinisation of soils may cause changes to the distribution of plants and animals.

The impact of increasing coastal hazards will affect Queensland councils in the areas of:

- Litigation and legal liability
- Community expectations
- Land use planning and development assessments
- Asset and infrastructure planning and management

In response to this, the QCoast2100 program was developed to provide councils in Queensland with assistance to advance coastal hazard adaptation planning. The Coastal Hazards Adaptation Program (QCoast2100) will support all Queensland local governments impacted by existing and future coastal hazards to advance adaptation planning. The Program will facilitate the development of high quality information enabling defensible, timely and effective local adaptation decision-making through access to tools, technical and expert support and grants for eligible councils.

The Program is funded by Queensland's Department of Environment and Science (DES, formerly the Department of Environment and Heritage Protection - DEHP) and will be delivered by the Local Government Association of Queensland (LGAQ).

The CHAS program will be delivered through eight phases and each of the phases can be categorised under three themes:

- Commit and get ready
  - Phase 1: Plan for life-of-project stakeholder communication and engagement (Completed 2017)
  - Phase 2: Scope coastal hazard issues for the area of interest (Completed 2017)
- Identify and assess
  - Phase 3: Identify areas exposed to current and future coastal hazards (This phase)
  - Phase 4: Identify key assets potential impacted
  - Phase 5: Risk assessment of key assets in coastal hazard areas

5057-03-R01

- Plan, respond and embed
  - Phase 6: Identify potential adaptation options
  - Phase 7: Socio-economic appraisal of adaptation options
  - Phase 8: Strategy development, implementation and review

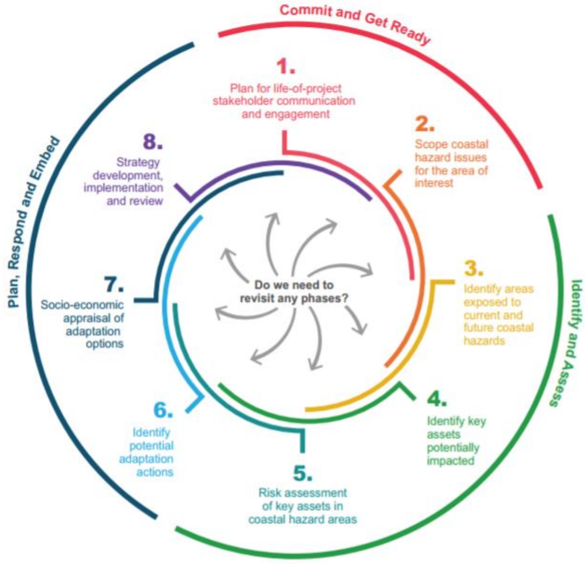


FIGURE 1-1 CHAS PROJECT PHASES

1.2 Phase 3 - Identify areas exposed to current and future coastal hazards

1.2.1 Overview

As described in the *Coastal Hazard Technical Guideline Determining Coastal Hazard Areas* (DEHP, 2013) (the Guide), the implications of climate change-induced sea level rise and the potential increase in tropical cyclone intensity for Queensland's coast include a progressive worsening of coastal hazards, including:

- Storm tide inundation:
  - Sea level rise will increase the apparent severity and frequency of storm tide inundation and will cause inundation to occur further inland
  - Increased cyclone and storm intensity will add to the magnitude of storm tide events and the extent of inundation
- Coastal erosion:
  - Increased water levels will accelerate coastal erosion
  - Sediment transport patterns may be altered by shifts in wave direction triggering changes to the form and location of shorelines

5057-03-R01

- Low-lying land may be permanently inundated
- Increased cyclone and storm activity will escalate the severity of coastal erosion events.

The purpose of Phase 3 is to identify areas exposed to current and future coastal hazards. The assessment of storm tide, coastal erosion and permanent inundation from sea level rise has been used to delineate the areas exposed to coastal hazards and the scale of the exposure. This information will then be used to identify exposed tangible and intangible assets (Phase 4) and the risk they may be subject to (Phase 5). This will also assist in the conceptual design of adaptation options

1.2.2 Study area

The Phase 2 – Scoping Study identified the merit of undertaking refined future storm tide hazard mapping along the at-risk shoreline of the LGA to support the development of the CHAS. It also identified the need to undertake further investigations of existing and future erosion hazard along the at-risk soft foreshore of Miara, Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach.

The project study area and the key coastal study locations are shown in Figure 1-2.

1.2.3 Event frequency

When discussing the severity and occurrence of natural events such as storms, engineers and scientists assign a measure of an event's severity by way of either an *Average Recurrence Interval* (ARI) or an *Annual Exceedance Probability* (AEP).

Where an ARI (sometimes also referred to as a Return Period) is assigned, it represents the average time that elapses between two events that equal or exceed a particular condition. For instance, a 100-year ARI event is one which is expected to be equalled or exceeded on average once every 100 years. However, since such events occur randomly in any particular timeframe under consideration (rather than at precise regular or cyclical intervals), they have a probability of occurrence within that time. However as noted in the now superseded 1987 edition of *Australian Rainfall and Runoff* (Institution of Engineers Australia, 1987):

> *"Use of the terms "recurrence interval" and "return period" has been criticised as leading to confusion in the minds of some decision makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance."*

Use of the term ARI can lead to misperceptions, such as the viewpoint that having just experienced a 100-year ARI event, there will not be another one like it for 100 years. This is not correct. It is therefore preferable to express the occurrence of a storm event in terms of Annual Exceedance Probability (i.e. AEP). This trend in technical nomenclature is reflected in recent updates of *Australian Rainfall and Runoff* (Geosciences Australia, 2016)

For example, "*a storm tide level of RL+2.4m above AHD at Burnett Heads has a 1% (i.e.0.01) probability of being equalled or exceeded in any one year"* can be more correctly (and more appropriately) understood than the equivalent statement of *a "storm tide level of RL+2.4m above AHD at Burnett Heads has an average recurrence interval of 100 years"*.

Consequently, throughout reporting for this CHAS, the Annual Exceedance Probability (AEP) is used in preference to Average Recurrence Interval (ARI) or Return Period when discussing event severity and/or occurrence. Nevertheless Table 1-1 is provided to assist in appreciating the relationship between AEP and ARI. Typically though, ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP.

TABLE 1-1 RELATIONSHIP BETWEEN AVERAGE RECURRENCE INTERVAL AND ANNUAL EXCEEDANCE PROBABILITY

Average Recurrence Interval) ARI)	Annual Exceedance Probability (AEP)
1 year	63%
2 years	39%
5 years	18%
10 years	10%
20 years	5%
50 years	2%
100 years	1%

1.2.4 Planning horizons

Adaptation actions in the CHAS need to be undertaken in the short, medium and long term planning horizon. Therefore, the following planning horizons and associated hazard events have been adopted when assessing coastal hazards for this CHAS:

- 2040: +0.2m sea level rise – near the current state of play, identifying immediate risks;
- 2070: +0.4m sea level rise – provides a medium to long-term outlook of risks, allowing adequate time for adaptation strategies to be implemented, while allowing time to monitor and verify projected coastal hazard scenarios.
- 2100: +0.8 sea level rise – allows for transparency of the potential risks predicted to occur by the end of the century, informing the decision-making process.

To perform the risk assessment in the later Phase 5 of the CHAS leading practice recommends to estimate the likelihood of an event by identifying different levels of probability when identifying coastal hazard lines. Therefore, to understand the impacts and risks associated with more frequent as well as rare storm/cyclone events, the following Annual Exceedance Probability (AEP) events have been assessed for both the storm tide inundation and shoreline erosion hazards:

TABLE 1-2 AEP EVENT AND RELATIONSHIP TO LIKELIHOOD OF OCCURENCE

AEP event	Likelihood of Occurrence
10%	Almost certain
5%	Likely
2%	Possible
1%	Unlikely

5057-03-R01

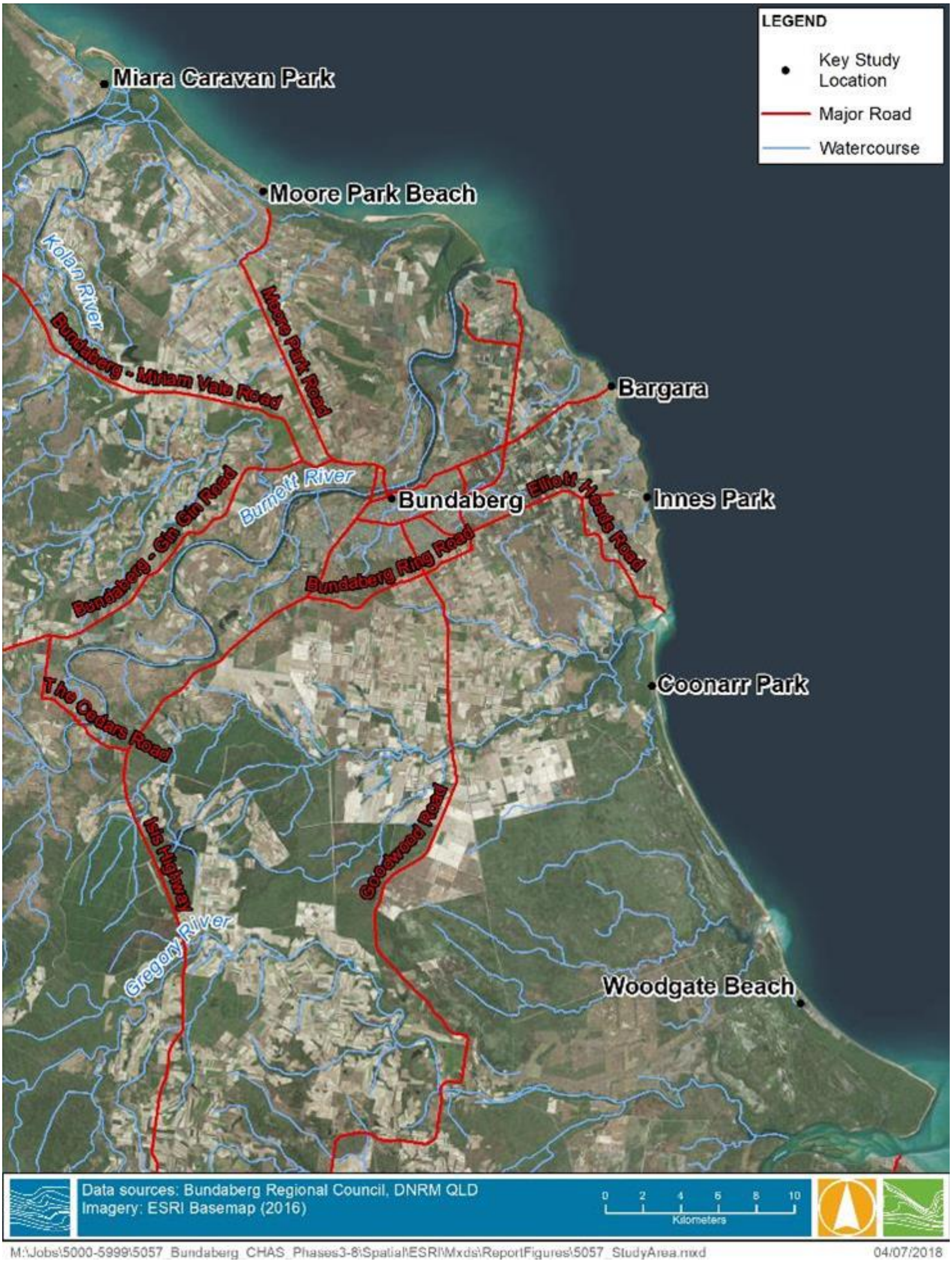


FIGURE 1-2 STUDY AREA

5057-03-R01

2 DATA AND INFORMATION

2.1 Topographic data

LiDAR flown in July 2016 was used as a base for the storm tide hazard inundation mapping. The LiDAR has a grid resolution of 1m and a vertical accuracy of 0.8m, covering the entire Bundaberg Regional Council LGA. An important first step was to verify the accuracy of the LiDAR by comparing it to the earlier 2011 LiDAR dataset which was used for the existing storm tide inundation mapping (BMT WBM, 2013) and three survey control benchmarks within the study area. The location of the three benchmarks, as well as a snapshot of the LiDAR comparison are shown in Figure 2-1.

The LiDAR comparison revealed that the 2016 LiDAR is on average 0.019m higher than the 2011 LiDAR, and the two datasets are generally in good agreement (within ±0.1m difference), as represented by the green areas on Figure 2-1. There are some differences within the waterways which could be attributed to water masking/processing of the LiDAR.

The results of the comparison between the survey benchmarks the 2016 LiDAR are presented in Table 2-1, and suggest that the 2016 LiDAR is sufficiently accurate and slightly more accurate than the 2011 LiDAR when compared to the survey benchmarks.

TABLE 2-1 COMPARISON OF LIDAR TO SURVEY BENCHMARKS

Benchmark Number	Benchmark AHD	2016 LiDAR	Difference (2016 LiDAR minus benchmark)	2011 LiDAR	Difference (2011 LiDAR minus benchmark)
86585	18.707m	18.667m	-0.040m	18.337m	-0.330m
85969	8.674m	8.780m	0.106m	8.600m	-0.074m
176448	4.545m	4.467m	-0.078m	4.309m	-0.158m
		Mean Difference	**-0.004m**		**-0.187m**

5057-03-R01

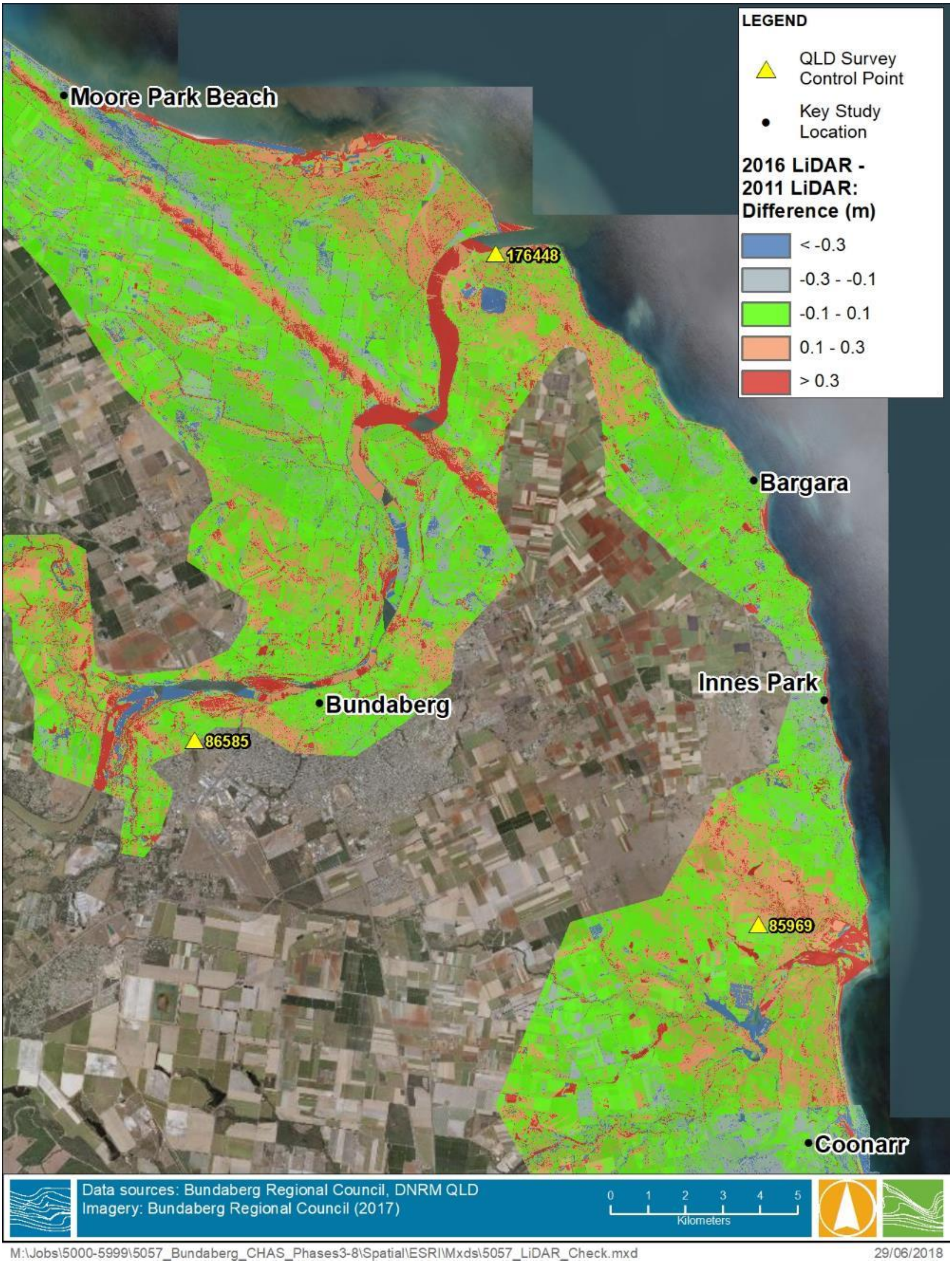


FIGURE 2-1 COMPARISON OF 2016 AND 2011 LIDAR, AND LOCATION OF SURVEY BENCHMARKS

5057-03-R01

2.2 Geology and geomorphology

An understanding of the geology and geomorphology is an important consideration to help understand past and future coastline behaviour. To assist with this, the SMARTLINE dataset available on the CoastAdapt platform is presented in Figure 2-2 which illustrates a generalised coastal geomorphology of the study area (http://coastadapt.com.au/coastadapt-interactive-map). This is based on the work of Sharples, Mount and Pedersen (2009).

The broad classes shown in the SMARTLINE mapping reflect the fundamental differences in susceptibility to coastal erosion, namely:

- Predominantly sandy – typically sandy types of shorelines, most readily eroded but also very mobile and capable of accretion (growth) as well as erosion.
- Predominantly soft rock – generally cohesive clayey material which are more resistant to erosion than sandy shorelines, but not as resistant as well-lithified rock. These may erode slowly but significantly over time, and do not rebuild as sandy shores may.
- Predominantly hard rock – most resistant to noticeable erosion on human time-scales although steeper hard rock shores may be notably unstable. Moderately sloping hard rock shorelines are considered to have negligible erosion hazard based on the lack of historical-observed instability in this shoreline type.

Major geographical features naturally divide the study area into the following three beach systems:

- Kolan River to Burnett River - Predominantly sandy
- Burnett River to Elliott River - Predominantly hard rock
- Elliott River to Burrum River - Predominantly sandy

The Hervey Bay Beaches Report (BPA 1989a) provides a comprehensive review of the geology and geomorphology of the study area and has been used to provide a description of the three beach systems.

Information specific to the locations of Miara, Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach is detailed in the discussion of erosion prone areas in Section 4.

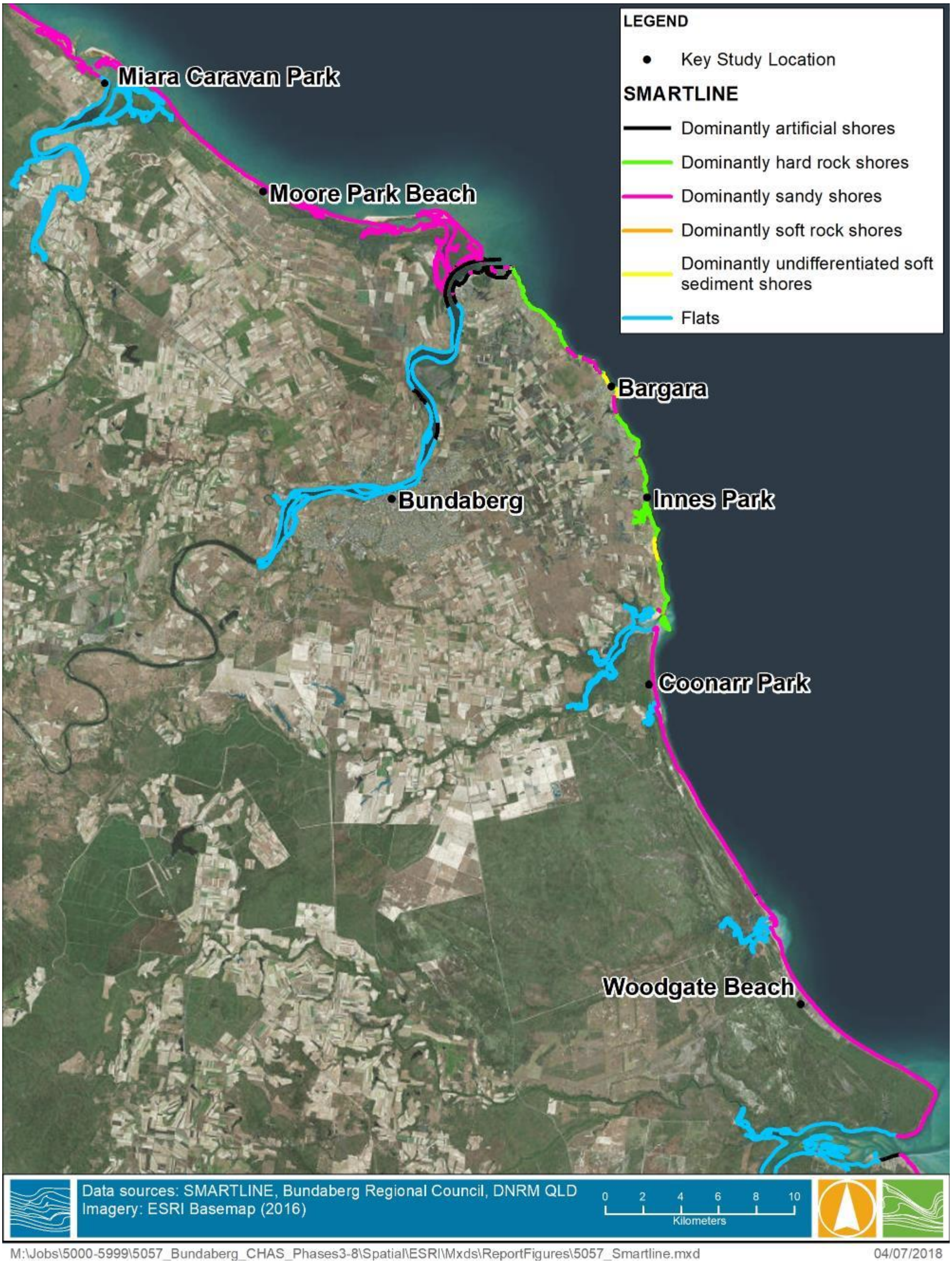


FIGURE 2-2 COASTAL MORPHOLOGY AS DEFINED BY SMARTLINE ON THE COASTADAPT PLATFORM

5057-03-R01

2.2.1 Kolan River to Burnett River

This 25 km section of coastline sweeps gently between the deltas of the Kolan and Burnett Rivers as illustrated in Figure 2-3. In the north, the control is provided by the Kolan River delta and variations in the location of the mouth of the river have a major impact on the behaviour of adjacent beaches of Miara and Moore Park Beach. In the south, the Burnett River delta controls the beach shape and the river is a major sand source.

The coastline is convex seawards at both the Kolan River spit and Barubbra Island end close to the Burnett River - while the Moore Park Beach portion is concave seawards.

The coast system comprises two coastal sand barriers, an inner barrier with degrading beach ridges of Pleistocene age, and an outer barrier with well-preserved beach ridges and barrier spits, of Holocene age. The two barriers are separated along most of their length by a triangular shaped, elongated area of coastal grassland. The Pleistocene inner barrier fringes the bedrock margin, and the Holocene outer barrier lies seaward of the Pleistocene barrier.

The Hervey Bay Beaches Report (BPA, 1989a) noted that at the time of the report, erosion was occurring both north and south of Moore Park Beach as a result of major changes to the entrance configurations of the Kolan and Burnett Rivers. Moore Park Creek enters the sea about 3 km south of Moore Park Beach. Records indicate the creek mouth has previously migrated as far north as the township. The entrance was artificially moved to about 4 km south of the township in the early 1950s and since that time it has been slowly moving north. The sand spit separating Moore Park Creek from the ocean has narrowed significantly in recent years.

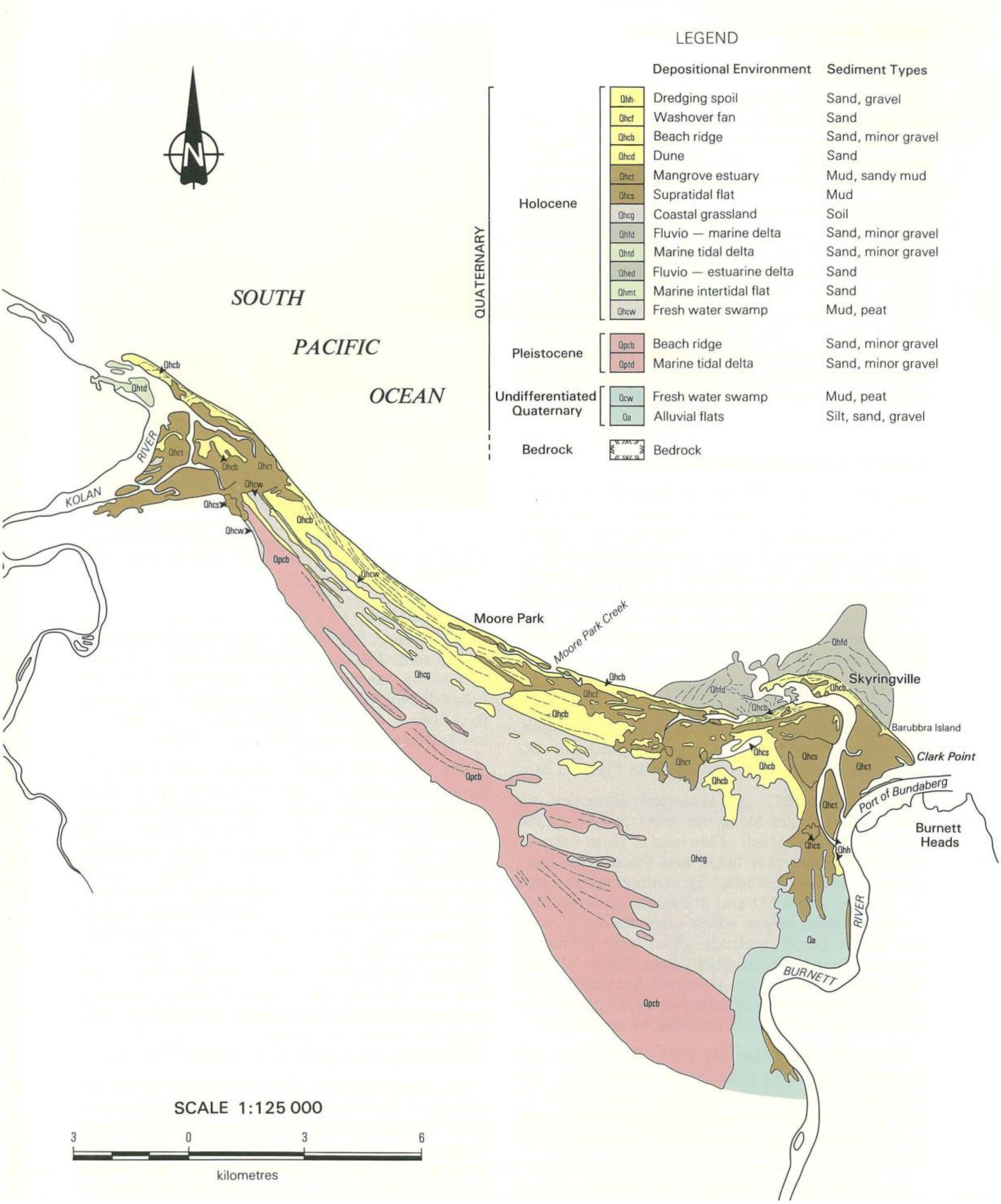


FIGURE 2-3 COASTAL GEOLOGY – KOLAN RIVER TO BURNETT RIVER (BPA, 1989A)

2.2.2 Burnett River to Elliott River

This 24km section of coastline consists of rocky foreshores of Hummock Basalt. Small sections of sand exist as pocket beaches, such as at Burnett Heads, Mon Repos, Neilson Park, Bargara, Kellys Beach, Innes Park and Elliott Heads as illustrated in Figure 2-4.

This beach system is underlain by basalt and areas between the sandy pockets are commonly strewn with boulders. This basalt coastline forms a major control point for the beaches to the north and south. The plan shape of this compartment is convex seaward, and it provides an effective barrier to the longshore sediment transport with sediment moving northwards and southwards from here (Figure 2-4).

At the shoreline, the basalt forms low vertical cliffs fringed by boulder slopes and wave cut rock platforms. Six of the twelve pocket beaches are backed by dunes six have small stream mouths and seven have been sites with dune instabilities and wind erosion with some transgressive parabolic dune formation. The small sandy pocket beaches in this section are underlain by rock, limiting the volumes of sand and are very susceptible to fluctuations in sand volume due to storm erosion. The geometry of this rocky shoreline has prevented significant beach accretion.

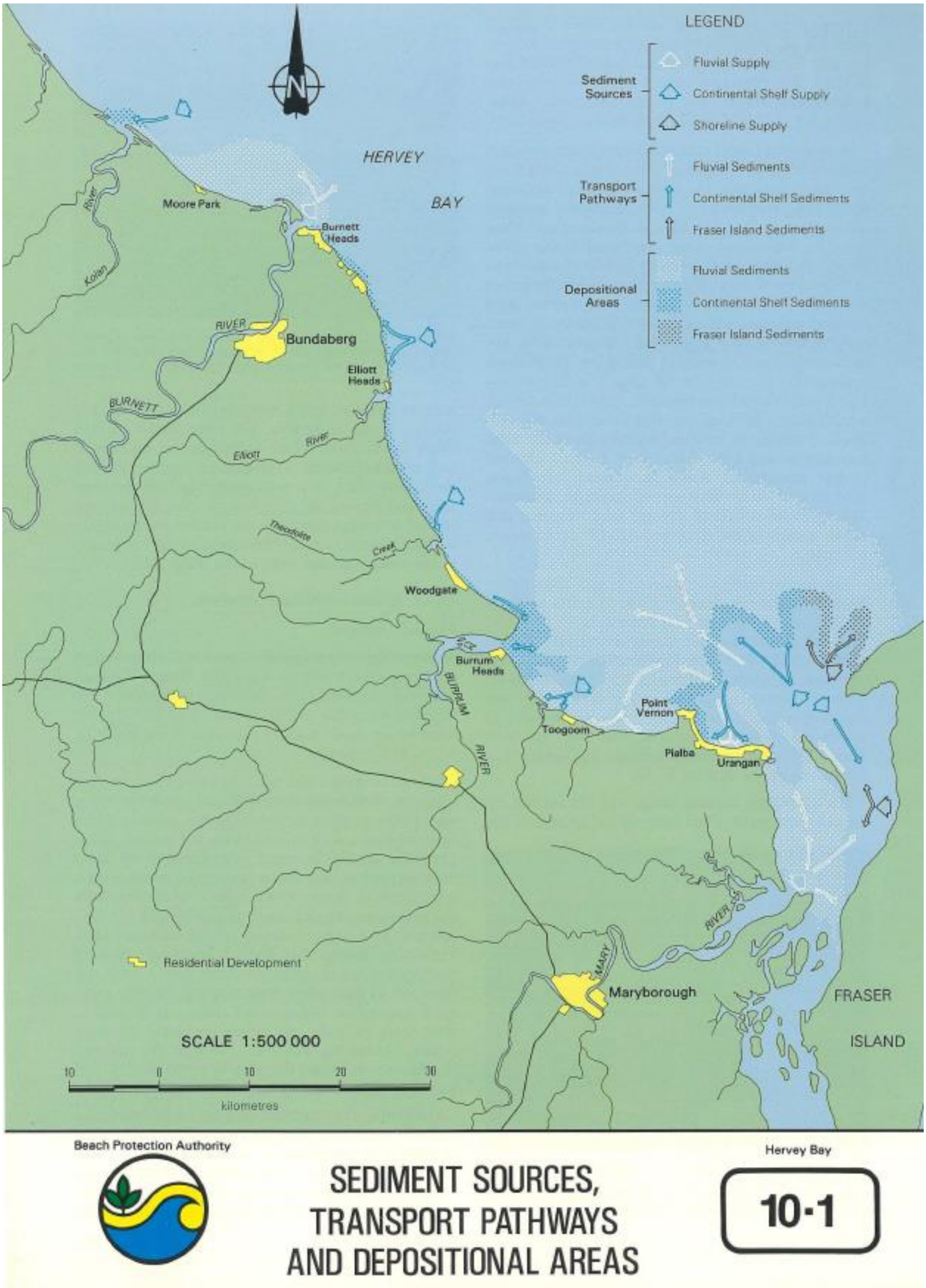


FIGURE 2-4 SEDIMENT TRANSPORT (HERVEY BAY BEACHES, 1989)

5057-03-R01

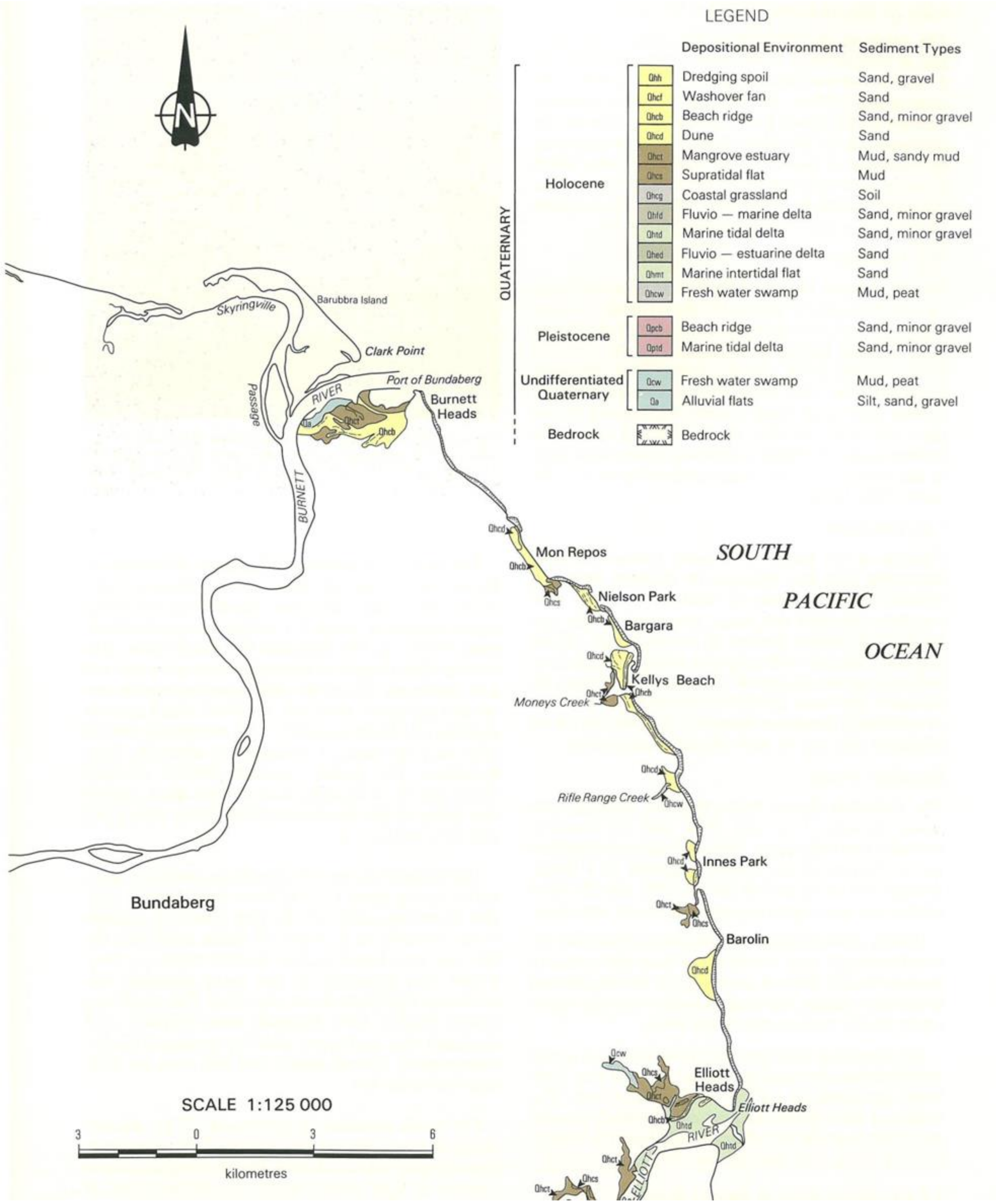


FIGURE 2-5 COASTAL GEOLOGY – BURNETT RIVER TO ELLIOTT RIVER (BPA, 1989A)

2.2.3 Elliott River to Burrum River

This 35 km section of coast includes the beaches that front the communities of Woodgate Beach and Coonarr as illustrated in Figure 2-6. The sandy shoreline curves gently between the Burrum River and Theodolite Creek. The beach system comprises a low depositional coastal with a very wide coastal plain. The majority of the coastal plain comprises beach ridge and dune barriers of Pleistocene age (2.6 million years to around 10,000 years before present). The Pleistocene barriers are fringed on their seaward side by Holocene (10,000 years before present) sand barriers of varying size.

