Clarkes Beach Addendum Coastal Assessment

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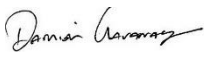
0 - Draft	26 March 2021	D Cavanagh		C Taylor	
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Executive Summary

During 2019 Clarkes Beach and surrounds experienced rapid coastline recession and loss of vegetation and beach access. To mitigate the coastal erosion risk to assets at the Reflections Clarkes Beach Holiday Park (RCBHP), a temporary geotextile sand container (sandbag) revetment was constructed in two sections 70m long in July 2019 as emergency coastal protection works (the Reflections seawall). The seawall was subsequently extended to the west by others to protect the Beach Byron Bay Café (the Café seawall).

Figure 1 Project area: Red bounded Reflections Clarkes Beach Holiday Park (15 Jan 2021)

Reflections is currently seeking development approval for the seawall in front of the RCBHP to be retained for approximately 5 years, so it can continue to protect the Holiday Park while Council completes the Coastal Management Plan and Reflections assesses opportunities for planned retreat.

The rationale for retaining the temporary wall for this period includes:

(1) Enable the protection of the Reflections Holiday Park in the short-term (i.e. 5 years).

(2) Enable the protection of the Aboriginal middens in the short-term (i.e. 5 years).

(3) Implement a coastal protection strategy for the subject site until such time (i.e. 5 years) that a new Plan of Management (PoM) has been prepared and its implementation has commenced for the subject site. Of note, the Plan of Management will consider coastal strategies (including planned retreat options) and liaison with Byron Shire Council as they develop their Coastal Management Program applicable to the subject site.

(4) Ensure safe workplace and safe environment for ongoing public access.

Figure 2 Reflections seawall (west) – immediately post construction (August 2019)

This coastal assessment has been prepared as an addendum to the EIS prepared by Planit Consulting on behalf of Reflections Holiday Parks for the retention of the seawall. This assessment focuses on impact of the seawall on the physical coastal processes of Clarkes Beach.

The specific development scenarios and scope considered in this assessment are:

- **Remove wall** (existing/base case) – Reflections seawall to be removed within a couple of months, followed by dune stabilisation and revegetation; and
- **Retain Wall** (proposed development case) – Reflections seawall to remain in place temporarily for a period of up to five years.

The scope of this project and assessment also considers what management works may be required to ensure the function, integrity and safety of the sandbags and public space. Supporting processes that don't require development consent, such as environmental protection works, will as considered strategically, as well as being pursued on an as-needs basis.

For the purposes of this assessment, it has been assumed that the Café seawall, also built as temporary emergency protection, has been removed (as of March 2021 it remains in place).

A functional assessment of the Reflections seawall has concluded that the seawall has been effective at preventing further dune erosion and shoreline retreat. The seawall is currently in good condition, but it is under-designed for the conditions and could fail in a 10-year ARI storm due to wave impact removing individual sandbags or wave run-up eroding the dune above/behind the wall (Table 1).

Table 1 Estimated Probability of Failure Conditions Occurring Over Time

Duration (Years)	Probability of Failure
1	5%
2	10%
5	23%
10	40%

The most significant effect of the seawall on coastal processes is the potential for 'end scour' – a region of locally increased storm erosion cutting into the dune immediately adjacent to the end of the seawall. Only very minor end scour has been observed to date and during the storms of 2019 and 2020 end scour was less significant than the general shoreline recession observed along the beach. However, in very large storms there is a possibility that end scour could threaten unprotected structures at the western end of the western wall. While the Café seawall is in place the threat to these structures is low.

The table below summarises the predicted impacts of the proposed development, i.e. retaining the Reflections seawall for the next 5 years.

Table 2 Summary of Assessed Impacts of Proposed Development

Area	Assessed Impact
Risk to built assets - inc. buildings, roads, services and beach access at risk from coastal erosion	**Positive** – Significantly more assets are protected by the seawall than may be at risk from end scour.
Coastal processes – impact on sediment transport dynamics and beach morphology both locally at the site and further afield within the Byron Bay embayment	**Negative** - End scour may threaten assets within a 100m of the western end of the wall in extreme storms - 'lock-up' of sediment behind the seawall reduces sediment supply to the rest of the beach. This effect is very minor but may be important in the context of cumulative impacts.
Public Safety – steep erosion escarpments cut into high dunes by storms can present a number of hazard to beach users such as falling from height, collapsing of unstable slopes and damage to beach access routes	**Positive** – The dune face and beach access points are stabilized over a significant distance (140m) by the seawall. Small chance of dangerous conditions at the western end of wall after storms, which can be managed by temporary fencing The seawall itself is low and built from rounded and soft materials, as such does not pose significant hazard to beach users.
Vegetation - vegetation cover is important for stabilising dunes and increasing resilience to erosion. Littoral rainforest has been mapped at the site, but it is not clear if still present	**Positive** – Seawall protects existing vegetation behind the wall from erosion, and by stabilizing the dune face promotes the establishment of new vegetation.

Area	Assessed Impact
Cape Byron Marine Park	**Neutral** - Changes to beach morphology in immediate vicinity of seawall may impact animal habitat within a limited area. - Removing the seawall would involve use of construction plant within the park, with a risk of spills and habitat damage. - Removing the wall risks further erosion of the dune, with a risk the debris or waste enters the park.
Alignment with SEPP – Proposed development was reviewed against the against Coastal SEPP and principles of Ecologically Sustainable Development	**Compliant** - in most areas **Mitigation Needed** - around the impacts of potential end scour, in particular risk of increased coastal hazard to adjacent land and public safety from high and steep erosion escarpments.

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1 Introduction

This coastal assessment has been prepared as an addendum to the Environmental Impact Statement (EIS) for:

> *Coastal Protection Works in a Littoral Rainforest Area - 1 Lighthouse Road, Byron Bay (Lot 410 DP729062) – Byron Shire LGA*

prepared by Planit Consulting on behalf of Reflections Holiday Parks.

The proposed coastal protection works considered are the retention of two sections of temporary sandbag seawall for a period of up to 5 years.

1.1 Background

In 2019 Clarkes Beach and surrounds experienced rapid coastline recession and loss of vegetation and beach access. This recession was associated with coastal erosion from a series of significant weather events and other coastal processes that continued through 2020.

To mitigate the coastal erosion risk to assets at Clarkes Beach Holiday Park, a geotextile sand container (sandbag) revetment was constructed in two sections in July 2019 as emergency coastal protection works (hereafter referred to as the 'Reflections seawall' as Reflections are the manager of the Clarkes Beach Holiday Park). The Reflections seawall provided protection to the Clarkes Beach Holiday Park and afforded them the opportunity to concurrently relocate a number of assets (primarily holiday cabins) away from immediate threat.

The continued coastal erosion in 2020 resulted in the placement of an adjoining geotextile sand container revetment to the west as emergency works to protect the Beach Byron Bay Café and was executed by others (hereafter referred to as the Café seawall). This seawall is to the immediate west of the Reflections seawall and it connects the two structures. Further consideration of the adjoining Café seawall is excluded in this investigation, and for all intents and purposes, it considered to have been removed.

Post seawall construction in July 2019, it was identified through consultation with the Arakwal people, that the Reflections seawall had been placed within close proximity and seaward of two Aboriginal Objects (AHIMS #04-5-0358 & AHIMS #04-5-0359). Reflections accordingly commenced an Aboriginal Cultural Heritage Assessment. The assessment identified amongst its findings that removal of the temporary seawall was not supported without an alternative long-term solution being determined.

Since 2019, BMT amongst others have been providing coastal management assistance to Reflections. BMT's involvement has included an initial review of options for dune stabilisation, advice regarding dune stability and regular site inspections from the time the seawalls were first placed through to the current day.

The Reflections seawall was originally constructed as emergency works, which can remain without development approval for up to 90 days. This time has now passed, and approval is now being sought to retain the walls for a longer period, affording protection to the dune and allowing time for a strategic Plan of Management to be developed.

1.2 Subject Site

The subject site of the proposal is Lot 410 of DP729062, which is an approximately 3.9 hectare irregular shaped parcel which accommodates part of the Reflections Clarkes Beach Holiday Park, a portion of Clarkes Beach and extends into the Cape Byron Marine Park (which in this location includes areas below the Mean High Water Mark) (refer Figure 1-1).

Within the subject site, the proposed coastal protection works are two seawalls of approximately 60 to 70m length each. For the purposes of this report, the spatial area proposed for coastal protection works is referred to as the 'Project Area'.

Figure 1-1 Project area: Red bounded Reflections Clarkes Beach Holiday Park (15 Jan 2021)

1.3 Assessment Scope and Objectives

BMT aims to address relevant coastal management issues to support consideration of this development approval (DA) application. The DA seeks approval to retain the Reflections seawalls placed in July 2019 for an approximate five-year period. The rationale for retaining the temporary wall for this period includes:

(1) Enable the protection of the Reflections Holiday Park in the short-term (i.e. 5 years).

(2) Enable the protection of the Aboriginal middens in the short-term (i.e. 5 years).

(3) Implement a coastal protection strategy for the subject site until such time (i.e. 5 years) that a new Plan of Management (PoM) has been prepared and its implementation has commenced for the subject site. Of note, the Plan of Management will consider coastal strategies (including planned retreat options) and liaison with Byron Shire Council as they develop their Coastal Management Program applicable to the subject site.

(4) Ensure safe workplace and safe environment for ongoing public access.

Currently Byron Shire Council have completed a Stage 1 Scoping Study (BMT, 2019) and Council are understood to be soon undertaking subsequent CMP stages.

The five-year timeframe is not fixed as there are a number of variables which affect the potential duration of the temporary works. It is acknowledged that future policy direction, monitoring of environmental conditions and impacts, as well as the design lifespan of the geotextile sand containers used may result in future removal or modification to the sandbag wall.

The specific development scenarios and scope considered in this assessment are:

- **Remove Wall** (existing/base case) – Reflections seawall to be removed immediately (within a couple of months), followed by dune stabilisation and revegetation; and
- **Retain Wall** (proposed development case) – Reflections seawall to remain in place temporarily for a period of up to five years.

The scope of this project and assessment also considers what management works may be required to ensure the function, integrity and safety of the sandbags and public space. Supporting processes that don't require development consent, such as environmental protection works, will as considered strategically, as well as being pursued on an as-needs basis.

The Coastal Assessment scope includes:

- Identifying the context and background of the seawall(s);
- Describing coastal processes and sediment transport for the study area and immediate surrounds;
- Describing the design standard of the Reflections seawall, expected longevity, maintenance and/or upgrades likely to be required;
- Describing the Reflections seawall's likely effectiveness for asset protection;
- Assessing the impact of the Reflections seawall, as well as consideration of the impacts of removing it. Specifically, consideration will be given to potential impacts to in-situ Aboriginal Objects, holiday park assets, public safety, mapped littoral rainforest and the Cape Byron Marine Park (Marine Estate Management Authority);
- Assessing alignment with the Coastal Management SEPP and principles of ecologically sustainable development; and
- Developing a monitoring program including monthly visual and photographic inspections of each wall, any end scour impacts/rates, geotextile sand container integrity and any resultant

public safety implications. An annual report would also be produced including all information from monthly inspections.

Limitations:

- Assessment is based on desktop review with limitations on time and scope. This has placed a reliance on previous studies and publicly available data;
- No site investigations undertaken (except survey) and no specific geotechnical investigations under the wall were available at the time of the assessment;
- Limited details of initial wall construction are available; and
- No site-specific wave modelling or sediment transport calculations were performed.

Predictions of impact are based on a conceptual understanding of the coastal processes at the site and are primarily qualitative.

1.4 Planning Context

1.4.1 Planning Approval

Coastal Protection Works are permitted with consent by virtue of clause 19(2)(b) of State Environmental Planning Policy (Coastal Management) 2018 (Coastal Management SEPP). The proposal is also identified a 'Designated Development' by clause 10 of the Coastal Management SEPP because the Reflections seawall is located within land mapped as littoral rainforest.

Accordingly, as per the provisions of State Environmental Planning Policy (State and Regional Development) 2011, the proposal is identified as 'Regionally Significant Development' and the Northern Regional Planning Panel is identified as the consent authority for this application.

1.4.2 Coastal Management Plan

A Coastal Management Plan is under development for Byron Bay.

Currently Byron Shire Council have completed a Stage 1 Scoping Study (BMT, 2020) and Council are understood to be preparing for the subsequent CMP study stages. The current vision included in the Stage 1 CMP reads as,

> *"Adequately resource and fund management of the iconic and internationally recognised Byron coastline to conserve and promote its inherent natural values.*
>
> *These inherent values underpin the coasts enviable cultural, amenity, recreational use, local and tourism values and they will be kept central in the development of future management approaches.*
>
> *Future management approaches will address existing and emerging threats such as climate change through planning for a resilient coastline that is prepared to address multiple challenges in a flexible and adaptive manner; including consideration of novel funding approaches"*

The vision speaks to the natural values of the coastline and how they underpin the current environmental setting, aspects of cultural connection and recreational use. The CMP acknowledges the need to respond to existing and emerging coastal challenges in a flexible and adaptive manner.