In the north, between the Elliott River and Theodolite Creek, the Holocene barriers are narrow. They comprise beach sand deposits surmounted by tall foredunes, which have been further blown into small parabolic dunes at Coonarr. Between Theodolite Creek and the Burrum River is a wide Holocene strandplain, which consists of several sets of beach ridges. Each set comprises several parallel beach ridges, but each shows a slight to major angular discontinuity with the preceding and succeeding sets. The Pleistocene barrier also seem to consist of separate beach ridges, although individual ridges are not visible.

The shape of this shoreline is controlled in the south by the presence of the Burrum River. Theodolite Creek has a major influence on the alignment of the northern end of this beach and also on the beaches to its immediate north. Theodolite creek has an active delta area and local accretion of this delta is evident in the shape of the coast. All of the beaches along this section are fairly wide and sandy but with much more limited intertidal flats than those to the immediate south.

The Hervey Bay Beaches Report notes that beach areas immediately south of Theodolite Creek and the Elliott River experience erosion as a result of changes to the entrance configuration of these waterways.

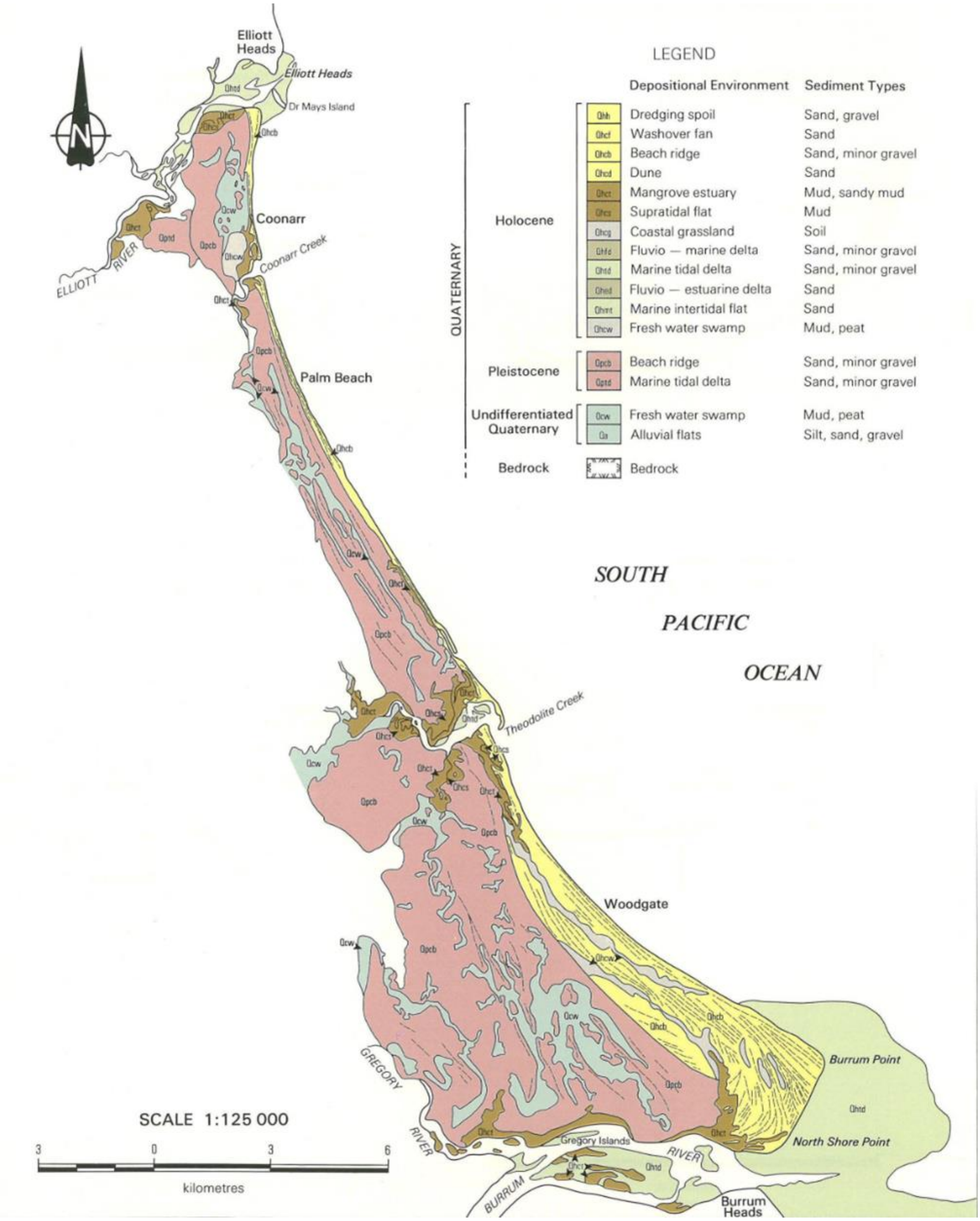


FIGURE 2-6 COASTAL GEOLOGY – ELLIOTT RIVER TO BURRUM RIVER (BPA, 1989A)

3 OCEANOGRAPHY AND COASTAL PROCESSES

3.1 Ocean water levels

When considering the processes that shape shorelines it is necessary to consider the ocean water levels that prevail from time to time. This appreciation not only relates to the day-to-day tidal influences, but also to the storm surges which occur as a result of extreme weather conditions. The expected impacts of climate change on sea levels also need to be considered.

As ocean waves propagate shoreward into shallower water, they begin to "feel" the seabed. The decreasing depths cause the waves to change direction so as to become aligned to the seabed contours and to also shoal up in height until such time as they may break - dissipating their energy as they do so. Just how much wave energy reaches the shoreline is therefore determined largely by the depth of water over the seabed approaches. Ocean water levels and the seabed bathymetry are important aspects in this process of wave energy transmission.

Consequently, it is necessary to have a thorough understanding of the following ocean levels on local foreshores:

- *Astronomical tides* - this is the "normal" rising and falling of the oceans in response to the gravitational influences of the moon, sun and other astronomical bodies. These effects are predictable and consequently the astronomical tide levels can be forecast with confidence.
- *Storm tides* - this is the combined action of the astronomical tide and any storm surge that also happens to be prevailing at the time. Surge is the rise above normal water level as a consequence of surface wind stress and atmospheric pressure fluctuations induced by severe synoptic events (such as tropical cyclones).

3.1.1 Astronomical tides

The tidal rising and falling of the oceans is in response to the gravitational influences of the moon, sun and other astronomical bodies. Whilst being complex, these effects are nevertheless predictable, and consequently past and future astronomical tide levels can be forecast with confidence at many coastal locations. Tidal planes have been published for various locations within the study area. As an example of the tidal information available at locations within the study area, the tidal planes for Woodgate Beach at Theodolite Creek (DTMR, 2018) are summarised in Table 3-1.

TABLE 3-1 TIDAL PLANES AT WOODGATE BEACH, THEODOLITE CREEK (2018)

Tidal Plane	to AHD	to Chart Datum
Highest Astronomical Tide (HAT)	2.12 m	3.89 m
Mean High Water Springs (MHWS)	1.29 m	3.06 m
Mean High Water Neaps (MHWN)	0.67 m	2.44 m
Mean Sea Level (MSL)	0.01 m	1.78 m
Mean Low Water Neaps (MLWN)	-0.56 m	1.21 m
Mean Low Water Springs (MLWS)	-1.18 m	0.59 m
Lowest Astronomical Tide (LAT)	-1.77 m	0.00 m

5057-03-R01

In a lunar month, the highest tides occur at the time of the new moon and the full moon (when the gravitational forces of sun and moon are in alignment). These are called *spring* tides and they occur approximately every 14 days. Conversely *neap* tides occur when the gravitational influences of the sun and moon are not aligned, resulting in high and low tides that are not as extreme as those during spring tides.

For example, it can be seen in Table 3-1, that the maximum possible astronomical tidal range at Woodgate Beach is 3.89 m, with an average range during spring tides of 2.47 m and 1.23 m during neap tides.

Spring tides tend to be higher than normal around the time of the Christmas / New Year period (i.e. December - February); and in mid-year (i.e. around May - July). The various occurrences of particularly high spring tides are often referred to in lay terms as *king tides* - in popular terminology meaning any high tide well above average height.

The widespread notion is that king tides are the very high tides which occur around Christmas or in the New Year. However, equally high tides occur in the winter months, but these are typically at night and therefore are not as apparent as those during the summer holiday period - which generally occur during daylight hours.

Since tidal predictions are computed based on astronomical influences only, they inherently discount any meteorological effects that can also influence ocean water levels from time to time. When meteorological conditions vary from the average, they can cause a difference between the predicted tide and the actual tide. This occurs within the Hervey Bay region to varying degrees. The deviations from predicted astronomical tidal heights are primarily caused by strong or prolonged winds, and/or by uncharacteristically high or low barometric pressures.

Differences between the predicted and actual times of low and high water are primarily caused by wind. A strong wind blowing directly onshore will “pile up” the water and cause tides to be higher than predicted, while winds blowing off the land can have the reverse effect. Clearly the occurrence of storm surges associated with severe storms and cyclones can significantly influence ocean water levels.

3.1.2 Storm tides

The level to which ocean water can rise on a foreshore during the passage of an extreme storm event or a cyclone is typically a result of several different effects. The combination of these various effects is known as *storm tide*. Figure 3-1 illustrates the primary water level components of a storm tide event. A brief discussion of each of these various components is offered below.

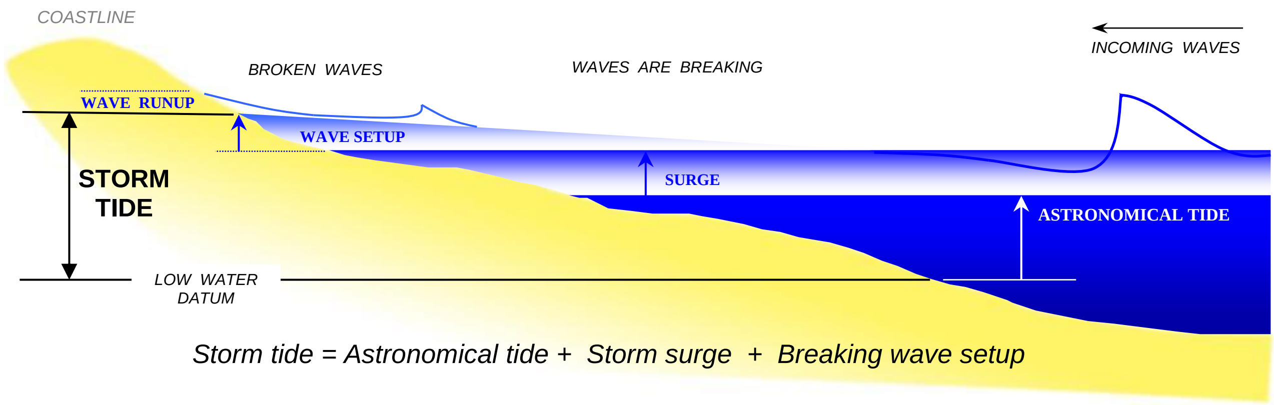


FIGURE 3-1 COMPONENTS OF A STORM TIDE EVENT

5057-03-R01

As discussed previously, the astronomical tide is the normal day-to-day rising and falling of ocean waters in response to the gravitational influences of the sun and the moon. The astronomical tide can be predicted with considerable accuracy. Astronomical tide is an important component of the overall storm tide because if the peak of the storm were to coincide with a high spring tide for instance, severe flooding of low lying coastal areas can occur and the upper sections of coastal structures can be subjected to severe wave action.

Storm surge is the increase in the ocean water level is caused by the severe atmospheric pressure gradients and the high wind shear induced on the surface of the ocean by a severe storm or tropical cyclone. The magnitude of the surge is dependent upon several factors such as the intensity of the storm, its overall physical size, the speed at which it moves, and if associated with a cyclone - the direction of its approach to the coast, as well as the specific bathymetry of the coastal regions affected. To predict the height of storm surges, these various influences and their complex interaction are typically replicated by numerical modelling techniques using computers.

The strong winds associated with severe storms generate waves which themselves can be quite severe. As these waves propagate into shallower coastal waters, they begin to shoal and will break as they encounter the nearshore region. The dissipation of wave energy during the wave breaking process induces a localised increase in the ocean water level shoreward of the breaking point which is called breaking wave setup. Through the continued action of many breaking waves, the setup experienced on a foreshore during a severe wave event can be sustained for a significant timeframe and needs to be considered as an important component of the overall storm tide on a foreshore.

Wave runup is the vertical height above the local water level up to which incoming waves will rush when they encounter the land/sea interface. The level to which waves will run up a structure (or a natural foreshore) depends significantly on the nature, slope and extent of the land boundary, as well as the characteristics of the incident waves. For example, the wave runup on a gently sloping beach is quite different to that of say a near-vertical concrete seawall. Since this component is very dependent upon the local foreshore type, it is not normally incorporated into the determination of the storm tide height. Nevertheless, it needs to be considered separately during the assessment of the storm tide vulnerability of foreshores.

3.1.2.1 Existing information

The Phase 2 – Scoping Study undertaken previously as part of the Bundaberg Region CHAS, identified a number of available reports detailing storm tide levels appropriate for the Bundaberg Region. These reports are summarised in Table 3-2.

TABLE 3-2 AVAILABLE REPORTS

Title	Summary	Relevance
Bundaberg Coastal Storm Tide Study – BMT WBM 2013	A detailed technical assessment of cyclonic storm tide inundation for the Bundaberg region. The study involved development of a detailed numerical modelling system to simulate tropical cyclone generated storm surge events. Storm tide estimates provided for events from 5% AEP to 0.01% AEP for existing mean sea level and for a climate change scenario assuming +0.8m sea level rise and a 10% increase in maximum cyclone intensity. Coincident riverine flooding in the Bundaberg River was analysed but does not appear to have been included in developing the final design storm tide estimates.	Provides the most update to date information for local scale coastal inundation hazard and adaptation assessments. The work meets many of the requirements of the minimum standards regarding coastal inundation.
Bundaberg Storm Tide Adaptation Project Review of Storm Tide Inundation Studies – Griffith University 2016	The report is a technical review of the BMT WBM (2013) and GHD (2014) analyses to address an issue with conflicting storm tide heights at two residential Bundaberg sites.	The review concludes that the storm tide levels reported in the NDRP study (see above) are likely to be unreliable. The overall conclusion is that the BMT WBM report provides more accurate estimation of storm tide levels at Bundaberg based on current practice.
Hervey Bay Beaches – a detailed study of coastline behaviour along the mainland beaches of Hervey Bay, South-east, Queensland, Australia – Queensland Beach Protection Authority, 1989a	Storm Tide Inundation (Section 7.4) A numerical modelling study was undertaken to establish extreme coastal water levels for 14 locations along the coastline from Gladstone to Inskip Point. The report also provides wave setup and run-up estimates along the same coastline. No sea level rise simulations were included	The storm tide estimates along the coastline between Baffle Creek and Burrum Heads (Table 7.7) can be compared directly to those in Table 4-3 of the (2013) storm tide study. For all locations, the storm tide estimates in this study exceed the (2013) values by between 0.4 to 0.7m for the 1% AEP event. This has implications for the cyclone related erosion calculated as part of the erosion prone area width determination. The adopted storm tide levels used for the calculations (detailed in Table 11.4) corresponds to approximately the 1% AEP values from this study.

5057-03-R01

Title	Summary	Relevance
Department of Science, Information Technology, Innovation and the Arts, NDRP Storm Tide Hazard Interpolation Study Report, GHD, 2014	This study uses existing local storm tide studies to prepare a state wide storm tide dataset for the 20, 50, 100, 200, 500, 1,000 and 10,000 year ARI event as well as the Theoretical Maximum Storm Tide (TMST).	Provides the most update to date information for local scale coastal inundation hazard and adaptation assessments for the required return periods. The work meets many of the requirements of the minimum standards regarding coastal inundation.

The existing storm tide study for the Bundaberg Region (BMT WBM, 2013) only addressed the effect of cyclonic conditions, and it was not within the scope to consider non-cyclonic storm surge events. The earlier study (BPA, 1989a) also evaluated storm surge events on the Bundaberg Region coastline, reporting levels significantly higher than those determined by the 2013 study. It was noted in the 2013 study that for some locations within the study area, the predicted peak 1% AEP cyclonic storm tide level was below HAT, indicating that non-cyclonic storm events are likely to produce more extreme water levels for more frequent events. The implication is that the storm tide level results from the WBM study only apply for cyclonic events > 1%AEP.

For the purposes of the CHAS more frequent events are required (e.g. the 10%, 5%, 2% and 1% AEP event). Therefore, the NDRP Storm Tide Hazard Interpolation Series from the Queensland Government (GHD, 2014) has been adopted for the purpose of the CHAS. The storm tide levels for the key study locations including wave setup and excluding wave runup are presented in Table 3-3 below.

TABLE 3-3 STORM TIDE AEPS INCLUDING WAVE SETUP

AEP %	Moore Park Beach (mAHD)	Bargara (mAHD)	Innes Park (mAHD)	Coonarr (mAHD)	Woodgate Beach North (mAHD)	Woodgate Beach Central (mAHD)	Woodgate Beach South (mAHD)
5	2.22	2.24	2.25	2.28	2.22	2.26	2.36
2	2.30	2.33	2.34	2.36	2.30	2.31	2.45
1	2.75	2.60	2.48	2.49	2.38	2.37	2.55

The NDRP dataset does not include levels for the 10% AEP event, which can therefore not be used in later phases of the CHAS.

3.2 Wind climate

The wind climate around the Bundaberg Region study area is measured by the Bureau of Meteorology (BoM) at the following locations:

- Lady Elliott Island (039059) located 80km off the coastline in the northern study area;
- Bundaberg Airport (039128) 15km inland from the coastline;
- Sandy Cape Lighthouse (039085) located at the northern end of Fraser Island which is 80km from the Bundaberg coast;
- Cato Island (20061) located 365km offshore;
- Seventeen Seventy (039314) located at the extreme Northern end of the study area (outside the study area); and

- Hervey Bay Airport (04045), at the southern end of the study area (outside of the study area).

A summary of the available data at each location is shown in Table 3-4 below.

TABLE 3-4 AVAILABLE WIND DATA SUMMARY

Wind Gauge	Data Resolution	Date Available
Lady Elliott Island (039059)	9:00am and 3:00pm Observations	1957 - 1987
	3-hourly Observations	1987 – 2015
	Continuous (received at one hourly timesteps)	2015 - 2018
Bundaberg Airport (039128)	3 Hourly Observations	1942 – 2014 (Significant data gaps 1946-1959, 1971-1990)
	Continuous (received at one hourly timesteps)	2014 - 2018
Sandy Cape Lighthouse (039085)	9:00am and 3:00pm Observations	1957 - 1986
	3 Hourly Observations	1986 - 2018
Cato Island (20061)	3 Hourly Observations	1971 - 1990
	Continuous (received at one hourly timesteps)	1990 - 2018
Seventeen Seventy (039314)	3 Hourly Observations	1986 – 2015
	Daily Observations	2015 – 2018
Hervey Bay Airport (04045)	3 Hourly Observations	1999 - 2014
	Continuous (received at one hourly timesteps)	2014 - 2018

The data from the Lady Elliott Island gauge is considered to be most representative of the conditions which generate waves within Hervey Bay and along the Greater Bundaberg coastline. The Bundaberg Airport and Hervey Bay Airport gauges, whilst located close the study area, are significantly impacted by topographic features and the interaction of sea and land temperatures on wind conditions during the morning and evening.

The Seventeen Seventy gauge is located close to the coastline and is also thought to represent wave-generating open water conditions. However, it has a shorter record than the Lady Elliott Island gauge and has decreased from a 3-hourly resolution to daily readings since 2015. Sandy Cape Lighthouse appears to be in a reasonable location on Fraser Island. However, the record contains several major data gaps and sparse readings at times. Cato Island is thought to be another high-quality wind dataset. However, it is in a much more exposed location than what is typical of conditions in Hervey Bay and immediately offshore of the Bundaberg Region coastline. Consequently, the data displays more extreme wind speeds. For these reasons, Lady Elliott Island gauge was selected to use in the modelling of wind generated waves at the site.

The wind climate representing the full 61-year dataset is shown in Figure 3-2. The wind climate is dominated by winds from the south-east quadrant. Wind speeds are generally below 10m/s with strongest winds from the south-east. There is also a significant fraction of northerly winds, whilst the south-west quadrant and north-east quadrant winds are rare.

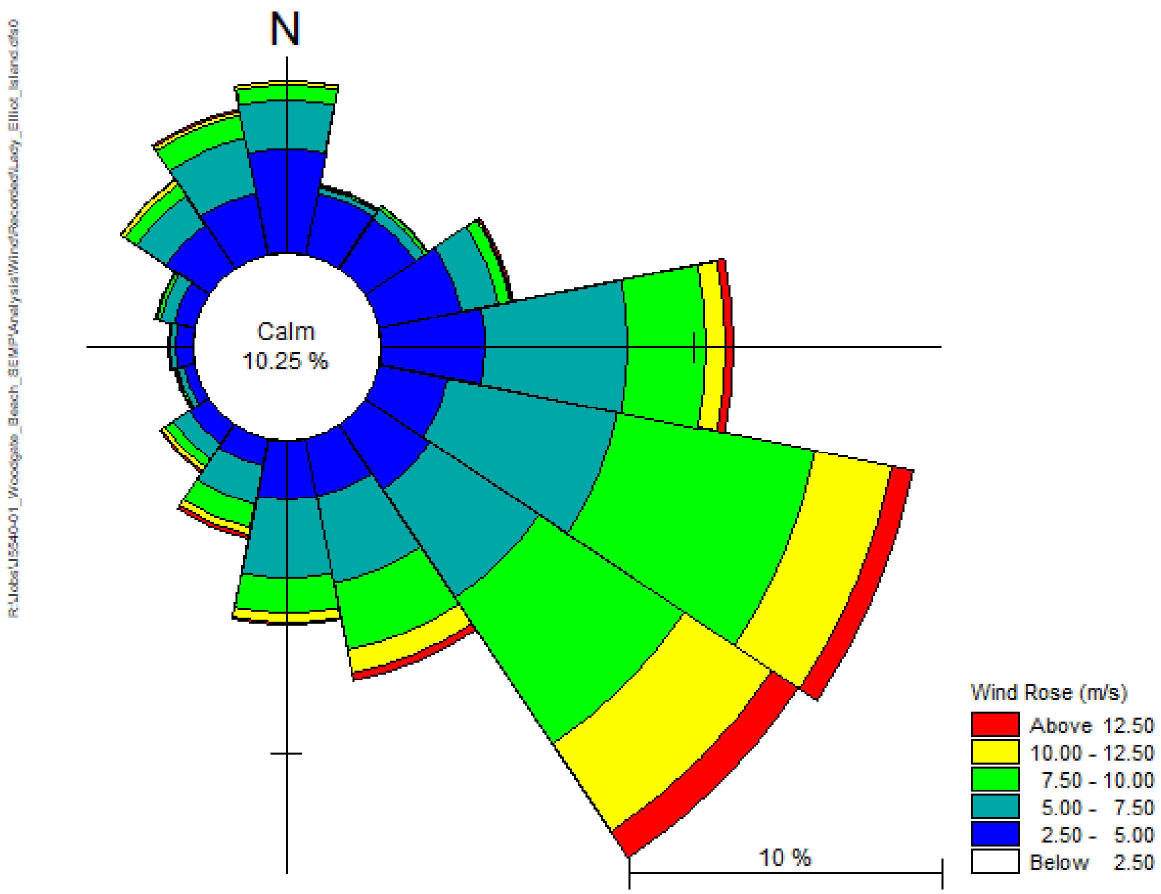


FIGURE 3-2 WIND CLIMATE LADY ELLIOTT ISLAND GAUGE

3.3 Wave climate

The wave climate in the study area consists of two significant sources;

- Fetch limited wind-waves, only generated by local winds blowing across Hervey Bay, and
- Waves generated in the open ocean that propagate from the Coral Sea, over the southern Great Barrier Reef and around the northern tip of Fraser Island.

The southern extent of the Bundaberg Region (and most of Hervey Bay) is partially protected by Fraser Island from south-east swell waves generated in the Coral Sea. This protection is reduced towards the northern end of the study area, with the coastline from Moore Park Beach northwards being exposed to easterly swells. However, Fraser Island still blocks the predominate south-easterly swells. The Bundaberg Region coastline is also afforded some protection from north-easterly swells by the Southern Great Barrier Reef.

Whilst Fraser Island limits the fetch for easterly and south-easterly wind-generated waves within Hervey Bay, there is nevertheless a 40 km to 60 km fetch capable of generating substantial waves.

5057-03-R01

Both wave sources were evaluated using spectral wave modelling, as described below.

3.3.1 Wind generated waves

To transform offshore wave conditions to the Bundaberg Region coastline and to generate wind waves in Hervey Bay, a spectral wave model (including Hervey Bay, the southern Great Barrier Reef and the entire Bundaberg Region coastline) was developed for this study. DHI's proprietary Spectral Wave modelling software was used for this analysis.

The model is a flexible mesh model which allows for a varying grid resolution across the model domain. In the area offshore, the model resolution is in the order of 30 km^2. The resolution is refined as proximity to the coastline decreases and the mesh resolution offshore of Bundaberg Region coastline is around 5000 m^2 – or a side length of 100 m. This model has been calibrated to wave data measured by the Bundaberg Waverider Buoy located off Burnett Heads. Wave direction could not be calibrated because the wave buoy did not measure wave directions.

Offshore bathymetric data for modelling purposes was determined through a combination of Marine and Safety Queensland soundings, supplemented by Coral Sea 100-metre bathymetry obtained from the Commonwealth of Australia (2010). The digital elevation model (DEM) of the model domain is presented in Figure 3-3.

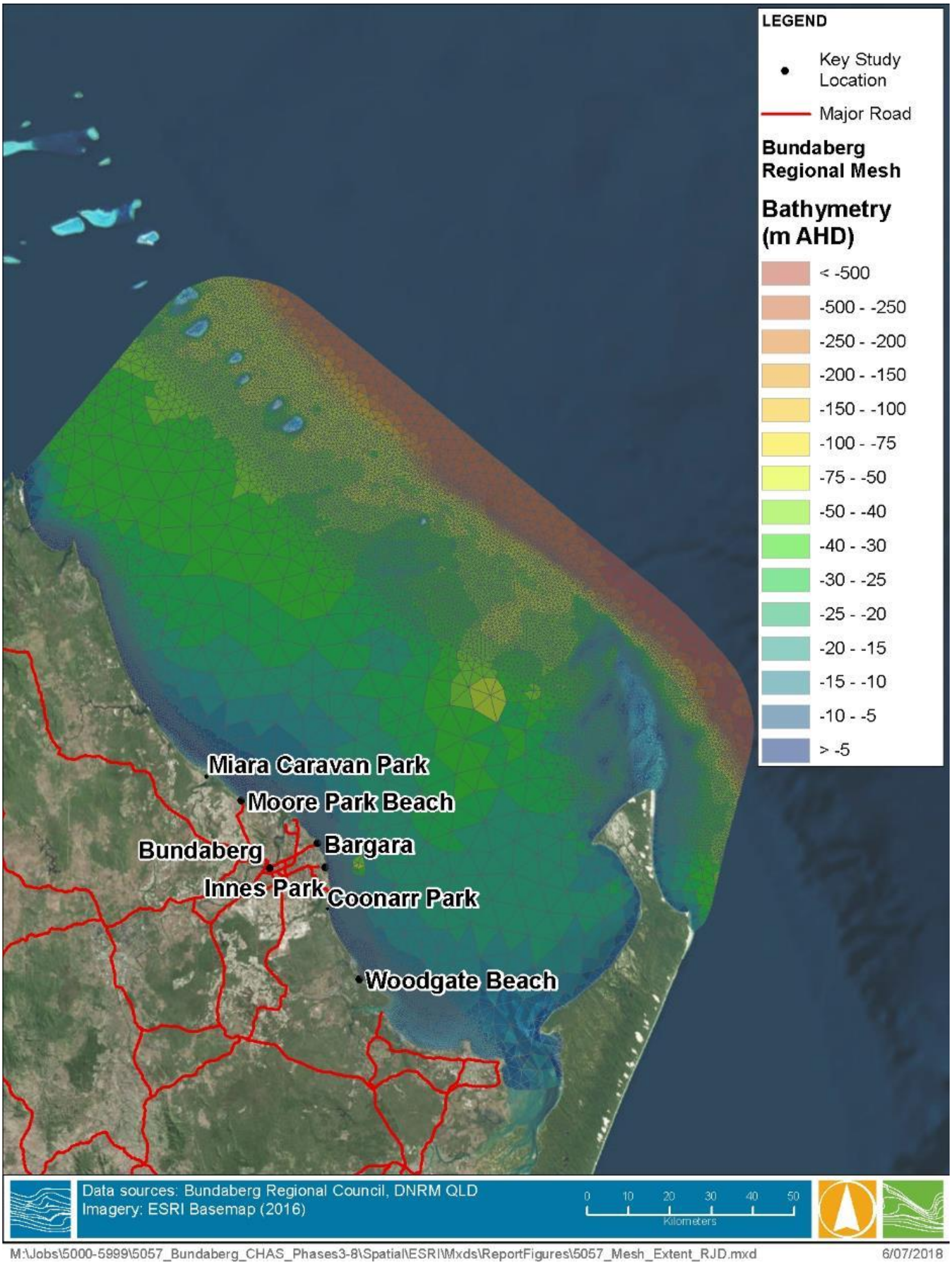


FIGURE 3-3 SPECTRAL WAVE MODEL BATHYMETRY AND MESH RESOLUTION

The significant wave heights[1] and periods generated by the model follow measured values very closely. An example of this close correlation is shown in Figure 3-4 for the period of November 2015 to January 2016.

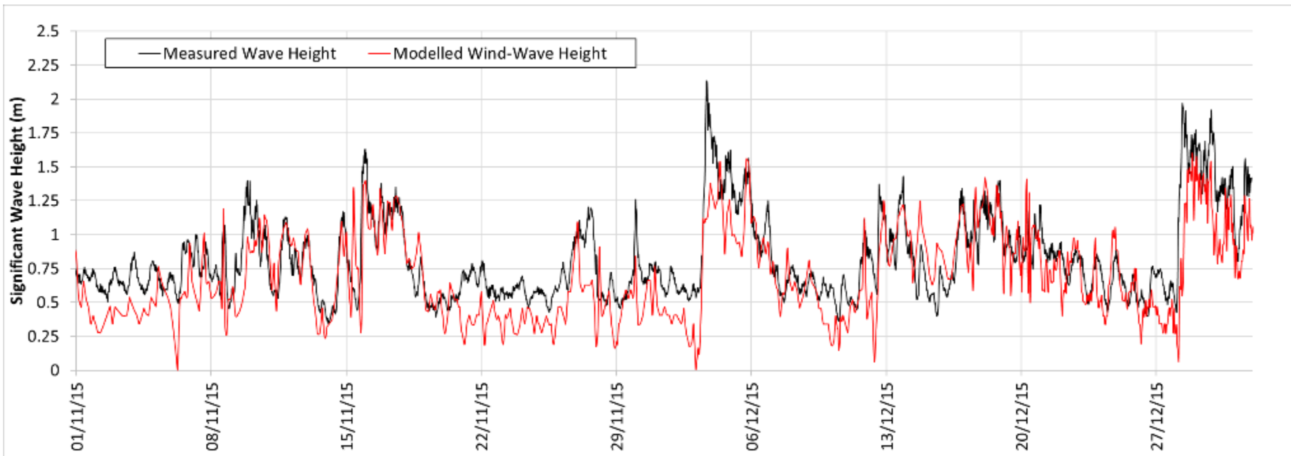


FIGURE 3-4 EXAMPLE WAVE HEIGHT CALIBRATION

The spectral wave model was developed to capture refraction and shoaling of waves as they approach the study area. Wind data measured at Lady Elliott Island (1959 – 2018), discussed in Section 3.2, was used to generate a wave climate for the last 59 years across the study area. The annual wave climate was extracted at a number of key locations along the Bundaberg coastline, namely; Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach. Wave extractions were taken in 8 m depth of water directly offshore of these locations. Wave conditions along the study site in the offshore waters do not vary considerably from this.

The wind climate is reflected in the wind-wave climate presented in Figure 3-5, with waves from the south-east through to east-northeast heavily represented. Wind-waves from the south-east are not as dominant as the wind climate would suggest, due to the limited fetch across Hervey Bay to the south-east. The restricted south-east fetch results in a high percentage of larger waves (>0.5m) from the east and east-northeast. There is also a significant fraction of waves from the direct north, and this direction is more heavily represented in the wind-wave climate compared to the wind climate. This is due to the significant northerly fetch out to the Coral Sea.

[1] Due to the random nature and size of waves in the ocean, the term *significant wave height* is used by engineers and scientists as a wave height representative of the sea state. It represents the average of all of the third-highest waves that occur over a particular time frame. As this is a statistical representation, there can be individual waves much higher than this occurring within the sea state.

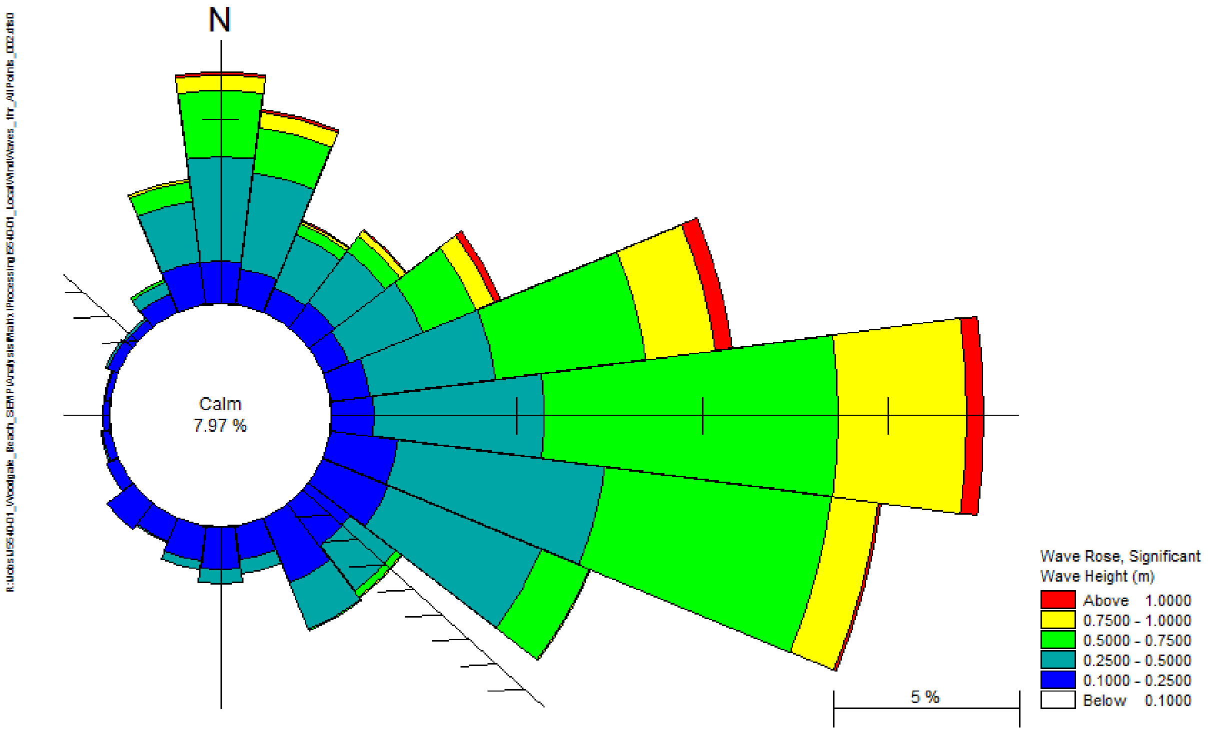


FIGURE 3-5 WOODGATE BEACH WAVE CLIMATE – WIND GENERATED WAVES ONLY

3.3.2 Offshore-generated waves

Wave conditions have been established offshore of Hervey Bay and the Bundaberg Region using data extracted from the NOAA Wave Watch 3 (WW3) global reanalysis. The global reanalysis includes higher resolution modelling around the coast of Australia over the period of 1979 through to 2018. This model has been extensively validated with buoy and satellite information and has been found in previous studies to provide a very reliable description of deep water wave conditions.