The objectives for the Cape Byron to South Golden Beach CMP reflect those of the Coastal Management Act, being:

- *(a) to protect and enhance natural coastal processes and coastal environmental values including natural character, scenic value, biological diversity and ecosystem integrity and resilience, and*
- *(b) to support the social and cultural values of the coastal zone and maintain public access, amenity, use and safety, and*
- *(c) to acknowledge Aboriginal peoples' (Bundjalung of Byron Bay – Arakwal Bumberlin people) spiritual, social, customary and economic use of the coastal zone, and*
- *(d) to recognise the coastal zone as a vital economic zone and to support sustainable coastal economies, and*
- *(e) to facilitate ecologically sustainable development in the coastal zone and promote sustainable land use planning decision-making, and*
- *(f) to mitigate current and future risks from coastal hazards, taking into account the effects of climate change, and*
- *(g) to recognise that the local and regional scale effects of coastal processes, and the inherently ambulatory and dynamic nature of the shoreline, may result in the loss of coastal land to the sea (including estuaries and other arms of the sea), and to manage coastal use and development accordingly, and*
- *(h) to promote integrated and co-ordinated coastal planning, management and reporting, and*
- *(i) to encourage and promote plans and strategies to improve the resilience of coastal assets to the impacts of an uncertain climate future including impacts of extreme weather events, and*
- *(j) to ensure co-ordination of the policies and activities of government and public authorities relating to the coastal zone and to facilitate the proper integration of their management activities, and*
- *(k) to support public participation in coastal management and planning and greater public awareness, education and understanding of coastal processes and management actions, and*
- *(l) to facilitate the identification of land in the coastal zone for acquisition by public or local authorities in order to promote the protection, enhancement, maintenance and restoration of the environment of the coastal zone, and*
- *(m) to support the objects of the Marine Estate Management Act 2014.*

The CMPs management objectives reflect the objectives of the Coastal Management Act and support the CMP vision. The proposal to retain the Reflections seawall is consistent with and supports many of the CMP objectives. This Coastal Assessment report will, however, consider potential impacts of the proposal which may not be consistent with other CMP objectives .

1.5 Data sources

A range of data has been acquired and analysed for the purpose of this report as summarised below:

- Nearmap Aerial Imagery – airborne images are recorded by Nearmap at high resolution at semi-regular intervals. This data is available upon subscription and has been acquired and analysed for the purpose of this report for 7 dates between 11/03/2019 and 15/01/2021.
- Manly Hydraulics Laboratory – Byron wave rider data was acquired from MHL. This data is recorded at hourly intervals for significant and maximum wave heights, periods and wave directions. Data from Jan 2010 – Nov 2020 was analysed to assess ongoing trends and peak storm events that relate to this study. Wave-rider buoy is located approximately 10km off Ballina.
- Surveys:
  - NSW Beach Profile Database – UNSW Water Research Laboratory. This database provides an extensive record of beach profiles in New South Wales. Profiles were extracted from this source along Clarkes and Main Beach, Byron Bay, from 1947 to 2020, with specific focus on analysis of the 2019-2020 period.
  - Kennedy Surveying provided features surveys of the area at two dates during the study period. Surveys include locations of features such as the Reflections seawall, vegetation lines, tide level, Reflections assets and other physical features. Survey dates were:
    - 12 July 2019; and
    - 11 September 2020.

1.5.1 Relevant Previous Studies

This section presents a summary of key previous studies that have been referenced in this report and makes brief comment on findings. This is not to be considered a comprehensive list of all the studies completed for the area but those that are specifically relevant to this report.

Byron Shire Coastline Hazards Assessment Update (BMT WBM, 2013)

The Byron Coastal Hazards Assessment Update report presents a summary of the regional and local coastal processes operating on the Byron coastline. The report presents the methodology and outcomes for the definition of coastal hazards affecting the study area coastline, including a detailed assessment of shoreline recession hazard and subsequent mapping for the Byron Bay Embayment, determined from local knowledge, various survey data sources, analysis of photogrammetry data and numerical risk modelling. The Study provides definition of the erosion hazards using a risk-based approach providing for variability and uncertainty, particularly beach

erosion and recession for the immediate, 2050 and 2100 timeframes, taking account of ENSO (El Niño-Southern Oscillation) variability and projected future sea level rise. An in-depth description is given on sediment transport patterns in the area and indicates a net littoral drift rate of 200,000 m^3/year at Clarkes Beach, compared to about 400,000 m^3/year near New Brighton and 550,000 m^3/year at the Gold Coast.

Clarkes Beach Holiday Park Dune Stabilisation Optioneering Report (BMT, 2019)

This report documents the dune stabilisation options assessment undertaken for the Clarkes Beach Holiday Park. The report notes impacts to assets by coastal processes at the time of writing, summarises coastal processes, hazards and likely extents of hazards. Options considered are analysed with a risk assessment and shortlisted for further discussion to inform recommendations. Recommended options were dune rehabilitation and management, beach and dune access management and reconfiguration of park assets.

Coastal Management Program (Stage 1) - Scoping Study Cape Byron to South Golden Beach (BMT, 2020)

This scoping study fulfils Stage 1 of the NSW Government process for developing a Coastal Management Program (CMP). The report reviews existing information and data, establishes the strategic context for coastal management, outlines key management issues, reviews current management arrangements, identifies knowledge gaps, and develops a forward plan for CMP Stages 2 to 5.

Reflections Seawall End Scour Review (BMT, 2020)

This letter considers erosion events within the Byron Bay embayment that led up to the construction of the Reflections seawall. It also quantifies end effects of the seawall by analysis of beach profiles and site photographs in the period after the construction of the seawall. Findings indicated that the Reflections seawall was considered unlikely to have contributed to erosion in front of the adjacent Beach Byron Bay Café in the year following construction.

Temporary Seawall Site Inspection Updates (BMT, 2019-21)

A series of site inspection updates have been recorded in Electronic Transmission format at frequent intervals (weekly immediately following construction in 2019, less frequently into 2020/21). These were aimed at recording sandbag condition and identifying potential end erosion effects. These inspections were usually conducted at low tides, and shortly after large storm/erosion events had taken place. Comments are also made on beach and scarp condition and extensive photographs were taken from consistent positions.

End effects of geobag wall fronting Reflections Holiday Park (UNSW, 2020b)

This letter quantifies and contextualises recent erosion observed in the Byron Bay embayment, including end effects from geotextile sand container revetments. Historical analysis of toe of dune location and aerial photography as well as a literature review quantifies long-term erosion trends. Theoretical calculations and aerial photography measurements are then used to estimate the

end-effects of the Reflections seawall, which is then compared to other erosion rates in the bay for context. The results of this indicated that end effects of the Reflections seawall was relatively negligible compared to other known sources of erosion.

Aboriginal Cultural Heritage Assessment Report prepared for Reflections Holiday Parks (Everick Heritage, 2019)

This report details the results of an Aboriginal Cultural Heritage Assessment Report ('ACHAR') and associated Aboriginal community consultation for the proposed dune stabilisation works at the Reflections Clarkes Beach Holiday Park. The intent of this ACHAR is to understand the potential impacts of the dune stabilisation works on the cultural values of middens located at the site. The ACHAR concluded that there is not community support for the removal of the Reflections seawall without an alternative long-term solution being put in place, that an Aboriginal Heritage Impact Permit should be sought for revegetation/midden salvage/beach access reinstatement works and that extensive reporting relating to any potential salvage works is maintained.

2 Site Conditions and Sandbag Wall

2.1 Site Description

Reflections Clarkes Beach Holiday Park (RBCHP) is situated adjacent to Clarkes Beach, a north facing beach on the eastern edge of Byron Bay, NSW (Figure 2-1).

Figure 2-1 Clarkes Beach area of concern

Since approximately 2010, and more significantly in the last few years, the Clarkes Beach back dune has been eroding towards the RCBHP. After an erosion event in mid-2019 where beach access stairs from RCBHP were lost, the park constructed two temporary geotextile sand container (sandbag) walls at the base of the erosion scarp attempting to halt the erosion (referred to as the Reflections seawall as per Figure 2-2). In the following year, the Beach Byron Bay Café adjacent and to the west of the RCBHP constructed a continuation of the temporary geotextile sand container revetments along their beach frontage (referred to as the Café wall – see Figure 2-3).

Figure 2-2 Reflections seawall (west) - immediately post construction (August 2019).

Figure 2-3 Red bounded Reflections Clarkes Beach Holiday Park and yellow bounded Beach Byron Bay Cafe with temporary seawalls in front. (15 Jan 2021)

Beach profile data from the last 70 years (UNSW, 2020) shows a cycle of erosion and sand deposition, with the dune scarp migrating backwards and forwards multiple times. Figure 2-4 shows the beach profile history directly in front of Reflections Clarkes Beach Holiday Park, at the current location of the western seawall from 1947 until 2020.

In 1947, the dune scarp was situated approximately 5 to10 m forward of where it currently sits. In 1987 the scarp had retreated to a position similar to where it is today. In 1996 the scarp was again approximately 5 m seaward of its current position. Mirroring this cycle, the elevation of the beach berm at the toe of the dune fluctuates between approximately 4 m AHD (when the beach is full) and 1 m AHD (when the beach is eroded). Historical beach widths, defined as being from the dune toe to the mean water line, have fluctuated between approximately 50 m and 1 m.

In this context, the current (June 2020) erosion is similar to that seen in the 1980's with similar dune scarp placement, beach height and beach width.

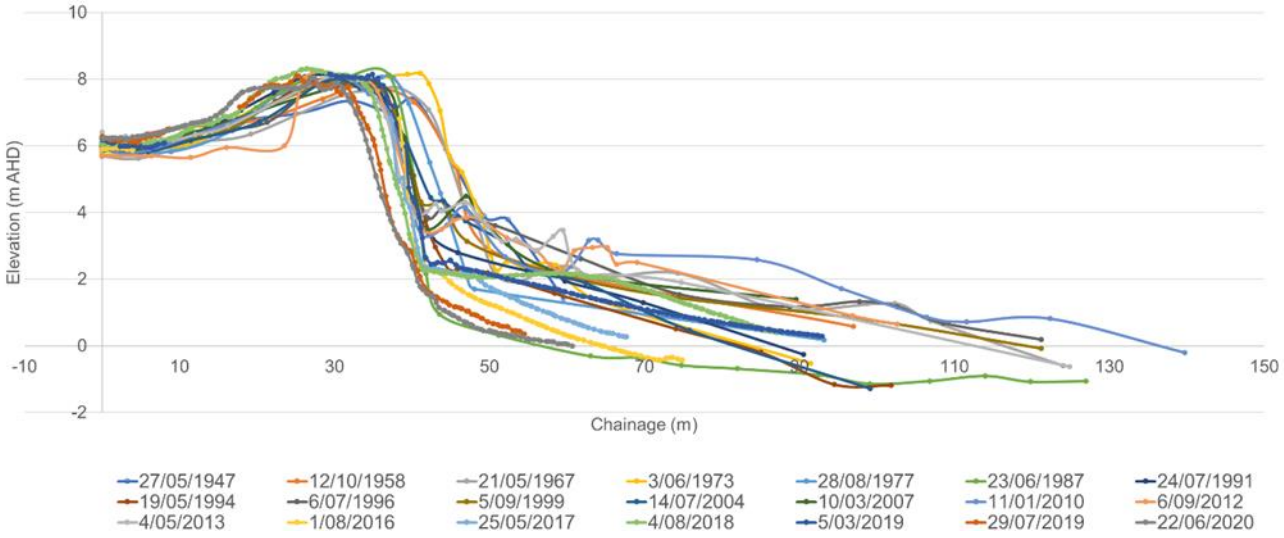

Figure 2-4 All recorded beach profiles for Clarkes Beach from 1947-Present (UNSW, 2020)

According to geological bores drilled from the top of the dune (Geoserve 2019), the Clarkes Beach dune area comprises fill overlying mixed sand and silty sand to a depth of approximately 8 m. Clayey sand and silty clay underly this to a depth of at least 12 m from the top of the dune. Estimations from the beach profile data (Figure 2-4) show that the clay layer begins at approximately 0 m AHD and is most likely a continuance of the deposits exposed in the surf zone as sand has been depleted. This soft, organic, dark-coloured clay layer has some capacity to limit short-term storm erosion, however, if continually exposed for long time periods, this layer is erodible and therefore will not halt long-term coastal retreat.

Additional to this and as shown in Figure 2-5, there is also a lighter-coloured clay outcrop (possibly 'coffee rock') sitting just offshore to the east of the Reflections holiday park boundary. This clay outcrop likely causes local attenuation of wave energy which is likely responsible for the seaward land bulge immediately east of the gully.

An extensive search of the Aboriginal Heritage Information Management system (AHIMS) by Hill, T *et al*. (2019) identified three significant indigenous middens sites in or near the Reflections Clarkes Beach Holiday Park site, each of which are marked for reference in Figure 2-5 below. The potential impacts to these middens under current and potential future conditions are discussed in subsequent sections.

Figure 2-5 Locations of the three Indigenous middens close to the Reflections Clarkes Beach Holiday Park site. Noting the significant exposure of both the dark-coloured clay layer and the light grey clay outcrop in the surf zone (4 July 2020).

2.2 Wall Construction

A timeline of key events at Reflections Clarkes Beach Holiday Park is provided in Table 2-1. This includes erosion events and impacts, survey dates and construction/protection works.

Table 2-1 Timeline of Events

Date	Event	Source
2017-18	Ongoing erosion of dune, necessitated removal of the guest lounge at the RCBHP	Pers. comm. Cameron Clark
January 2019	First beach access lost to erosion	Pers. comm. Cameron Clark
June/July 2019	Series of erosion events; Second beach access lost	Pers. comm. Cameron Clark, Reflections, photos
12 July 2019	Kennedy feature survey	Survey report
~20 to ~30th July 2019	Construction of the Reflections seawall	Pers. comm. Cameron Clark, Reflections, photos
29 July 2019	Blue Coast drone survey. NSW Beach Profile Database photogrammetry survey	Survey report. NSW BPD
End of August 2019	3 Cabins moved landward at RCBHP	Photo dated 29 August
Late May 2020	Erosion event resulting in new scarp west of Reflections seawall	Site photos, wave data
22 June 2020	NSW Beach Profile Database photogrammetry survey	NSW BPD
11 Sept 2020	Kennedy feature survey	Survey report
26 Oct 2020 to ~ 7 Nov 2020	Construction of the Beach Byron Bay Café seawall	Pers. comm. Cameron Clark, Reflections, BMT site visit and photos
14 Dec 2020	Erosion event (storm and king tide) causing overtopping of Reflections seawall	News articles, personal comm.
Jan/Feb 2021	Sand begins to return to Clarkes Beach, increasing beach volume and burying the lower part of the seawalls.	Site photos

Erosion events
Protection works
Surveys

It is our understanding that the Reflections seawall was constructed generally in accordance with the design section shown in Figure 2-6 (although with a lower crest level). According to this design, each geotextile sand container was sand filled to a volume of approximately 0.75 m^3 with dimensions of 1200 x 1600 x 400 mm (l x w x h). It is understood that each bag had an initial mass of over 1000 kg (Blacka *et al*. 2007).

From construction photos post construction surveys, it is known that the Reflections seawall was only constructed to a height of 5 sandbag layers (including toe layer). Approximate toe base elevation is 1.0 m AHD, crest elevation of is 2.5 to 3.0 m AHD. Wall slope is approximately 1V:1.5H, or slightly steeper in some locations to approximately 1V: 1.2H.

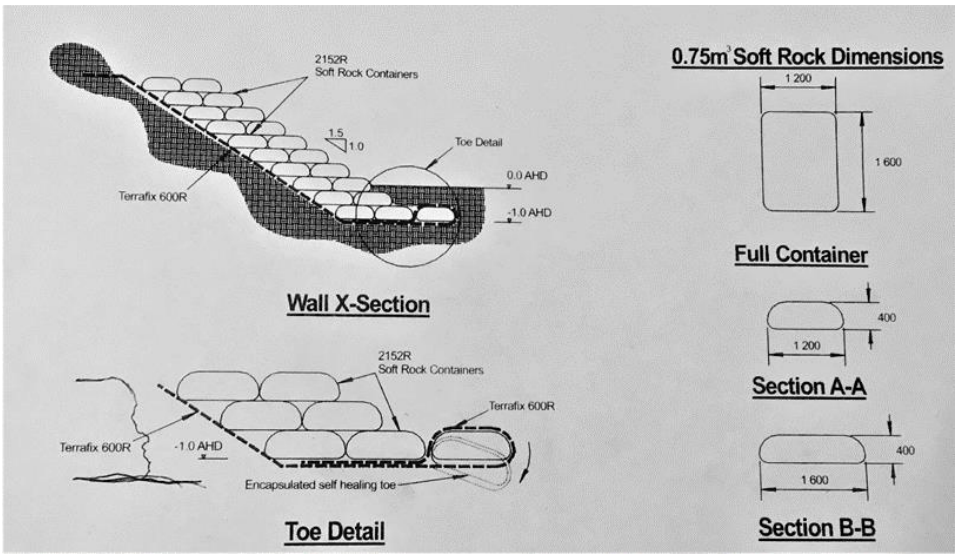

Figure 2-6 Standard Construction Drawings for Sandbag Seawall prepared by Soil Filters Australia

Figure 2-7 Construction of Reflections seawall (east) with geotextile filter directly overlying the clay layer. July 2019.

During construction, there were some known variations to the design and some differences between Reflections east and west seawalls. It is understood that prior to the placement of sandbags the slope was trimmed, a toe trench excavated, and a geotextile installed on foundation material for both walls. The eastern wall foundation material was observed during construction to be the clay-layer (believed to be approximately -1.0 m AHD elevation), however, it is reported that the western seawall foundation material is unconsolidated sand. Figure 2-8 shows western wall shortly after completion.

Immediately after the Reflections seawall was constructed, limited effort was made to shape or revegetate the back-dune scarp. It was rather, allowed to slump naturally to its angle of repose (more stable position) before revegetation of the area began. Figure 2-8 and Figure 2-9 show the wall sections immediately post construction.

Figure 2-8 Reflections seawall (west) immediately post-construction (2 August 2019).

Figure 2-9 Reflections seawall (east) immediately post-construction (2 August 2019).

3 Coastal Processes

3.1 Byron Bay – Regional Setting

Coastal processes at Byron Bay are highly complex, with interactions at regional to local scales, temporally and spatially. The predominant south easterly wave climate in NSW generates regional net northerly sediment transport, which increases in strength moving northward along the NSW coast. In the NSW north coast sediment compartment within which Byron is located, net longshore sand transport increases from about 150,000-200,000 m^3/year at the Clarence River to about 550,000 m^3/year at the Gold Coast (Point Danger). The stability of the beaches and dunes in Byron are therefore predominantly dependent on these larger scale coastal processes and regional sediment transport patterns.

The positive gradient in the net longshore sediment transport between Clarence River and the Gold Coast (Point Danger) of about 350,000-400,000 m^3/year along 150km of coastline would potentially lead to average shoreline recession for an active vertical beach zone of about 0.15-0.18 m/year (that is, the beaches supply the longshore sediment transport gradient, resulting in erosion of the shoreline). Research by Patterson (2013) indicates that there remains a residual net shoreward sand supply into the shore-face from the inner continental shelf, offsetting some of the shoreline recession that could otherwise result from the longshore transport gradient to an estimated average recession of less than 0.1m/year in Byron Bay (BMT WBM, 2013).

Further evidence of the underlying long-term recession occurring at Byron Bay is the relative absence of Holocene (last 10,000 years) dune barriers, with older Pleistocene dune barriers and clay layers commonly outcropping on the beach and surf-zone at the eastern end of the embayment. The Holocene barriers that would have developed here have since been removed by erosion associated with the northward gradient of longshore drift.

The deep-water wave climate of the northern NSW coast comprises a highly variable wind wave climate superimposed on a persistent long period moderate to high energy swell arriving predominantly from the southeast to east direction sectors (Figure 3-1, Manly Hydraulics Laboratory 2020). Two types of storm wave generation, east coast lows and tropical cyclones, are dominant in determining the prevailing extreme wave climate. BMT WBM's (2013) analysis found a distinct seasonal pattern with more southerly directions in winter and more easterly directions in summer. The plan shape of the shoreline along the region reflects the dominant southeast swell conditions and northward net movement of beach sand. This manifests as a series of crenulate shaped embayments, more hooked at their southern ends and aligned more uniformly and relatively consistently at north-northeast (approx. 20°) at their northern ends.

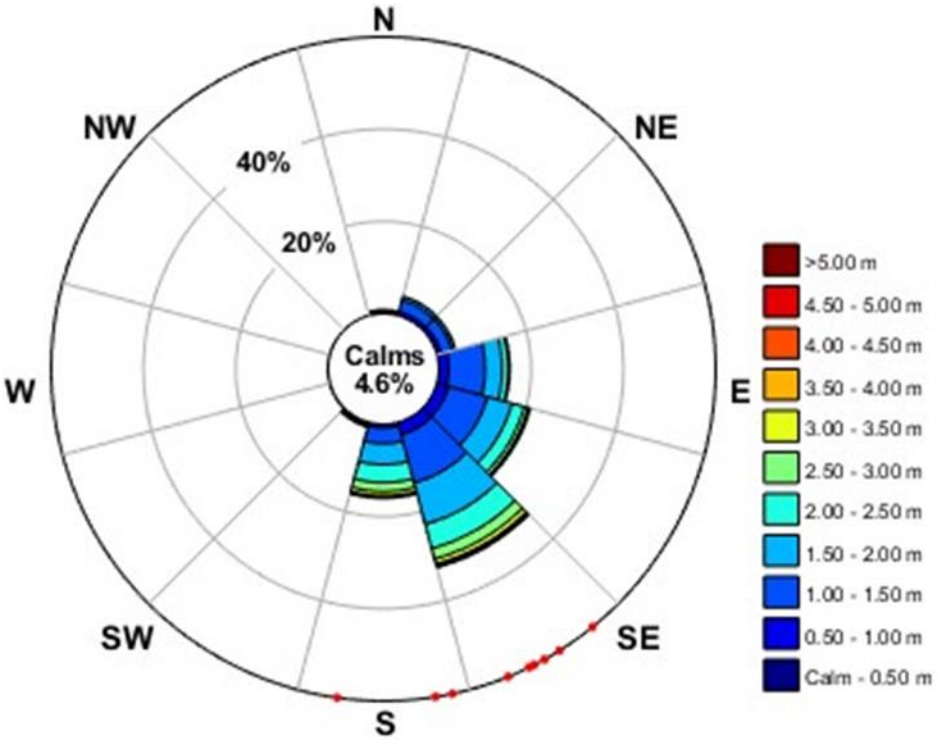

Figure 3-1 Wave height rose for Byron Bay Wave Buoy Data (2017-2020)

(Data Source: Manly Hydraulics Laboratory 2020)

There appears to be a tendency for high-energy storm wave occurrences that can be related to ENSO (El Nino – Southern Oscillation) patterns, with periods of high energy southerly waves coincident with El Nino conditions (e.g. 2002-03); and high energy waves from east to east-southeast coincident with La Nina phases (e.g. early 2009, 2011-12 and 2020) (BMT WBM, 2013).

Modelling of waves to nearshore by BMT WBM (2013) illustrated that there is relatively direct propagation of east to north-east waves onto the Byron shoreline, with these wave directions producing the maximum wave height coefficients at the shoreline. The persistence of more easterly swells is believed to be a significant factor in the enhanced erosion of the shoreline evident in the eastern corner of the embayment throughout 2019-20. For south-east to southerly waves there are zones of substantial wave height reduction evident along the sheltered beach areas north and west of headlands. Cape Byron in particular has a profound sheltering effect at the shoreline to its north and west that may extend to the Gold Coast for more southerly waves.

The nearshore wave coefficients combined with the substantial natural variability in the wave climate occurring over the longer term (years and decades) has significant consequent effects on shoreline behaviour. Southerly waves tend to cause higher rates of northward sand transport along the northern parts of embayments, including more headland bypassing, while having reduced energy and lower sand transport potential in the sheltered southern embayment areas. Easterly waves cause higher transport rates at the more east-west oriented shorelines towards the southern embayment area (such as Clarkes Beach) but reduced transport (or downcoast transport) at the north-south oriented northern areas. Less frequent northerly swells redirect

sediment in the process of bypassing the headland onto the eastern beaches, but can also impede the supply of sediment from the south of the headland. Higher wave coefficients of these swells on the inner-embayment beaches also result in increased erosion in the short-term. These alongshore sand transport differentials and varying exposure to wave energy result in fluctuations in erosion and accretion patterns along the coastline, particularly as visible 'pulses' of sediment deposits moving along the embayment shoreline, also known as a sand slug.

BMT WBM (2013) determined the regional net longshore sediment transport rate past Cape Byron to be ~400,000 m^3/year, based upon new modelling done for that study, plus several previous analyses using different techniques by the lead author for the BMT WBM (2013) report, Dean Patterson (see Patterson, 2007; Patterson 2013). These values differ from that of preceding reporting (PWD, 1978) that were determined without the modelling and analytical techniques that are available today and based upon "subjective" analysis and observations. Aside from this, there is quite substantial agreement between the PWD (1978) and BMT (2013) studies.

Sediment transport patterns across the Byron Bay embayment have been described by PWD (1978) and BMT (2013) with arguably similar conclusions. Based upon these reports, sand transport pathways northwards around Cape Byron are as follows.

- Sand may be worked along shore in the highly active surf-zone/littoral zone in ~ 6-10m water depth where longshore and cross-shore sand movements occur, with net littoral movements to the north. BMT WBM (2013) suggest approximately half of the transport past Cape Byron follows this path.
- Sand may be deposited between approximately Cape Byron and Julian Rocks, and gradually worked north-west towards New Brighton under wave action beyond the active surf-zone, out to ~ 15-25 m water depth. BMT WBM/Patterson termed this "cross-embayment transport", however the description of this sediment transport process matched closely the PWD (1978) description of waves producing oscillating forces on the bed and subsequent northwards sand transport.
- BMT WBM (2013) suggest approximately 50,000 m^3/year of the littoral drift transport is intercepted by the southwards directed East Australian Current (EAC) and lost to a deep-water sediment sink. This unique element of the Byron Bay coastline is the interaction of a net northerly littoral drift with the EAC which runs from north to south along the east coast of Australia, at typical speeds of 1-2m/s and in water depths greater than 40-50m. at these depths, the EAC does not typically influence sediment transport in the surf-zone of east coast beaches, but offshore of Cape Byron, the shoreface dips sharply and steeply to water depths of 40-50m, at slopes of 1:18 to 1:30 (PWD, 1978). This places the northerly littoral drift currents immediately next to the southerly directed EAC, resulting in some of the northerly littoral sand being sheared off by the EAC where it is then effectively lost from the coastal system at water depths of 40m+.