Modelled wave data was extracted at the Coral Sea model boundaries of the spectral wave model. The resolution of the global model around the Australian coastline is 1/15th of a degree, or approximately 6 km east-west by 7.5 km north-south. Data has been extracted offshore to allow more detailed modelling to transform these wave conditions inshore using a higher resolution model as described above. The wave conditions extracted at the offshore model boundary are presented in Figure 3-6. This wave rose indicates that offshore wave conditions are almost always from the east to south-east direction, which is the dominant swell direction off Queensland's southern coastline. The strongest waves are also from these dominant directions, with maximum waves heights over 9 m predicted by the model. Generally, wave conditions are moderate, with an average height of over 1.5 m.

The wave periods for all waves are generally high, with periods typically in the 8.0 to 12.0 second range. The peak wave period for extreme wave heights greater than 6 m is typically 11 seconds. Long period waves, generated by distant storms, coincide with much smaller waves and wave periods in excess of 15 seconds are limited to wave heights of 2 m. The highest wave periods are above 19 seconds; however these are associated with waves of less than 2 m in height.

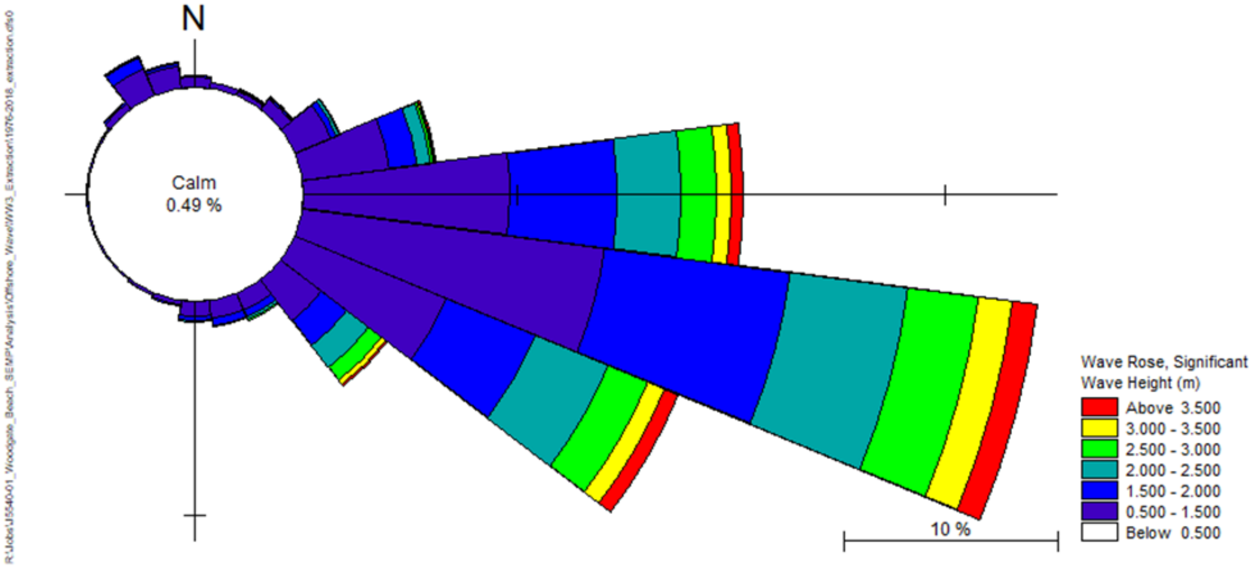


FIGURE 3-6 OFFSHORE WAVE CONDITIONS INPUT

Whilst the offshore conditions show a predominately south-east through to east large wave climate, throughout the Bundaberg Region study area most of these waves are significantly modified or blocked by Fraser Island (and to some extent also by the Southern Great Barrier Reef) as they propagate shoreward. The spectral wave model was used to translate these waves from offshore to 8 m depth of water at the critical locations of Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach.

An example of the wave transformation process is presented in Figure 3-7 for Woodgate Beach. As expected it shows a significantly milder wave climate than offshore conditions. Woodgate Beach is only exposed to a narrow band of small swell waves from the north-east, typically in the 0.1m – 0.5m wave height range. Other inshore locations show similar characteristics.

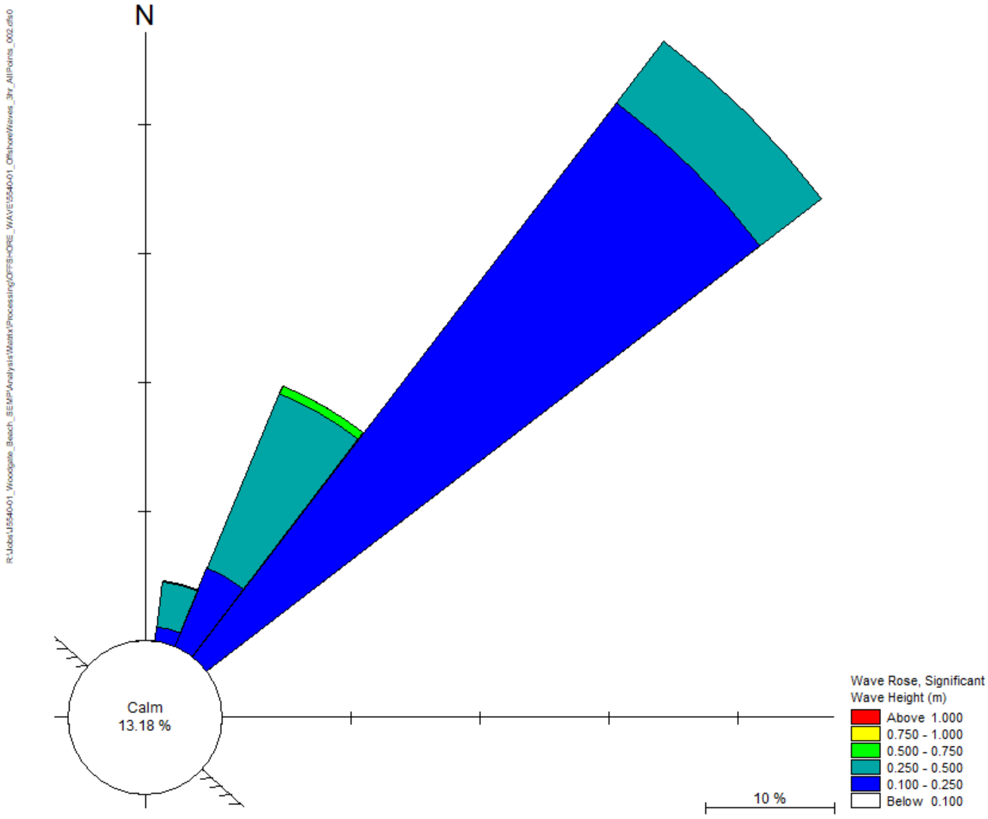


FIGURE 3-7 OFFSHORE WAVES REACHING WOODGATE BEACH

3.3.3 Summary

As the wave climate is a combination of both offshore and locally generated waves, the results of the offshore and local extreme value analysis were combined to determine a representative wave climate at the various investigation sites. The resulting significant wave heights are shown in Table 3-5.

TABLE 3-5 SIGNIFICANT WAVE HEIGHT AEP FOR KEY STUDY LOCATIONS

AEP %	Moore Park Beach Hs (m)	Bargara Hs (m)	Innes Park Hs(m)	Coonarr Hs (m)	Woodgate Beach Hs (m)
10	3.03	3.41	3.53	2.84	2.56
5	3.24	3.63	3.78	3.01	2.77
2	3.51	3.92	4.1	3.2	2.96

The wave period utilised within the modelling was consistent across all sites and storm AEP's, with a value of 10 seconds. This value was adopted since BPA (1989b) wave data recording program suggested major meteorological events in Bundaberg between 1977 and 1988 had a maximum period of approximately 10 seconds, with Cyclone Freda recording a 10.06 second peak period in 1981 as the largest storm event occurring between 1979 and 1988.

5057-03-R01

3.4 Sediment transport

A comprehensive data collection program was taken to inform the Hervey Bay Beaches Report (Beach Protection Authority, 1989a), seeking to characterise the currents likely to cause sediment movements and affect beach processes. The principal findings were:

- Tidal currents:
  - Outside the surf zone, currents south of the Burnett River are tidal with a slight dominance of flood currents over ebb currents.
  - Well offshore, tidal currents are almost perpendicular to the coast while nearer inshore they change direction and velocities reduce in magnitude.
  - Tidal currents are generally larger to the south, decreasing steadily moving northwards. The Burrum River concentrates local tidal flows, causing larger than average velocities at the entrance.
- Wind induced currents:
  - Wind induced currents obscure tide reversals seaward of the surf zone between the Kolan and Burnett Rivers.
- Storm/cyclone induced currents:
  - No data was collected under storm or cyclone conditions. However, it is expected that such events will produced significant currents across the area with the magnitude and directions of these currents similar to those measured under less severe conditions between the Kolan and Burnett Rivers.

Two main mechanisms exist for the transport of fluvial (river) and coastal sediments within the Bundaberg Region. These are:

- The combined action of waves and currents (wind and tidal) acting on the seabed to mobilise sediment. This process can generate both longshore and cross-shore sediment transport.
- Large scale short term transport during flood in the form of sediment laden density currents, which can travel great distances along the coast driven by the discharge from the various flooding rivers and creeks.

3.4.1 Sediment sources

Extensive geological investigations (Stephens, et.al. 1988) have identified that sand is primarily supplied to the beaches throughout Hervey Bay from two major sources, namely:

- Fluvial supply from the Mary and Burnett Rivers - other watercourses such as the Kolan, Elliott and Burrum Rivers, and Beelbi and Theodolite Creeks have limited catchments and are not significant sources of sand supply to the beaches of Hervey Bay.
- Sand that is moved off the continental shelf by wave action, in conjunction with wind-induced currents and tidal currents.

A conceptual representation of these processes is offered in Figure 3-8. This figure has been reproduced from the Hervey Bay Beaches report (Beach Protection Authority, 1989a).

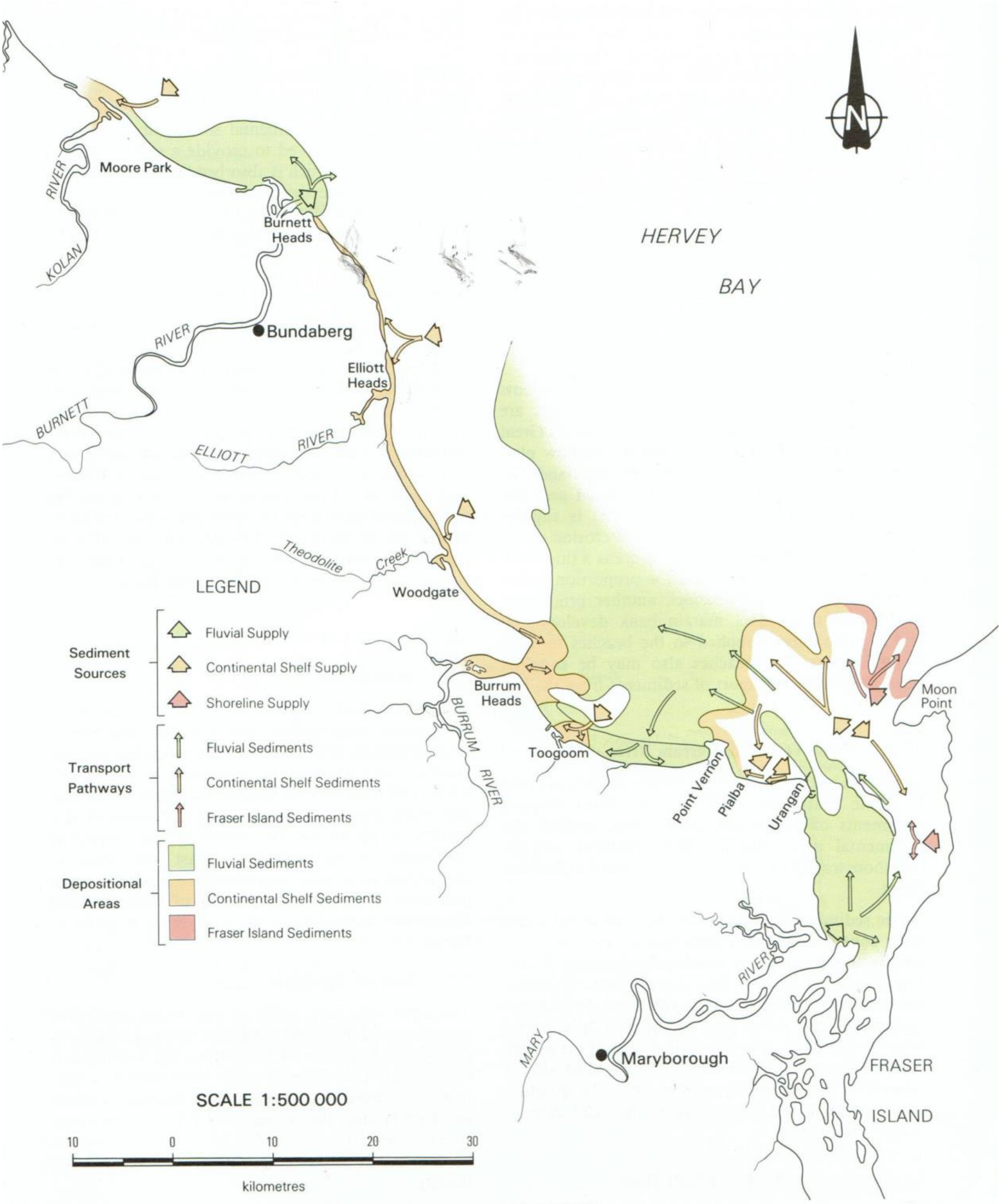


FIGURE 3-8 SEDIMENT SUPPLY PATHWAYS IN HERVEY BAY2

[2] This Figure 3-8 has been substantially reproduced from Figure 3.5 page 33 of the *Hervey Bay Beaches* report (Beach Protection Authority, 1989)

Fluvial Supply

Mary River

Sediments supplied by the Mary River are delivered to Great Sandy Strait, from where strong tidal currents sweep them northwards into the southern-most regions of Hervey Bay. The transport of these fluvial sediments by tidal currents in the Strait is as bedload (i.e. swept along the seabed) and as suspended load (i.e. entrained and kept in suspension above the seabed as they are swept along).

As the physical constraints of tidal channels within the Strait broaden, the tidal currents decrease in strength - resulting in fluvial sediments being deposited on the seabed. Subsequent wave action reworks the finer sand fractions of this fluvial deposit shoreward, reaching the beaches and nearshore areas between Port Vernon and Burrum Heads. Coarser sand fractions accumulate more broadly across the seabed as a fan-shaped deposit extending northwards within Hervey Bay, contributing to the sediments of the continental shelf.

Burnett River

Sediments delivered to the coast by the Burnett River are worked by both wave energy and by tidal currents. Due to its exposed location in the northern part of Hervey Bay (near the Bay's confluence with the open ocean), it is waves that play the dominant role in transporting this fluvial sand. The predominant east and southeast wave climate means that most of the sand delivered by the Burnett River moves alongshore towards the northwest. Consequently, most of the sands on the beaches to the north of the Burnett River are derived from the river itself. Only a small portion of Burnett River sand moves southward and is restricted to those beaches immediately south of the river entrance.

Burrum River

As noted in discussions above, the Burrum River is not considered to be a significant source of sand for Hervey Bay beaches. However, some comment is warranted due to the proximity of this river entrance to the foreshores of Woodgate Beach. The large sand shoals at the entrance are part of the ebb-tide delta of the estuary. This delta comprises fine- to medium-grained, quartzite sands derived primarily from the Mary River catchment, not from the catchment of the Burrum River. These sediments have subsequently been transported by waves onshore off the continental shelf within Hervey Bay; and delivered to the tidal currents near Burrum Point by littoral drift.

The entrance shoals have therefore been primarily formed by waves and currents working sediments off the continental shelf, not by fluvial supply from the Burrum River. Nevertheless, wave energy along with flood and tidal flows at the mouth of the Burrum River play a significant role in shaping these shoals and influencing their interaction with nearby sand foreshores.

Continental Shelf Supply

The continental shelf within Hervey Bay supplies littoral sediments in two quite different ways. In the Great Sandy Strait, sand has been reworked primarily by tidal currents to form a fan-shaped tidal delta prograding northwards into Hervey Bay. By contrast, the continental shelf north of around Burrum Heads experiences greater wave energy, which transports sand shoreward - where it is redistributed along the beach as littoral drift. As noted above, sand derived from the continental shelf has become incorporated into the tidal delta at the entrance to the Burrum River.

This trend for onshore transport of sand off the continental shelf continues northwards – to at least as far as the Kolan River (Beach Protection Authority, 1989a).

3.4.2 Sediment Supply Pathways in Hervey Bay

Based on the above consideration of regional sand sources, general trends regarding pathways for the supply of sand to the beaches of Hervey Bay can be summarised as follows:

1. The beaches between Urangan and Burrum Heads are supplied with a combination of sand derived from the Mary River and sand that has been moved onshore from the continental shelf within Hervey Bay.
2. North of the Burrum River to a location just south of the Burnett River, the beaches are predominantly supplied with sand from the continental shelf. This includes the foreshores of the Woodgate SEMP study area.
3. The beaches north of the Burnett River comprise of sand supplied by the Burnett River itself, with some minor contribution from the adjacent continental shelf.

Once sand is moved by these littoral pathways into the active beach systems along the western shores of Hervey Bay, it is then moved by longshore drift processes that are driven by wave action. Cross-shore transport also occurs, which under some conditions acts to increase the volume of sand on local beaches, but at times sand can be rapidly eroded off local beaches – typically during storm/cyclone events.

The various sediment sources, transport pathways and depositional areas throughout Hervey Bay are shown conceptually on Figure 3-8.

4 STORM TIDE INUNDATION

4.1 Introduction

Storm tide inundation mapping for the Bundaberg Region is currently available for present-day climate conditions and for a single storm tide event having 1% AEP; and for a single future sea level rise of +0.8 m. To date, more frequent tidal inundation events have not been mapped. The resolution of the underlying terrain data which was used to previously map storm tide levels was also less than required under the Minimum Standards and Guideline developed for the QCoast$_{2100}$ program.

To support the development of the CHAS and inform the understanding of the likely storm tide inundation hazard, the following approach has been adopted:

- Review of new terrain data for the study area (detailed in Section 2.1),
- Review of storm tide levels (detailed in Section 3.1.2),
- Estimation of storm tide levels associated with more frequent (>1% AEP) events (namely 10%, 5%, 2% AEPs) (detailed in Section 3.1.2),
- Generation of storm tide levels for future conditions (+0.2m, +0.4m, +0.8m)
- Revised mapping of storm tide inundation extents (including wave setup),
- Mapping of HAT across the Bundaberg Region study area under current and future sea level conditions (+0.2m, +0.4m, +0.8m)

4.2 Storm tide inundation mapping

The storm tide inundation mapping was undertaken using the existing Queensland Government, NDRP Storm Tide Hazard Interpolation Series (GHD, 2014).

Mapping has been applied based on the 1m-resolution 2016 LiDAR surface (rather than the previous 5m resolution) to produce a more accurate map of the inundation extents and depths. An example map comparing the previous 1% AEP mapping, produced at 5m-resolution, with the current 1% AEP mapping produced at the much improved 1m-resolution is presented in Figure 4-1.

Storm tide Inundation maps have been prepared for the 1% AEP storm tide event and for future climate scenario (+0.8m of sea level rise). The mapping includes the effects of wave setup. The storm tide inundation mapping can be accessed via the mapping portal. An example of the mapping is shown in Figure 4-2 for Woodgate Beach.

Erosion prone area maps have been prepared for the 1% AEP event inclusive of 0.8m sea level rise An example of the mapping is shown in Figure 4 2 for Woodgate Beach.

Additional mapping for the full range of AEP events and sea level rise scenarios will be prepared during later phases of the CHAS as required to fully understand the coastal hazard impacts and inform the risk assessment.

.

5057-03-R01

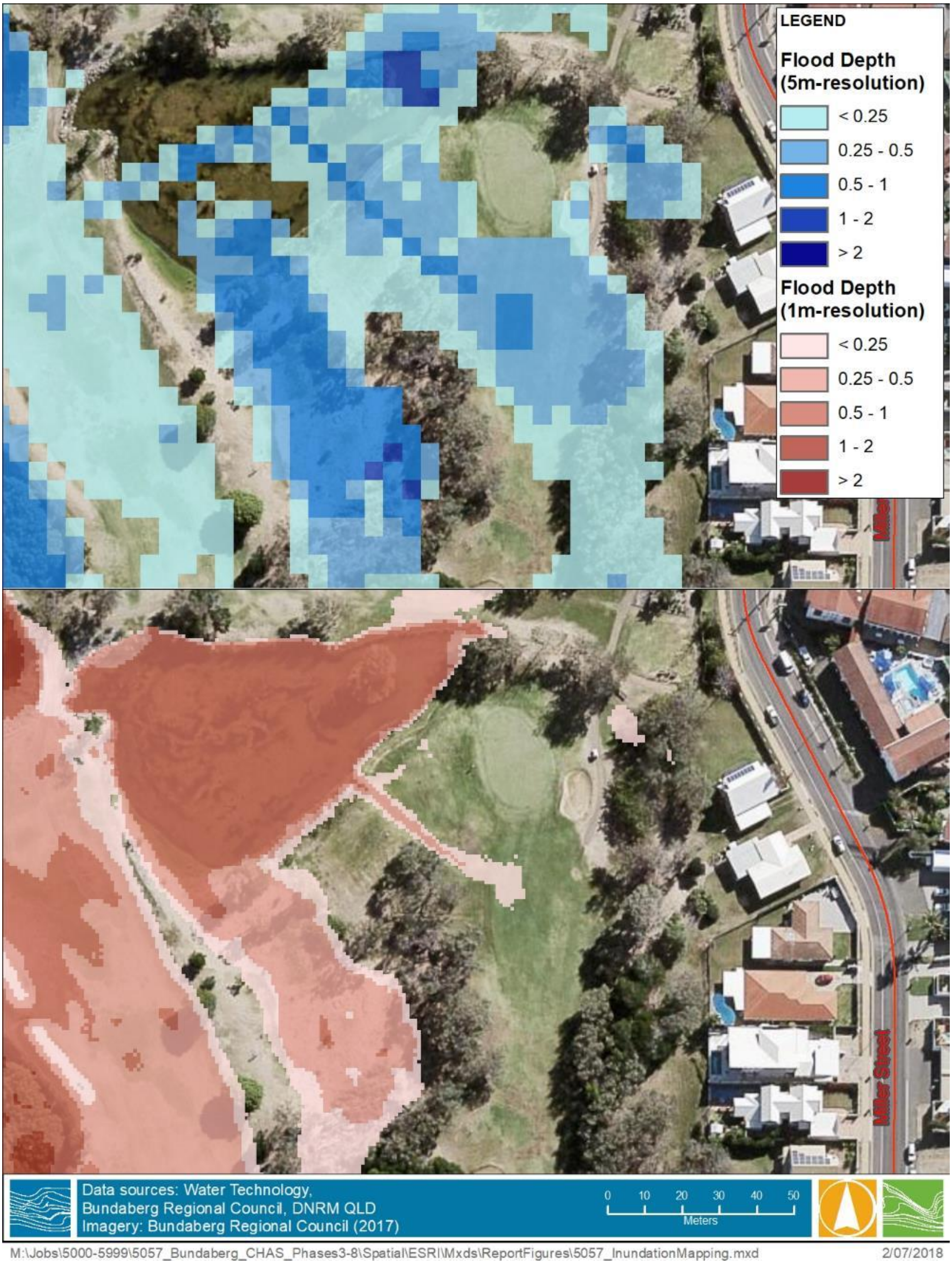


FIGURE 4-1 COMPARISON OF 5M AND 1M-RESOLUTION INUNDATION MAPPING

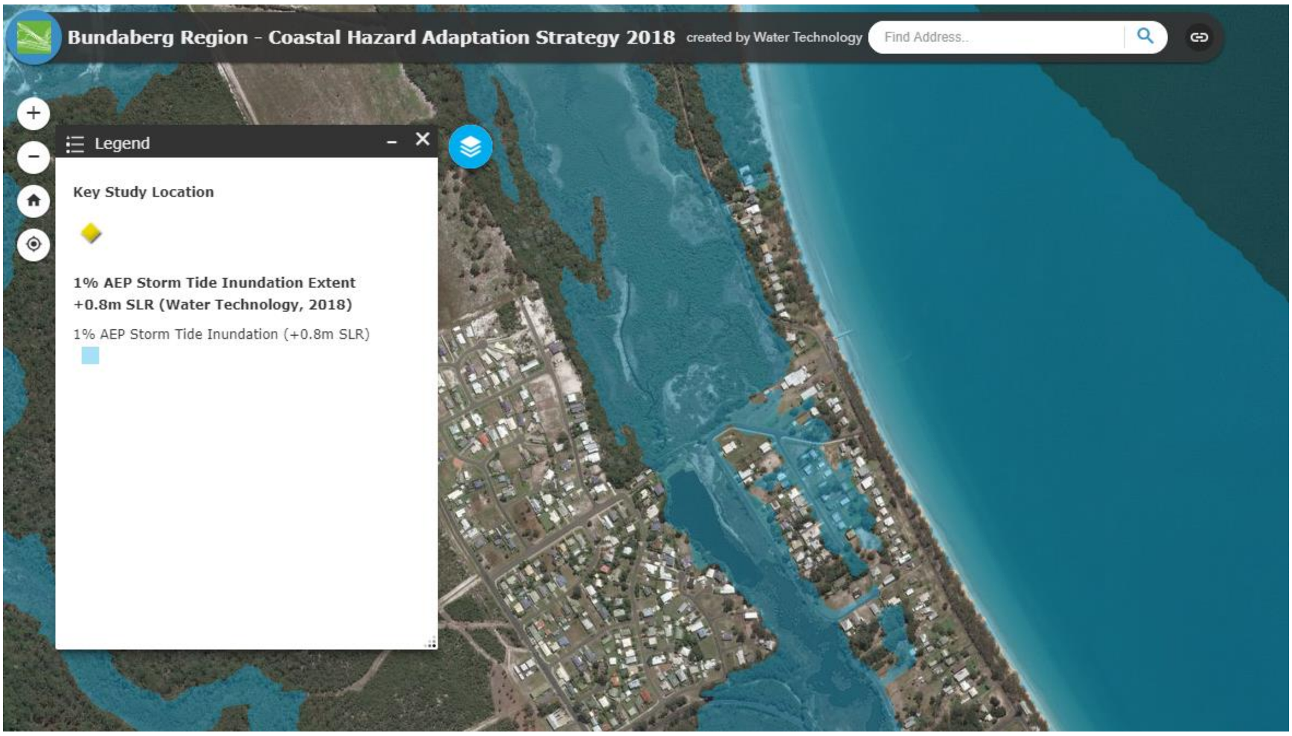


FIGURE 4-2 STORM TIDE MAPPING EXAMPLE FOR WOODGATE BEACH

5 EROSION PRONE AREA

5.1 Introduction

The provision of a foreshore buffer zone is based on the philosophy that natural processes shaping shorelines should be accommodated rather than prevented. The most fundamental means of accommodating these processes is to avoid locating coastal developments within dynamic foreshore areas affected by accretion and erosion cycles. An adequate buffer zone allows for the maintenance of these natural fluctuations without the high cost of property protection works, adverse impacts on beach amenity, or the risk of storm damage to foreshore infrastructure.

The buffer zone concept has been an intrinsic part of the coastal management policy of the Queensland Government since the establishment of the (now disbanded) Beach Protection Authority in 1968.

The determination of an appropriate width for the buffer zone is not a simple matter, as it requires an understanding of the complex interaction of the many physical processes acting on any particular foreshore. When nominating buffer zones along the Queensland coastline, the Department of Environment and Science (formerly the Department of Environment and Heritage Protection) has designated local *Erosion Prone Areas*.

Within the CHAS framework, it is also necessary to consider a range of future conditions when assessing risk, and for developing meaningful triggers for adaptation responses. Therefore, the erosion prone areas have been determined for +0.2, +0.4m and +0.8m sea level rise scenarios.

The Queensland Government has previously mapped the Erosion Prone Area (EPA) for the whole Council coastal area. As part of Phase 3, six key study locations with a sandy foreshore were assessed in further detail, Miara, Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate. No analysis was undertaken on the remainder of Council's coastal areas, instead the existing Queensland Government data for erosion prone areas was adopted for all other areas.

These following sections describe the erosion prone area analysis for Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach. The earlier analysis of erosion for Miara detailed in Water Technology (2014) has been utilised for that location.

5.2 Erosion prone area for sandy coasts

Erosion hazard widths are determined to accommodate potential erosion of foreshores over a specified planning period. Both short term (storm related) and longer term (gradual) trends are included in the assessment - together with an allowance for potential sea level rise associated with climate change. Provision is also included for a factor of safety on the estimates. The following relationship was originally used by the (then) Beach Protection Authority (BPA) for determining erosion prone area widths throughout Queensland. This formula continues to be applied by the Queensland Government (DEHP, 2013) as a method of assessing erosion prone areas on sandy coastlines. It is referred to throughout this report as the "BPA formula".

$$E = [(N \times R) + C + S] \times (1 + F) + D$$

Where:

E = erosion prone area width (meters)

N = planning period (years)

R = rate of long-term erosion

5057-03-R01

C = short term erosion from the design storm or cyclone (meters)

S = erosion due to sea-level rise (meters)

F = factor of safety

D = dune scarp component to allow for slumping of the erosion scarp

The values of R, C, S and D have been determined for Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach using:

- historic data and new data collected to support the development of the CHAS,
- site specific modelling undertaken specifically for this CHAS, and
- sea level rise projections of +0.2m, +0.4m and +0.8m.

The coastal hazard area assessments and assumptions are described further in following sections of this report. The erosion prone area extent as calculated from the BPA formula has been mapped according to the Coastal Hazard Technical Guide (DEHP, 2013). The widths are measured inland from the line of present day HAT. This was adopted for consistency across the study area. A summary of the results of the analysis if provided by location within Appendix A and by storm event in Appendix B. Miara is not included in this analysis as it is located within the Kolan River estuary and hence the sandy coast methodology outlined above is not appropriate.

5.2.1 Planning period

The planning horizon for the erosion hazard assessment includes consideration of the +0.2, +0.4 and +0.8m sea level rise scenarios, which can nominally relate to the years 2040 (22 years from present), 2070 (52 years from present) and 2100 (82 years from present) respectively. Therefore, erosion hazard widths have been determined for each of these three different planning horizons.

The planning period for sea level rise is different to the one that relates to the long term erosion rate, which is discussed in more detail in the below chapter (i.e. the value of N in the BPA formula).

5.2.2 Rate of long term erosion (R)

There are two main causes of long-term erosion on a foreshore, namely

- a continuing net loss of sand from the beach system (typically as a result of a deficit in natural sand supply to a coastal reach), resulting in an on-going recession of the shoreline.
- a progressive rise in sea level causing a shoreline readjustment.

The latter is considered separately under the current methodology for assessing erosion prone areas in Queensland, since the component *S* in the formula addresses this specific phenomenon. Consequently, it is ongoing deficit of sand from the active littoral system which is considered to contribute to long-term erosion.

Long-term changes in sediment supply to foreshores manifest themselves as long-term erosion or accretion. They are typically associated with natural processes – such as offshore sand bar migrations; sediment delivery to the coast by flood events; meandering of tidal channels or creek and river entrances; along with other such phenomenon.

If there have been no significant coastal works or infrastructure developments which might have initiated changes to the natural littoral regime, the rate of any ongoing long-term recession (i.e. the value of *R* in the BPA formula) at the site can be estimated by investigating past natural trends.

5057-03-R01

The long-term erosion component is intended to capture historical trends in shoreline position. DEHP (2013) outlines two basic approaches to obtain an estimate of long term erosion:

- Extrapolation of past trends deduced from the geological record or evidenced from surveys and aerial photographs; or
- Calculation of the present-day local sediment budget for the beach. Any deficit (or surplus) is converted into a horizontal movement of the shoreline that can be extrapolated over the planning period.

For the purposes of this assessment, comparisons of historical cross-sectional profiles taken by the Beach Protection Authority with new surveys at the same locations were used to define the long-term recession trends at Moore Park Beach, Bargara, Innes Park, Coonarr and Woodgate Beach. This interpretation was supplemented with comparisons of historic aerial imagery at each of the sites. The results of the analysis are summarised in Table 5-1, related figures including the location of the transects, profile sections and aerial imagery can be found in Appendix D. The bold numbers represent the long term erosion rates that were adopted for the relevant location (most conservative rate per section). Bargara has been split into 2 sections, Bargara North which is in a long term recession and Bargara South which is stable/accreting. Woodgate Beach has been split into 3 different sections (North, Central, South) which is why all 3 values have been adopted for the relevant beach section. Moore Park Beach has a long term recession trend, therefore the erosion prone area has been assessed on the basis of a single segment. The adjacent segments being the transition zones to the next segment.

TABLE 5-1 RESULTANT LONG-TERM EROSION RATES (R)[3]

Location	Observation record	Transect ID	Shoreline Movement	Total Distance (m)	Annual Rate (m/year)
Moore Park Beach	1981-2018	GOOB 199.50	Recession	12	-0.32
		GOOB 200.00	Recession	18	-0.49
		GOOB 201.00	Recession	10	-0.27
		GOOB 202.00	Stable	-	0
		GOOB 203.00	Recession	4	-0.11
		GOOB 204.00	Recession	17	-0.46
		GOOB 205.00	Recession	39	**-1.05**
Bargara	1979-2018	WOONG 175.50	Accretion	5	+0.13
		WOONG 176.00	Accretion	5	+0.19
		WOONG 176.50	Recession	9	**-0.23**
		WOONG 177.00	Accretion	6	+0.15
Innes Park	1956-2017	Aerial imagery comparison only	No change	-	**0**
Coonarr	1979-2018	WOONG 159.50	Stable	-	0
		WOONG 160.00	Recession	8	**-0.21**
Woodgate Beach	1979-2018	Woodgate North (ISIS 144-143)	Recession	25.5	**-0.65**

5057-03-R01

[3] See Appendix C for locations

Location	Observation record	Transect ID	Shoreline Movement	Total Distance (m)	Annual Rate (m/year)
		Woodgate Central (ISIS 142-139)	Stable	0	**0**
		Woodgate South (ISIS 138-133)	Recession	19.5	**-0.5**

When considering the timescale to apply to long-term erosion trends (excluding sea level rise, i.e. the value of *N* in the BPA formula) the *EHP Guideline* advocates the use of 50 years for cyclical erosion typically of a decadal scale. This should not be confused with the planning horizon when considering future climate change effects - which relate to planning periods extending to the years of 2040, 2070 and 2100 (refer to discussions in Section 5.2.1 above).

5.2.3 Storm erosion (C)

The large waves, elevated water levels and strong winds generated by a storm or cyclone can cause severe erosion on sandy foreshores. The selection of the appropriate parameters which constitute the "design" storm is unfortunately not a straightforward nor simple task. It involves the joint occurrence of large waves and elevated ocean water levels.

Wave characteristics and the storm surge can generally be estimated for a storm/cyclone of any given intensity and size, however the storm tide level depends upon when the peak surge occurs in relation to the astronomical tide. A large surge with severe waves occurring at low tide might result in less erosion than a mild surge and moderate wave conditions occurring at high tide.

The beaches of the Bundaberg region are tide dominated characterised by a relatively steep sandy upper beach slope (sometimes referred to as a perched beach) fronted by wide flat intertidal approaches comprised of finer sediments. Therefore, given that beach erosion along the project foreshores is more sensitive to storm tide level than to the height of the waves, an appropriate approach is to adopt a severe storm tide occurring in association with a "moderate" wave event. This is the approach also proposed by the DEHP Guidelines.

To calculate the short-term erosion component C, several combinations of water levels and significant wave heights were assessed. The AEP's for each of these components along with the inferred overall storm event AEP can be found within Table 5-2.

TABLE 5-2 STORM TIDE AND WAVE AEP USED FOR EACH STORM AEP

Storm Tide AEP %	Significant Wave Height AEP %	Inferred Overall Storm AEP%
5	5	**5**
2	5	**2**
1	2	**1**

SBEACH modelling

5057-03-R01

To determine the short term erosion component from a design storm event, the storm induced beach change model SBEACH was used. SBEACH is a dynamic computational model and considers the transient nature of beach profile adjustments. The model simulates the changes of the cross-shore beach, berm, and dune erosion produced by storm waves and elevated ocean water levels. It was developed by the Coastal Engineering Research Centre of the US Army Corps of Engineers, specifically for examining the performance of beach systems subject to onshore/offshore sand movements under strong wave action. This system is used extensively throughout the world by the coastal engineering profession when investigating beach response to storm waves.

The storm tide water levels and wave heights for the various AEP events have been presented in the previous sections of the report and were used as input into the SBEACH models. Water levels and wave heights can be input as time varying. Water levels have been included to represent an average spring tide peak in the Bundaberg region which peaks 6.5 hours into the 13 hour modelled storm event. The shape defined for significant wave height reaches its peak earlier and remains there for 2 hours and 45 minutes, which is characteristic of a regular storm duration. Characteristic shapes for hydrographs of significant wave height and water level used within the SBEACH analyses are presented in Figure 5-1.

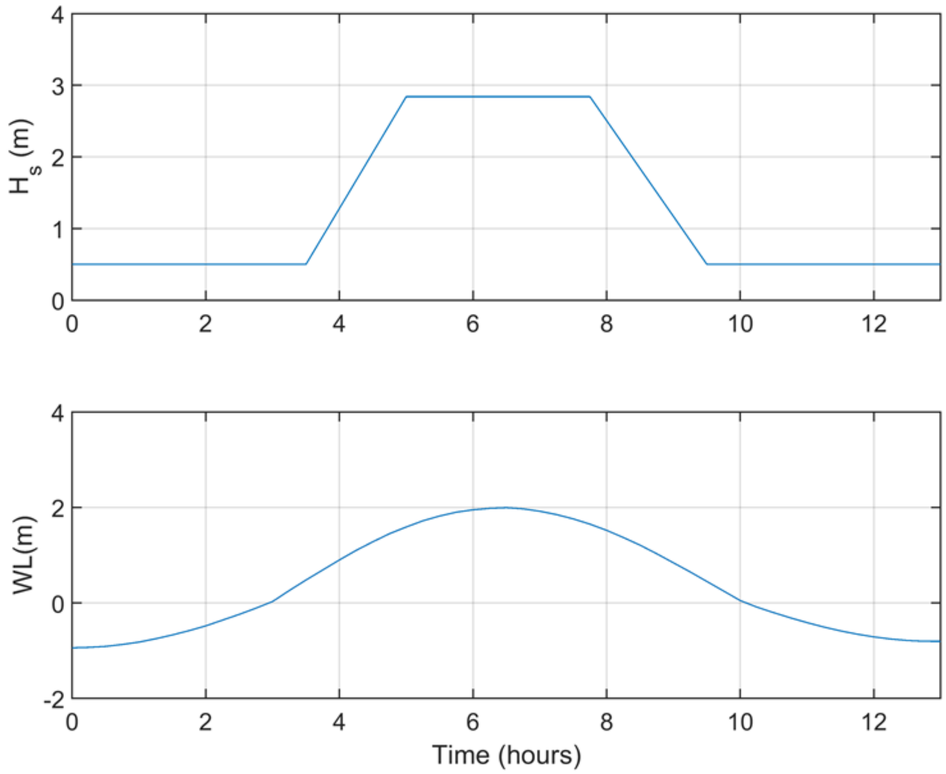


FIGURE 5-1 CHARACTERISTIC TIME SERIES USED FOR SIGNIFICANT WAVE HEIGHT (HS) AND STORM TIDE (WL)

The sand grain particle sizes used within the analysis were obtained from the sediment analysis undertaken in May 2018. The sediment size adopted for each location was that for the sample extracted at the dune of each profile - since this is the location where the short-term erosion is being investigated. Due to no sampling being undertaken at Innes Park, the D_{50} value for Bargara was adopted due to their proximity, similar wave climate and beach orientation. The resultant dune D_{50} for all locations are reported below in Table 5-3.

5057-03-R01

TABLE 5-3 SEDIMENT SIZES FOR THE VARIOUS PROFILE LOCATIONS

Location	D_{50} (mm)
Moore Park Beach	0.3
Bargara	0.25
Innes Park	0.25
Coonarr	0.21
Woodgate Beach North	0.17
Woodgate Beach Central	0.25
Woodgate Beach South	0.25

The SBEACH model runs were completed in order to calculate the short term erosion from a design storm event and the results are presented in Table 5-4.

TABLE 5-4 SBEACH RESULTS - SHORT TERM EROSION IN METRES (C)

AEP Storm (%)	Short Term Erosion (m)						
	Moore Park Beach	Bargara	Innes Park	Coonarr	Woodgate Beach North	Woodgate Beach Central	Woodgate Beach South
5	29	16.1	14.5	16.8	11.3	25.4	12.1
2	31	16.1	14.5	16.8	11.3	25.4	12.1
1	33	16.1	16.5	22.8	11.3	27.4	14.1

5.2.4 Erosion due to sea level rise (S)

The Queensland Government considers that there is a significant body of evidence supporting a projected sea level rise of approximately 0.8 metres on the Queensland coastline by the year 2100. Consequently, this provision is made in the assessments of erosion prone area widths by the BPA formula.

The "Bruun Rule" (Figure 5-2) is a commonly used method for determining shoreline response to a rise in sea level. It is based on the concept of an equilibrium beach profile being maintained during gradual sea level rise – by transferring sand from the upper beach down into the nearshore zone. The beach profile is therefore maintained by way of a landward shift of the shoreline.

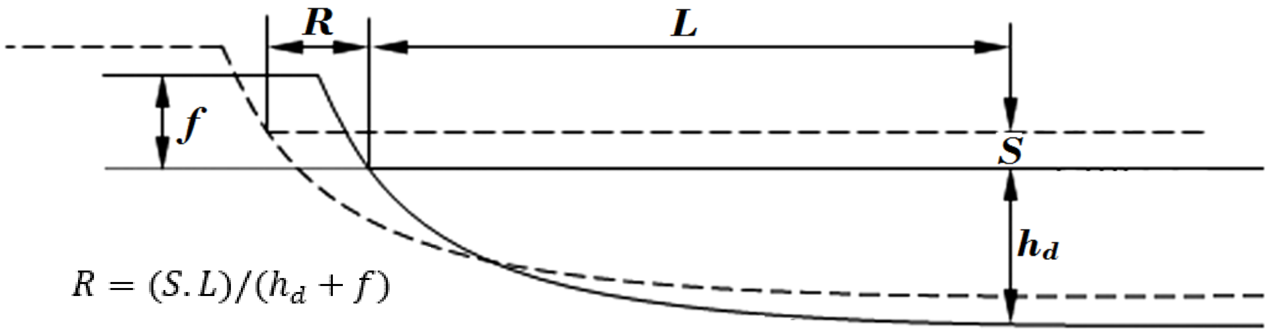


FIGURE 5-2 BRUUN RULE

The results of the assessment for the locations of Moore Park Beach, Bargara, Innes Park, Coonarr, and Woodgate Beach are presented in Table 5-5.

TABLE 5-5 RESULTANT EROSION DUE TO SEA LEVEL RISE IN METRES (S)

Location	Dune height (m)	Active Profile Length (m)	Depth of Closure (m)	Recession (+0.2m SLR)	Recession (+0.4m SLR)	Recession (+0.8m SLR)
Moore Park Beach	4.6	260	3.64	6.3	12.6	25.2
Bargara	8.6	180	4.27	2.8	5.6	11.2
Innes Park	5.5	115	4.44	2.3	4.6	9.3
Coonarr	6.8	150	3.63	2.9	5.8	11.5
Woodgate Beach North	4.8	200	3.44	4.9	9.7	19.4
Woodgate Beach Central	4.2	130	3.17	3.5	7.0	14.0
Woodgate Beach South	4.8	165	3.14	4.2	8.4	16.7

5.2.5 Factor of safety (F)

Whilst the calculation procedures applied to the determination of erosion prone areas are consistent with sound coastal engineering principles, they are nevertheless subject to various uncertainties and limitations. Consequently (and in accordance with normal engineering practice) a factor of safety is applied to the calculations.

A value of 40% is currently adopted by the Coastal Hazards Technical Guide (1993) as an appropriate factor of safety when calculating the width of the Erosion Prone Area (i.e. the value of F in the formula is 0.40). However, this is applied only to the short-term, long-term and sea level rise components - not the recession due to collapse of the dune scarp.

The Technical Guide further states that the Factor of Safety is warranted since there is no conscious effort made to select conservative values associated with the short-term, long-term and sea level rise components.

It is pertinent to note that by adopting the same factor of safety (of 0.4) for the various future climate scenarios considered by this CHAS, there is a varying element of conservatism incorporated into the outcomes when applying the BPA formula.

As an example of this varying conservatism, comment is offered as follows.

5057-03-R01

A major consideration for determining the extent of the erosion hazard is the calculated shoreline recession caused by a particular storm AEP. When using (say) the 1% AEP storm to calculate the short-term erosion for all climate scenarios (+0.2m sea level rise by the year 2040, +0.4m rise by 2070, and +0.8m by 2100) there is a different likelihood of a 1% AEP event occurring within each of those three planning periods.

A 1% AEP event has a 20% probability of occurring within the coming 22 years (to the +0.2m sea level rise scenario expected around 2040); whereas the same storm has a 56% probability of occurring in the coming 82 years (to +0.8m sea level rise in 2100). By assigning the same factor of safety to the short-term erosion prediction of the 2040 scenario as to the 2100 scenario, there is inherently a more conservative value of the overall erosion hazard calculated for the shorter planning period to 2040. This would support adopting lower factor of safety's (rather than 0.4) for the shorter planning periods associated with +0.2m and +0.4m sea level rise scenarios.

However, the approach adopted for this Phase 3 of the CHAS is to adopt the 0.4 factor of safety across all three planning periods. But in doing so, to be mindful when undertaking subsequent phases of the CHAS (particularly Phase 4 when assessing assets and values threatened by these future erosion extents) that there may be merit in revisiting the calculations of erosion extent for the +0.2m and +0.4m sea level scenarios.

5.2.6 Dune slumping (D)

For cases where the foredune is not overtopped, the calculations of beach profile response typically assess the erosion only as far as the limit of wave runup. However, subsequent collapse or slumping of the erosion scarp can threaten structures located immediately behind the scarp.

Typically, the slope from the toe of the erosion scarp up to the foreshore area behind will flatten further than its natural angle of repose, to a slope of approximately 1 vertical to 2.5 horizontal. Consequently, an additional component to account for this aspect is included as the component *D* in the calculation of the Erosion Prone Area width which are presented in Table 5-6.

TABLE 5-6 RESULTANT EROSION DUE TO DUNE SLUMPING IN METRES (D)

AEP Storm (%)	Dune Slumping (m)						
	Moore Park Beach	Bargara	Innes Park	Coonarr	Woodgate Beach North	Woodgate Beach Central	Woodgate Beach South
5	0.0	1.8	2.5	5.2	0	0	0
2	0.0	2.5	2.8	6.8	0	0	0
1	0.0	2.5	2.2	0.8	0.8	0	0

5.2.7 Summary of Erosion Prone Area for Sandy Coasts

The below Table 5-7presents a summary of the final erosion prone area width for each key study location for the 0.8m sea level rise and 1% AEP event. The last column presents a comparison to the existing erosion prone area width from the Department of Environment and Science (DES).

In most locations the updated erosion prone area width is reduced compared to the previous one prepared by DES. There are only two exceptions at Moore Park Beach and Woodgate North:

- At Moore Park Beach the detailed analysis provided a larger long- and short term erosion component than what was adopted by DES, which results in a larger erosion prone area width.
- The Woodgate SEMP study that is currently underway highlighted that the long and short term erosion patterns differ in the north, central and south section of Woodgate. Therefore the existing section BUR003 from DES was split up into more sections (BUR003a to d). At the northern end of the beach the updated erosion prone area exceeds the previous one from DES due to increased long term erosion.

A full summary of the resulting Erosion Prone Area width presented by location in Appendix A and by event in Appendix B.

Appendix C contains a summary table of the State erosion prone area segments (Bur001 to Bur061) and highlights which sections have been updated as part of this study.

Additional detail for the Erosion Assessment is also included in Appendix D.

5057-03-R01

TABLE 5-7 +0.8M SEA LEVEL RISE AND 1%AEP EROSION HAZARD AREA WIDTH

Location	Sea level rise (m)	Storm Event (AEP%)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Factor of Safety	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)	EPA Segment
Moore Park Beach	0.8	1	82	1.05	33	25.2	0.4	0	**202**	160	BUR052
Bargara (Kellys Beach North)	0.8	1	82	0.23	16.1	11.2	0.4	2.5	**67**	70	BUR034
Bargara (Kellys Beach South)	0.8	1	82	0.00	16.1	11.2	0.4	2.5	**41**	70	BUR032
Innes Park	0.8	1	82	0.00	16.5	9.3	0.4	2.2	**38**	120	BUR027
Coonarr	0.8	1	82	0.21	22.8	11.5	0.4	0.8	**73**	165	BUR015
Woodgate Beach North	0.8	1	82	0.65	11.3	19.4	0.4	0.8	**118**	110	BUR003d
Woodgate Beach Central	0.8	1	82	0.00	27.4	14.0	0.4	0	**58**	110	BUR003c
Woodgate Beach South	0.8	1	82	0.50	14.1	16.7	0.4	0	**101**	110	BUR003b

5.3 Erosion prone areas for soft rock coasts

On a soft rock coast, once the material is eroded, these shorelines cannot recover to their former state as sandy beaches do. The frequency and severity of erosion on soft rock shorelines is likely to increase as a result of future climate change. Increases in water level, associated with sea level rise or storm events may also expose less resistant portions of the profile to erosive forces.

Based on the SMARTLINE dataset, the only identified soft rock shoreline is located at Elliott Heads. This location was not a key study location and soft rock erosion was therefore not analysed as part of this study.

5.4 Erosion prone areas for hard rock coasts

The central section of the Bundaberg coast is dominated by a rocky foreshore, rather than sand, and is therefore less prone to erosion.

The rate of recession of rocky shorelines is determined by the following factors:

- Inherent properties of the substrate,
- Wave climate (magnitude and exposure),
- Accumulation and retention of slope-foot materials, and
- Presence of engineering structures (seawalls etc).

Hard rock shorelines are generally exposed, as their natural resistance to erosion allows them to persist as headlands while softer shorelines to the sides erode. Rock material is episodically detached from the slope and subsequently moved by wave action.

Hard rock shores are the least susceptible to erosion. Steeply sloping hard rock shorelines, such as hard bedrock cliffs, while highly erosion resistant, can be subject to block falls and slumping. These fallen rocks can act as a self-armouring mechanism providing some protection to the toe of the cliff. The rate of recession of hard rock shorelines is very low, however the risk associated with a failure can be high as significant portions break off.

Sharples et al (2013) notes

> "*Many steep coastal slopes are mantled by bedrock talus blocks (unconsolidated slope deposits) derived from past instability and prone to ongoing slumping, while bedrock block falls from vertical faces will occur periodically in response to basal wave erosion gradually undermining the cliff base. It is therefore necessary to treat steep to cliffed hard rock shores as potentially susceptible to erosion and recession*."

Sharples et al (2013) presents methods to estimating cliff and steep slope recession. These approaches require additional geotechnical information and would be appropriate for localised studies only.

Detailed geotechnical data of the rock is not readily available and therefore the erosion prone area for those sections cannot be determined in more detail than what was already done as part of the State's erosion prone area mapping ("possible bedrock" BUR018-BUR048).

5.5 Erosion prone areas for estuaries

Erosion in estuaries is mainly dominated by channel migration and tidal flow. An increase in water levels due to sea level rise and during storm surges will result in higher flow velocities on the estuary banks which will cause an increase in erosion. Also, with increased water levels, salinity ingress will increase resulting in dieback of more freshwater dependent fringing vegetation, which then exposes the softer estuarine sediments to erosion.

The erosion hazard extent for these areas is represented by the default erosion prone area width of the maximum of Highest Astronomical Tide (HAT) plus 40m inland or HAT plus 0.8m sea level rise in accordance with the QLD State Erosion Prone Area Mapping. In areas with limited erosion drivers (e.g. limited wind fetch, isolated from channel migration process) the extent could be optimised to HAT plus 10m. This detailed mapping analysis could be undertaken in future CHAS phases if more refinement is required in certain key locations.

5.6 Erosion Prone Area Mapping

Erosion prone area maps have been prepared for the 1% AEP event inclusive of 0.8m sea level rise and have been provided via the mapping portal. An example of the mapping is shown in Figure 4-2 for Woodgate Beach.

Additional mapping for the full range of AEP events and sea level rise scenarios will be prepared during later phases of the CHAS as required to fully understand the coastal hazard impacts and inform the risk assessment.

6 SUMMARY OF COASTAL HAZARD MAPPING FOR EACH KEY STUDY LOCATION

6.1 Overview

A brief overview of the results of the coastal inundation and erosion assessments and related mapping is presented for the locations of Miara, Moore Park Beach, Bargara, Innes Park, Coonarr, and Woodgate Beach. Storm tide Inundation and erosion hazard area mapping has been undertaken for the broader Bundaberg Regional Council area. The discussions below consider the impact of the coastal hazards associated with the 1% AEP with 0.8m sea level rise.

6.1.1 Storm tide inundation hazards

The storm tide levels from the NDRP Storm Tide Hazard Interpolation Study (GHD, 2014) have been adopted for the storm tide inundation mapping and erosion analysis for the 1% AEP event. The mapping has been updated to include 0.8m sea level rise for the planning horizon 2100.

6.1.2 Erosion hazards

All erosion hazard extents have been analysed in detail for the key study locations. In addition, the estuary areas have been included in this analysis. These estuarine areas represent the largest erosion hazard areas for the Bundaberg Region and extensively cover low lying regions around each estuary, such as is shown in Figure 6-2 at Miara. There may be specific features such as banks or levees in these areas which would limit the potential extent of inundation and hence future erosion, however they cannot be assessed at the regional scale of this project.

Appendix A contains details of the various erosion assessments for each of the key study locations and Appendix C contains a full list of the erosion prone area for the region.

6.2 Miara

The major flooding of the Kolan River during the passage of Ex-Tropical Cyclone Oswald in 2013 created a new ocean entrance of the Kolan River. This changed entrance configuration enabled waves to impact on the Miara foreshore during specific wave events. The Miara coastline is not a typical sandy beach like most of the Bundaberg coastline, as there is no significant dune and very little sediment available in the upper areas of the foreshore profile. A typical profile shown in Figure 6-1.

The Miara Caravan Park is located immediately behind the shoreline and has significant recreational values. In the vicinity of the caravan park some of the area has had rock placed on an as-needed basis to facilitate the protection of trees, roads and other assets. Despite Miara (and more specially the caravan park) lying behind a barrier island at the Kolan River mouth, there is an existing erosion threat.

A previous analysis of the erosion issues at Miara has been undertaken (Water Technology, 2014). Sections of that report are presented in Appendix D.

For the identification of areas exposed to erosion hazard, the shoreline at Miara has been considered within the estuarine mapping approach, as discussed in Section 5.5. This results in significant areas of the shoreline, including the caravan park, being within the resulting erosion hazard area.

Storm tide inundation is also a significant issue at this location. The coastal hazard mapping indicates that the majority of the site being inundated by a 1% AEP event. The extent of this inundation can be observed in the mapping portal and is illustrated in Figure 6-2.

FIGURE 6-1 MIARA FORESHORE

5057-03-R01

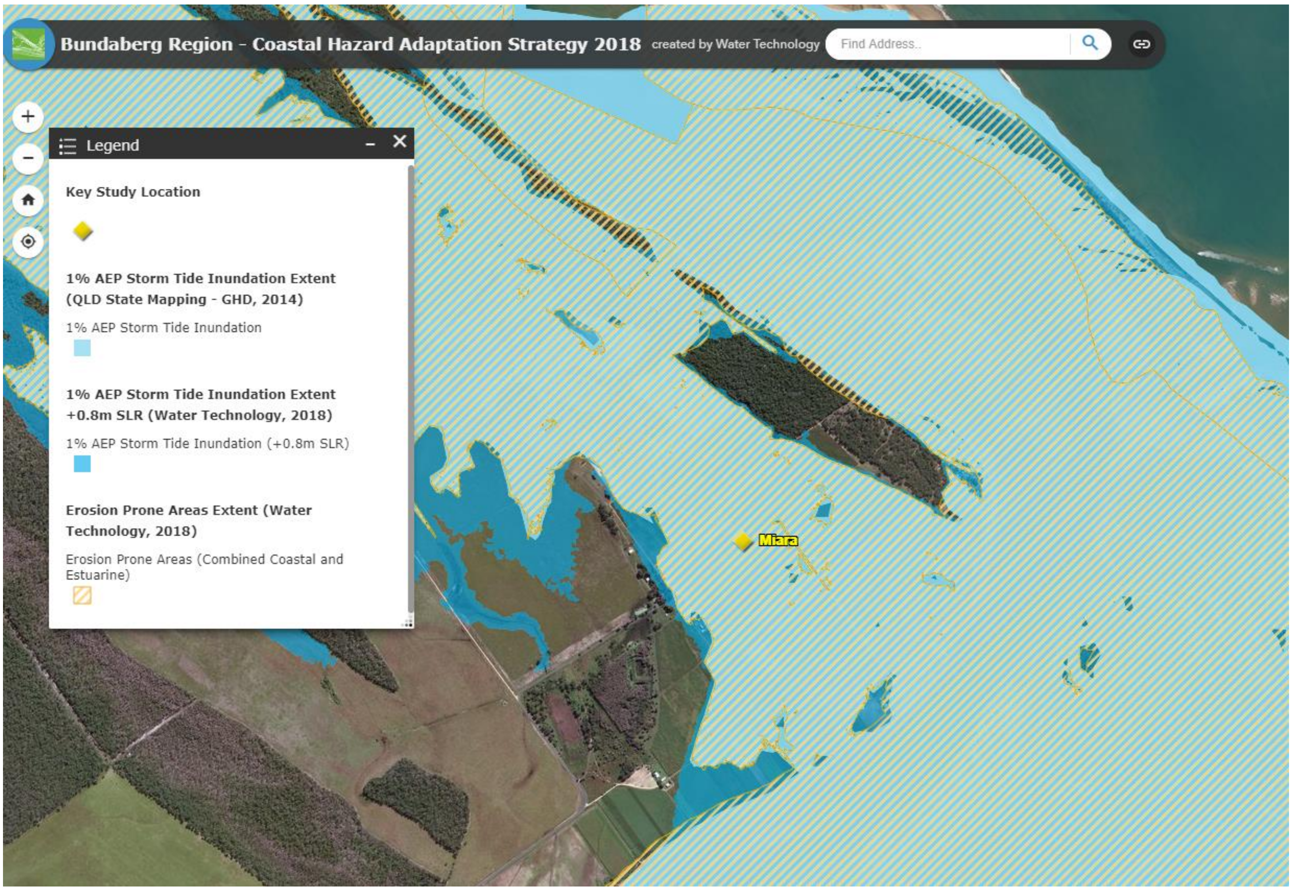


FIGURE 6-2 MIARA COASTAL HAZARD AREA MAPPING

6.3 Moore Park Beach

The approximately 15 km length of foreshore west of the Burnett River mouth is known as Moore Park Beach.

The major source of sediment supplied to the Moore Park Beach area is the Burnett River. Barubbra Island is located in the Burnett River delta forming the south-eastern end of Moore Park Beach. The island consists of a low barrier sand spit and a sand dune backed by extensive mangrove swamps. Further west, this transitions into Moore Park Beach, a sandy beach facing north / north-east and backed by a low vegetated dune, as shown in Figure 6-3. This beach type continues through to the variable Kolan River mouth at the far north-western end of Moore Park Beach. Landforms are dominated by a massive system of beach ridges formed during the Pleistocene and Holocene period. These beach ridge/chenier complexes extend 20 km inland near the Burnett River, grading to approximately 8 km inland near the Kolan River.

Recent erosion issues have forced the abandonment of the Moore Park Surf Lifesaving Clubhouse. At the time of this study, the significant erosion that forced the closure of the clubhouse is no longer visible, with sand having moved back to the site as part of normal cycles of erosion and accretion. The extent of recent beach rehabilitation in this area is shown in Figure 6-3. The northern end of Moore Park Beach is available for four-wheel drive vehicle access. Whilst long-term and short-term beach erosion is an ongoing issue at Moore Park Beach, the low elevation of the township also means that storm tide inundation is a considerable coastal hazard.

Moore Park Beach frontage is a sandy shoreline, with a large estuarine area to the south east. The mapping undertaken to identify the erosion hazard for this study (with an example near the surf lifesaving club shown in Figure 6-4) indicates that:

- The updated Erosion Hazard Area is larger than the one previously adopted by the State.
- The township of Moore Park Beach is impacted by the erosion prone area extent from the seaward side as well as from inland due to the estuarine erosion prone area which extends from the low-lying wetlands that envelop the township.
- The estuarine area to the south east of the main township is broadly inundated, with the erosion hazard extent extending upstream through the township from the line of the existing HAT to the HAT plus 0.8m sea level rise scenario.

Storm tide inundation is likely to be a significant threat to this township. It is noted that king tide/drainage gates have been installed across the major flow paths immediately east of the township. However, these are likely to be overtopped in a small storm event. Limited direct inundation from the ocean is predicted to occur at the southern end of the township under present-day climate scenario. However, more extensive inundation of areas to the landward side of the settlement is predicted to occur. This will be as a result of storm tide inundation of the Kolan River estuary system to the north; and the coastal creeks and the Burnett River to the south. Although only a limited number of properties are inundated, all access routes to the township are adversely affected.

FIGURE 6-3 MOORE PARK BEACH TYPICAL DUNE

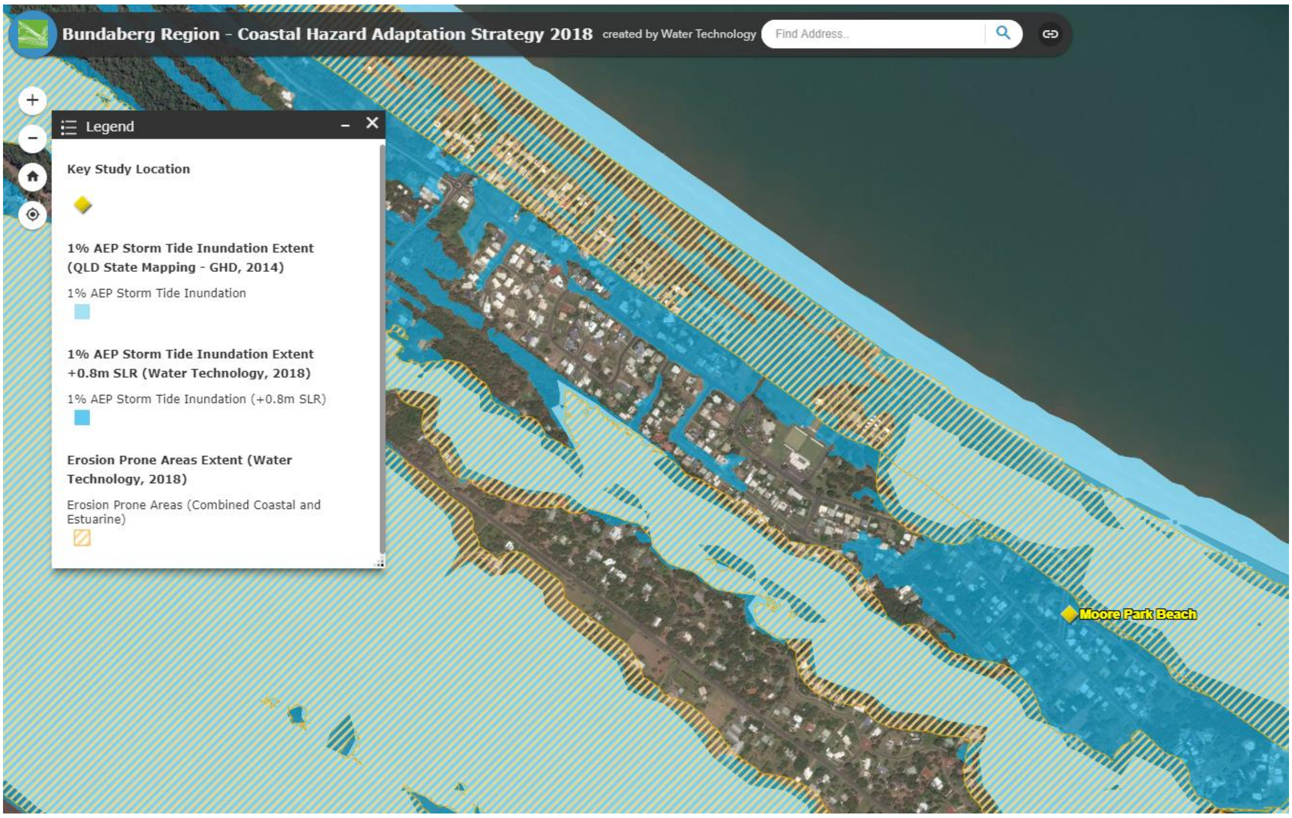


FIGURE 6-4 MOORE PARK BEACH COASTAL EROSION HAZARD AREA MAPPING

6.4 Bargara

The shoreline at Bargara is a mix of sandy shoreline and hard rock shoreline. Kellys Beach, located at the southern end of Bargara, is the most significant stretch of sandy coastline in this area and such is the focus of this assessment. It is approximately a 1.5km length of sandy beach contained by rocky headlands.

Kellys Beach is under high development pressure. Development is currently located on the immediate dune area with only minimal buffers to houses and other infrastructure. Whilst the typical dune system is low and vegetated, the Kellys Beach foredune areas are highly modified. As shown in Figure 6-6, some landowners have built seawalls and retaining walls adjacent to the beach. The northern end of Kellys Beach is a popular swimming area known as 'the basin'. This man-made swimming lagoon is protected by a rock perimeter.

A rocky headland is located at the northern end of Kellys Beach. This headland sweeps around into the town centre of Bargara. As shown in Figure 6-7, the area consists of intermittent rocky foreshores and sandy shores. It is highly modified by four groynes, a piled beach platform at the rear of the beach and also a low sandy dune system at some locations.

North of the main township areas the beach is rocky and less erosion-prone northwards to Nielson Beach.

An example of the mapped erosion hazard area is shown in Figure 6-8.

For the erosion hazard area mapping, in general:

- Beachfront properties are within the extent of the erosion hazard for the event considered.
- The estuary area behind Kellys Beach is likely to be susceptible to erosion hazard affecting the wetlands and the golf course.

Mapping indicates that storm tide inundation is likely to be limited to the existing beach areas and the estuarine/lagoon areas associated with Moneys Creek. Under future sea level rise scenarios, there is a predicted increase in the inundation area within the estuary and potential for impacts on The Causeway road, Causeway Drive and streets around Ian Cossart Park.

FIGURE 6-5 TYPICAL DUNE AT NORTHERN END OF KELLYS BEACH

FIGURE 6-6 KELLYS BEACH LOCALISED EROSION PROTECTION

5057-03-R01

FIGURE 6-7 NORTHERN BARGARA GROYNEFIELD

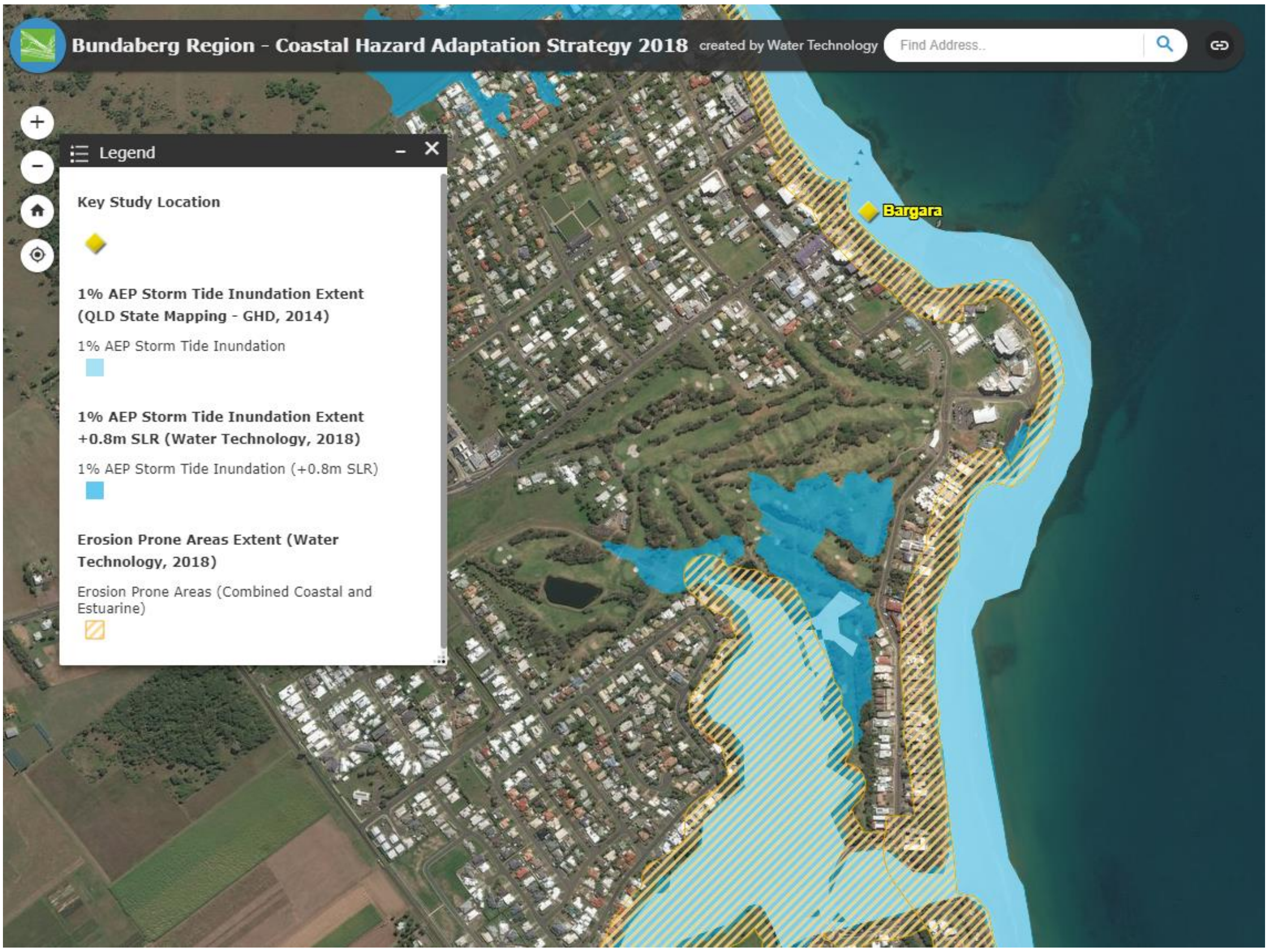


FIGURE 6-8 NORTHERN KELLYS BEACH COASTAL HAZARD AREA MAPPING

6.5 Innes Park

The foreshore at Innes Park is dominated by a hard, rocky shoreline and so has a narrow erosion hazard area. Mapping indicates that storm tide inundation is the more dominant coastal hazard in this location. There is a seawall at the downstream end of Palmer Creek and it is considered likely that seawall would protect the esplanade road embankment against erosion from river flows rather than erosion by waves.

Mapping indicates that there are beachfront properties are within the erosion hazard area and also some properties that are located around the creek inlet are likely to be impacted within the estuarine erosion prone area.

Mapping indicates that storm tide inundation may affect a limited number of properties in the vicinity of the Palmer Creek mouth.