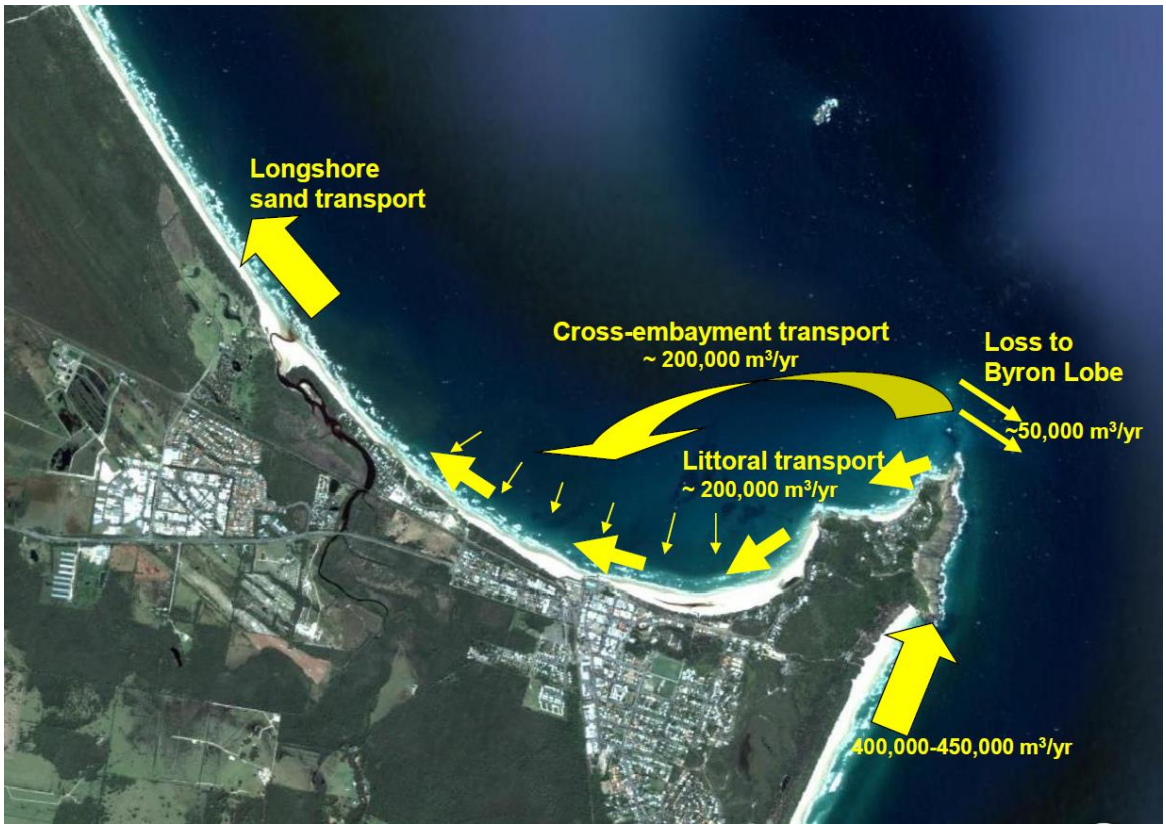

Figure 3-2 Conceptual model of sediment transport processes at Cape Byron (BMT WBM, 2013)

The BMT WBM (2013) and Patterson (2013) studies provided an extension of the (PWD) 1978 study. BMT WBM (2013) utilised the data and incorporated the findings of that earlier work with a further 40 years of highly accurate photogrammetric and LiDAR topographic beach profile data, a long time series wave record from various sources including a local wave rider buoy, and substantially improved mathematical modelling programs and capabilities compared with what was available in 1978. The BMT WBM (2013) and Patterson (2013) studies also adopted a regional approach that required consideration of the interactions with adjacent embayments.

3.2 Clarkes Beach – Local Setting

3.2.1 Coastal Processes

Clarkes Beach is situated in the south-eastern area of the Byron Bay embayment, and as such is subject to a unique combination of coastal processes on a local scale. The beach experiences significant shoreline fluctuations under prevailing weather and sediment transport conditions, while the impacts of region-wide trends due to net northerly littoral drift are also apparent. As part of the southern extent of the embayment, Clarkes Beach is out of the path of sediment that is transported by cross-embayment transport and as such is dominated by the littoral transport into and along the embayment.

The high rates of erosion recently observed on Clarkes Beach are the combined result of this large-scale transport process that appears to have left the broader embayment relatively devoid

of sand; and local scale processes that, without sand in the broader embayment, have impacted directly on the beach face and dunes, to produce substantial erosion. It is understood that such trends in this area are cyclical in nature and this phase of erosion will be followed by a phase of accretion. This occurs under conducive conditions where sediment deposits that are present in the outer embayment (transported by southerly swells in the process termed cross-embayment transport) are redirected toward the littoral zone by timely northerly swell events, causing a 'pulse' of sediment to migrate east to west along the southern shoreline of the embayment. This is supported by the presence of a large sediment deposit which has been monitored as it migrated along the beach at The Pass, which has now reached Clarkes Beach and replenished the beach substantially.

As a beach within the inner-embayment area, Clarkes Beach is well protected from southerly swells. Wave coefficients within this area are quite low for this swell direction, and considering the southerly swell dominance in the area, Clarkes is usually relatively well protected. Wave penetration of easterly to north-easterly swells is significantly larger and during these events beach erosion is experienced.

A sediment depleted shoreline intermittently uncovers outcrops of clay on Clarkes Beach. The geological formations interact with the sediment transport processes in the area and can be expected to have the following localised effects:

- Dissipation of wave energy, reducing the wave impacts on the shoreline immediately behind. This is often observed as a shoreline bulge, where sand has accreted in lee of the outcrop in the lower wave energy conditions.
- Impacts on littoral drift in the nearshore area immediately surrounding the exposed outcrop may include blocking or diverting the longshore sand transport from reaching the shoreline immediately downdrift.
- Such effects will vary in occurrence depending on the incident wave conditions, with south-easterly waves more likely to generate littoral transport which may then be blocked by the outcrop; and easterly waves reducing littoral transport, but also being dissipated on the outcrop.
- The effects of the outcrop are likely to only be evident when the feature is exposed.

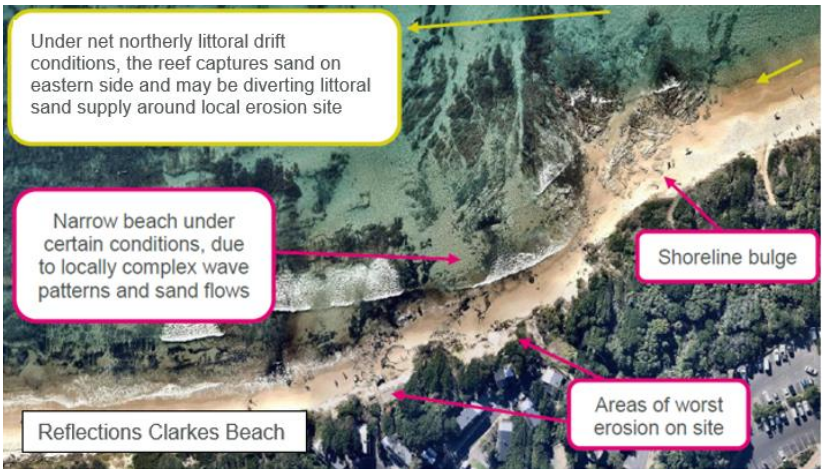

Figure 3-3 Clarkes Beach Outcrop (Source: Nearmaps, 2019)

3.2.2 Recent Wave Climate

Data sourced from the Manly Hydraulics Laboratory (recorded by the Byron Bay wave-rider buoy) has been collated to identify key storm events across the period of interest. The current location of the Byron wave-rider buoy is approximately 10km off the coast of Ballina, 25km south of Cape Byron (see Figure 3-4). As such, it is representative of the regional wave climate, but not for the inner embayment.

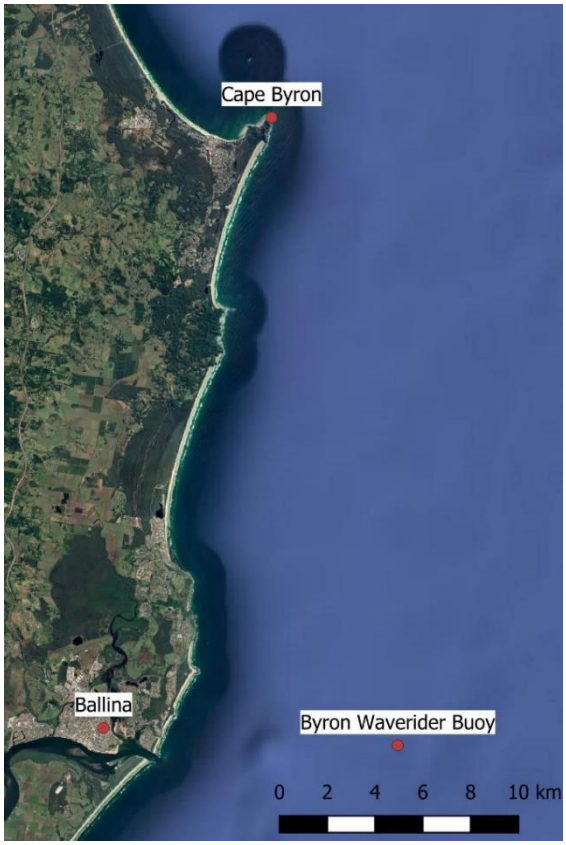

Figure 3-4 Byron Wave-rider buoy current location

Periods where significant wave heights peak are highlighted in Figure 1 below. Maximum wave heights were recorded on 23rd February 2019, and a few months later on 5th June; these events caused significant erosion, loss of beach accesses on Clarkes Beach and triggered the immediate construction of the Reflections seawall. The recorded data also shows a period of sustained high wave energy throughout 2020, and although it does not peak at the levels of the 2019 storms, this consistent trend of high wave action contributes significantly to rates of erosion. An average significant wave height (from data recorded 2017-20) has also been included on this graph to highlight this period of increased wave energy. Directional analysis also completed for this dataset showed a predictable southerly-dominant swell direction, although it should be noted that the high energy event on 14/02/2020 was of a direction slightly north of east.

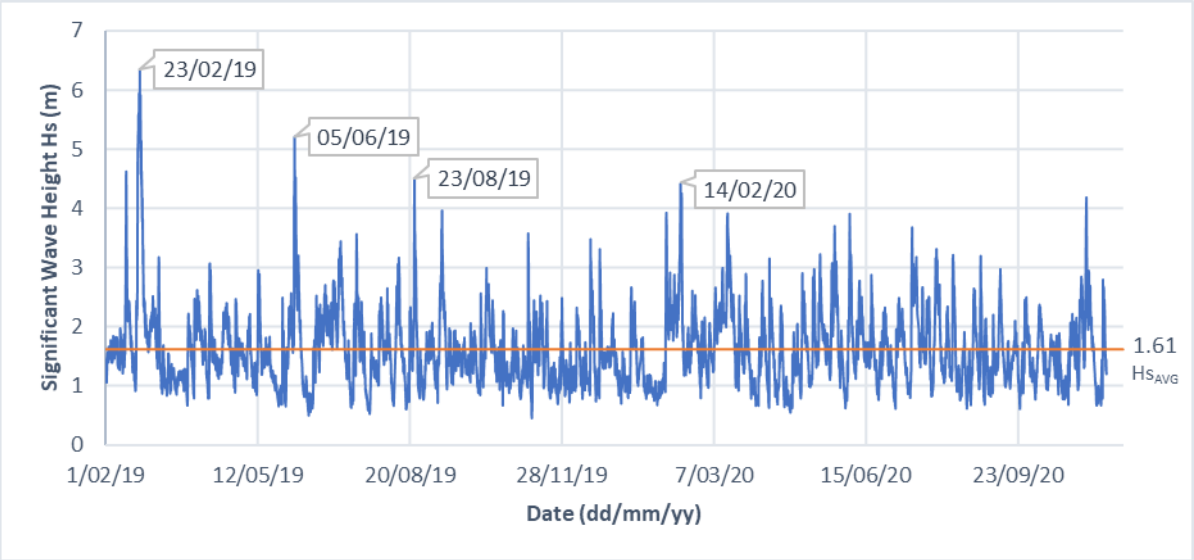

Figure 3-5 Significant Wave Height vs Date for Byron Bay

(Data: Collected and Provided by Manly Hydraulics Laboratory, Owner: NSW Department of Planning, Industry and Environment)

3.2.3 Coastal Hazards

Coastal hazards arise where coastal processes interact with our use and development of coastal land and assets, or where human development has impeded natural coastal processes. The coastal hazards defined in the *Coastal Management Act 2016* are described in Table 3-1, and their relevance/importance at the Reflections Clarkes Beach Holiday Park site is noted.

Table 3-1 Coastal Hazards and Definitions – *Coastal Management Act 2016*

Coastal Hazard	Definition	Importance at Reflections site
Beach erosion	A reduction in beach sand volume and/or a landward movement of the shoreline over the short term (days to months), usually associated with a storm event or a series of storms. Beach erosion occurs due to one or more process drivers: waves, tides, currents, ocean water level, and downslope movement of material due to gravity.	Highly relevant to RCBHP. Erosion events are described throughout Section 3.
Shoreline recession	A net landward movement of the shoreline over time, due to an ongoing deficit of sediment to the shoreline which may be caused by natural or anthropogenic causes, and / or sea level rise.	Highly relevant to RCBHP. Ongoing recession trends are described in Section 3 and resulted in Reflections seawall construction, which is detailed in Section 2.
Coastal lake or watercourse entrance instability	Coastal lake and watercourse entrances are highly active environments with their shape constantly changing in response to processes such as alongshore sediment transport, tidal flows, storms and catchment flooding. There are a variety of potential hazards and risks associated with the dynamic nature of natural and trained entrances, including erosion or accretion of adjacent shorelines.	Low level of importance at RCBHP. Nearby gully (to the east) and stormwater outlet at the centre of Reflections seawall may cause local scour of beach but their locations are fixed
Coastal inundation	High tides combined with storm surge, wave run-up and sea level rise may overtop coastal barriers (e.g. dunes, seawalls) and may inundate low lying land through and adjacent to the entrances of coastal lakes or watercourses.	Low level of importance at RCBHP site. High dunes protect this site from inundation.
Coastal cliff or slope instability	Land slip, rock falls and reduced stability of adjacent land at: • natural or trained bedrock cliffs and slopes, or • dunes immediately after an erosion event where the slope slumps to the angle of repose of the sand as it dries.	Medium to low level of importance at RCBHP site. No rock cliffs exist at the site. vertical scarps may form in dunes and then slump after erosion events. This creates a Zone of Reduced Foundation Capacity which must be considered for internal infrastructure.
Tidal inundation	The inundation of land by tidal action under average meteorological conditions and the incursion of sea water onto low lying land that is not normally inundated, during a high sea level event such as a king tide or due to longer-term sea level rise.	Low level of importance at the site. High dunes protect this site from such inundation under current and predicted future tide levels.
Foreshore erosion and inundation	Erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.	Low level of importance at the site due to high dunes and no significant watercourses.

4 Functional Assessment of Wall

4.1 Design Conditions

For analysis of the potential design life of the Reflections seawall, design criteria have been defined for average recurrence intervals (ARIs) of 1, 10 and 100 years based on previous studies.

4.1.1 Water Level

Design water levels adopted from levels defined for Fort Denison (commonly adopted for NSW Coast) from DECCW (2010) are:

- 1-year ARI – design water level 1.24m AHD;
- 10-year ARI – design water level 1.35m AHD; and
- 100-year ARI – design water level 1.44m AHD.

4.1.2 Offshore wave climate

BMT WBM (2013) provides a description of the offshore wave climate, reproduced below.

Table 4-1 Extreme significant wave height estimates (BMT WBM, 2013)

ARI (Years)	East Coast Lows Hs (m)	Tropical Cyclones Hs (m)	Combined Hs (Allen and Callaghan) (m)	Byron 1hr Hs Kulmar et al (2005) (m)
2	4.85	3.89	5.02	5.4
5	5.67	4.60	5.83	6.0
10	6.10	5.20	6.29	6.3
20	6.47	5.83	6.71	6.7
50	6.90	6.73	7.28	7.3
100	7.20	7.46	7.75	7.6

Modelling of wave penetration coefficients indicated waves from the north/north-east penetrate to the site most (BMT WBM, 2013). These waves are usually caused by tropical cyclones. Based on analysis of the last 10 years of wave data from Manly Hydraulics Laboratory (2020), waves of this size have periods of 10 to 15 seconds.

4.1.3 Storm Demand Volumes

The storm demand, or 'storm bite', is a defined volume of sediment that could be expected to be removed by erosive forces during a given storm event. These are usually defined as a m^3/m volume. BMT (2013) defines the 100-year ARI storm demand value through modelling, which are interpreted into lower recurrence intervals by UNSW (2020b).

- 1-Year ARI – $5m^3/m$;
- 10-year ARI – 78 m^3/m; and

- 100-year ARI – 150 m^3/m.

4.2 Wall Condition

This section details a condition assessment of the Reflections seawall based on general visual inspections and photographic records.

The main defects observed in the walls are sandbag displacement and bag puncture and deflation (Figure 4-1 and Figure 4-2). Photographic records show that one to two sandbags have been displaced from western ends of both the eastern and western wall. Sandbag displacement is due to hydrodynamic stability issues where sandbags are essentially knocked from the seawall structure by waves breaking on the seawall. Sandbag deflation is reported to have occurred during the first few months from wall construction where sandbags were inadvertently punctured during construction and thus, apparently has little do with hydrodynamic energy impacting the seawall.

In summary, there is seemingly no difference between the damage observed in the Reflections seawall east or west sections with both having approximately 0 to 5% damage sustained since construction. Although these defects have not yet greatly affected the function of the wall, it does demonstrate that waves in storms events have already directly impacted the seawall with sufficient energy to move sandbags.

Figure 4-1 Displacement and deflation of sandbags from Reflections seawall (east) (5 November 2020)

Figure 4-2 Displacement of sandbags from Reflections seawall (west) (15 October 2020)

Currently, approximately 20 months since construction, the Reflections seawall is generally in good condition (as defects have been amended), still largely functioning as intended and stable. Especially pertinent to mention is that since December 2020 when erosion was severe (Figure 4-2), there has been an influx of sand from the pass (since January 2021) filling in Clarkes Beach significantly with only the two top layers of sandbags now visible above beach level (Figure 4-3). There has also been some vegetation growth on the now-slumped erosion scarp behind the sandbag wall, stabilising the dune face.

Figure 4-3 Reflections seawall (east) - 21 February 2021.

4.3 Design Life Assessment

The design life assessment of the current Reflections seawall was conducted by considering the likelihood of various failure modes occurring within the next 5 to 10 years. The failure modes considered are (1) hydrodynamic stability – wave energy impacting the wall directly causing wall destabilisation and collapse, (2) scour caused by waves acting to undermine to toe of the seawall and (3), wave run-up overtopping the wall causing dune scour behind the seawall.

4.3.1 Hydrodynamic Stability

The potential for destabilisation of the Reflections seawall caused by direct wave impact was analysed by comparing depth limited waves (waves where wave heights are directly controlled by water depth) of ARI 1, 10 and 100 years to a standard sandbag wall stability chart (Figure 4-4) (Hornsey et al. 2011). This calculation conservatively assumed the beach profile was fully scoured down to the clay layer and that the breaker index was 1.2 for all scenarios.

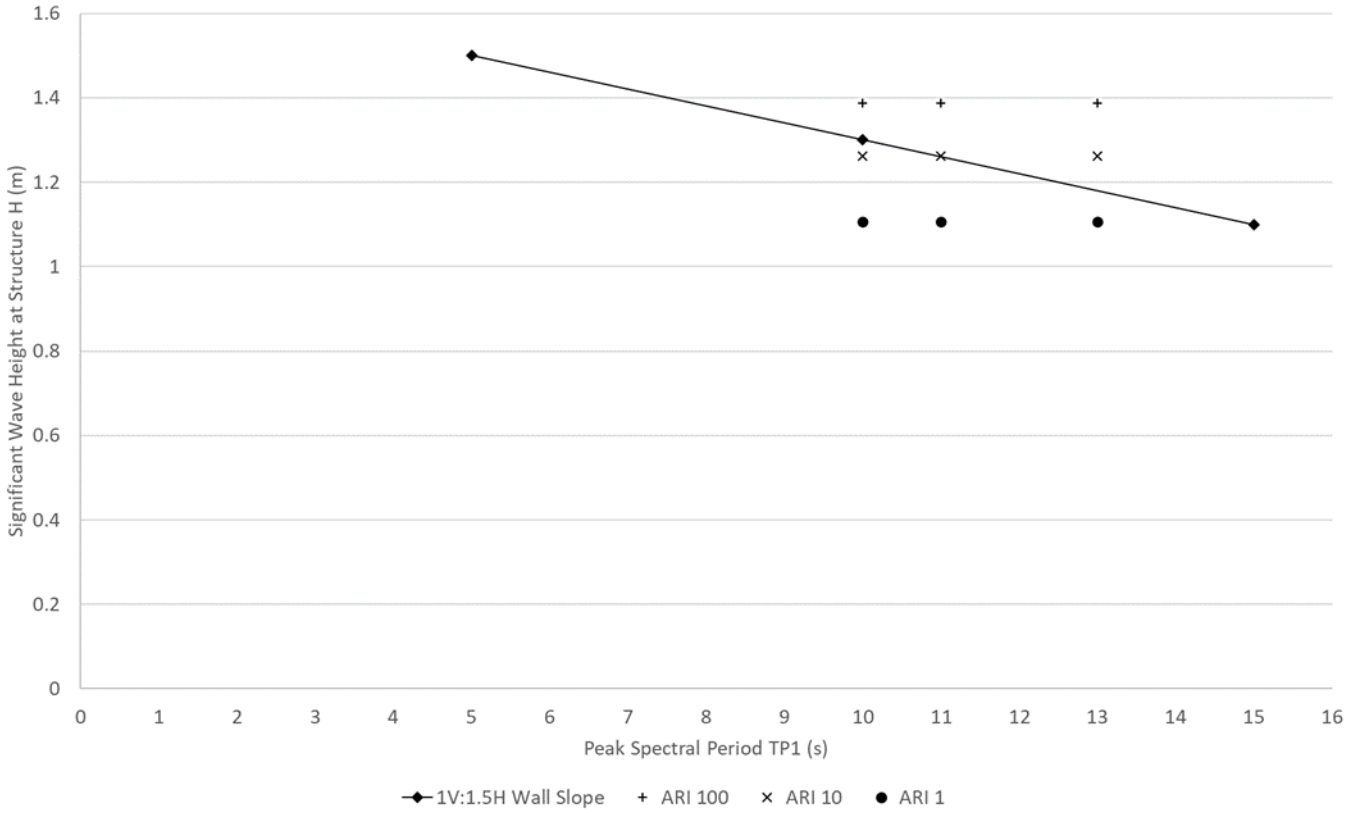

Figure 4-4 0.75 m^3 Sandbag seawall stability chart wall slope 1V:1.5H reproduced from Hornsey et al. (2011) with depth limited wave calculation results marked.

The solid line in Figure 4-4, shows the predicted failure point for a 1:1.5 sloped sandbag seawall. This is defined by Hornsey et al. as greater than 15% of sandbags are displaced from the seawall. The results from this analysis, thus, show that with a conservative estimate of the wave height, a **1-year ARI** event and below would **cause damage to the seawall but not failure**. A **10-year ARI** event is forecast to straddle the line of stability, meaning **the seawall could fail** in these conditions. Under **100-year ARI** conditions the **wall is predicted to fail**.

The Reflections seawall has only been in place for less than two years and has already seen some limited bag displacement and bag deflation seen (Figure 4-2 and Figure 4-3), in line with the above model predictions.

A 10-year ARI event has an Annual Exceedance Probability (AEP) of 10%. This means that on any given year where the beach profile is scoured, there is a 10% chance the wall will fail.

4.3.2 Toe Scour

The likelihood of failure due to toe scour of the Reflections seawall differs between the eastern and the western sections. The base of the eastern section of the seawall is based on the clay layer which extends out into the surf zone (Figure 2-7). This layer is reasonably resistant to short term erosion from single storm events; thus, it is unlikely that this wall portion will be undermined due to toe scour. The base of the western section of the seawall has been reported to sit on

unconsolidated sand above the design elevation of -1.0 m AHD. If this is the case, this wall faces a greater likelihood of being undermined due to toe scour.

To date, neither seawall section has suffered significant toe scour, even when the beach was severely scoured in October 2020 (Figure 4-2).

4.3.3 Wave Run-up Overtopping

Wave run up was calculated for the Byron Shire at Main Beach, analogous to Clarkes Beach by BMT WBM (2013). SWAN wave modelling outputs were used to determine nearshore conditions for wave run-up determination. The design deep water conditions for assessment of wave run-up and overtopping potential were:

- 100-year ARI significant wave height of 7.5m from direction just north of east (with wave coefficients greatest at the shoreline under this wave direction).
- 100-year ARI storm tide (or, ocean water) level of 1.44m AHD, the value commonly adopted for the NSW coastline (from Fort Denison).

Run-up levels are provided for the present day, and for 2050 and 2100 including 0.4 m and 0.9 m sea level rise, in Table 4-2.

These levels are adopted for use at Clarkes Beach, although they may be slightly conservative as Clarkes is more sheltered than Main Beach.

Table 4-2 Calculated 100yr ARI wave run-up levels from BMT WBM (2013)

Location	Nearshore Wave Height (Hs, m)	Run-up Component (m)	Run-up level Inc. Storm Tide + SLR (m AHD)		
			Present	2050	2100
Main Beach	2.85	2.43	3.87	4.27	4.77

Comparing the predicted run-up levels to the elevation of the top of the Reflections seawall at approximately 2.5 m AHD shows that on a current storm high tide, a 100-year storm would produce waves which would overtop the wall by approximately 1.37 m. This would cause significant scour of sand behind the seawall, potentially causing a cavity to form behind the seawall, leading to seawall collapse. As sea level rise progresses, the situation will worsen with higher volumes overtopping the seawall in storms.