FIGURE 6-9 INNES PARK FORESHORE

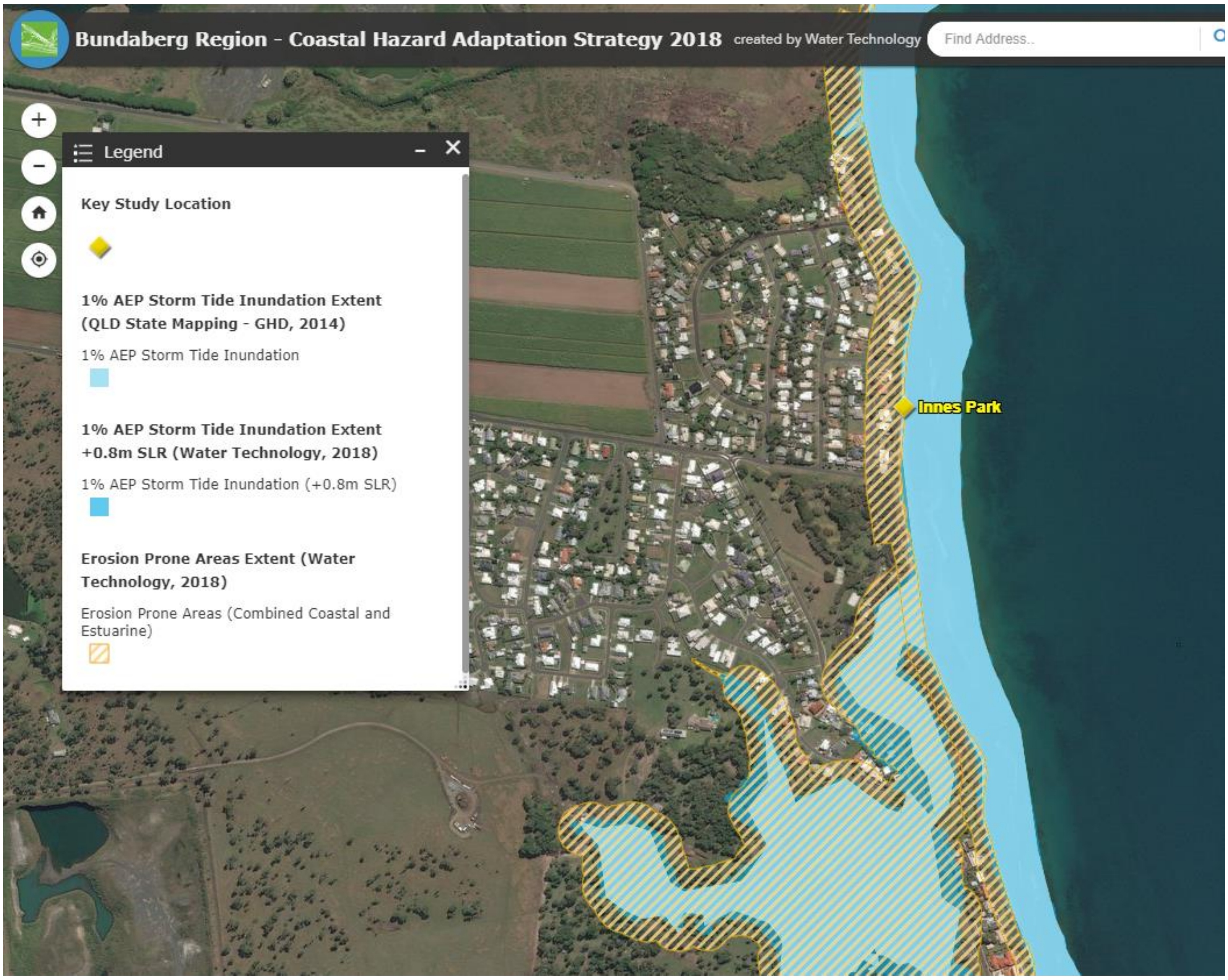


FIGURE 6-10 INNES PARK COASTAL HAZARD AREA MAPPING

6.6 Coonarr

Whilst the main township of Coonarr is located on the Coonarr River approximately 1km inland from the coast, there are a number of properties on Coonarr Esplanade adjacent to the beach. There have been instances of dune erosion reported on frontages to these properties in the past. Erosion scarps are evident at the site, as shown in Figure 6-11. Typically, there is a wide intertidal, sandy beachfront with high vegetated dunes at the rear of the beach.

BPA (1989a) notes that erosion occurs north of Coonarr near the mouth of the Elliott River. It is suggested that the erosion is a result of major changes to the river mouth, and it appears to be highly variable. Near the mouth of the Elliott River there is an active erosion scarp with no foredune and the river delta has caused a flattening of the profile out to approximately 1000 metres offshore.

The erosion hazard analyses suggests.

- Erosion hazard area impacts the coastal road and the front of properties at Coonarr Park.
- Apart from Coonarr Park, the sandy shoreline erosion hazard area has limited impact on built assets.

With respect to storm tide inundation, it appears that Coonarr Park is the major area affected, with the rear of properties and access routes likely to be inundated. The Coonarr township is not inundated by the storm tide scenario mapped.

FIGURE 6-11 TYPICAL COONARR DUNE

5057-03-R01

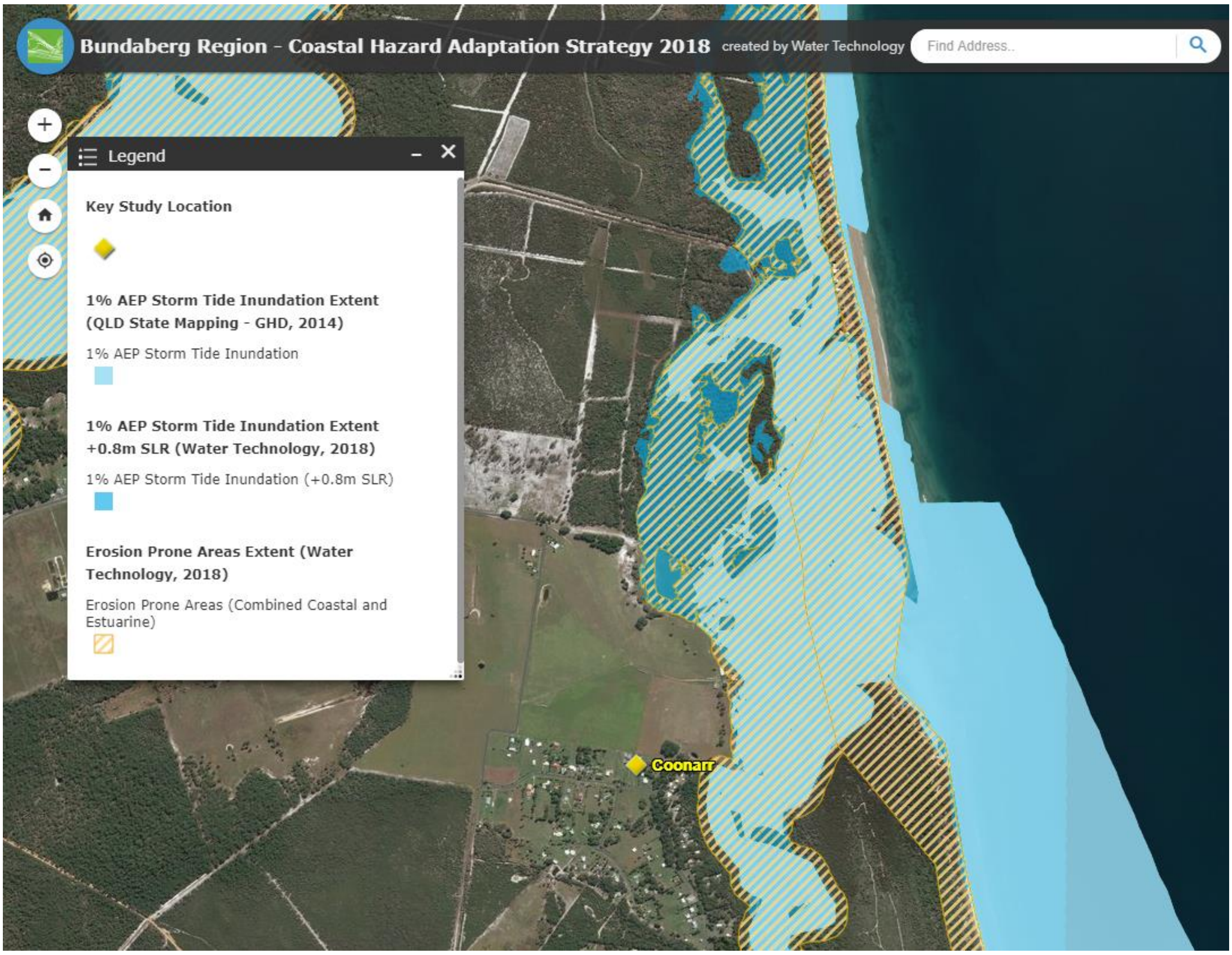


FIGURE 6-12 COONARR COASTAL HAZARD AREA MAPPING

6.7 Woodgate Beach

Much of Woodgate Beach is fronted by moderately high, vegetated dunes as is shown in Figure 6-13. The coastline forms a concave shape from south-east to north-west. Woodgate Beach is subject to longshore sediment transport and cross-shore sand transport during storms which can result in significant erosion of the foreshore. It should be noted that a Shoreline Erosion Management Plan is currently underway for Woodgate Beach (Water Technology, 2018) and the information presented in this report may be superseded by the outcomes of that study.

The calculated extent of the erosion hazard for Woodgate provides the following information:

- Due to the use of a number of surveyed profiles along the Woodgate Beach area to predict long- and short-term erosion (as part of the more detailed Woodgate Shoreline Erosion Management Plan (SEMP)) the calculated erosion hazard extents for Woodgate Beach are variable, whereas the Queensland Government's erosion prone area mapping has a single value along the extent of the township. Therefore, the original erosion prone area at Woodgate BUR003 has been split up into more sections as presented in Appendix C.
- The erosion hazard areas extend across the foreshore, reaching approximately one block into the existing township.

- Existing long-term erosion has caused issues at the northern end (near the boat ramp, see Figure 6-13) and the southern ends of the township (in a national park area Figure 6-14). Strategies to manage these erosion issues are considered in the Woodgate Beach SEMP project (Water Technology, 2018).

Mapping suggests limited storm tide inundation of Woodgate Beach for the 1% AEP event from the seaside, however, there is a significant potential flow path originating from Theodolite Creek. This flow path follows the low-lying land between First Ave and Ocean View Drive / Lorikeet Ave and then crosses Acacia Street. Access to the settlement via Acacia Street could be adversely affected.

FIGURE 6-13 NORTHERN WOODGATE BEACH, NEAR BOAT RAMP – RECENT EROSION

FIGURE 6-14 SOUTHERN WOODGATE BEACH AT NATIONAL PARK RECENT EROSION

FIGURE 6-15 TYPICAL WOODGATE BEACH DUNE

5057-03-R01

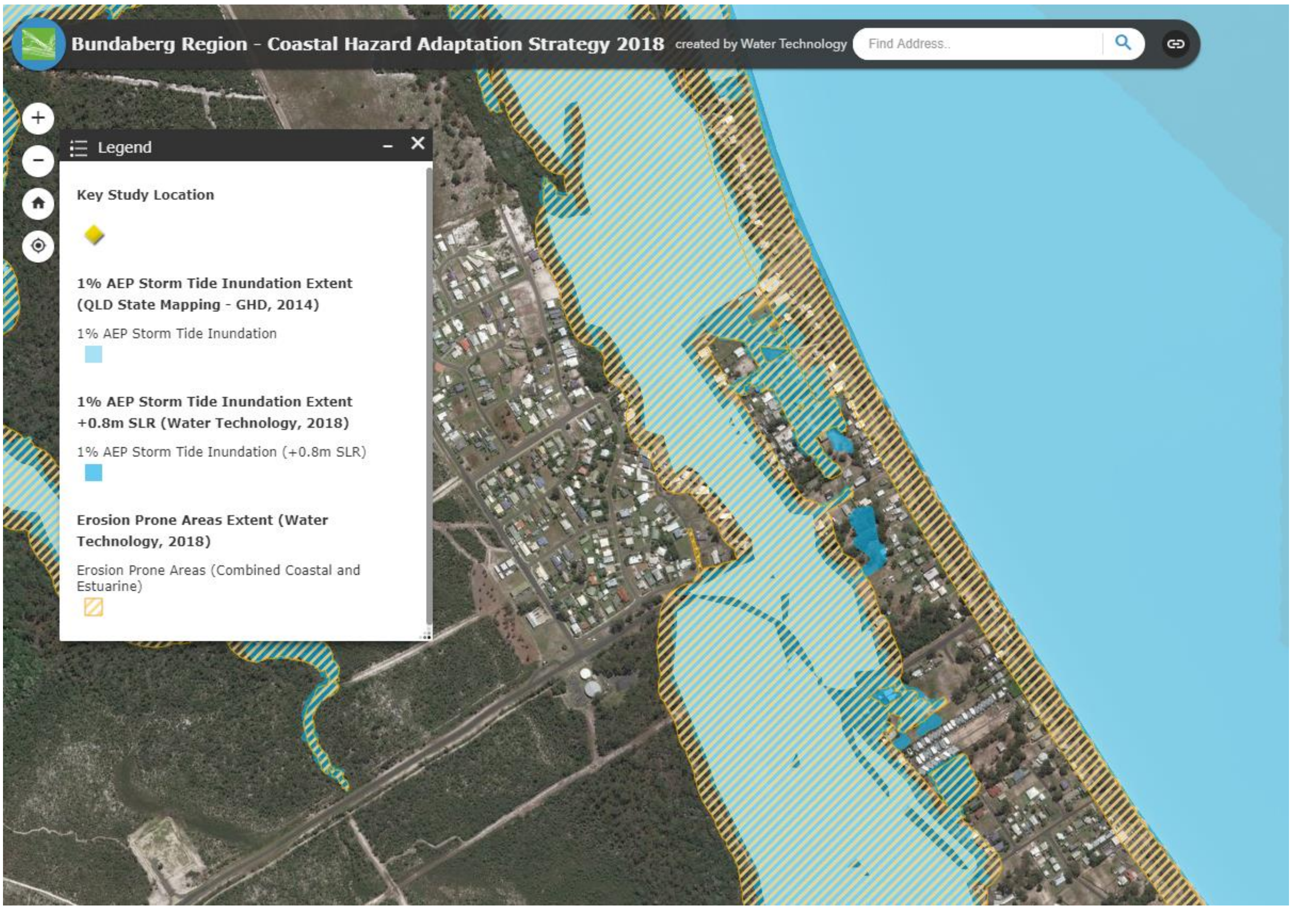


FIGURE 6-16 COASTAL HAZARD MAPPING – WOODGATE BEACH

5057-03-R01

7 REFERENCES

Institution of Engineers, Australia (1987) Australian Rainfall and Runoff: A Guide to Flood Estimation, Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT

Beach Protection Authority, (1989a). Hervey Bay Beaches – a detailed study of coastline behaviour along the mainland beaches of Hervey Bay, South-East, Queensland, Australia. June 1989.

Beach Protection Authority (1989b). *Wave Data Recording Programme – Burnett Heads Region*. Report No. W05.2. Prepared by the Coastal Management Program of the Department of Harbours and Marine on behalf of the Beach Protection Authority.

BMT WBM, 2013. Bundaberg Coastal Storm Tide Study. Prepared for Bundaberg Regional Council, November 2013

Coastal Hazards Technical Guide (1993) https://www.ehp.qld.gov.au/coastalplan/pdf/hazards-guideline.pdf

Geosciences Australia, 2016, Australian Rainfall and Runoff http://arr.ga.gov.au/arr-guideline

GHD, 2014. Department of Science, Information Technology, Innovation and the Arts, NDRP Storm Tide Hazard Interpolation Study Report, June 2014.

Griffith University, 2016. Bundaberg Storm Tide Adaptation Project: Review of Storm Tide Inundation Studies. Griffith Centre for Coastal Management, March 2016

Institution of Engineers Australia, 1987, Australian Rainfall and Runoff

NCCARF, 2016: Datasets Guidance 1: Shoreline Explorer. Present-day coastal sensitivity to flooding and erosion. CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast. https://coastadapt.com.au/sites/default/files/docs/sediment_compartments/QLD04.04.03.pdf

Sharples, C. Mount, R. and Pedersen, T. (2009). The Australian Coastal Smartline Geomorphic and Stability Map Manual, School of Geography and Environmental Studies, University of Tasmania

State of Queensland, 2015. Coastal Hazard Areas Map – Storm Tide Inundation Areas, Version 4 – October 2015

State of Queensland, 2016. Coastal Hazard Areas Map – Erosion Prone Areas, Version 6 – October 2016

Stephens, A.W., Holmes, K.H. and Jones, M.R., 1988. "*Modern Sedimentation and Holocene Evolution of the Hervey Bay Coast"* Marine & Coastal Investigations Project Report MA12. Queensland Department of Mines. December 1988.

Stockdon, H.F., Holman, R.A., Howd, P.A., and Sallenger, A.H. 2006, Empirical parameterization of setup, swash, and runup: Coastal Engineering, v. 53, no. 7, p. 573-588.

Trenhaile, A.S., 2011: Predicting the response of hard and soft rock coasts to changes in sea level and wave height; Climatic Change, Vol. 109, p. 599-615.

Water Technology 2014. Miara Foreshore DEHP Information Request. Prepared for Bundaberg Regional Council.

Water Technology. (2018, in progress). Woodgate Beach Shoreline Erosion Management Plan. Prepared for Bundaberg Regional Council.

APPENDIX A
EROSION HAZARD AREA ANALYSIS – PARAMETER SUMMARY BY LOCATION

TABLE A-1 MOORE PARK BEACH – EROSION HAZARD AREA WIDTH [4]

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	1.05	23.1	29	6.3	0.0	82	-
	2				31		0.0	85	-
	1				33		0.0	87	-
+0.4m Sea Level Rise	5	52		54.6	29	12.6	0.0	135	-
	2				31		0.0	137	-
	1				33		0.0	140	-
+0.8m Sea Level Rise	5	82		86.1	29	25.2	0.0	196	-
	2				31		0.0	199	-
	1				33		0.0	202	160

5057-03-R01

[4] Department of Infrastructure, Local Government and Planning, *Connecting Brisbane*, State of Queensland, 2017.

TABLE A-2 BARGARA (KELLYS BEACH NORTH) – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0.23	5.06	16.1	2.8	1.8	35	-
	2				16.1		2.5	36	-
	1				16.1		2.5	36	-
+0.4m Sea Level Rise	5	52		11.96	16.1	5.6	1.8	49	-
	2				16.1		2.5	50	-
	1				16.1		2.5	50	-
+0.8m Sea Level Rise	5	82		18.86	16.1	11.2	1.8	66	-
	2				16.1		2.5	67	-
	1				16.1		2.5	67	70

5057-03-R01

TABLE A-3 BARGARA (KELLYS BEACH SOUTH) – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0	0	16.1	2.8	1.8	28	-
	2				16.1		2.5	29	-
	1				16.1		2.5	29	-
+0.4m Sea Level Rise	5	52		0	16.1	5.6	1.8	32	-
	2				16.1		2.5	33	-
	1				16.1		2.5	33	-
+0.8m Sea Level Rise	5	82		0	16.1	11.2	1.8	40	-
	2				16.1		2.5	41	-
	1				16.1		2.5	41	70

5057-03-R01

TABLE A-4 INNES PARK – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0	0	14.5	2.3	2.5	26	-
	2				14.5		2.8	26	-
	1				16.5		2.2	29	-
+0.4m Sea Level Rise	5	52		0	14.5	4.6	2.5	29	-
	2				14.5		2.8	30	-
	1				16.5		2.2	32	-
+0.8m Sea Level Rise	5	82		0	14.5	9.3	2.5	36	-
	2				14.5		2.8	36	-
	1				16.5		2.2	38	120

5057-03-R01

TABLE A-5 COONARR – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0.21	4.62	16.8	2.9	5.2	39	-
	2				16.8		6.8	41	-
	1				22.8		0.8	43	-
+0.4m Sea Level Rise	5	52		10.92	16.8	5.8	5.2	52	-
	2				16.8		6.8	54	-
	1				22.8		0.8	56	-
+0.8m Sea Level Rise	5	82		17.22	16.8	11.5	5.2	69	-
	2				16.8		6.8	71	-
	1				22.8		0.8	73	165

TABLE A-6 WOODGATE BEACH NORTH – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0.65	14.3	11.3	4.9	0	43	-
	2				11.3		0	43	-
	1				11.3		0.8	43	-
+0.4m Sea Level Rise	5	52		33.8	11.3	9.7	0	77	-
	2				11.3		0	77	-
	1				11.3		0.8	78	-
+0.8m Sea Level Rise	5	82		53.3	11.3	19.4	0	118	-
	2				11.3		0	118	-
	1				11.3		0.8	118	110

5057-03-R01

TABLE A-7 WOODGATE BEACH CENTRAL – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0	0	25.4	3.5	0	40	-
	2				25.4		0	40	-
	1				27.4		0	43	-
+0.4m Sea Level Rise	5	52		0	25.4	7.0	0	45	-
	2				25.4		0	45	-
	1				27.4		0	48	-
+0.8m Sea Level Rise	5	82		0	25.4	14.0	0	55	-
	2				25.4		0	55	-
	1				27.4		0	58	110

TABLE A-8 WOODGATE BEACH SOUTH – EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP %)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
+0.2m Sea Level Rise	5	22	0.5	11	12.1	4.2	0	38	-
	2				12.1		0	38	-
	1				14.1		0	41	-
+0.4m Sea Level Rise	5	52		26	12.1	8.4	0	65	-
	2				12.1		0	65	-
	1				14.1		0	68	-
+0.8m Sea Level Rise	5	82		41	12.1	16.7	0	98	-
	2				12.1		0	98	-
	1				14.1		0	101	110

5057-03-R01

APPENDIX B
EROSION ASSESSMENT INPUTS AND ANALYSIS – PARAMETER SUMMARY BY EVENT

TABLE B-1 +0.2M SEA LEVEL RISE SCENARIO EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP%)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
Moore Park Beach	5	22	1.05	23.1	29	6.3	0.0	82	-
	2				31		0.0	85	-
	1				33		0.0	87	-
Bargara (Kellys Beach North / South)	5		0.23 / 0.00	5.1 / 0.0	16.1	2.8	1.8	35 / 28	-
	2				16.1		2.5	36 / 29	-
	1				16.1		2.5	36 / 29	-
Innes Park	5		0.00	0.0	14.5	2.3	2.5	26	-
	2				14.5		2.8	26	-
	1				16.5		2.2	29	-
Coonarr	5		0.21	4.6	16.8	2.9	5.2	39	-
	2				16.8		6.8	41	-
	1				22.8		0.8	43	-
Woodgate Beach North	5		0.65	14.3	11.3	4.9	0.0	43	-
	2				11.3		0.0	43	-
	1				11.3		0.8	43	-
Woodgate Beach Central	5		0.00	0.0	25.4	3.5	0.0	40	-
	2				25.4		0.0	40	-
	1				27.4		0.0	43	-
Woodgate Beach South	5		0.50	11.0	12.1	4.2	0.0	38	-
	2				12.1		0.0	38	-
	1				14.1		0.0	41	-

TABLE B-2 +0.4M SEA LEVEL RISE EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP%)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
Moore Park Beach	5	52	1.05	54.6	29	12.6	0.0	135	-
	2				31		0.0	137	-
	1				33		0.0	140	-
Bargara (Kellys Beach North / South)	5		0.23 / 0.00	12 / 0.00	16.1	5.6	1.8	49 / 32	-
	2				16.1		2.5	50 / 33	-
	1				16.1		2.5	50 / 33	-
Innes Park	5		0.00	0.00	14.5	4.6	2.5	29	-
	2				14.5		2.8	30	-
	1				16.5		2.2	32	-
Coonarr	5		0.21	10.92	16.8	5.8	5.2	52	-
	2				16.8		6.8	54	-
	1				22.8		0.8	56	-
Woodgate Beach North	5		0.65	33.8	11.3	9.7	0.0	77	-
	2				11.3		0.0	77	-
	1				11.3		0.8	78	-
Woodgate Beach Central	5		0.00	0	25.4	7.0	0.0	45	-
	2				25.4		0.0	45	-
	1				27.4		0.0	48	-
Woodgate Beach South	5		0.50	26	12.1	8.4	0.0	65	-
	2				12.1		0.0	65	-
	1				14.1		0.0	68	-

5057-03-R01

TABLE B-3 +0.8M SEA LEVEL RISE EROSION HAZARD AREA WIDTH

Sea Level Rise Scenario (m)	Storm Event (AEP%)	Planning Period, N (Years)	Rate of Long-Term Erosion, R (m/year)	Total Long-Term Erosion, N x R (m)	Storm Induced Short-Term Erosion, C (m)	Erosion due to Sea Level Rise, S (m)	Dune Scarp Component, D (m)	Erosion Hazard Area Width for Scenario, E (m)	DES Existing Erosion Prone Area Width (m)
Moore Park Beach	5	82	1.05	86.1	29	25.2	0.0	196	-
	2				31		0.0	199	-
	1				33		0.0	202	160
Bargara (Kellys Beach North / South)	5		0.23 / 0.00	18.9 / 0.00	16.1	11.2	1.8	66 / 40	-
	2				16.1		2.5	67 / 41	-
	1				16.1		2.5	67 / 41	70
Innes Park	5		0.00	0.00	14.5	9.3	2.5	36	-
	2				14.5		2.8	36	-
	1				16.5		2.2	38	120
Coonarr	5		0.21	17.2	16.8	11.5	5.2	69	-
	2				16.8		6.8	71	-
	1				22.8		0.8	73	165
Woodgate Beach North	5		0.65	53.3	11.3	19.4	0.0	118	-
	2				11.3		0.0	118	-
	1				11.3		0.8	118	110
Woodgate Beach Central	5		0.00	0.00	25.4	14	0.0	55	-
	2				25.4		0.0	55	-
	1				27.4		0.0	58	110
Woodgate Beach South	5		0.50	41	12.1	16.7	0.0	98	-
	2				12.1		0.0	98	-
	1				14.1		0.0	101	110

APPENDIX C
SUMMARY OF EROSION PRONE AREA FOR BUNDABERG COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

EPA Seg_new	EPA_2018 comment	EPA_seg_Old	LGA_New	Location	Seg-length (km)	EPA width 2015 recalc plus SLR	EPA_2018 1%AEP	Features EPA_Width_New_Text	Extra_Note_New	GIS_start_X	GIS_start_Y	GIS_end_X	GIS_end_Y
BuR001		SC3375F_1	Bundaberg Regional	North shore Pt to Burrum Pt.	3.22158	400	400*			152.61077	-25.17299	152.63257	-25.15164
BuR002		SC3375F_2	Bundaberg Regional		0.57858	Transition	Transition*	Trans 400 m to 110m	Transition	152.63257	-25.15164	152.62836	-25.14807
BuR003a	Keep, reduce length	SC3375F_3	Bundaberg Regional	Woodgate		110	110*			152.62836	-25.14807	152.58674	-25.12661
BuR003b	Woodgate South	New Segment	Bundaberg Regional	Woodgate			101			152.58674	-25.12661	152.57987	-25.12142
BuR003c	Woodgate Central	New Segment	Bundaberg Regional	Woodgate			58			152.57987	-25.12142	152.55538	-25.09422
BuR003d	Woodgate North	New Segment	Bundaberg Regional	Woodgate			118			152.55538	-25.09422	152.55108	-25.08285
BuR004	Delete	~~SC3375F_4~~	~~Bundaberg Regional~~	~~Woodgate~~	~~0.18997~~	~~Transition~~	~~Transition*~~	~~Trans 600m to 165m~~	~~Transition~~	~~152.55396~~	~~-25.09155~~	~~152.55330~~	~~-25.08994~~
BuR005	Delete	~~SC3375F_5~~	~~Bundaberg Regional~~	~~Woodgate~~	~~0.81732~~	~~215~~	~~215~~			~~152.55330~~	~~-25.08995~~	~~152.55108~~	~~-25.08285~~
BuR006		SC3375F_6	Bundaberg Regional	South of Theodolite CK	0.53593	Transition	Transition*	Trans 118m to 400m	Transition	152.55108	-25.08285	152.54930	-25.07828
BuR007		SC3375F_7	Bundaberg Regional	Theodolite Creek	1.59741	400	400*			152.54930	-25.07828	152.54359	-25.06480
BuR008		SC3376F_2	Bundaberg Regional		0.14326	Transition	Transition*	Trans 400m to 215m	Transition	152.54359	-25.06480	152.54279	-25.06373
BuR009		SC3376F_3	Bundaberg Regional		3.82336	215	215*			152.54279	-25.06373	152.52234	-25.03460
BuR010		SC3376F_4	Bundaberg Regional		0.14140	Transition	Transition*	Trans 215m to 115m	Transition	152.52234	-25.03460	152.52161	-25.03351
BuR011		SC3376F_5	Bundaberg Regional	Palm Beach	6.91479	115	115*			152.52161	-25.03351	152.49090	-24.97759
BuR012		SC3376F_6	Bundaberg Regional	south of Coonarr CK	0.53643	Transition	Transition*	Trans 115m to 400m	Transition	152.49090	-24.97759	152.48994	-24.97282
BuR013		SC3376F_7	Bundaberg Regional	Coonarr Creek	0.98818	400	400*			152.48994	-24.97282	152.48807	-24.96405
BuR014		SC3376F_8	Bundaberg Regional	North of Coonarr CK	0.42954	Transition	Transition*	Trans 400m to 73m	Transition	152.48807	-24.96405	152.48726	-24.96024
BuR015	Coonarr	SC3376F_9	Bundaberg Regional	Coonarr Beach	1.53046	165	73			152.48726	-24.96024	152.48523	-24.94652
BuR016		SC3376F_10	Bundaberg Regional	south of Elliott River	1.02068	Transition	Transition*	Trans 73m to 400m	Transition	152.48523	-24.94653	152.48595	-24.93733
BuR017		SC3376F_11	Bundaberg Regional	Elliott River	0.63998	400	400*			152.48595	-24.93733	152.48607	-24.93154
BuR018		SC3376F_12	Bundaberg Regional	North side of mouth of Elliott River	0.12446	35	35	Possible Bedrock		152.49123	-24.92252	152.49183	-24.92154
BuR019		SC3376F_13	Bundaberg Regional		0.27675	75	75*	Possible Bedrock		152.49183	-24.92154	152.49261	-24.91914
BuR020		SC3376F_14	Bundaberg Regional		1.75922	35	35**	Possible Bedrock		152.49261	-24.91914	152.49043	-24.90336
BuR021		SC3376F_15	Bundaberg Regional		0.27910	70	70**	Possible Bedrock		152.49043	-24.90336	152.48971	-24.90092
BuR022		SC3376F_16	Bundaberg Regional		0.83914	35	35**	Possible Bedrock		152.48971	-24.90092	152.48785	-24.89353
BuR023		SC3376F_17	Bundaberg Regional		0.10508	70	70**	Possible Bedrock		152.48785	-24.89353	152.48751	-24.89263
BuR024		SC3376F_18	Bundaberg Regional		0.33902	35	35**	Possible Bedrock		152.48751	-24.89263	152.48734	-24.88957
BuR025		SC3376F_19	Bundaberg Regional		0.10404	70	70**	Possible Bedrock		152.48734	-24.88957	152.48707	-24.88866
BuR026		SC3376F_20	Bundaberg Regional	coral cove	1.89303	35	35**	Possible Bedrock		152.48707	-24.88866	152.48364	-24.87183
BuR027	Innes park	SC3376F_21	Bundaberg Regional	Innes Park Creek	0.25801	120	38	Possible Bedrock		152.48364	-24.87183	152.48307	-24.86956
BuR028		SC3376F_22	Bundaberg Regional		0.96132	70	70*	Possible Bedrock		152.48307	-24.86956	152.48239	-24.86089
BuR029		SC3376F_23	Bundaberg Regional		1.34379	35	35**	Possible Bedrock		152.48239	-24.86089	152.47901	-24.84913
BuR030		SC3376F_24	Bundaberg Regional	Rifle Range Creek	0.29081	120	120*	Possible Bedrock		152.47901	-24.84913	152.47742	-24.84694
BuR031		SC3376F_25	Bundaberg Regional	Nudibranch Park	1.93323	35	35**	Possible Bedrock		152.47742	-24.84694	152.46931	-24.83110
BuR032	Bargara South	SC3376F_26	Bundaberg Regional	Kellys Beach	0.49693	70	41	Possible Bedrock		152.46931	-24.83110	152.46704	-24.82712

EPA Seg_new	EPA_2018 comment	EPA_seg_Old	LGA_New	Location	Seg-length (km)	EPA width 2015 recalc plus SLR	EPA_2018 1%AEP	Features EPA_Width_New_Text	Extra_Note_New	GIS_start_X	GIS_start_Y	GIS_end_X	GIS_end_Y
BuR033		SC3376F_27	Bundaberg Regional	Kellys Beach	0.27952	**120**	**120**	**Possible Bedrock**		152.46704	-24.82712	152.46608	-24.82474
BuR034	Bargara North	SC3376F_28	Bundaberg Regional	Kellys Beach	0.65559	**70**	**67**	**Possible Bedrock**		152.46608	-24.82474	152.46745	-24.81895
BuR035		SC3376F_29	Bundaberg Regional	Christsen Park	0.39993	**35**	**35****	**Possible Bedrock**		152.46745	-24.81895	152.46621	-24.81552
BuR036		SC3376F_30	Bundaberg Regional	Bargara	0.40936	**65**	**65***	**Possible Bedrock**		152.46621	-24.81552	152.46319	-24.81304
BuR037		SC3376F_31	Bundaberg Regional		0.87716	**35**	**35***	**Possible Bedrock**		152.46319	-24.81304	152.45767	-24.80691
BuR038		SC3376F_32	Bundaberg Regional	Nielson Park	0.36589	**65**	**65***	**Possible Bedrock**		152.45767	-24.80691	152.45593	-24.80401
BuR039		SC3376F_33	Bundaberg Regional		0.99952	**35**	**35***	**Possible Bedrock**		152.45593	-24.80401	152.44698	-24.80012
BuR040		SC3376F_34	Bundaberg Regional		0.17969	**120**	**120***	**Possible Bedrock**		152.44698	-24.80012	152.44521	-24.80002
BuR041		SC3376F_35	Bundaberg Regional	Oaks Beach	1.40406	**75**	**75***	**Possible Bedrock**		152.44521	-24.80002	152.43780	-24.78927
BuR042		SC3376F_36	Bundaberg Regional		0.37152	**35**	**35****	**Possible Bedrock**		152.43780	-24.78927	152.43546	-24.78668
BuR043		SC3376F_37	Bundaberg Regional	Mon Repos	0.24210	**75**	**75****	**Possible Bedrock**		152.43546	-24.78668	152.43450	-24.78468
BuR044		SC3376F_38	Bundaberg Regional		2.08446	**35**	**35****	**Possible Bedrock**		152.43450	-24.78468	152.41917	-24.77204
BuR045		SC3376F_39	Bundaberg Regional	Burnett Heads	0.27623	**75**	**75***	**Possible Bedrock**		152.41917	-24.77204	152.41833	-24.76967
BuR046		SC3376F_40	Bundaberg Regional	Burnett Heads	0.46117	**35**	**35***	**Possible Bedrock**		152.41833	-24.76967	152.41686	-24.76572
BuR047		SC3376F_41	Bundaberg Regional	Burnett Heads	0.17521	**75**	**75***	**Possible Bedrock**		152.41686	-24.76572	152.41635	-24.76420
BuR048		SC3376F_42	Bundaberg Regional	Burnett Heads	0.80676	**35**	**35***	**Possible Bedrock**		152.41635	-24.76420	152.41261	-24.75776
BuR049		SC3377F_1	Bundaberg Regional	Barubbra Island	3.84541	**0**	**0**	**Width of Island**		152.39838	-24.75382	152.36924	-24.73141
BuR050		SC3377F_2	Bundaberg Regional	north side of Burnett River	8.50777	**400**	**400***			152.37542	-24.74803	152.29547	-24.72365
BuR051		SC3377F_3	Bundaberg Regional		1.76001	**Transition**	**Transition***	**Trans 400m to 202m**	**Transition**	152.29547	-24.72365	152.28019	-24.71598
BuR052	Moore Park Beach	SC3377F_4	Bundaberg Regional	Moore Park	2.22771	**160**	**202**			152.28019	-24.71598	152.26214	-24.70440
BuR053		SC3377F_5	Bundaberg Regional		2.86209	**Transition**	**Transition***	**Trans 202m to 235m**	**Transition**	152.26214	-24.70440	152.24101	-24.68715
BuR054		SC3377F_6	Bundaberg Regional		0.54294	**Transition**	**Transition***	**Trans 235m to 400m**	**Transition**	152.24101	-24.68715	152.23772	-24.68326
BuR055		SC3377F_7	Bundaberg Regional	Kolan River, south side	3.33256	**400**	**400***			152.23772	-24.68326	152.21333	-24.66296
BuR056	Miara	SC3377F_8	Bundaberg Regional	Kolan River, Spits both sides of the river	2.55781	**0**	**0**	**Width of Spit & Islands**		152.21333	-24.66296	152.19149	-24.65125
BuR057		SC3377F_10	Bundaberg Regional	Kolan River, north side	0.00000								
BuR058		SC3377F_11	Bundaberg Regional		9.27899	**205**	**205***			152.18833	-24.65986	152.12393	-24.60002
BuR059		SC3377F_12	Bundaberg Regional		4.51980	**400**	**400***			152.12393	-24.60002	152.09481	-24.56900
BuR060		SC3377F_13	Bundaberg Regional		4.77122	**135**	**135***			152.09481	-24.56900	152.07043	-24.53206
BuR061		SC3377F_14	Bundaberg Regional	Baffle Creek, south side	1.94226	**400**	**400***			152.07043	-24.53206	152.06162	-24.51645

5057-03-R01

APPENDIX D
EROSION ASSESSMENT INPUTS AND ANALYSIS

D-1 Miara analysis

D-1-1 Background

Miara is located on the western bank of the Kolan River mouth estuary. The Kolan River originates in the Dawes Range and meanders across the coastal plains north of Bundaberg before flowing into Wide Bay at Miara. Prior to reaching the ocean the river is directed parallel to the coast north-westwards by a sand spit barrier which progresses along the coastline from the south. This sand spit protects the estuary and Miara from large swell wave energy.

Erosion has been observed along the riverbank at Miara since prior to the amalgamation of the Burnett and Bundaberg Shires. A trial groyne was constructed in the mid-2000's in an attempt to anchor sand placed during beach nourishment and sand nourishment has occurred on a number of occasions with limited success. As detailed in Water Technology (2014), the erosion along the shoreline is a function of changes to the sand spit and in particular the formation of new entrance channels.