4.3.4 Design Life

Because the Reflections seawall is most likely to fail though the occurrence of a rare event, i.e. a very severe storm, it is not possible to reliably estimate their remaining ‘design life’. The storm causing failure may occur in 1 year or 10 years. In this situation it is more useful to estimate the probability of failure over various time periods.

The Reflections seawall is assessed as being at risk of failure in a 10yr ARI storm event, if the beach is in an eroded condition pre-storm (as it was for most of 2019 and 2020), as this allows larger waves to reach the seawall. The Reflections seawall is likely to fail either by direct removal of sandbags by wave action or scour of the dune above/behind the seawall by overtopping waves.

Assuming the beach is in the eroded state approximately half the time, the average annual probability of failure (a greater than 10yr storm occurring and beach in eroded state) is around 5%. The estimated probability of a failure event over different time periods is provided in Table 4-3.

Table 4-3 Estimated Probability of Failure Conditions Occurring

Duration (Years)	Probability of Failure
1	5%
2	10%
5	23%
10	40%

To reduce the risk of failure, it would be necessary to:

- Rebuild with larger geotextile sand containers (sandbags) to provide greater hydrodynamic stability; and
- Increase the crest height to protect from overtopping.

Neither measure is sufficient on its own and increasing sandbag size is not a practical modification as it would involve effectively building a new wall.

Notwithstanding the theoretical design life discussed above, the Reflections seawall may last for many years and provide effective protection in minor to moderate storms during periods of low sand volume on the beach. If the seawall were damaged to the point of failure in a major storm event then significant erosion of the dune could occur potentially threatening assets, however this erosion would likely be less than would have occurred without the seawall present.

4.4 Coastal Process impact observed to date

Coastal process impacts caused by the construction of the Reflections seawall include end effects of the structure and disruption of long-shore littoral drift patterns. Particular concern has been raised about the end scour effects of this seawall on the beach areas to the west.

End-scour can occur on beaches where a hard structure (permanent/semi-permanent seawall) is built within the area of the beach subject to erosion by wave action. Wave energy can be focused with increased turbulence at the ends of the structure, which can cause accelerated erosion in these areas. Impacts are often distributed in a manner consistent with the diagram below, with the most significant impact being located directly adjacent to the structure. Considering these structures are usually built for protection on shorelines experiencing erosion, it is common to see continued erosion or shoreline retreat on the beaches surrounding the structure.

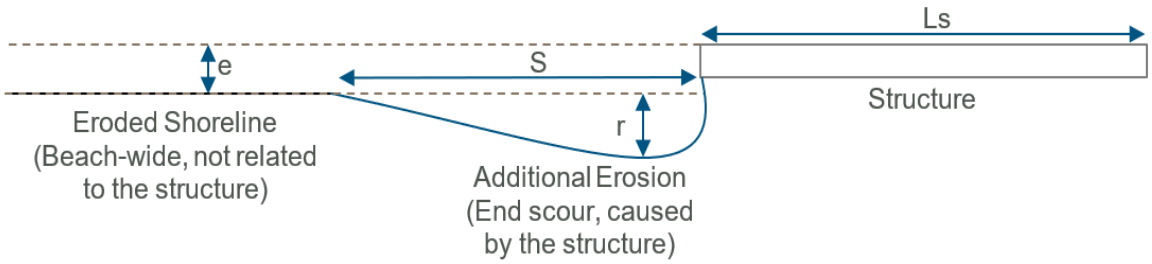

Figure 4-5 End scour effects of permanent coastal protection structures diagram

Seawalls can also impact costal processes by 'locking up' sediment that would otherwise be eroded and hence reduce the along-shore sediment supply to areas down-drift (to the west). Where this is the case erosion would be evident immediately on the western end of the structure.

To determine the potential effects of end scour caused by the Reflections seawall on the adjacent beach area, assessment of vegetation lines in aerial imagery, beach profiles from photogrammetry and site photos has been undertaken for the period of interest.

4.4.1 Vegetation Line Assessment to Date

Through the interrogation of aerial imagery (Nearmap), the vegetation line at the site can be plotted for a range of dates. The differences between the plotted vegetation lines give indication of erosion. Four dates in focus are:

- 11/06/2019 – latest image before construction of the Reflections Seawall (20/07/2019). This shows the position of the shoreline preceding the large storm events that necessitated the construction of the Reflections Seawall.
- 08/09/2019 – image taken soon after the construction of the Reflections Seawall. This shows the recently eroded vegetation line
- 04/07/2020 – image taken 12 months after the construction of the Reflections seawall. Indicates the trends occurring before the construction of the Beach Byron Bay seawall.
- 15/01/2021 – image taken after major erosion event and the construction of the Café seawall. Most recent image.

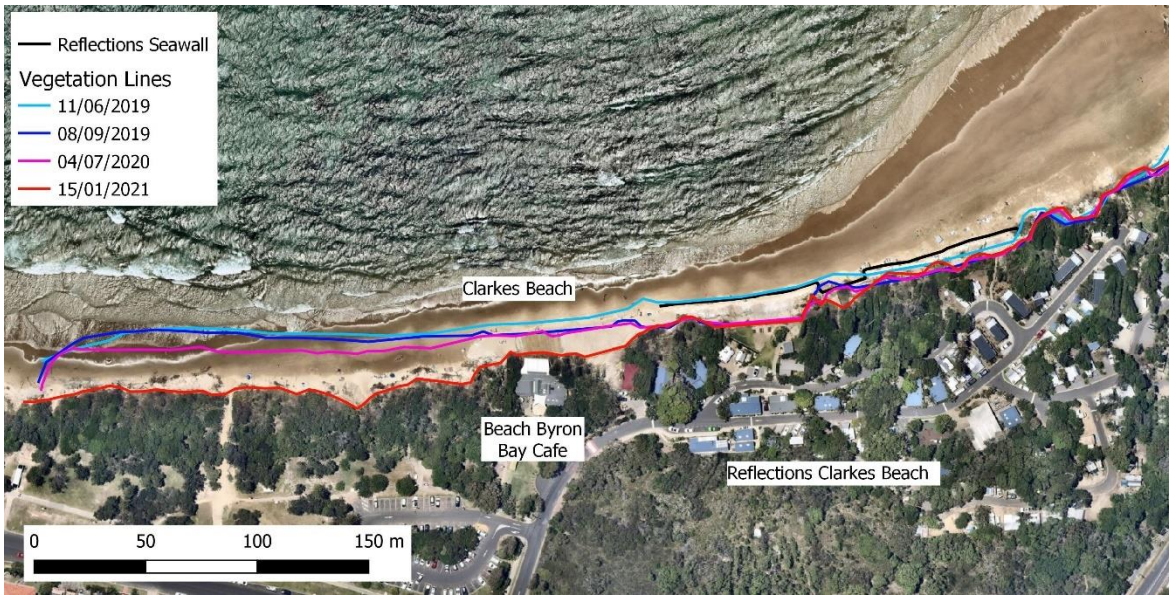

Figure 4-6 Clarkes Beach Vegetation lines between 2019 and 2021

(Image dated 15/01/2021, Nearmap)

As can be seen in Figure 4-6, there is evidence of erosion between June and September of 2019. This is the erosion that triggered the construction of the Reflections Seawall and likely occurred before July 2019, when the vegetation line behind the seawall would have stabilised.

Between September 2019 and July 2020, there is some localised recession of the vegetation line occurring to the west of the Reflections Seawall. This recession is noted as beginning further than 50m west of the Reflections seawall, and of roughly the same magnitude to the erosion that occurred at the Reflections site in 2019.

Between July 2020 and January 2021, there is significant erosion along Clarkes Beach. During this period, the Café seawall was constructed. The landward recession of the dune is approximately 10m within 100m to the west of the Reflections seawall, and approximately 20m further west of this.

The relative stabilisation of the shoreline immediately downdrift of the Reflections seawall between the 2019 and 2020 images combined with the evident beach-wide erosion trends (which are maximum at approx. 140m west of the Reflections wall) indicate that the impact of any end scour at the Reflections seawall to date is negligible compared to the beach-wide erosion trends observed. As per the commonly accepted impact area diagram shown in Figure 4-5, end scour would likely occur directly adjacent to a coastal protection structure, which is not a trend that is observed at this location.

4.4.2 Beach Profile Analysis

The NSW Beach Profile Database contains data from two photogrammetric surveys in the period of interest:

- 29 July 2019 – near the time of completion of the Reflections seawall; and

- 22 June 2020 – approximately 11 months after the completion of the Reflections seawall and 4 months before the construction of the Café seawall.

These surveys are well separated in time and provide a sound basis for the investigation of changes due to the reflections wall construction.

Several beach profile sections were considered (see Figure 4-7 below) to investigate changes in profile at various locations of interest; at the Reflections seawall; the immediate downdrift area on Clarkes Beach; and further west along Main Beach. This allowed for beach-wide trends to be compared with direct impacts of the Reflections seawall.

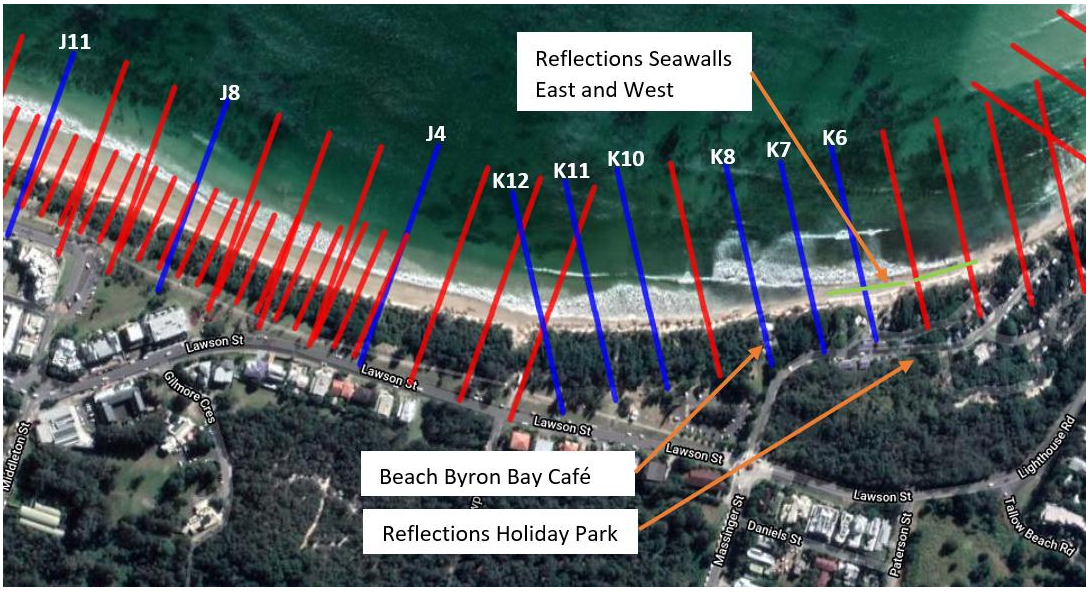

Figure 4-7 Study area plan - Analysed beach profiles (blue) and locations of interest

(Source: NSW beach profile database)

Profile K6 intersects the Reflections seawall (west), K7 is approximately 15m west of the end of this wall and K8 aligns with the Beach Byron Bay Café about 65m downdrift of the end of Reflections seawall (west). Beach profile comparisons are contained Appendix A at the end of this document. A summary from this analysis is shown in Table 4-4 below, which gives the landward movement of the dune erosion escarpment at the toe (at the 3m contour) and the crest (height varies).

Table 4-4 Profile Analysis Summary

Profile Section Location	Chainage (m west of Reflections seawall western end)	Dune Toe Movement (m Landward)	Dune Crest Movement (m Landward)
K6 – Reflection seawall (west)	-35	-2	0
K7 – West of Reflections seawall	15	2	5
K8 – Beach Byron Bay Café	65	0.5	8*
K10 – Clarkes Beach west of Café	160	7	9
K11 – Clarkes Beach west of Café	210	11	11
K12 – Clarkes Beach west of Café	260	-3	0
J4 – Main Beach	410	5	3
J8 – Main Beach	610	Accretion at toe	-1
J11 – Main Beach	760	Accretion	2

Key points from this analysis include:

- The crest of the escarpment generally moved further landward than the toe. This is attributed to very steep post-storm escarpments in the July 2019 profiles and more slumped profiles, close to the angle of repose in September 2020;
- There was very little movement of the escarpment toe (<2m) at K7 immediately west of the Reflections seawall or K8 at the café;
- There was a larger movement of the escarpment toe (7 to 11m) representing significant shoreline retreat at K11 and K12, the two profiles to the west of the café; and
- The observed pattern of erosion is not consistent with end scour effects or lack of sediment supply caused by the Reflections seawall because the worst affected areas are not immediately adjacent to the wall, but several hundreds of metres further west.

4.4.3 Site Photos

Regular site visits by a BMT Engineer have resulted in numerous photos being collated since the Reflections seawall was constructed in July 2019. The inspections are part of an ongoing monitoring program which aims to observe and record geotextile sand container condition and configuration along with general beach conditions including sand build up or depletion, dune, and dune vegetation conditions.

Photographs taken during these visits in the period of interest (at regular intervals following the construction of the Reflections seawall) serve to indicate the extent of end scour on the beach downdrift of the Reflections seawall. Figure 4-8 shows the end of the western wall immediately

after construction and the associated erosion scarp at that time. In this image the erosion scarp in the dune immediately to the west of wall is approximately 1m landward of the wall crest.

Figure 4-8 Western end of Reflections seawall (west) 2 August 2019 (within days of construction being completed)

The image in Figure 4-9 is approximately 15 months post construction and shows the extent of erosion downdrift of the Reflections seawall. In this image, the erosion scarp is approximately 2-3m landward of the wall crest. Figure 4-10 from the same day shows the consistent evidence of ongoing beach-wide erosion (dune escarpment, undermined vegetation, exposed rock on beach) visible for hundreds of metres.

Figure 4-9 Western end of western wall, 14 October 2020

Figure 4-10 Looking west from the western end of Reflections Wall, 14 October 2020

These three photos support the findings of the vegetation line and profile analysis:

- Erosion immediately to the west of Reflections seawall (west) is no more than 2-3m over this period (Figure 4-8 and Figure 4-9); and
- By October 2020 there is major erosion to the west of the Reflections seawall extending several hundreds of metres down the beach (Figure 4-10).

4.5 Functional Assessment

The objective function of the Reflections seawall is to provide temporary protection for RCBHP by halting the erosion of the dune. The wall has thus far, achieved this objective over the initially mandated 90-day period, and has provided continual protection for almost 2 years. The Reflections seawall remains functional with less than 5% of bags displaced although limited damage has been sustained since construction.

Analysis of air photos, beach profiles and site inspections have not identified that end scour or ‘lock up’ of sediment by the Reflections seawall has contributed to enhanced erosion along Clarkes and Main beaches (to the west of the Reflections seawall) during 2019 and 2020. Erosion that did occur further west was likely caused by storm events focusing wave energy in this area and the fluctuation in longshore sand supply from the east.

Since early 2021, a sand slug from The Pass has migrated down the point to Clarkes Beach and currently sits seaward of the Reflections seawall, protecting it from further damage.

Design life assessment suggest the wall may have a 10% risk of failure each year when the beach is in an eroded state. Upgrading the Reflections seawall to increase design life would involve a complete rebuild.

5 Impacts of Retaining or Removing the Reflections Seawall

This section presents a summary assessment of the impacts likely to stem from either retaining or removing the wall over a five year timeframe. Due to the limitations of the analysis undertaken combined with the complexities of the Clarkes Beach area, numerical values of impacts are provided only as likely ranges.

5.1 Coastal Processes

The Reflections seawall was originally constructed to afford temporary protection to assets with the Reflections Clarkes Beach Holiday Park (roads, cabins, services etc.) which were vulnerable to undermining by the receding dune scarp. The removal of this wall will thus impact the erosion hazards to various assets in the park as discussed below in Section 5.1.1.

Carley *et al*. (2013) have also outlined the potential physical impacts of coastal protection works on surrounding areas as follows:

- Altered erosion and accretion seaward of the seawall (Toe Scour);
- Altered erosion and accretion either side (alongshore) from the seawall (End Scour);
- Altered longer term recession and progradation alongshore from the seawall (Sediment Lock-up);
- Propensity to form rips;
- Changes to wave runup; and
- Changes to surfing amenity.

Each of these potential physical impacts are discussed below in subsequent sub-sections.

5.1.1 Impact on Erosion Hazard

In July 2019, immediately after a severe storm erosion event, and just prior to the Reflections seawall being constructed, the dune scarp was surveyed and the immediate zone of reduced foundation capacity (ZRFC) was mapped in the Clarkes Beach area (BMT, 2019). Because the Reflections seawall was constructed immediately after this analysis was performed, the dune scarp is still in the same position and the ZRFC's mapped still provide a good description of the hazards if the walls were to be removed. The immediate ZRFC is shown as the red line in Figure 5-2. Also shown as orange and yellow lines are the estimated 50-year and 100-year hazard lines calculated using sea level rise and landward recession rates. It is important to note also that Figure 5-2 shows the site prior to layout changes made by Reflections. This included removing cabins 4, 5, 17, 18 and 21, and shifting cabin 19 back approximately 5 m.

Figure 5-1 shows an example of Cabin 19 prior to its landward shift, which was mapped to be vulnerable to collapse due its proximity to the receding dune scarp. If the reflections wall were removed and the scarp continued to recede landward, this cabin could soon again be in the

ZRFC. Cabin 19 exemplifies other cabins in similar situations in the park (Cabins 1, 2, 3, 8, 9 and the cottage) which may also become vulnerable to damage/collapse if the wall was removed.

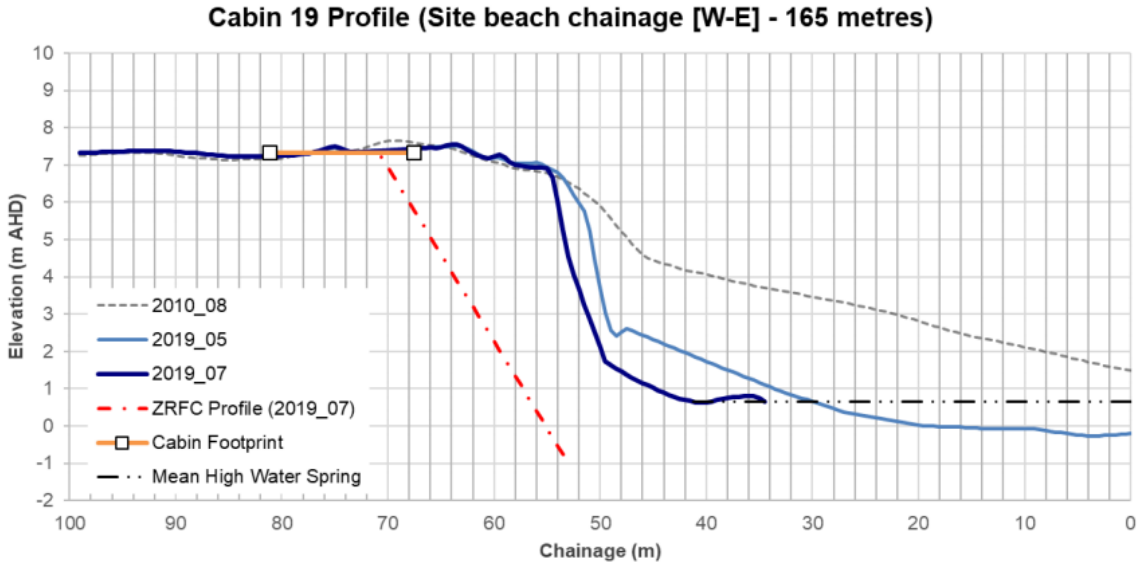

Figure 5-1 Example profile showing the Zone of Reduced Foundation Capacity (ZRFC) for the dune prior to wall construction. (Rollason, Downes 2019).

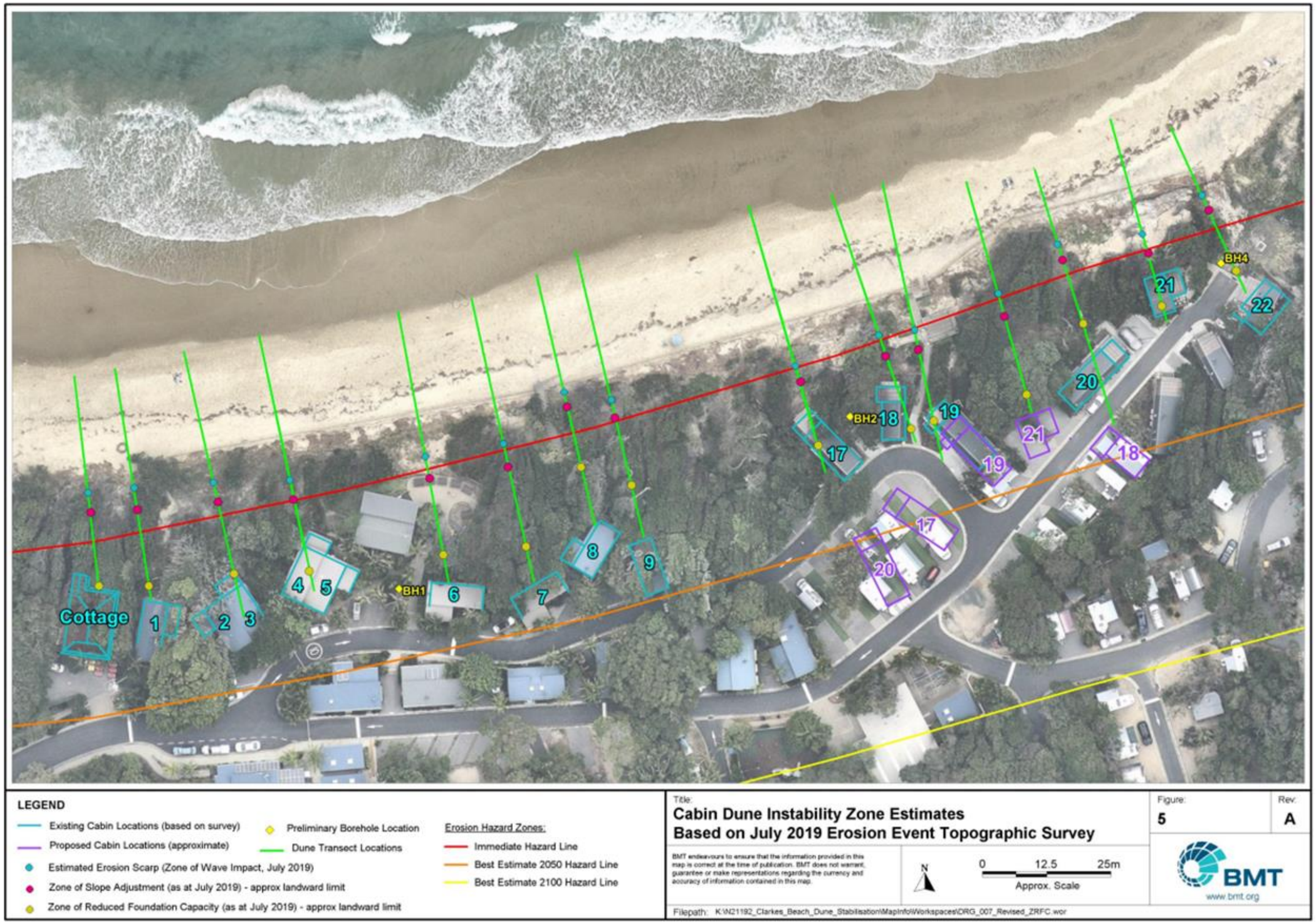

Figure 5-2 Map showing the immediate, 50-year and 100-year hazard lines immediately prior to seawall construction (BMT, 2019).

5.1.2 Beach Scour at Wall Toe

Carley *et al*. (2013) outline that when a seawall is constructed on a shoreline undergoing long-term erosion, lowering of the beach profile seaward of a seawall (toe scour) often occurs. This is because the general erosion of the coast acts to transport sediment away from a site via either longshore or cross-shore transport. When a seawall is placed in front of a dune system to stop that erosion, the sand constituting the beach is eroded instead.

Clarkes Beach is believed to be a receding area of coastline with recession evident since approximately 2010. As such, toe scour at the base of the Reflections seawall is a potential issue. Comparisons between beach profiles from areas without a seawall and profiles of the Reflections seawall (Table 5-1) suggests, however, that negligible beach lowering has occurred at the toe of the wall. This could be due to the presence of the clay layer in the surf zone which acts to dissipate wave energy and prevent further lowering of the beach.

Table 5-1 Averaged dune/wall toe levels for Clarkes Beach.

Profiles	Date	Type	Average Dune/Wall Toe Height (m AHD)
K4, K5, K6	22/06/2020	Wall	2.54
J3, J6, J8, J10, J13, K11	22/06/2020	No Wall	2.57

5.1.3 End Scour Hazards

End scour occurs when seawalls focus wave energy with increased turbulence at the ends of the structure. This causes the dune scarp immediately adjacent to the wall to recede at a faster rate than the already eroding coastline, causing a scallop of dune to be removed (Figure 4-5).

Carley *et al*. (2013) provides a technique for predicting the maximum extent of seawall end scour effects based on observations of various seawalls in Australia. This compares structure length and design storm erosion with resulting end effect factors and accounts for beach-wide trends. Using this technique UNSW (2020b) conducted analysis of the end effects of the Reflections seawall, with the following theoretical maximum erosion for given ARI events, and nominal width and length of impact areas (variables r and S in Figure 4-5) recessions based on a typical 5m tall dune.

- r = 5 m^3/m for 1-year ARI erosion (≈ 1m landward);
- r = 78 m^3/m for 10-year ARI erosion (≈ 16m landward);
- r = 150 m^3/m for 100-year ARI erosion (≈30m landward); and
- S = 190m longshore distance (west).

Although these theoretical potential erosion values were calculated thus, UNSW (2020b) highlights that:

"The Reflections geobags (seawall) *end effect is smaller than theory, probably because of the following factors:*

- *The structure is low and able to be overtopped by waves, thus providing sand from above its crest*
- *The structure has only been in place for about 15 months*
- *The beach planform in the vicinity of Reflections is governed by rock outcrops below the Captain Cook car park and Thompsons Rock, further west towards The Pass."*

Visual site inspections over the last 18-months have validated this assessment by UNSW showing that end effects caused by the Reflections seawall are smaller than predicted and in fact not distinguishable from the underlying dune recession seen west of the seawall to Main Beach (see Section 4.4.1 and Figure 4-10).