Analysis of historical aerial photography indicates that prior to the 2013 entrance opening the spit grew northward at an average of 40 m per year over a 45-year period following the previous river breakthrough (1959 to 2004). This growth rate was not constant and the growth of the spit between images varied depending on the regional wind and wave conditions. The BPA (1989a) report estimates that a volume of 130,000 m^3 of sand was lost from the beaches between the Burnett River and the Kolan River, primarily due to the reformation of the sand spit between 1948 and 1982.

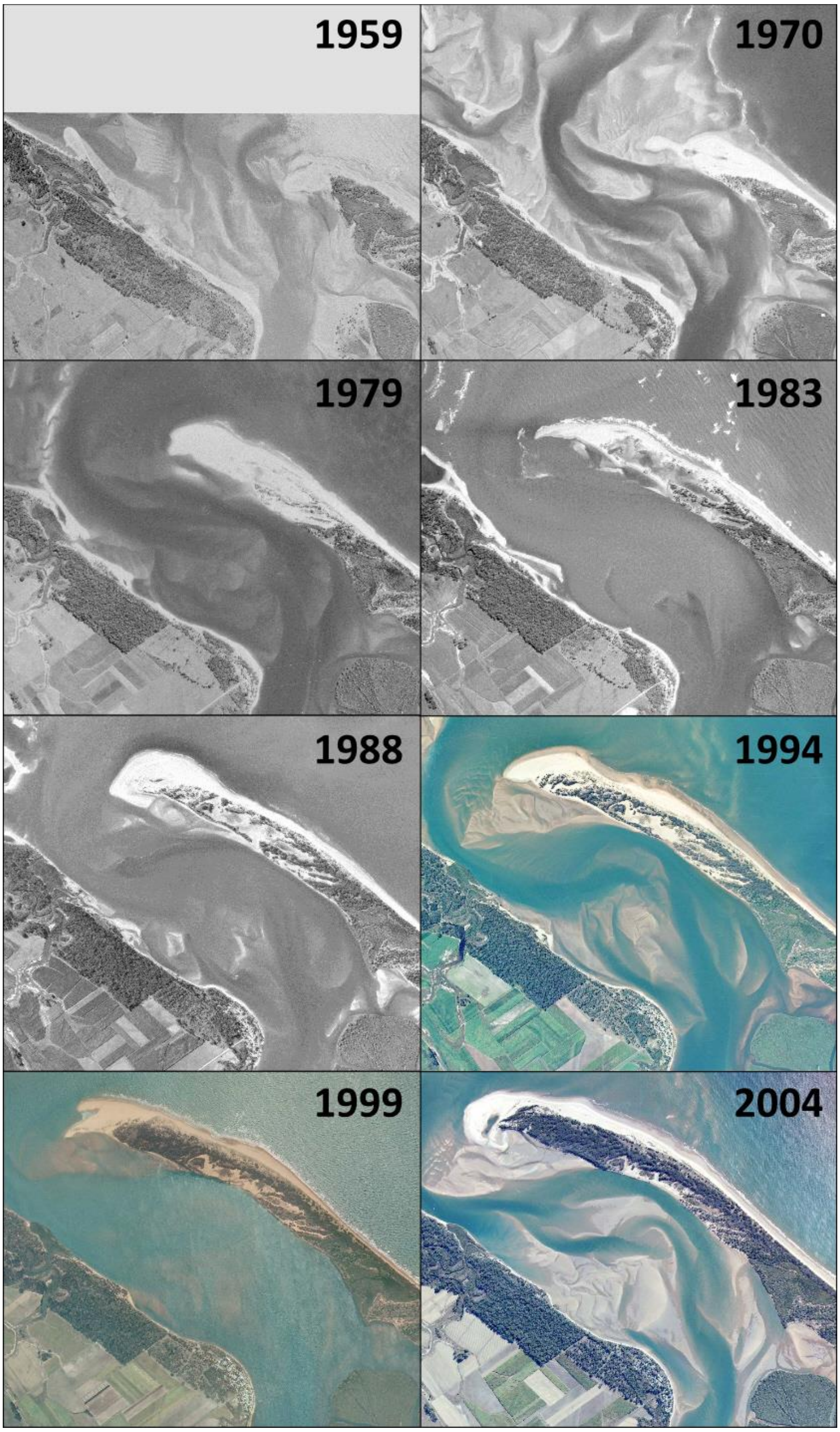


FIGURE D-1 HISTORICAL AERIAL PHOTOGRAPH COMPARISON – MIARA

In general, a low gradient, meandering river such as the downstream end of the Kolan River at Miara scours banks on the outside of a bend and accretes sand on the inside. However, during a flood these banks can be eroded or even cut through completely. This occurred upstream of the Miara Caravan Park (MCP) during the 2013 flood.

The MCP is located on the inside of the river bend where sediment accumulates during low flow periods. Inland of the MCP, the 1959 aerial image (top left) indicates the land here had been cleared for farming. The river bend and MCP area was left as scrubland, perhaps an indication that this land may have been subject to flooding and unsuitable for farming.

Following the breach and loss of the spit in the 1940s the edge of the vegetation (generally considered to be the tidal limit) along the north-eastern foreshore at the MCP site was eroded back between 20 and 30 m from the shoreline location in 2013. Along the eastern face the shorelines are in a similar (+/- 10 m) position both then and now. To the south the 1959 shoreline is a maximum 60 m shoreward of the 2013 position. The vegetation is much sparser in 1959 and the corner may have been eroded during the flood which caused the spit breach.

A depression is located landward of the MCP and may be evidence of an older flow path or foreshore orientation.

By 1979 (centre, top), the vegetation along the shoreline has shifted seaward, particularly around the north-eastern coast of the MCP. Further east however, there has been a large cutback in the shoreline, potentially a result of the changing wave conditions as the spit migrated northwards on the outer beach.

The top right image shows Miara in 1988. The campground is well established at this point. As the spit reformed and provided protection to the foreshore from ocean conditions, sediment has accreted on the river bend and the land has gradually shifted seaward and vegetated the area which was beach in 1979. In contrast to the 1959 and 1979 images, there is no sandy beach adjacent to the foreshore and could be an indication of the reduction in sediment from the river due to the 1975 construction of the Fred Haigh Dam, trapping sediment upstream of the structure which would have naturally been delivered to the estuary. By 1988 the line of the foreshore had pushed north-eastward over 60 m.

The 2004 image on the bottom left shows the shoreline has retreated from the 1988 position, similar to the 1959 position on the eastern face of the foreshore. Flooding in early 1990's may have scoured the foreshore here and caused a loss in beach and vegetation. Alternatively, the completion of the Bundaberg Irrigation Scheme in 1988 involved the construction of three water storages on the Kolan River (Fred Haigh Dam, the Bucca Weir, the Kolan Barrage), which all potentially retain river sediment upstream and prevent it being distributed downstream to the estuary.

The 2004 shoreline is around 5-10 m off the location of the existing shoreline. The retreat between 1998 and 2004 is over 40 m at the most north-eastern point on the bend and 20 m at the northern end of the MCP foreshore.

Relatively little change occurs between 2004 and 2017 as seen in the bottom centre and bottom right images of, Figure D-3 as the edge of the campground is along the foreshore and work is completed to maintain the shoreline position.

The following figures show the historic position of the shoreline at Miara relative to the most recent (2017) aerial imagery.

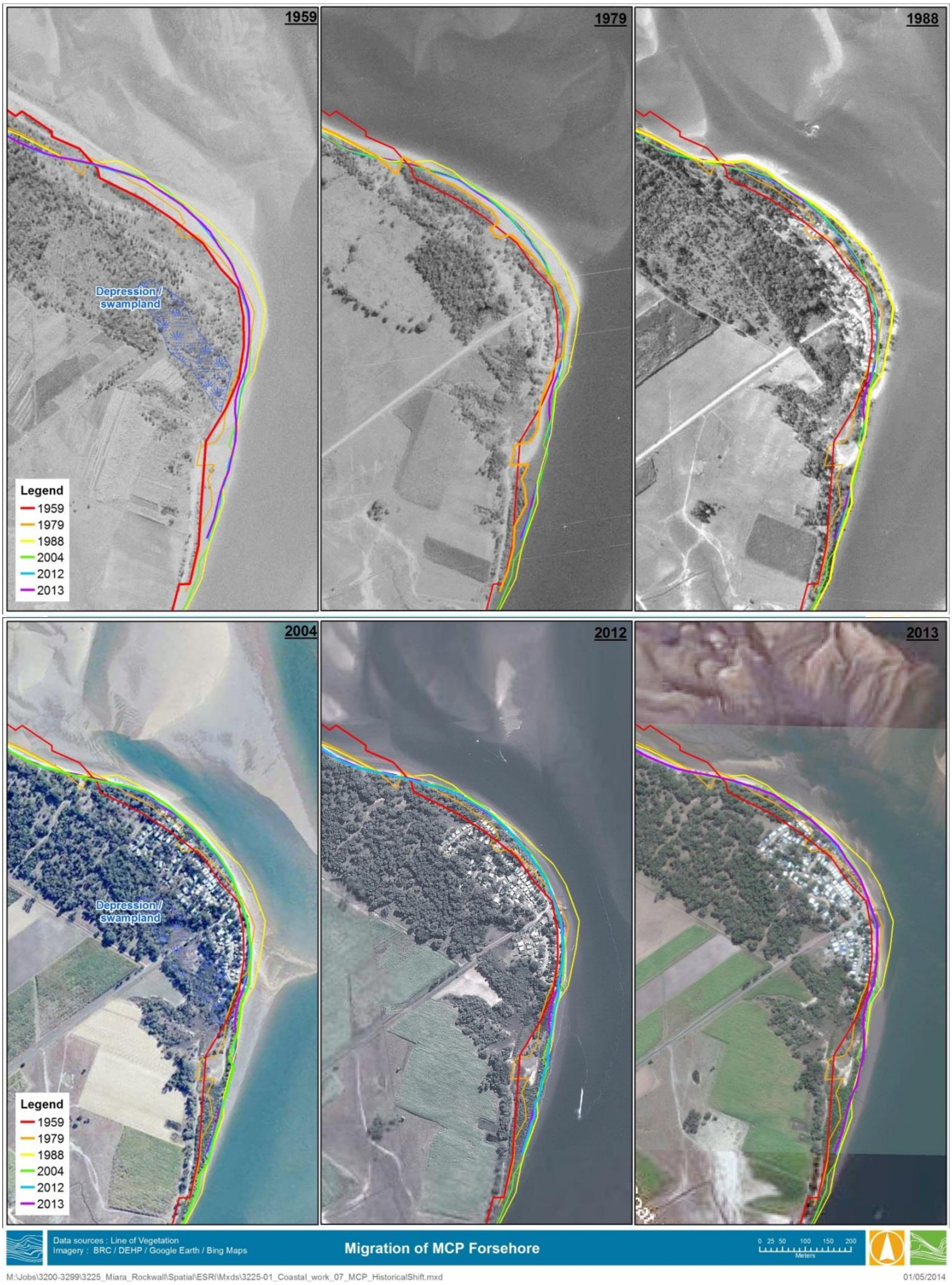


FIGURE D-2 HISTORIC IMAGERY COMPARISON – MIARA FORESHORE

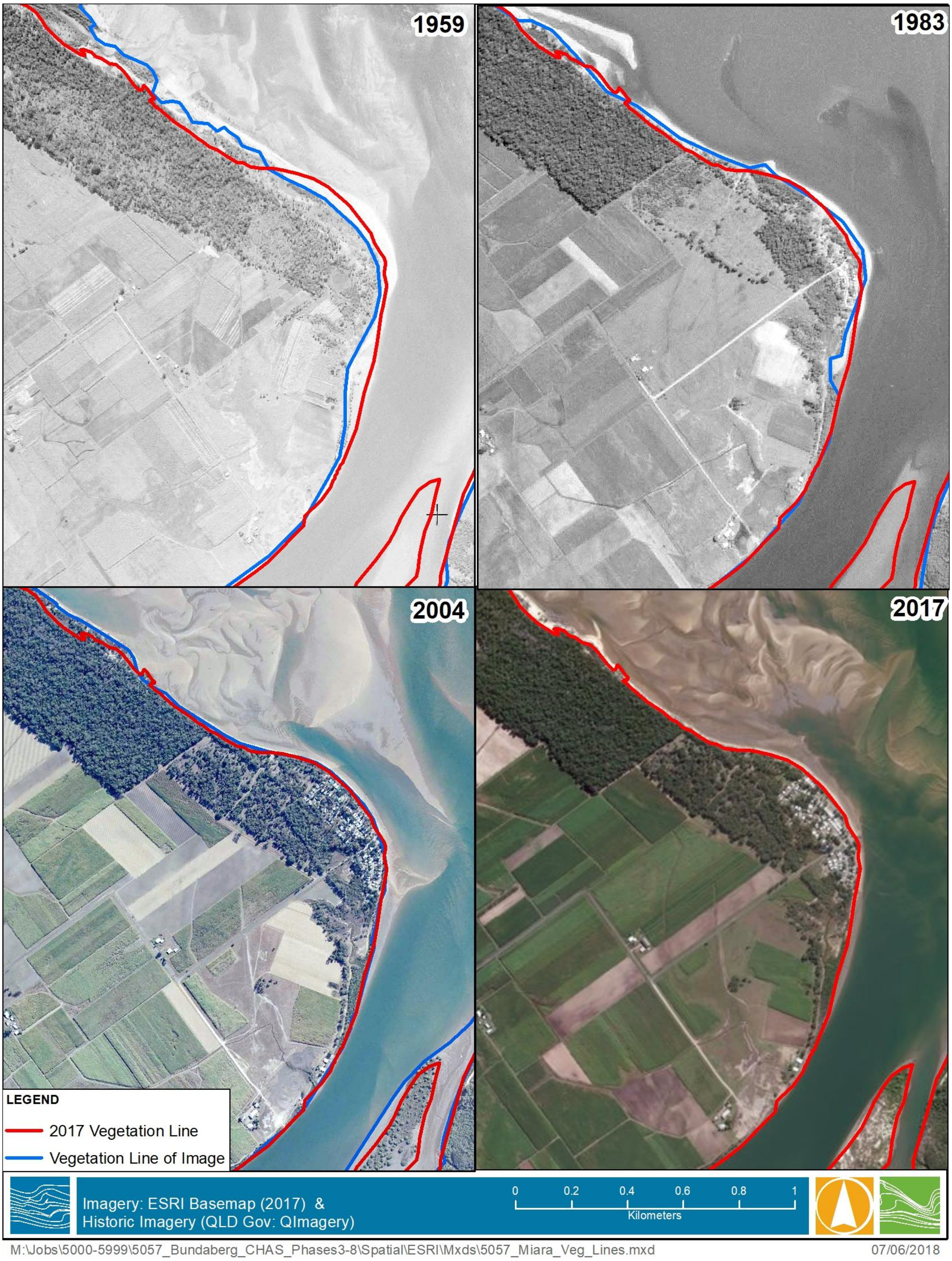


FIGURE D-3 HISTORIC SHORELINE COMPARISON AT MIARA TO 2017 IMAGERY

The 2014 study investigated the on-going erosion at the Miara foreshore, and in particular the area in front of the Miara Caravan Park (MCP). Findings included:

- Despite an apparent long-term trend of net sediment loss at this location, significant erosion appears to be episodic and tied to major events.
- Due to its location within the estuary, erosion is influenced by several factors, which include flood flows from the Kolan River, storm surges events, and tidal influences including king tides.
- The formation of a second entrance through the sandy spit can have a significant impact on erosion at Miara. For instance, following formation of the new river entrance through the sand spit in 2013, wind waves impacting the MCP beach can be generated over a much larger fetch (through the new entrance and into the open ocean) and larger swell waves which previously were blocked by the sand spit could be expected to impact the beach (albeit over a narrow range of directions, and limited in height at the MCP by the shallow depths within the estuary. The 2014 study found that the longshore transport of sediment within the Kolan River estuary was undergoing a readjustment due to the flood event and formation of the new entrance in 2013.
- If the spit were to completely erode, Miara would be exposed to the wave driven currents similar to those experienced at Moore Park beach. There is a net northward current offshore and the beaches erode at the south and accrete in the north in an attempt to align perpendicular with the long-term wave climate. The MCP may be protected from the most northward currents by the mangrove vegetated intertidal zone on the south side of the river, however some northward energy could result in the northern area of the campground eroding prior to a new spit forming. This can be seen occurring following the loss of the spit in the 1940s and 50s
- Predicted increases in sea-level rise will also contribute to erosion and shoreline retreat over the coming years as more of the beach profile is inundated. This is also expected to the relevant for the sandy spit.

D-2 Moore Park Beach analysis

D-2-1 Short term erosion assessment

TABLE D-1 MOORE PARK BEACH SBEACH SETUP

Storm AEP%	Max Slope Prior to Avalanching (degrees)	Grains Size Dn_{50} (mm)	Period (s)	Water Level (m)	Significant Wave Height (m)
5	34	0.3	10	2.22	3.24
2	34	0.3	10	2.30	3.29
1	34	0.3	10	2.75	3.51

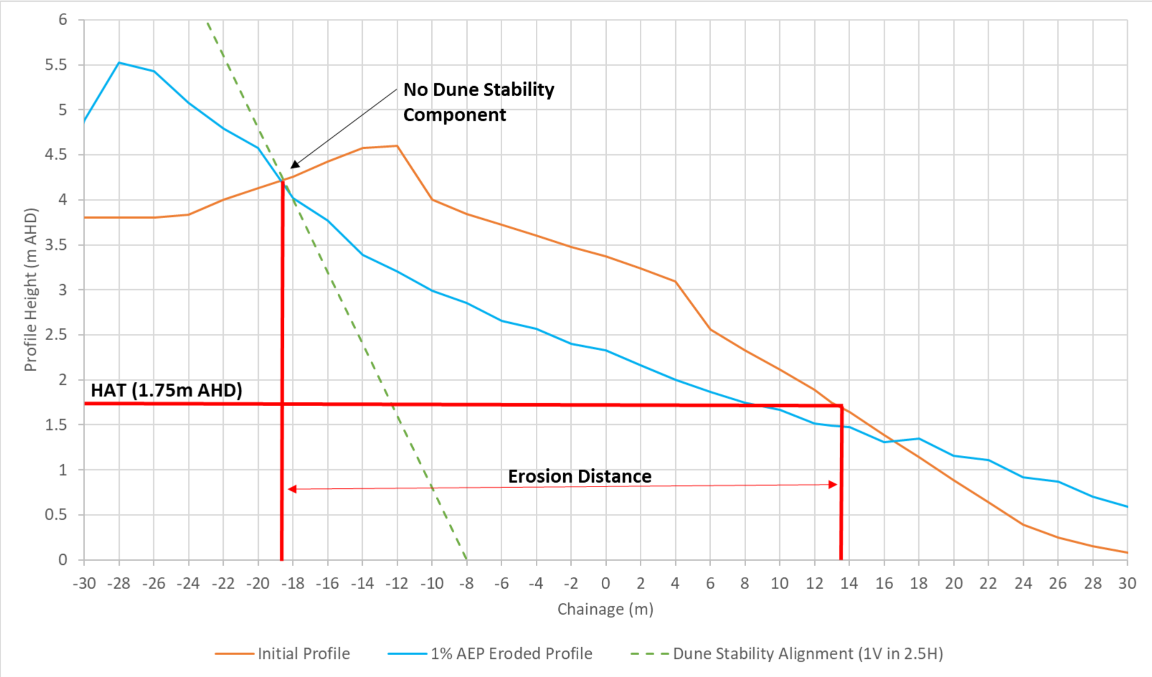


FIGURE D-4 SHORT TERM EROSION - MOORE PARK BEACH FOR 1% AEP EVENT

D-2-2 Long term erosion

The following figures present the comparison of profiles at Moore Park Beach and an overview of the historical imagery assessed. Long term erosion trends have been assessed at various beach profiles and measured at the upper dune profile at the line of HAT.

FIGURE D-5 BPA BEACH TRANSECTS - GOOBURRUM

5057-03-R01

FIGURE D-6 MOORE PARK BEACH PROFILE: GOOB 199.50

FIGURE D-7 MOORE PARK BEACH PROFILE: GOOB 200.00

FIGURE D-8 MOORE PARK BEACH PROFILE: GOOB 201.00

FIGURE D-9 MOORE PARK BEACH PROFILE: GOOB 202.00

5057-03-R01

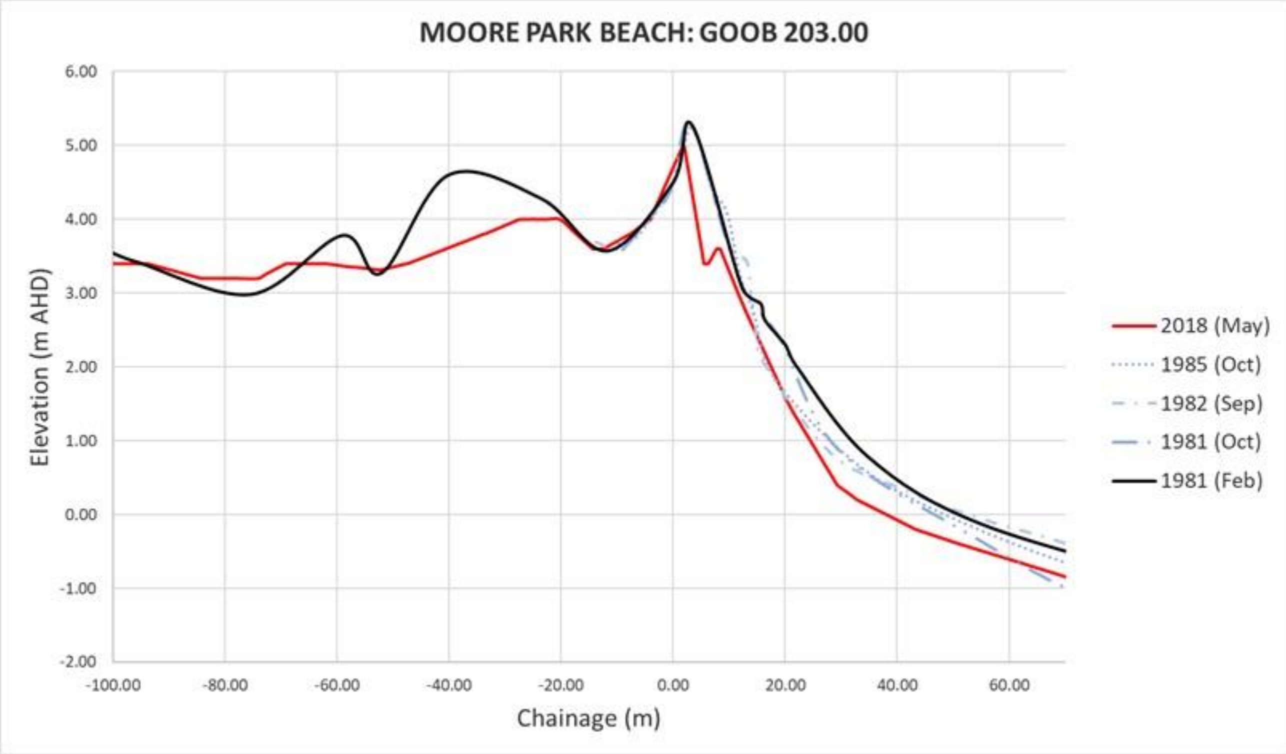


FIGURE D-10 MOORE PARK BEACH PROFILE: GOOB 203.00

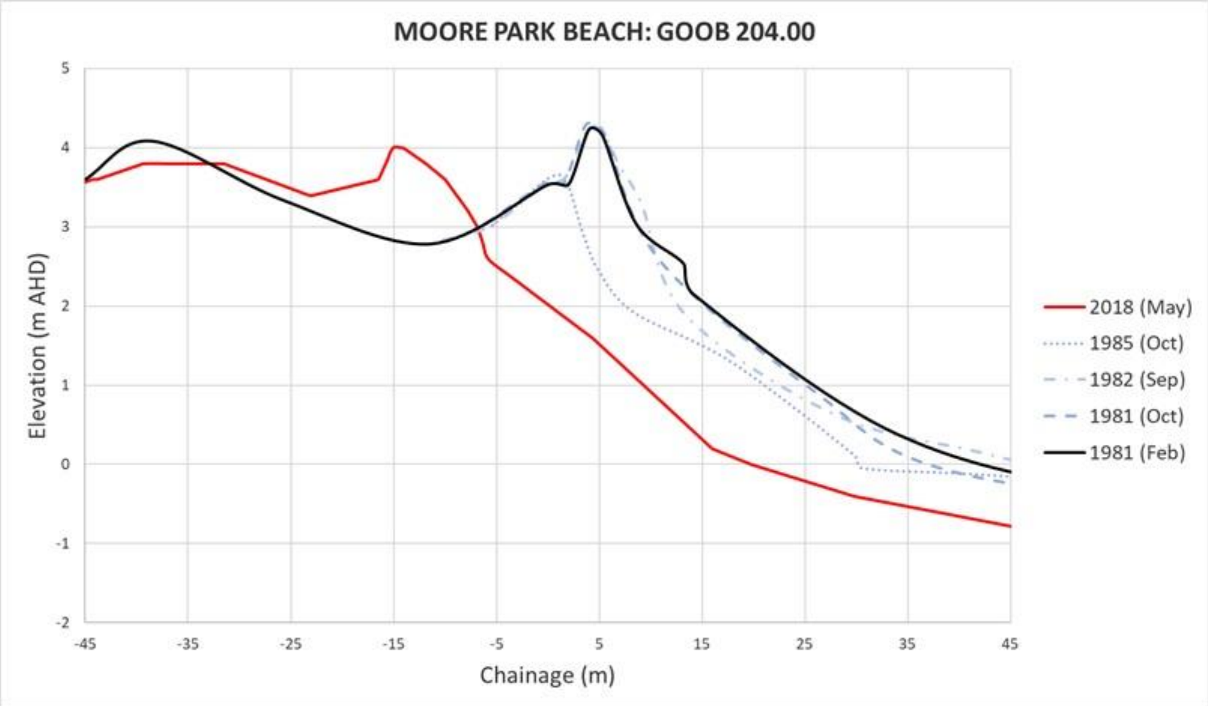


FIGURE D -11 MOORE PARK BEACH PROFILE: GOOB 204.00

5057-03-R01

FIGURE D-12 MOORE PARK BEACH PROFILE: GOOB 205.00

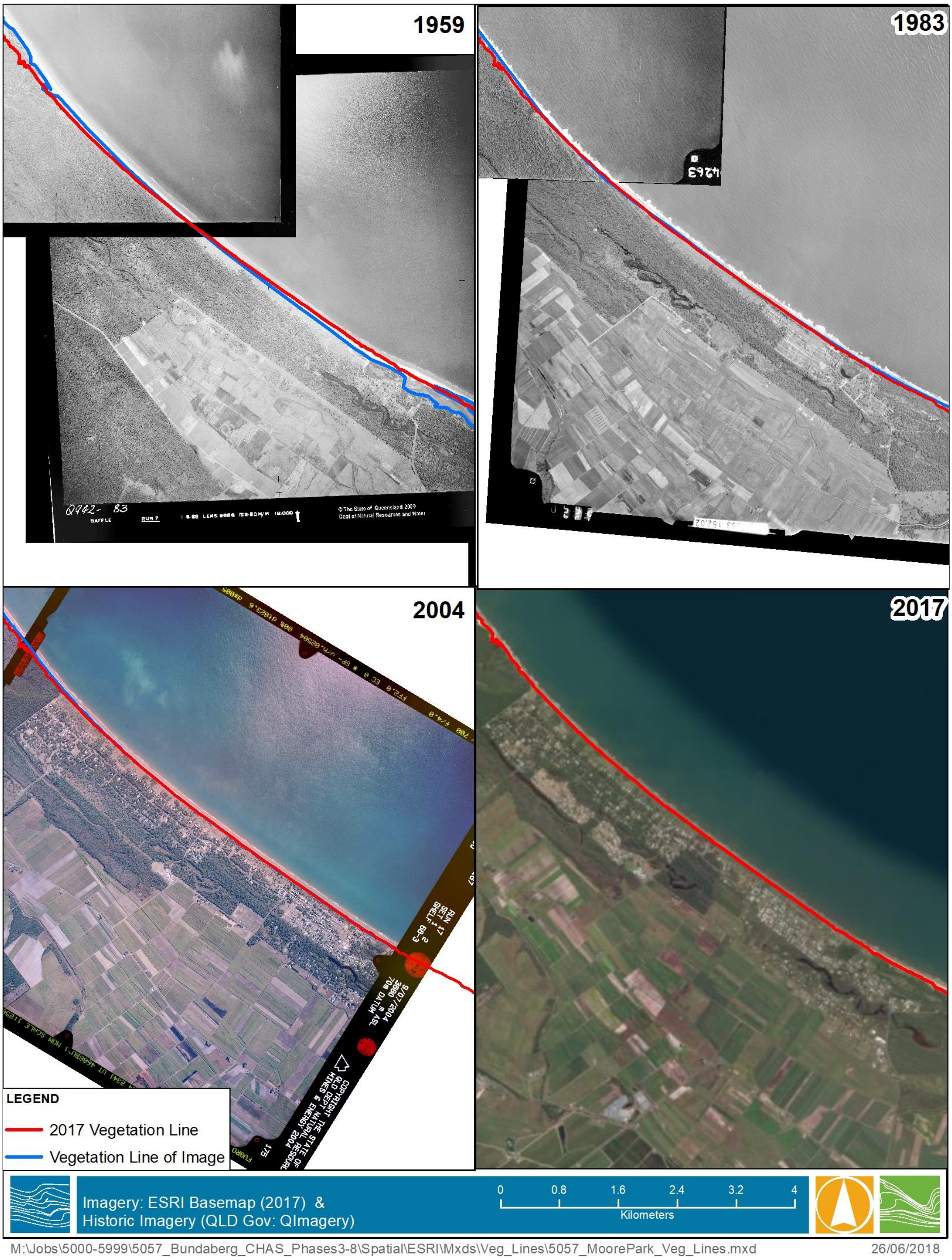


FIGURE D -13 EXAMPLE OF HISTORIC AERIAL IMAGERY COMPARISON – MOORE PARK BEACH

D-3 Bargara Analysis

D-3-1 Short term erosion assessment

TABLE D-2 BARGARA SBEACH SETUP

Storm AEP%	Max Slope Prior to Avalanching (degrees)	Grains Size Dn_{50} (mm)	Period (s)	Water Level (m)	Significant Wave Height (m)
5	34	0.25	10	2.24	3.63
2	34	0.25	10	2.33	3.68
1	34	0.25	10	2.60	3.92

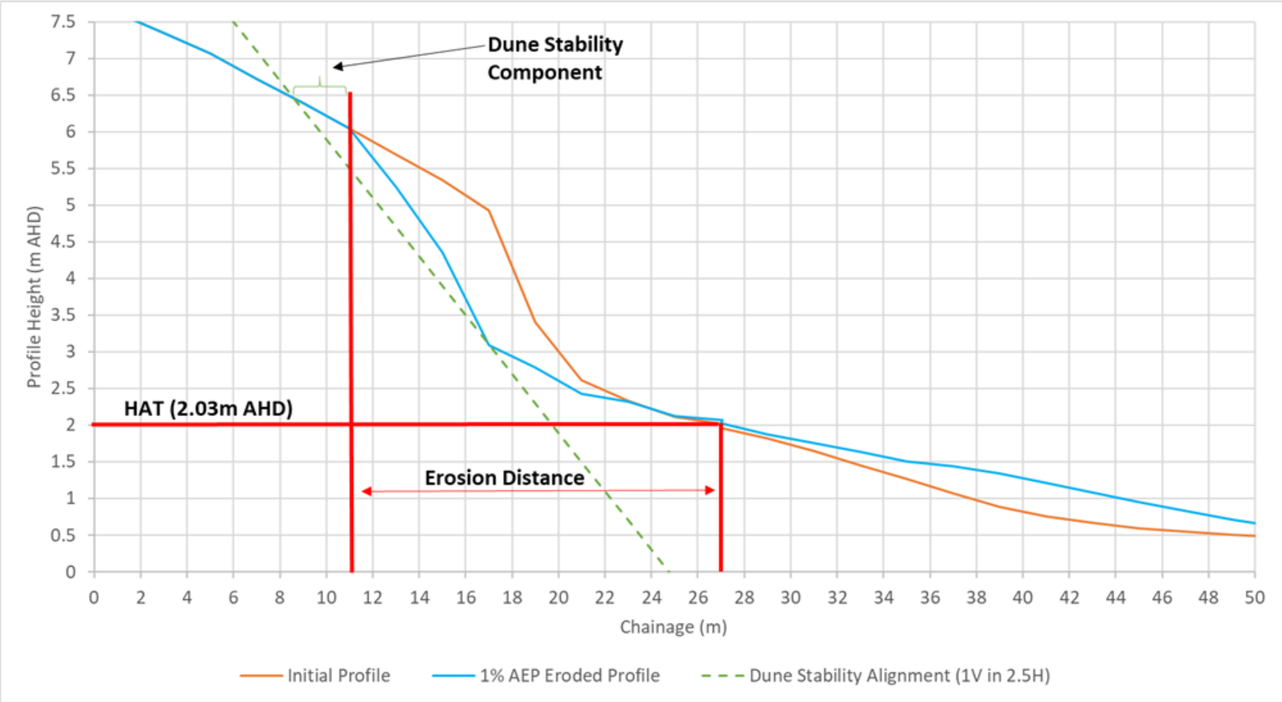


FIGURE D-14 SHORT TERM EROSION – BARGARA FOR 1% AEP EVENT

5057-03-R01

D-3-2 Long term erosion

The following figures present the comparison of profiles at Bargara and an overview of the historical imagery assessed.

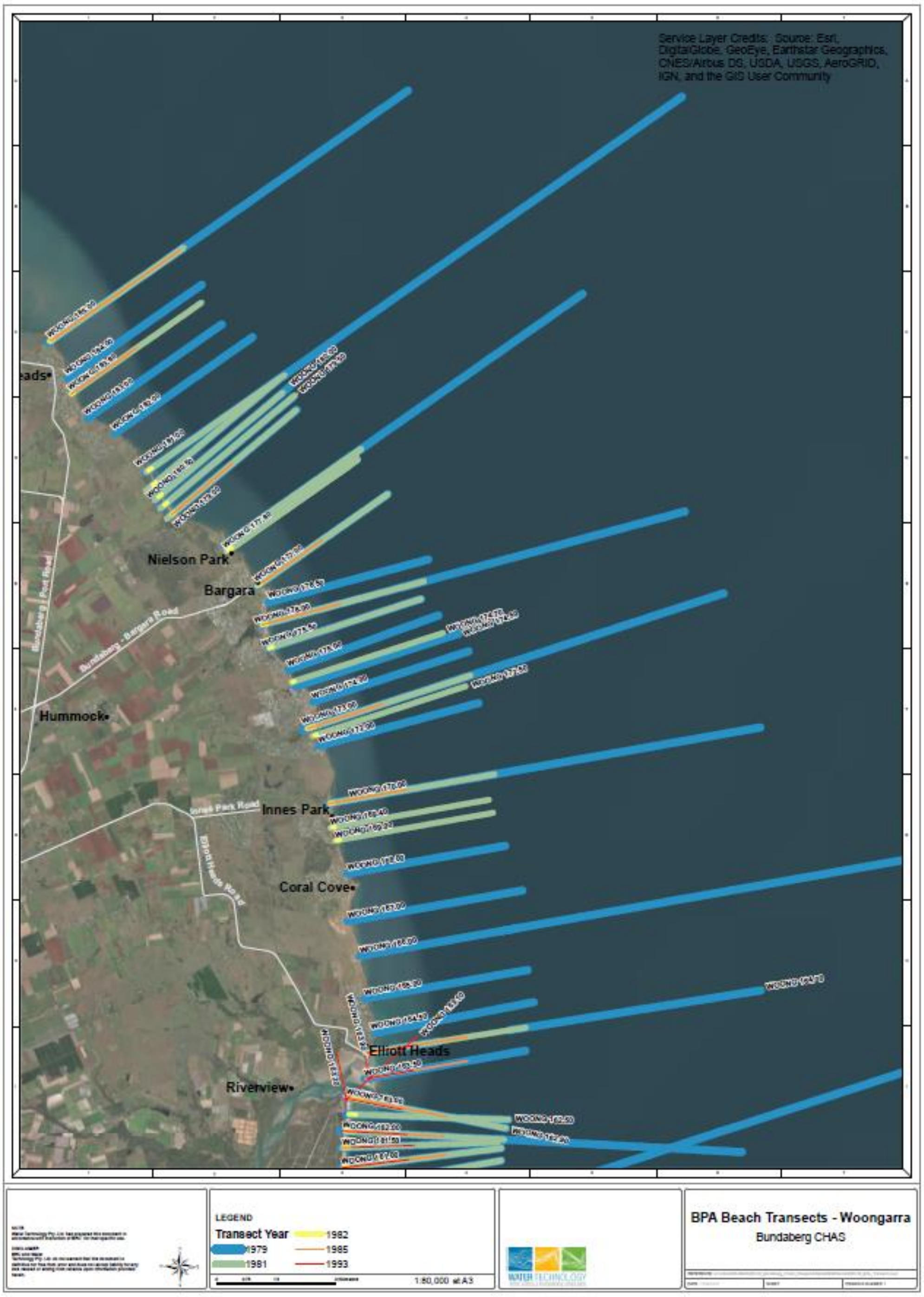


FIGURE D-15 BPA BEACH TRANSECTS - WOONGARRA

5057-03-R01

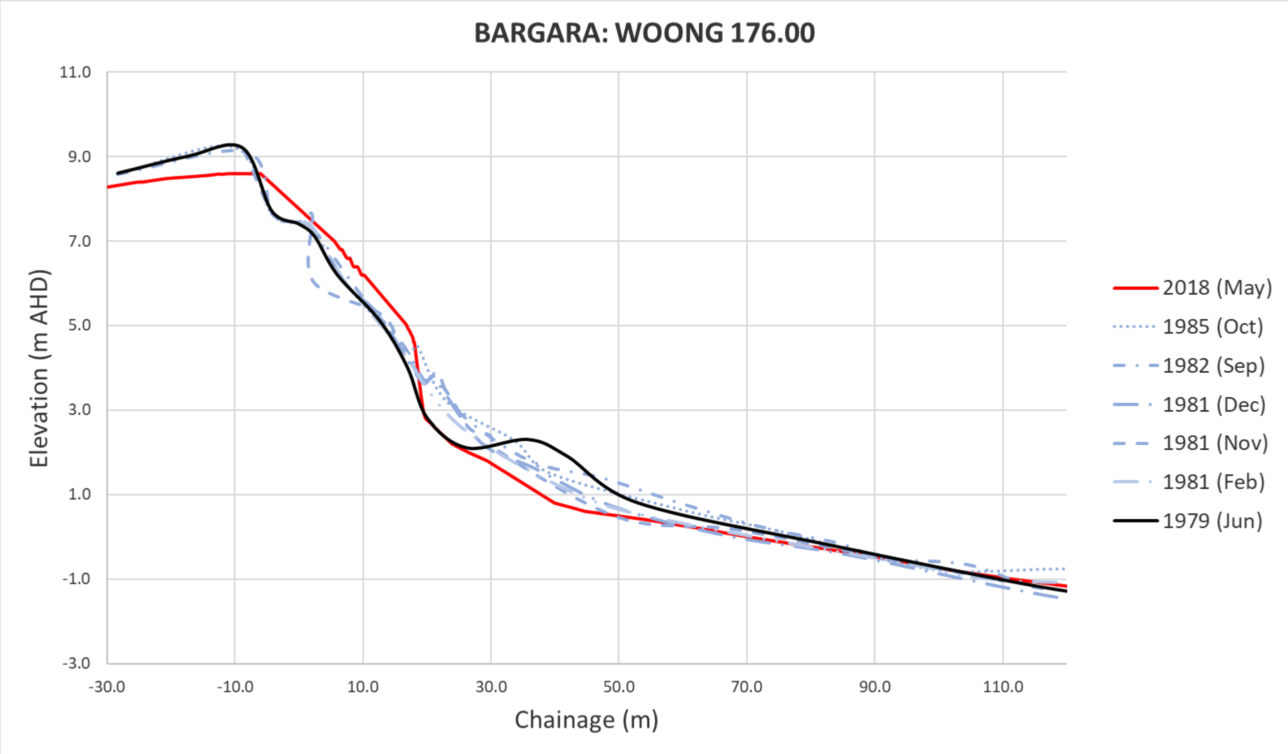


FIGURE D-16. BARGARA PROFILE: WOONG 176.00

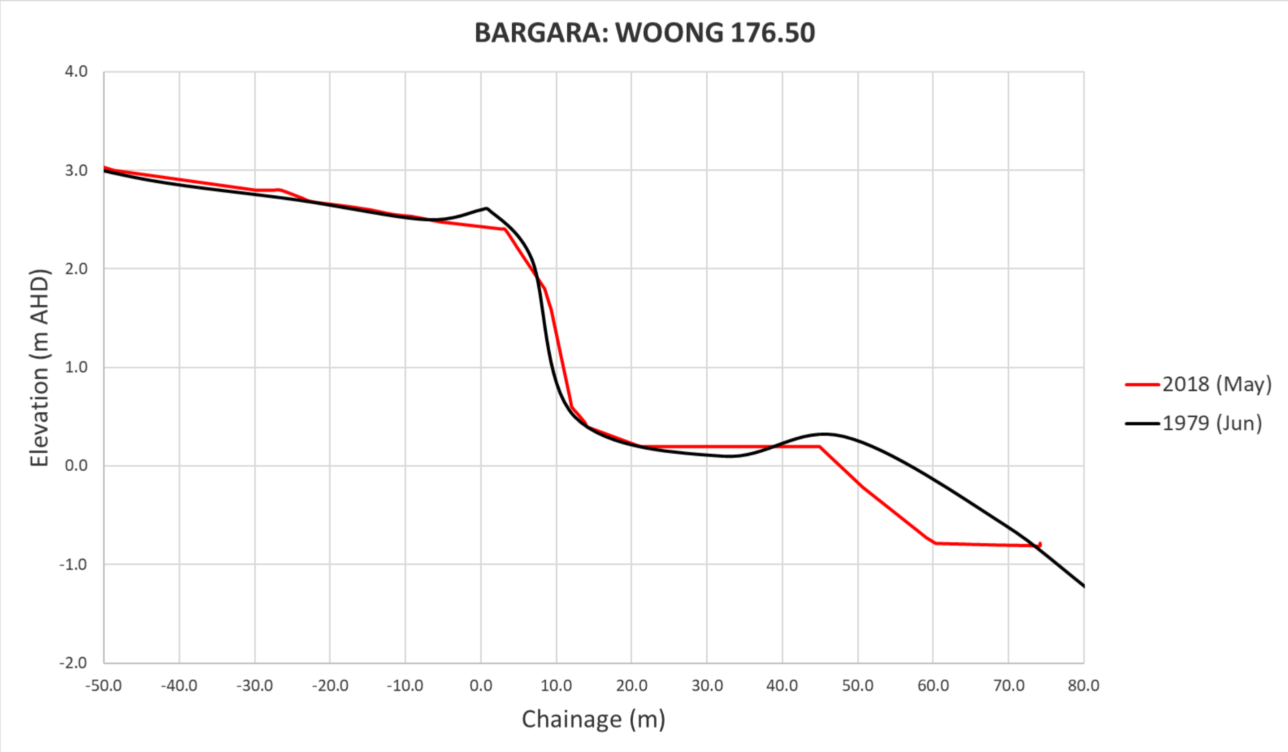


FIGURE D-17 BARGARA PROFILE: WOONG 176.50

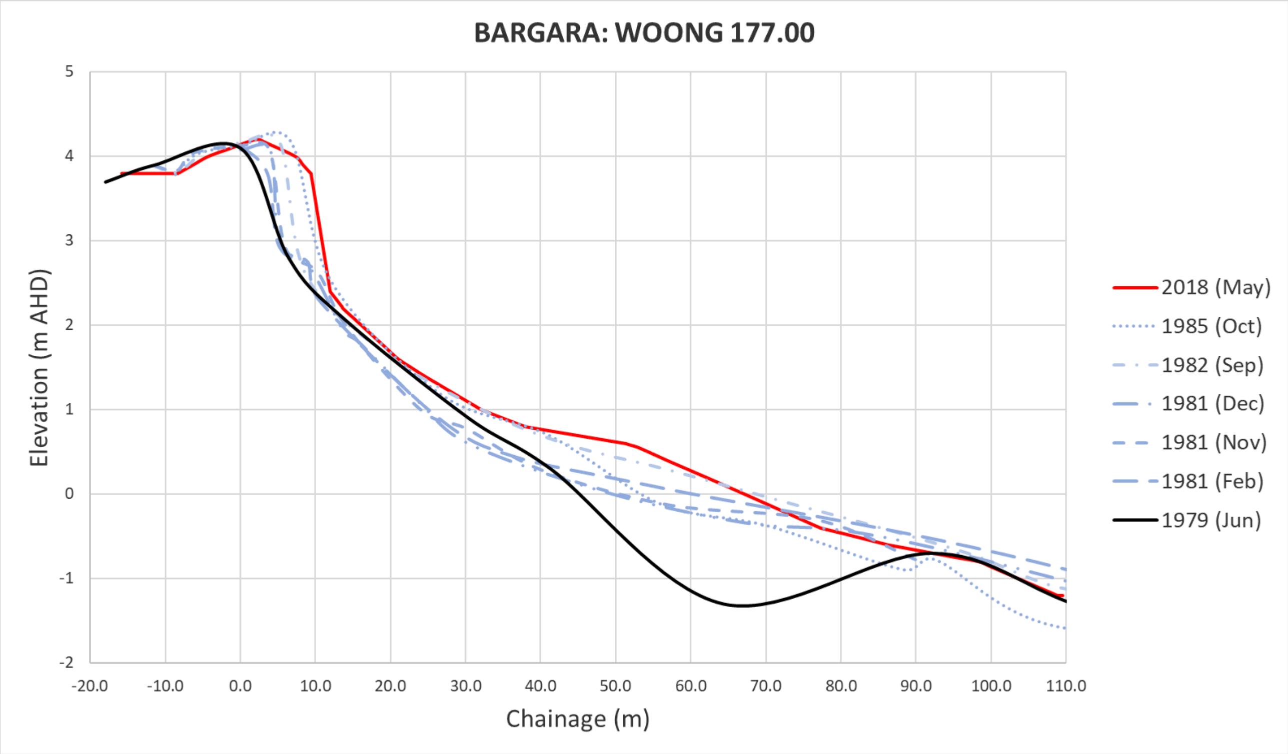
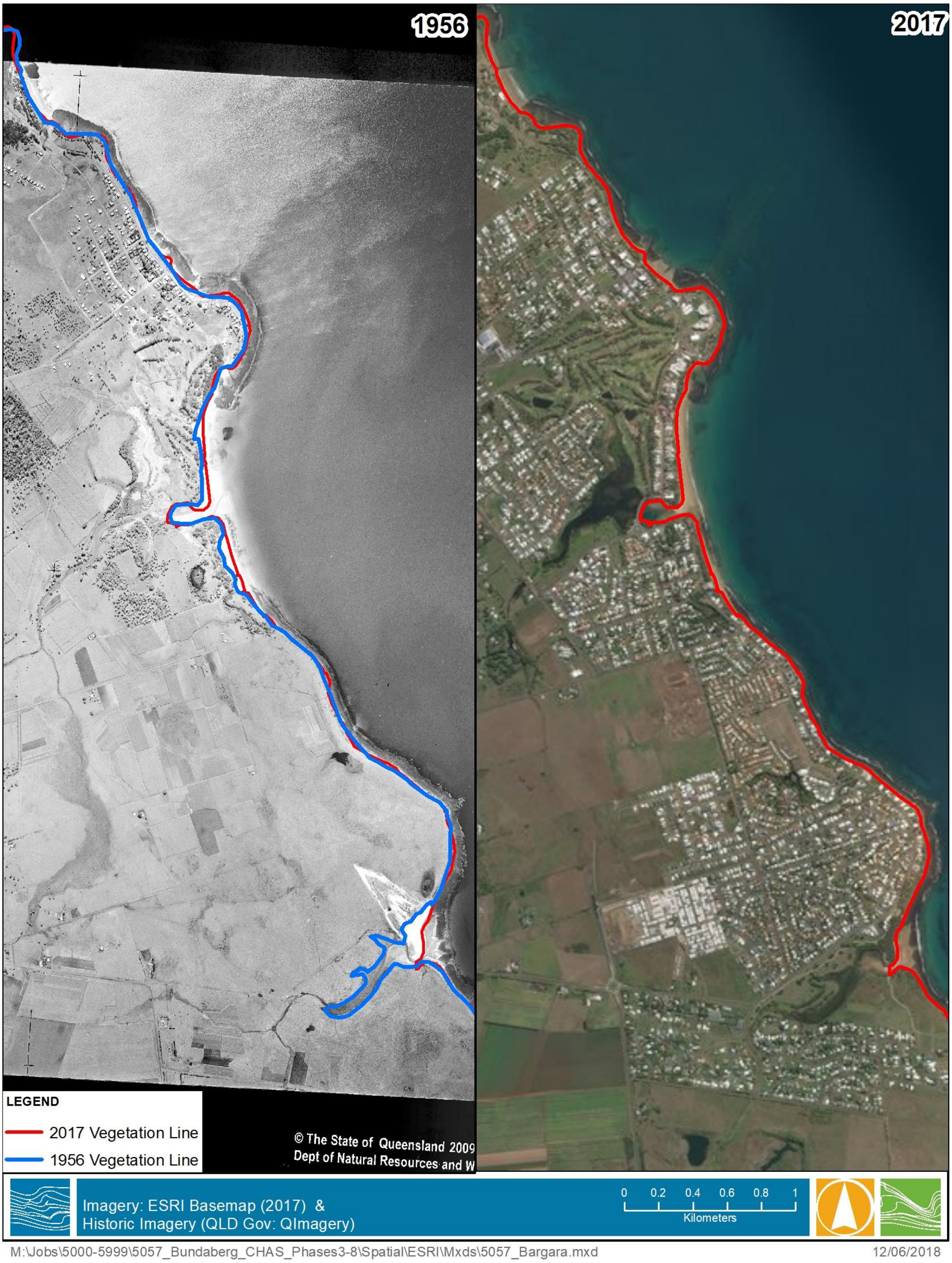


FIGURE D-18 BARGARA PROFILE: WOONG 176.50



5057-03-R01

FIGURE D-19 INDICATIVE COMPARISON OF HISTORIC IMAGERY AT BARGARA

D-4 Innes Park analysis

D-4-1 Short term erosion assessment

TABLE D -3 INNES PARK SBEACH SETUP

Storm AEP%	Max Slope Prior to Avalanching (degrees)	Grains Size Dn_{50} (mm)	Period (s)	Water Level (m)	Significant Wave Height (m)
5	34	0.25	10	2.25	3.78
2	34	0.25	10	2.34	3.83
1	34	0.25	10	2.48	4.1

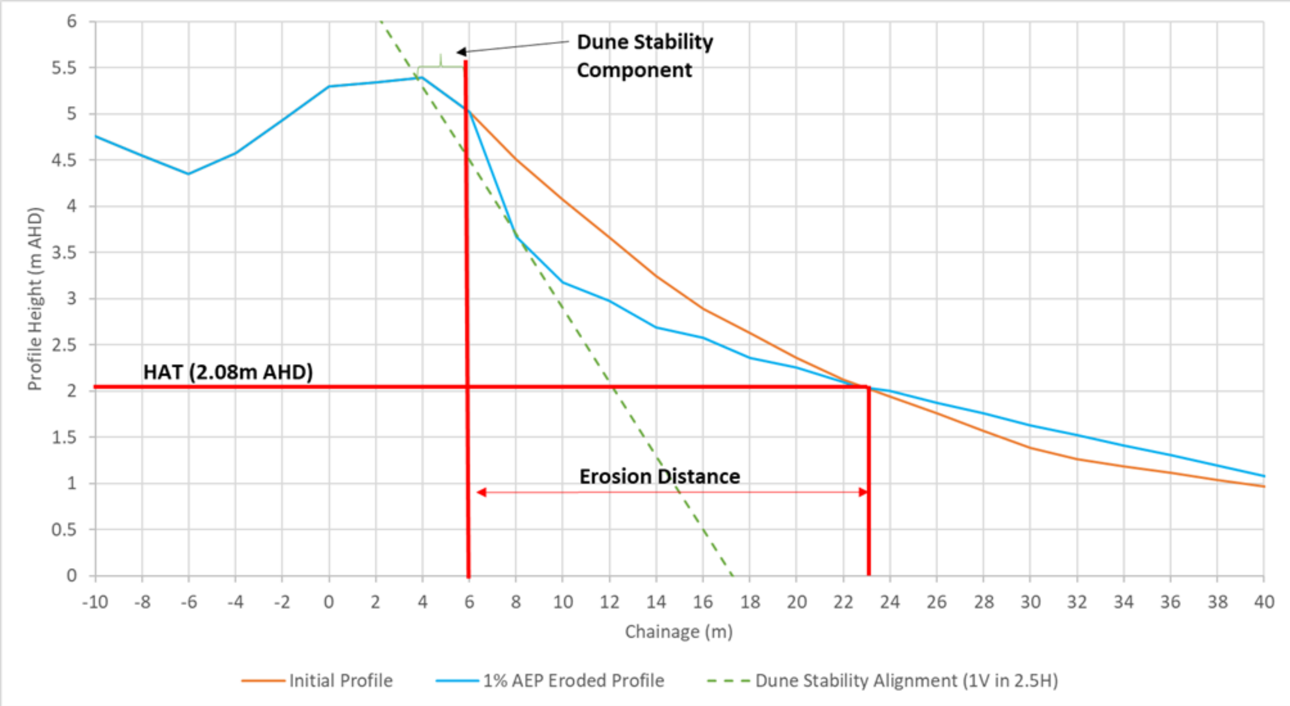


FIGURE D-20 SHORT TERM EROSION – INNES PARK FOR 1% AEP EVENT

D-4-2 Long term erosion

The following figures present the comparison of profiles at Innes Park and an overview of the historical imagery assessed.

FIGURE D-21 INNES PARK: WOONG 169.40

5057-03-R01

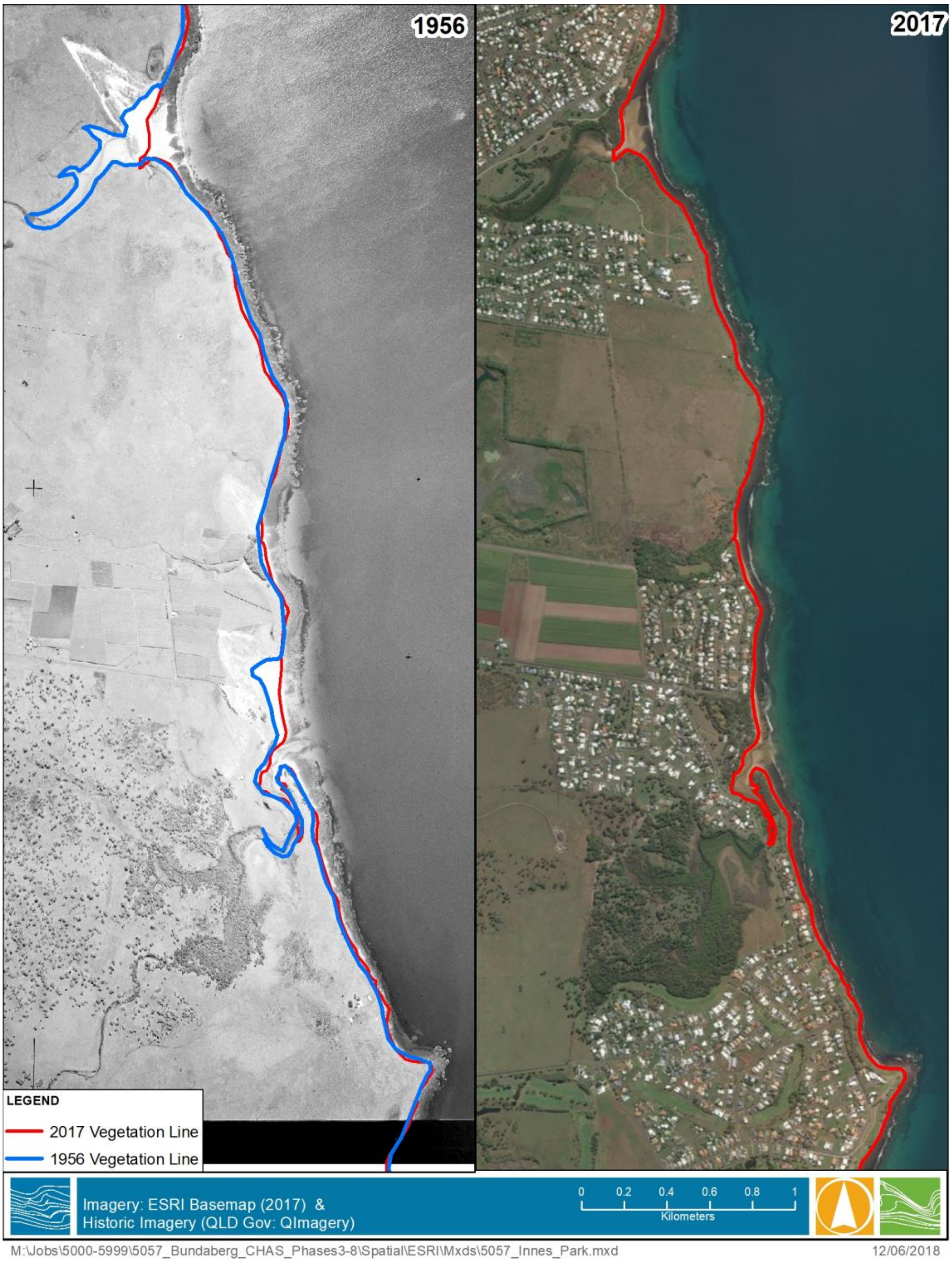


FIGURE D-22 EXAMPLE OF HISTORIC AERIAL IMAGERY COMPARISON – INNES PARK

D-5 Coonarr analysis

D-5-1 Short term erosion assessment

TABLE D -4 COONARR SBEACH SETUP

Storm AEP%	Max Slope Prior to Avalanching (degrees)	Grains Size Dn50 (mm)	Period (s)	Water Level (m)	Significant Wave Height (m)
5	34	0.21	10	2.28	3.01
2	34	0.21	10	2.36	3.04
1	34	0.21	10	2.49	3.20

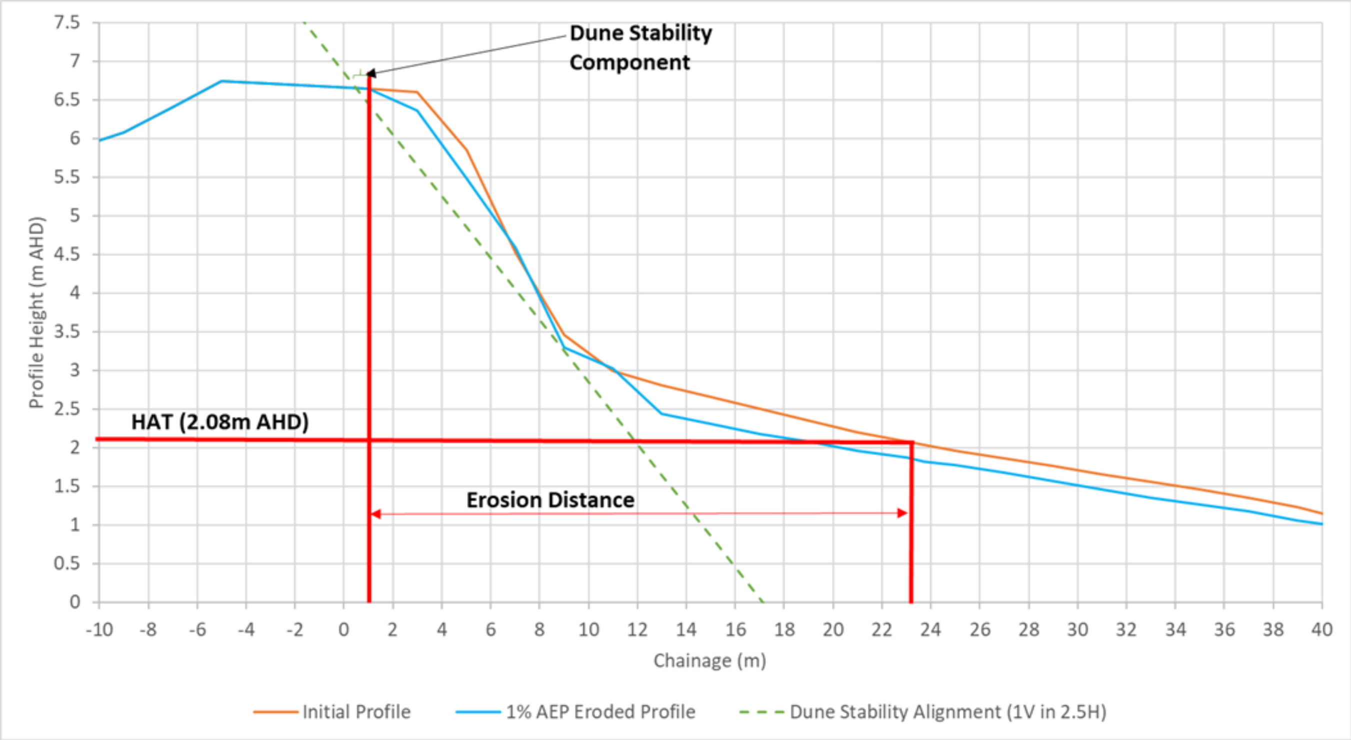


FIGURE D-23 SHORT TERM EROSION – COONARR FOR 1% AEP EVENT

D-5-2 Long term erosion

The following figures present the comparison of profiles at Coonarr and an overview of the historical imagery assessed.

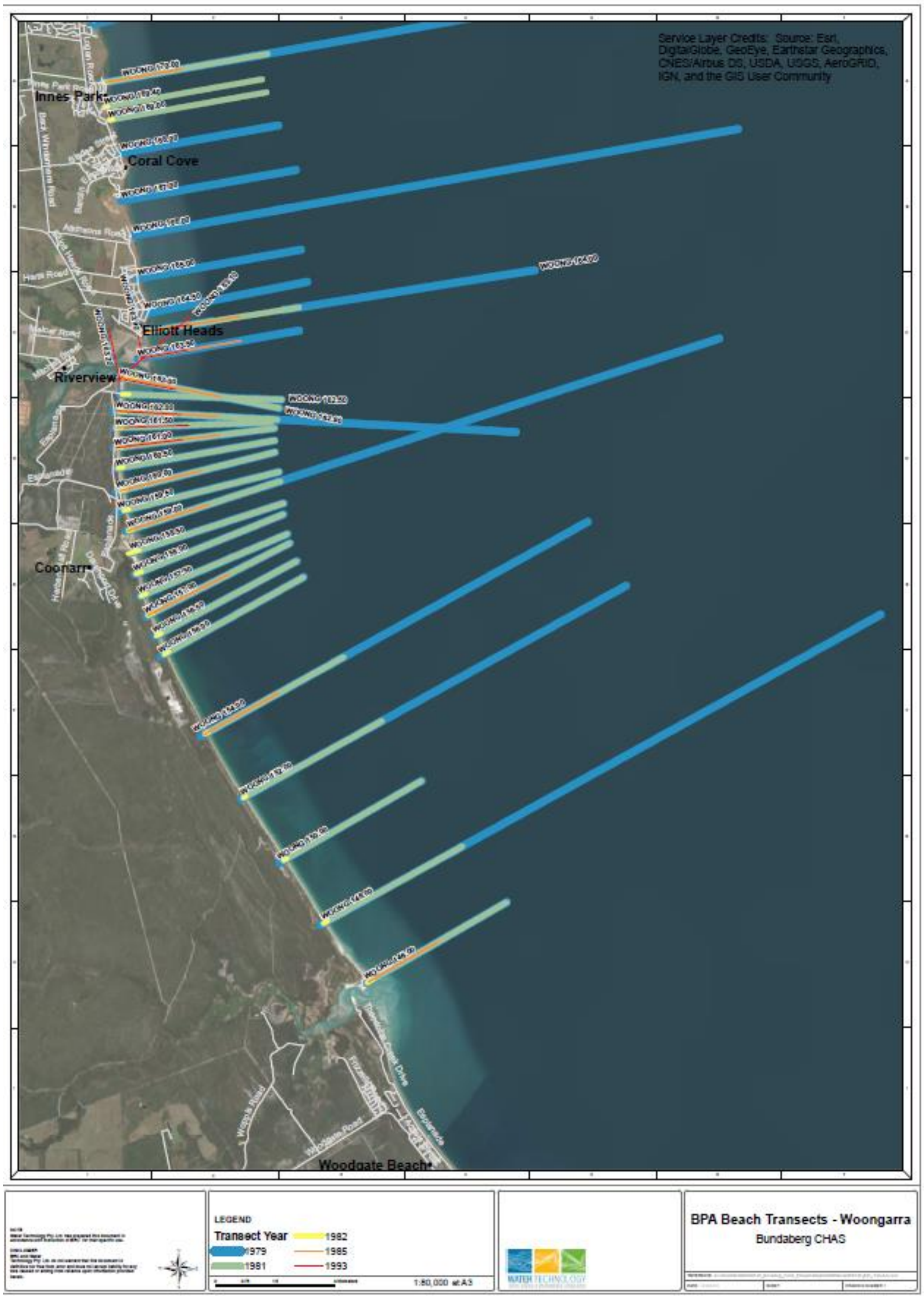


FIGURE D-24 BPA BEACH TRANSECTS - WOONGARRA

5057-03-R01

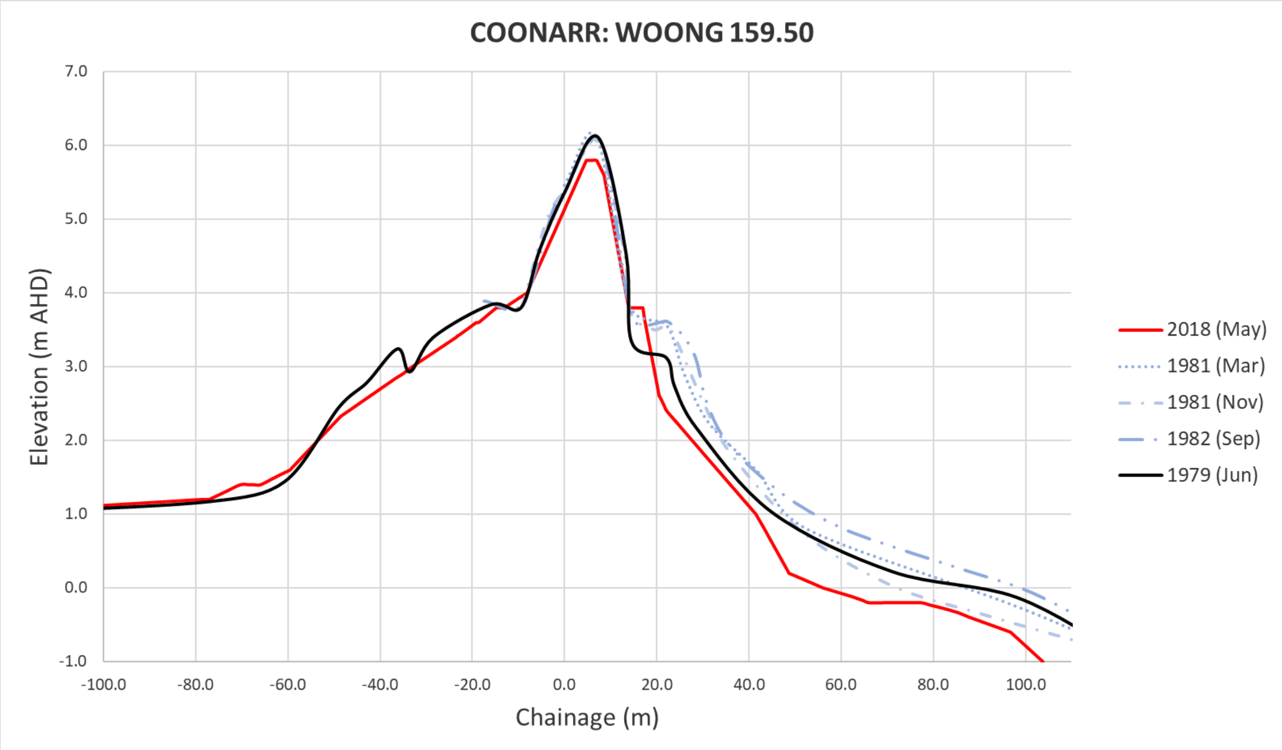


FIGURE D-25 COONARR PROFILE: WOONG 159.50

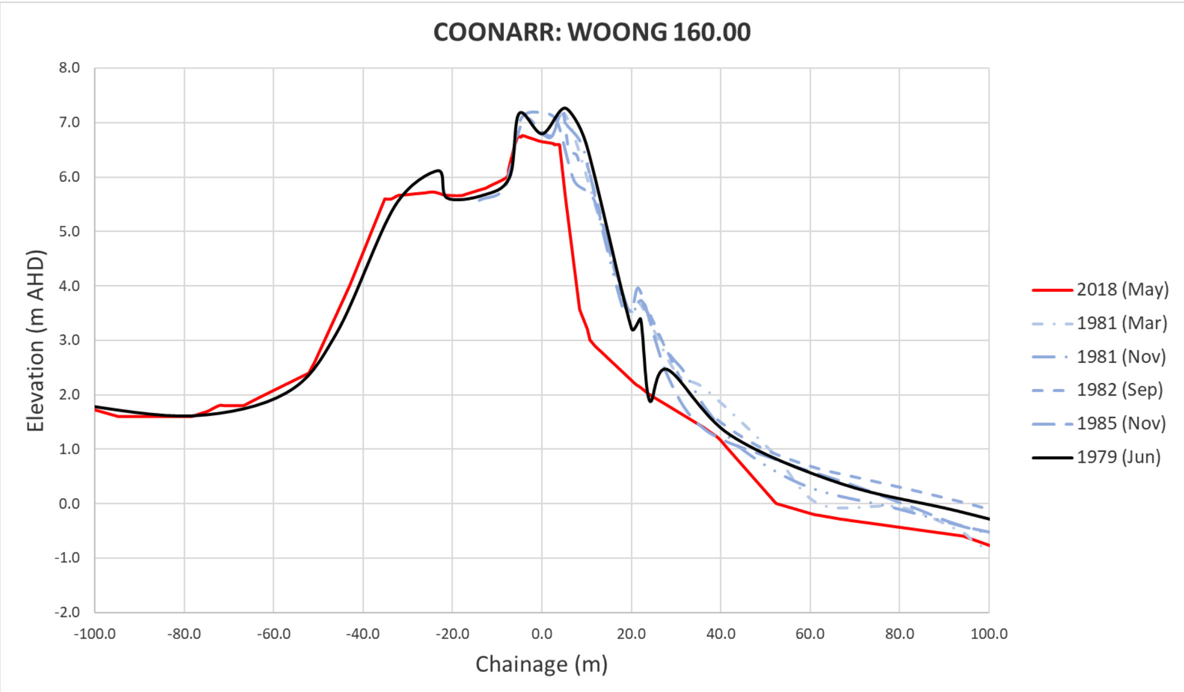


FIGURE D- 26 COONARR PROFILE: WOONG 160.0

5057-03-R01

FIGURE D- 27 EXAMPLE COMPARISON OF HISTORIC AERIAL IMAGERY COMPARISON – COONARR

5057-03-R01

D-6 Woodgate Beach Analysis (North, Central and South)

D-6-1 Short Term Erosion Assessment

TABLE D-5 SHORT TERM EROSION ASSESSMENT

Location	Storm AEP %	Max Slope Prior to Avalanching (degrees)	Grains Size Dn_{50} (mm)	Period (s)	Water Level (m)	Significant Wave Height (m)
Woodgate Beach North	5	34	0.17	10	2.22	2.73
	2	34	0.17	10	2.30	2.77
	1	34	0.17	10	2.38	2.96
Woodgate Beach Central	5	34	0.25	10	2.26	2.73
	2	34	0.25	10	2.31	2.77
	1	34	0.25	10	2.37	2.96
Woodgate Beach South	5	34	0.25	10	2.36	2.73
	2	34	0.25	10	2.45	2.77
	1	34	0.25	10	2.55	2.96

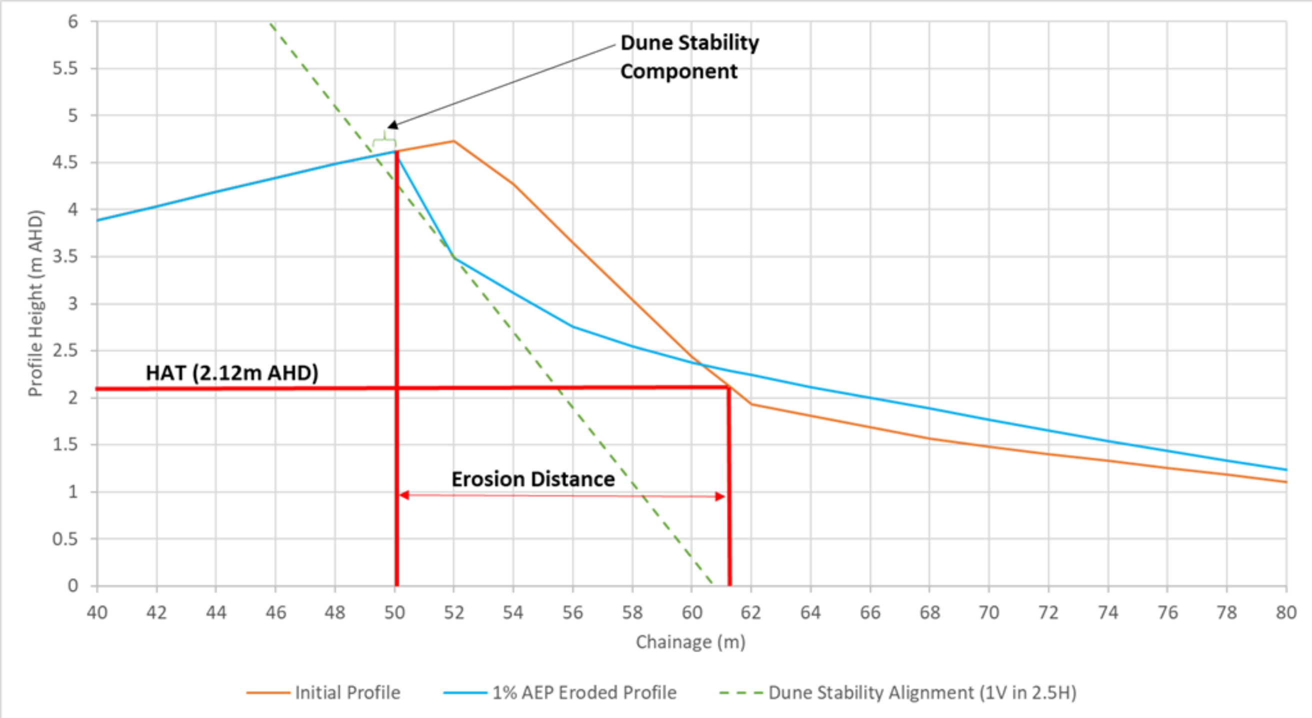


FIGURE D-28 SHORT TERM EROSION – WOODGATE BEACH NORTH FOR 1% AEP EVENT

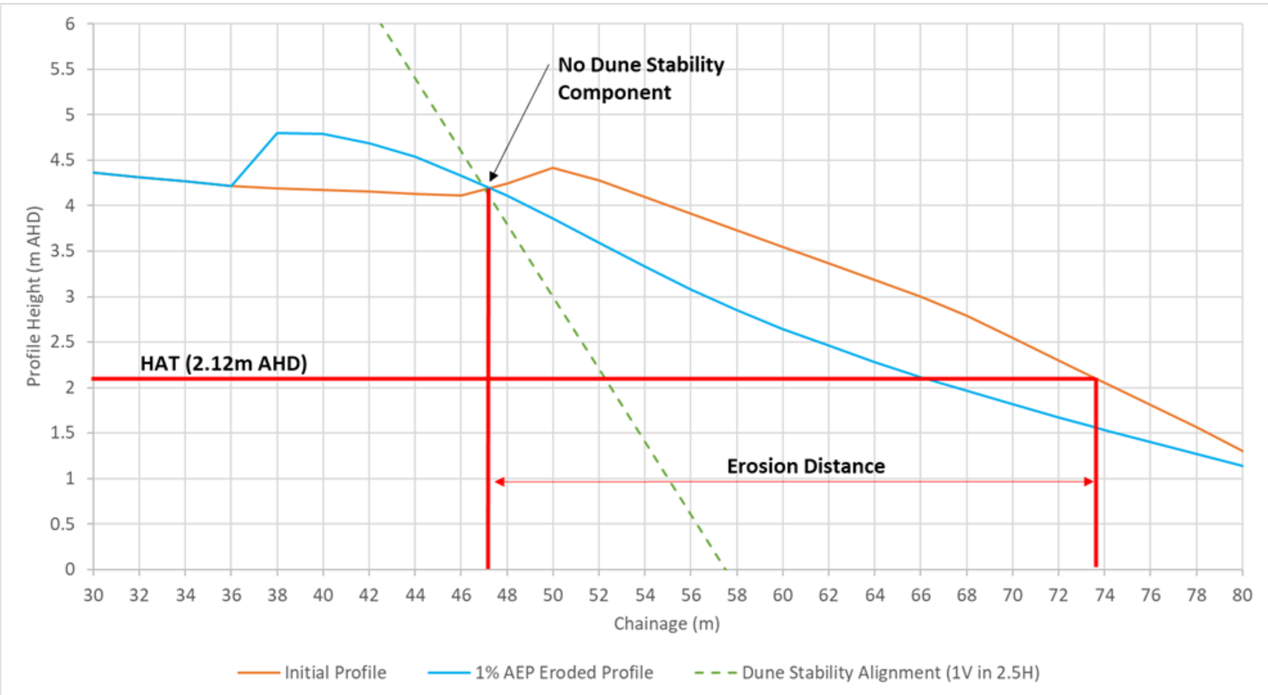


FIGURE D-29 SHORT TERM EROSION – WOODGATE BEACH CENTRAL FOR 1% AEP EVENT

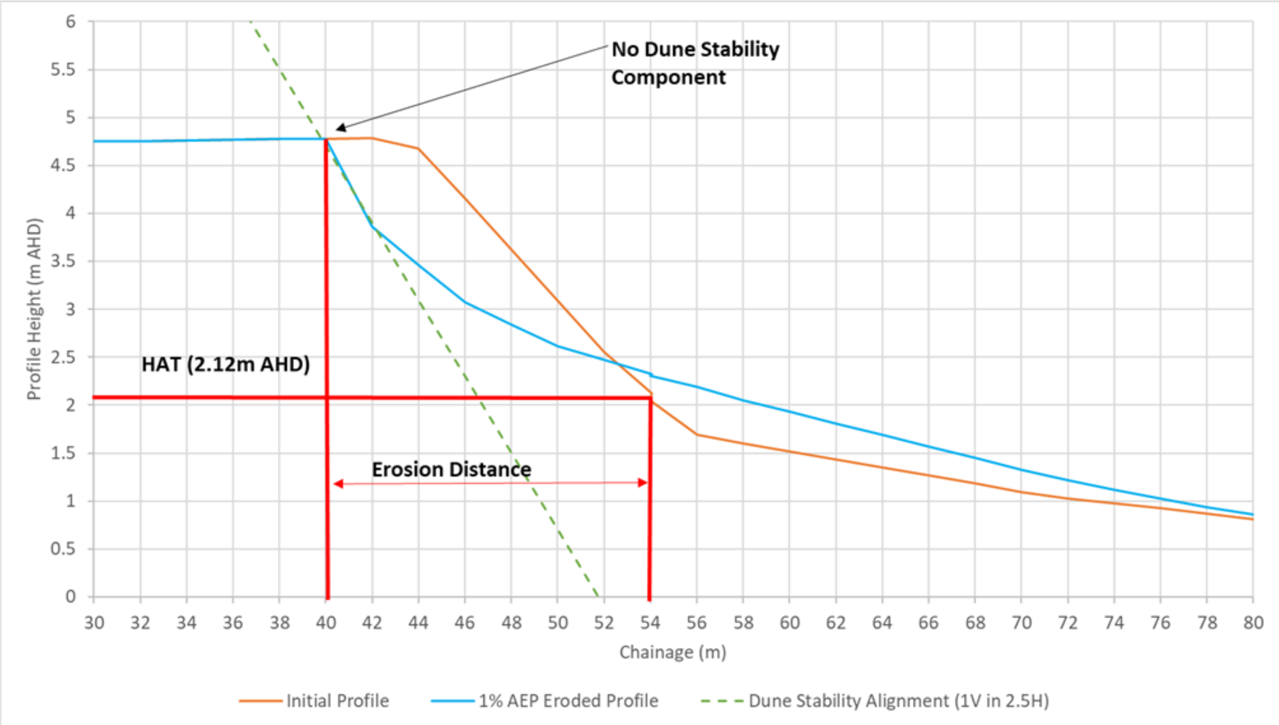


FIGURE D-30 SHORT TERM EROSION – WOODGATE BEACH SOUTH FOR 1% AEP EVENT

D-6-2 Long term erosion

The following figures present the comparison of profiles at Woodgate Beach and an overview of the historical imagery assessed.

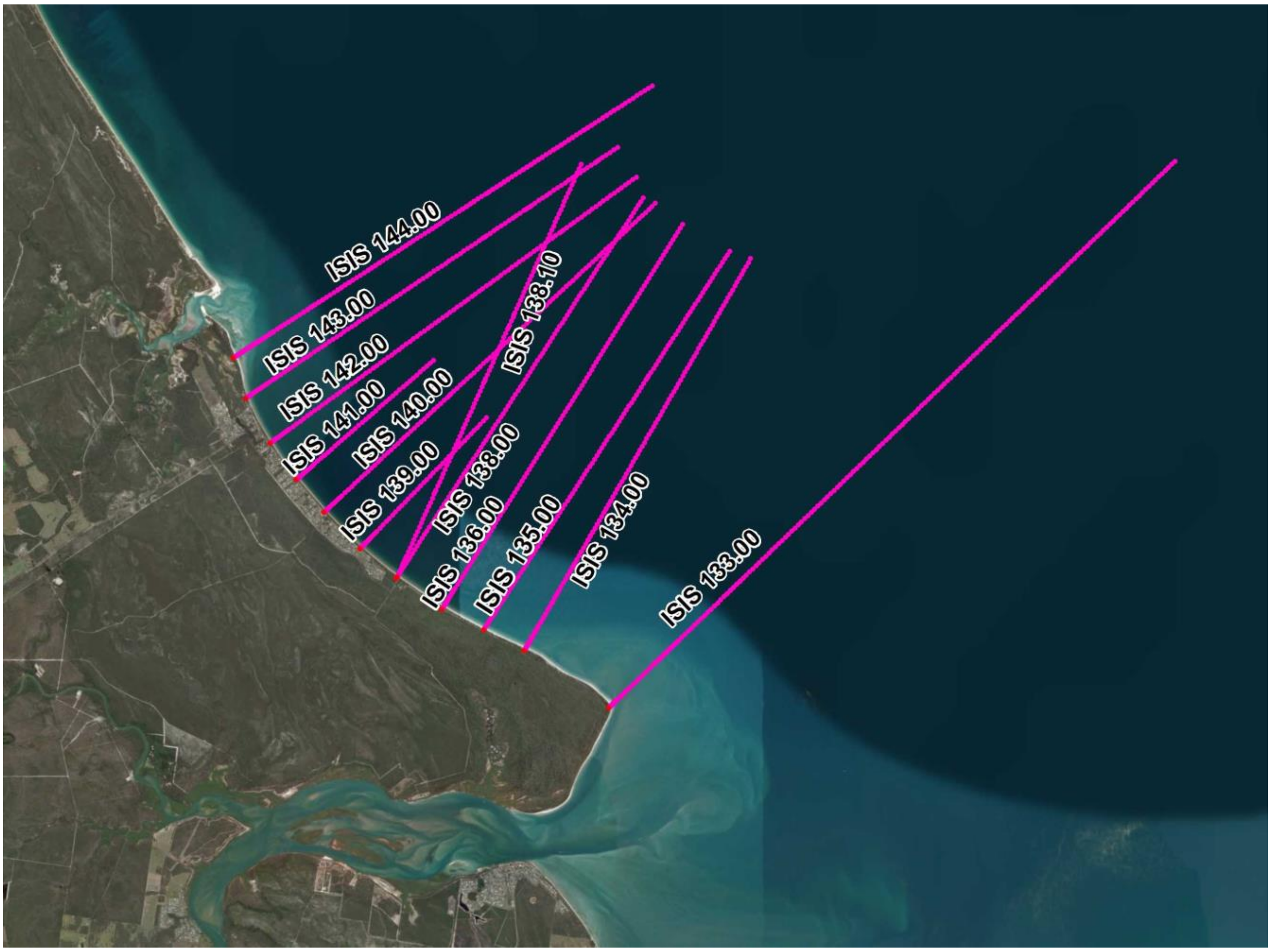


FIGURE D-31 BEACH TRANSECTS - WOODGATE BEACH

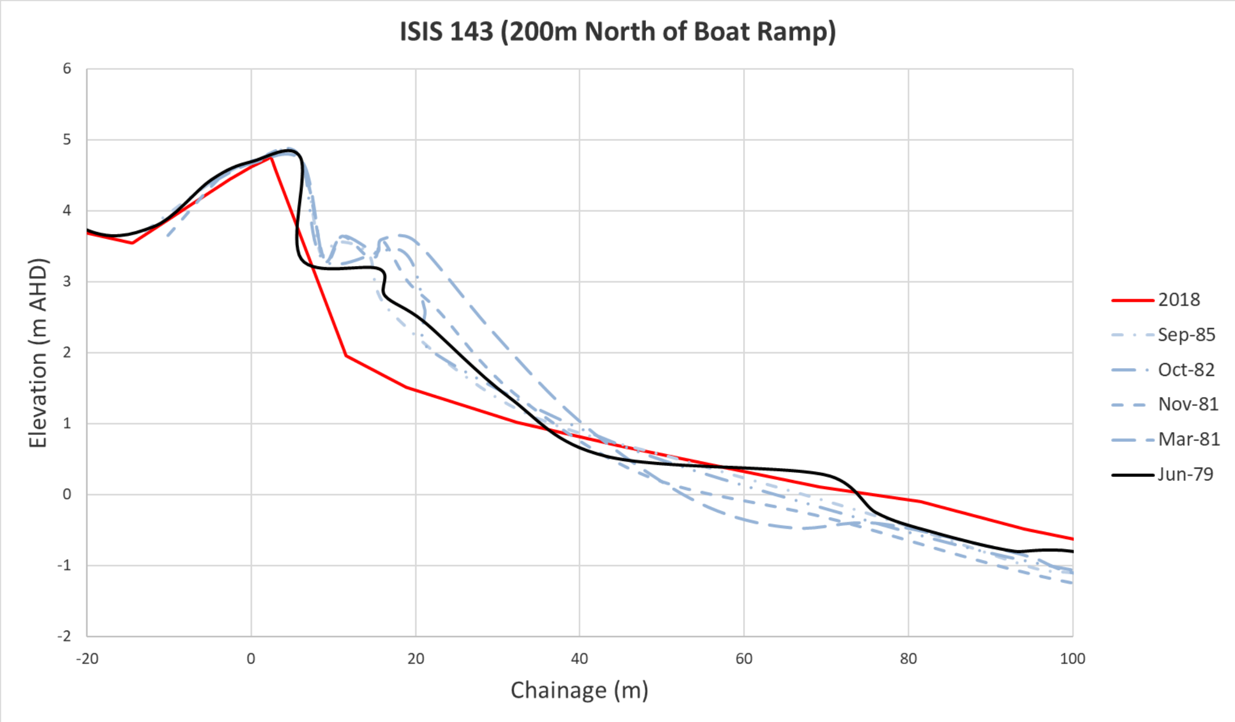


FIGURE D-32 WOODGATE PROFILE: ISIS 143

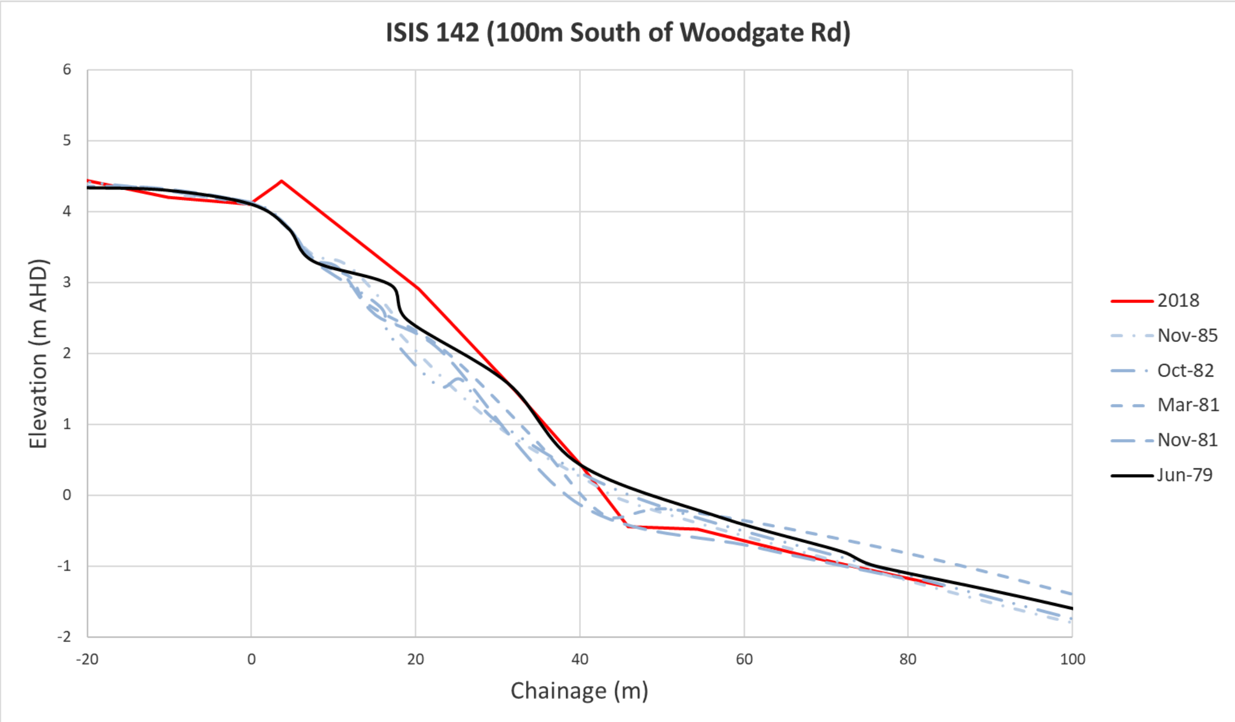


FIGURE D-33 WOODGATE PROFILE: ISIS 142

5057-03-R01

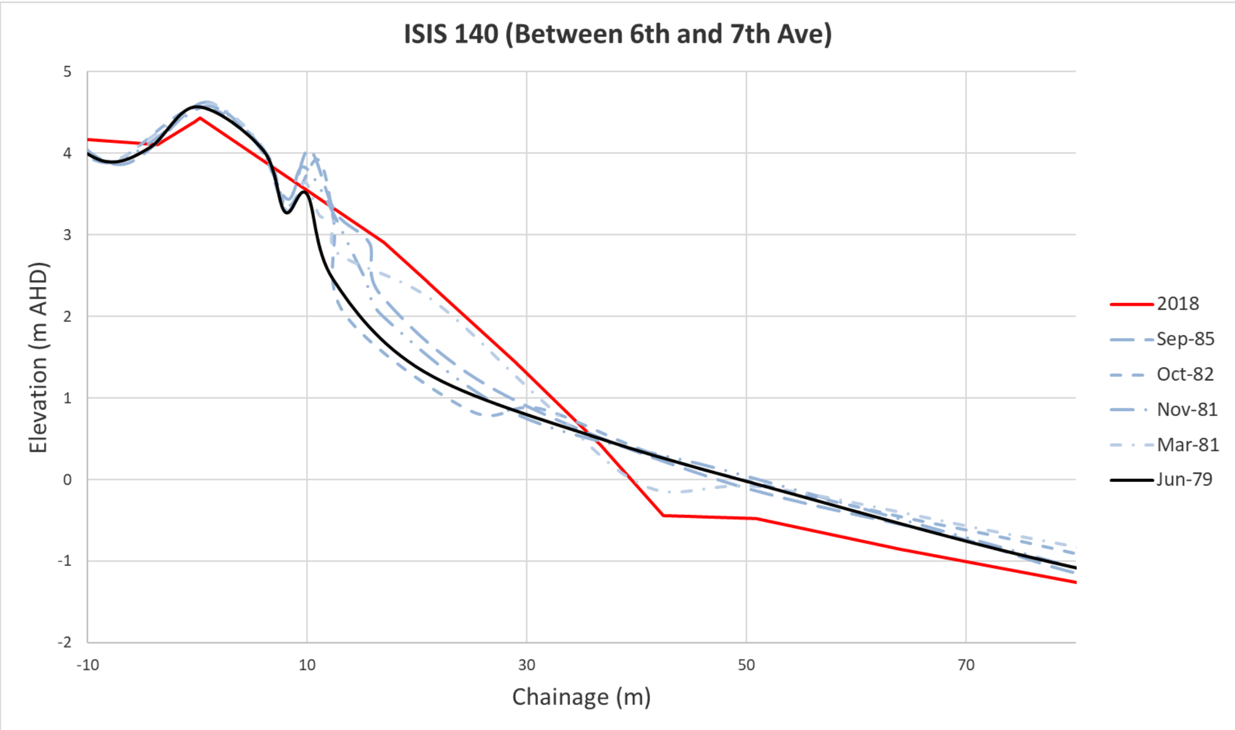


FIGURE D-34 WOODGATE PROFILE: ISIS 140

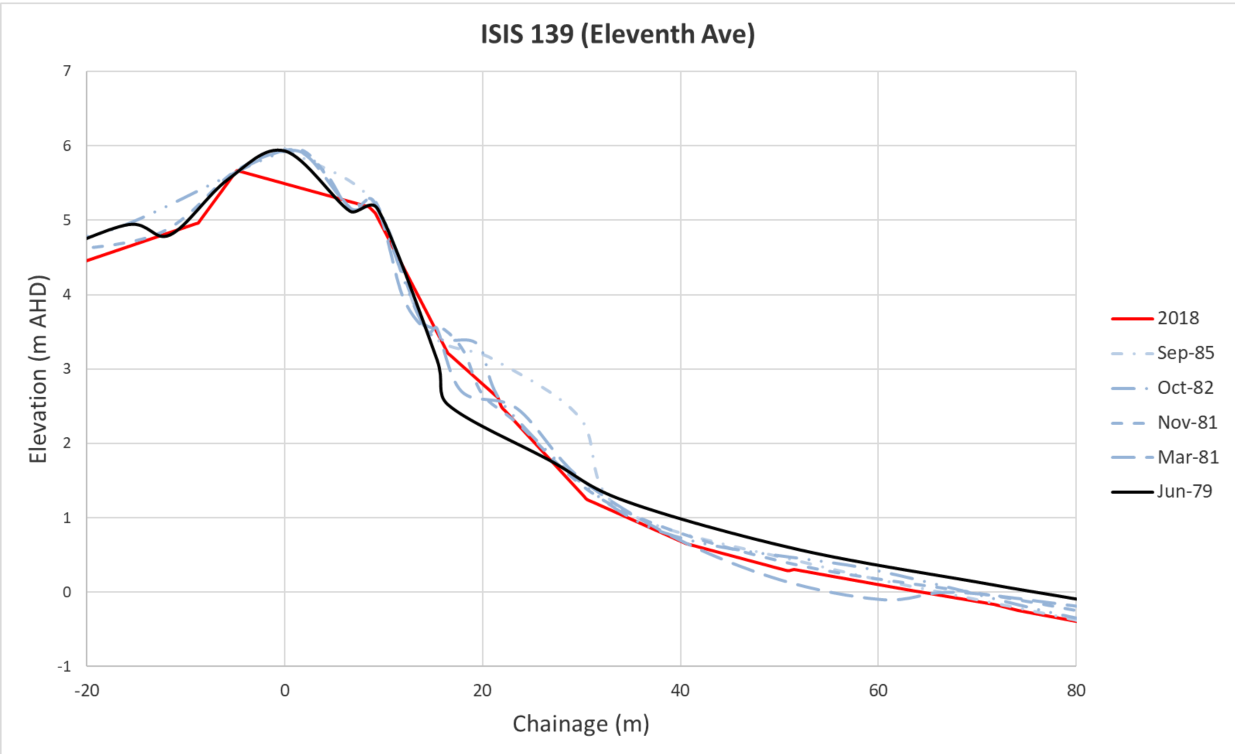


FIGURE D-35 WOODGATE PROFILE: ISIS 139

5057-03-R01

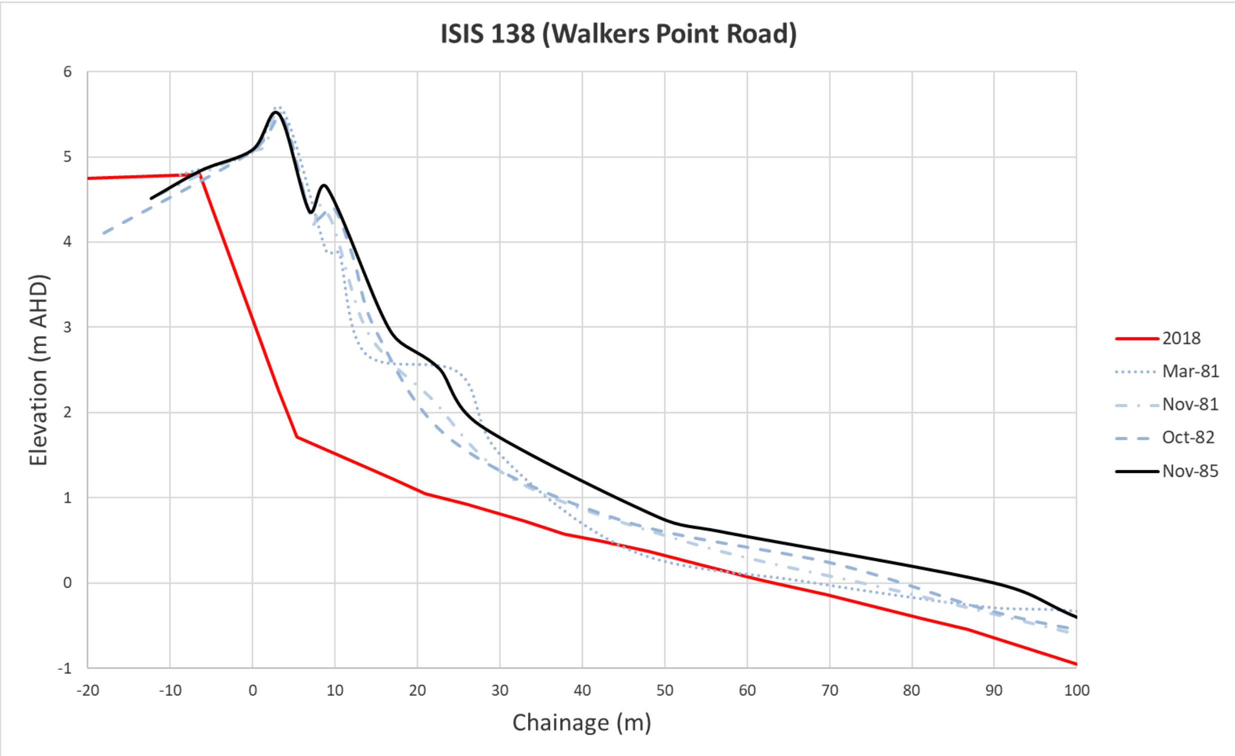


FIGURE D-36 WOODGATE PROFILE: ISIS 138

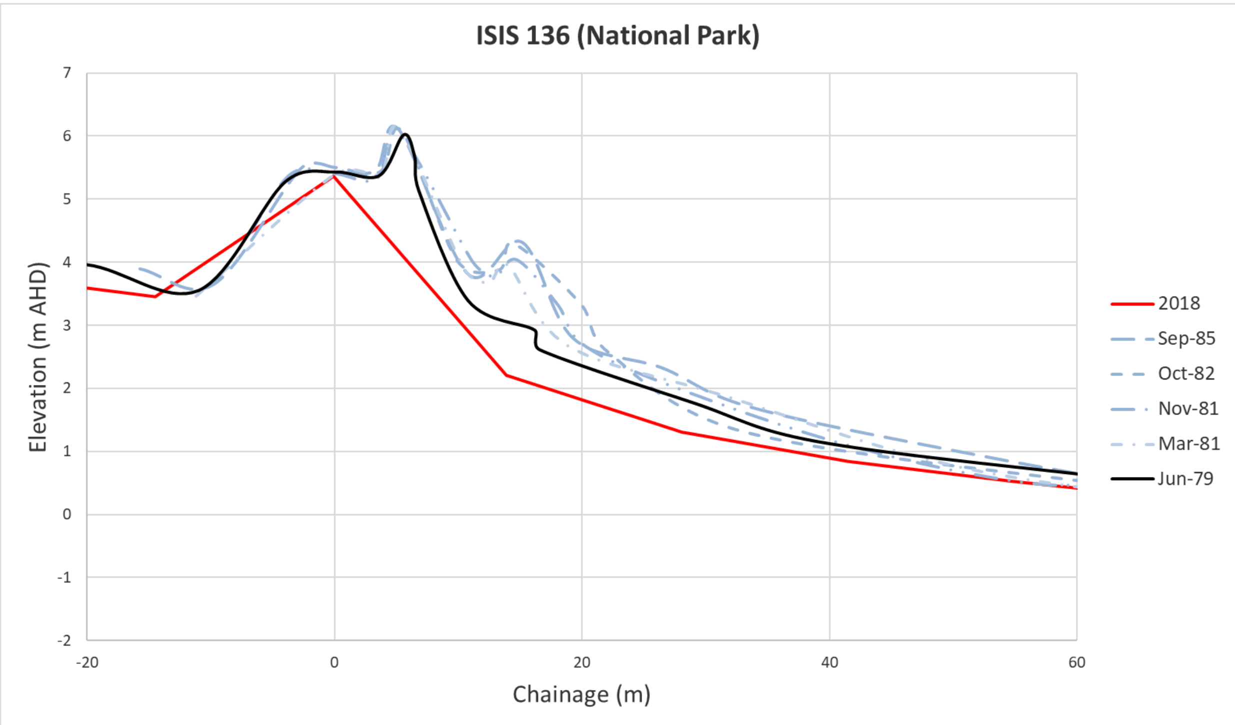


FIGURE D-37 WOOGATE PROFILE: ISIS 136

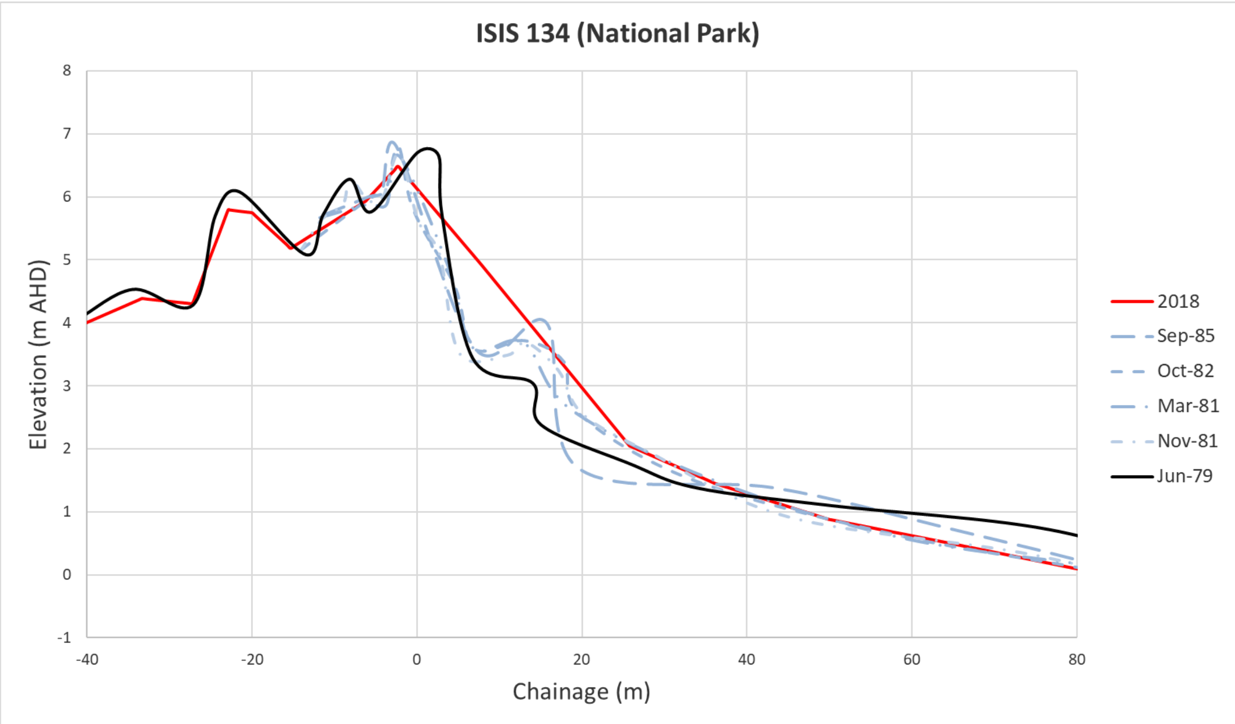
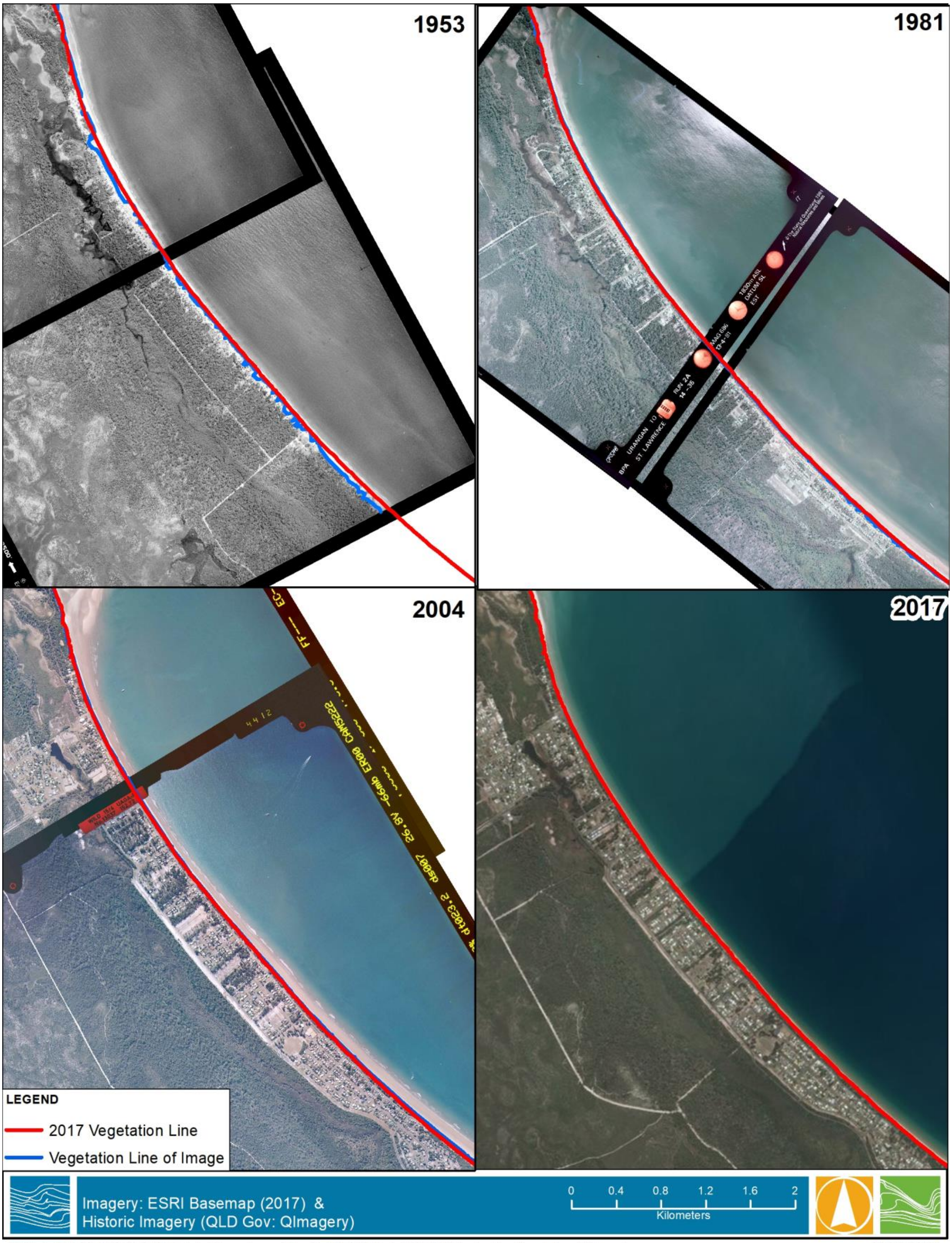


FIGURE D-38 WOOGATE PROFILE: ISIS 134



M:\Jobs\5800-5899\5840_Point_Grey_Lorne\Spatial\ESRI\Mxds\5057_Woodgate_Veg_LinesV2.mxd 06/07/2018

5057-03-R01

FIGURE D -39 INDICATIVE COMPARISON OF HISTORIC IMAGES AT WOODGATE BEACH

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800
Fax (03) 9558 9365

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000
Fax (08) 8357 8988

Geelong

PO Box 436
Geelong VIC 3220
Telephone 0458 015 664

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Brisbane

Level 3, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460
Fax (07) 3846 5144

Perth

Ground Floor
430 Roberts Road
Subiaco WA 6008
Telephone 0438 347 968

Gippsland

154 Macleod Street
Bairnsdale VIC 3875
Telephone (03) 5152 5833

Wimmera

PO Box 584
Stawell VIC 3380
Telephone 0438 510 240

www.watertech.com.au

info@watertech.com.au