Another limiting factor on erosion is the presence of the clay shelf offshore of the RCBHP site. This geological feature limits vertical scour and constrains the formation of rips which would otherwise contribute to end scour. The clay shelf extends about 100m west of the Reflections seawall and limits the development of end scour in this area.

Based on the above limiting factors as well as patterns of erosion observed to date, it is not likely that theoretical maximum end scour extents predicted by UNSW (2020b) will be reached, but 50% or less of this theoretical extent is considered a more reasonable estimate of maximum scour in light of site conditions.

However, there are a number of structures within the theoretical maximum end scour extents that could be impacted by end scour in a severe storm of a scale which hasn't been experienced since wall construction (>10-year ARI). This included the Café and cabins as outlined in rad in Figure 5-3.

While this analysis assumes the removal of the Café seawall has already occurred, in actual fact the Café seawall is in place currently. While it is in place, the risk to the café and other buildings is low. If the Café seawall were to be removed, the buildings in the vicinity would be at higher risk from the background coastal erosion hazard than the from the end scour effects.

Figure 5-3 Reflections Clarkes Beach Holiday Park site, seawall, and adjacent area to the west. (Image dated 04/07/2020, Nearmap)

5.1.4 Sediment Impoundment (Lock-up) Impact

Once a seawall has been constructed, the sand behind the wall can no longer erode. This sediment which otherwise would have been mobilised along the beach and deposited elsewhere is no longer available. The seawall can therefore create a sediment deficit (more sand leaving than arriving) further down the beach and increases erosion in these areas.

In the case of the Reflections seawall longshore sediment transport predominantly occurs east to west. The Reflections seawall thus creates a sediment deficit to the west. UNSW (2020b) also estimated the volume of sand trapped by the Reflections seawall at a maximum of 345 m^3/year. At Clarkes Beach, the estimated annual longshore volume of sand transported is 200,000 m^3/year, dominated by the westerly movement of sand slugs from the Pass. Thus, sediment lockup caused by the seawall is only 0.2% of the total longshore sand transport in the area.

This means that any increases in erosion down beach from the Reflections seawall would not likely be appreciably above background fluctuations. It further means that hazards stemming from any increased erosion to the west of the seawall would also be negligible.

Although the seawall at Clarkes Beach is only responsible for a small portion of down-beach erosion, if further seawalls were to be implemented along this stretch of coastline, cumulative impacts would add up and cause a much greater impact.

5.1.5 Rip Forming Propensity

Rip currents are often observed to occur at the seawall ends both in-situ and in scale experiments where seawalls are placed on sandy beaches (Carley *et al*, 2013). At the heads of such rips, upper beach erosion commonly occurs causing a ‘rip embayment’.

The surf zone seaward of the Reflections Clarkes Beach Holiday Park has both the clay layer and the clay outcrop which act to limit erosion and constrain the formation of rips. Because of this, the Reflections seawall is unlikely to increase the propensity for rips to form at the wall ends.

5.1.6 Groyne Effects

Groyne effect is described by Carley *et al* (2013) as the capture of sand on the incident side of a structure projecting out into the surf zone in an area undergoing longshore sediment transport. This can also cause increased beach erosion on the leeward side of the structure. A typical example of this is the main beach carpark seawall in Byron Bay which has some short groynes extending into the surf zone. When the sand is scoured from this area, the beach on the eastern side of the wall can be up to 25m seaward of the beach on the western side of the wall (Figure 5-4).

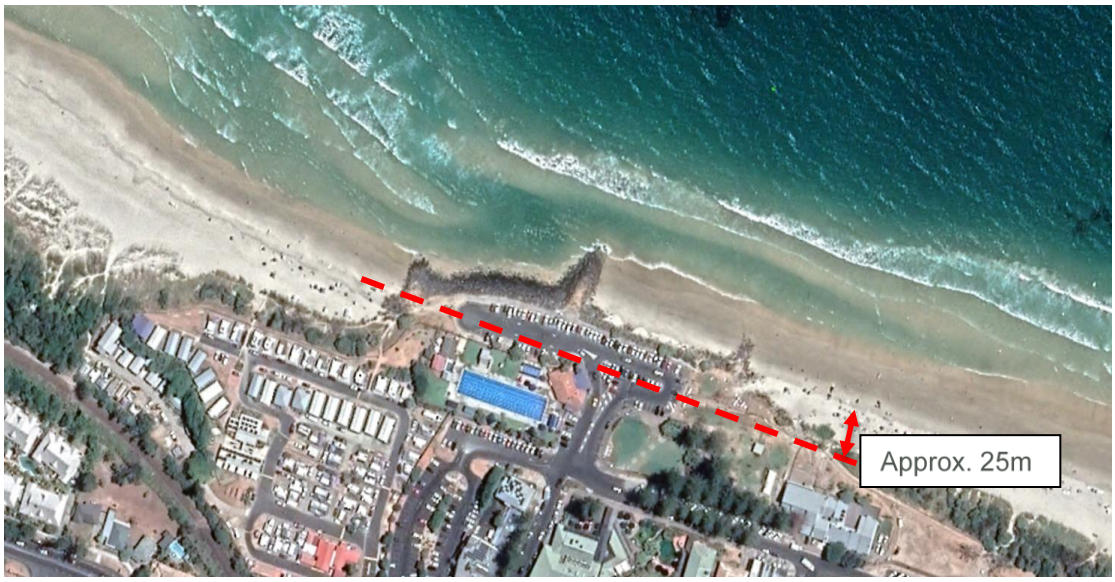

Figure 5-4 Main Beach (Jonson St) seawall/groyne and associated groyne effect (01/2019, Google Earth)

The Reflections seawall is set at the back of the beach, butting against the dune scarp. This means that even at times when the beach is fully scoured (e.g. Figure 2-5) the seawall is set back far enough that they are not in the surf zone and do not capture sediment. As such, groyne effect impacts of the Reflections seawall are negligible at Clarkes Beach.

5.1.7 Surfing Amenity Changes

Surfing amenity changes occur when coastal protection structures such as groynes or revetments cause waves to reflect back into the surf zone, potentially changing nearshore bathymetry. Regarding surfing amenity, these can interfere with the incoming waves in either a beneficial or detrimental way depending on a variety of variables. For example, backwash caused when waves break onto a shoreline revetment is detrimental to surfing amenity while long groynes with swell reflecting obliquely into the surf zone cause waves to 'wedge' and increase surfing amenity (e.g. Ballina North Wall).

Although Byron Bay is a mecca for surfers world-wide, Clarkes Beach itself is not a popular surfing location. The main surfing destinations in the vicinity of Clarkes Beach are 'The Pass', further to the east and 'The Wreck' west of the main beach carpark. Thus, because there is little surfing amenity to begin with at Clarkes Beach, any potential negative impacts (e.g. backwash) to surfing amenity in storm conditions would be negligible. No positive impacts would likely be seen either.

5.1.8 Summary of Impacts

Retaining Wall

Impacts of retaining the wall include:

(1) The Reflections Clarkes Beach Holiday Park assets (Cottage and various Cabins) are protected from short term erosion.

(2) Potential end scour at each end of the Reflections seawall. Potential to impact Cottage and Cabin 1.

(3) Minimal downdrift erosion due to 'lock-up' of sediments (approximately 0.2% of total erosional trend).

(4) Other effects as per Carley *et al* (2013) are not considered significant.

Removing Wall

Impacts of removing the wall include:

(1) Immediate and ongoing increased erosion hazard to assets in the Reflection park.

(2) Any end scour and sediment lock-up impacts to the west are removed.

5.2 Public Safety

As the site is a popular beach on public land the impacts on public safety must be considered. The major public safety risks relevant to the Refection's seawall are considered to be:

Risks related erosion in the areas protected by the seawall:

- The Clarkes Beach Holiday Park cabins and public areas are protected from erosion during severe storms. Without the seawall there are structures and that may be at risk of collapse in severe storms (refer section 5.1.1).

Risks related to erosion of dune in surrounding areas:

- Vertical dune scarp created by storm erosion, and subsequent collapse/slumping of the scarp. Pedestrians and beach users are at risk of falling from the top of the scarp or having material fall/collapse onto them at the bottom of the scarp. This process occurs over a wide scale whether or not the wall is in place, and increased erosion at the ends of the wall has been very minor to date (refer section 4.4.1). In local areas these risks can be managed by temporary fencing but when the erosion is beach-wide it may not be practical to fence the entire area.
- Instability of high dunes – even after the scarp has slumped to the angle of repose, the dune face may be unstable and dangerous to pedestrian trying the access the beach via the dune. This can be managed by providing alternative access points where necessary.
- Undermining of land and structures in surrounding areas that impacted by increased erosion in severe storms. There are structures in the area to the west that are at somewhat increased risk due to the wall – refer to section 5.1.3 This would only be the case in a very severe storm and the level of impact is difficult to quantify.

Risks related to the structure itself:

- Fall or trip hazards of the seawall – the wall is constructed of geotextile sand containers with a stepped profile with a maximum height of around 2m. One advantages of this type of structure is that the they are very 'pedestrian friendly' with rounded corners and a non-slippery surface. The risk of injury from falls and trips is considered very low.

5.2.1 Impacts of Retaining Wall

- Small locally increased storm erosion and the formation of high dune scarps at the ends of the wall leads to small increase in hazard to pedestrians at both top and bottom of scarps. Can be managed with local fencing.
- Increased risk to some surrounding public land and buildings to the west during severe storms. But this is offset by reduced risk to public land and buildings in the Holiday Park.

5.2.2 Impacts of Removing Wall

- Increased risk from high dune scraps in the area currently protected by the seawall.
- Decreased risk to some surrounding public land and buildings to the west during severe storms. But this is offset by increased risk to public land and buildings in the Holiday Park.

5.3 Cultural Heritage

The Cultural heritage of the Clarkes Beach area centres around the historic use of the area by the Bundjalung people. Three middens have been identified within the Reflections Park site shown in Figure 2-5, one in the gully to the east of the Reflections seawall and one landward of each of the western and eastern sections of the seawall (Hill *et al.* 2019). These middens have not been inspected to confirm precise locations, but from their mapped position it seems they are very likely to be at increased risk of disturbance and erosion if the seawalls are removed.

5.3.1 Impacts of Retaining Wall

- Midden 04-5-0358 behind the Reflections seawall (west) and 04-5-0359 behind the Reflections seawall (east) would be protected from erosion in the short term (up to 5 years).

5.3.2 Impacts of Removing Wall

- Middens in the dune behind both the Reflections seawall east and west sections (Middens 04-5-0359 and 04-5-0358 respectively) may be eroded out of the dune and destroyed. Midden 04-5-0199 to the east would not likely be affected.

5.4 Impacts on vegetation

A survey of vegetation at the RCBHP site has not been undertaken so this section focusses on potential impacts to vegetation (if present) arising from physical processes.

Protecting biodiversity provided by vegetation in the area is important. Ideally, the best way this is achieved is through a natural dune system with appropriate regeneration, though it is noted that vegetation communities along the Byron Bay embayment have already been impacted by coastal erosion. This is previously documented in Section 4.4.1.

The existence of mapped littoral rainforest in the study area is also acknowledged, and gazetted extents of which have been included in a feature survey by Kennedy Surveying. This feature survey also noted the locations of current forested areas and found large discrepancies between the mapped area of littoral rainforest and the actual locations of forested areas. The Reflections seawall sits largely out of the mapped littoral rainforest area, though the seawall footprint intersects the mapped littoral rainforest area for approximately 10m length of the Reflections seawall (east). Kennedy feature survey (Diagram 2, Sheet 2 of 2. *Sketch Showing Clarkes Beach Reflections Holiday Park,* 18062G.DWG. Kennedy Surveying. 30/09/2020) and our site inspections confirm no forested area is present in these areas. Concern has also been raised about impacts to wallum sand heaths in the area, although locations of these have not been specified and consideration of them is out of the scope of this report.

Dune vegetation (undescribed) is currently colonising the dune scape above the seawall, as shown in Figure 5-5.

Figure 5-5 Regeneration of dune vegetation above the Reflections seawall (east)

5.4.1 Impacts of Retaining Wall

- By limiting erosion, the seawall protects vegetation within the Holiday park (including littoral rainforest and wallum sand heath if present) from further losses to erosion.
- A stabilised dune creates a stable growing environment for regeneration of dune vegetation that has been eradicated by erosion. Such dune vegetation has begun to regenerate, as in Figure 5-5 above.

5.4.2 Impacts of Removing Wall

- Removal of the wall will expose the colonising dune vegetation and establish vegetation within the Holiday park (including littoral rainforest and wallum sand heath, if present) to coastal erosion. Immediate effects may be witnessed as the dune slumps without the support of the wall.
- Removal of the wall will create a “natural” dune face, which is mobile, and therefore supports ephemeral vegetation.

5.5 Impacts on Marine Park

The Cape Byron Marine Park extends from Lennox Head in the south to Brunswick Heads in the north and is split into five zoning categories (General Use, Sanctuary, Habitat Protection, Special Purpose and National Park/Nature Reserve). The Marine Park zoning at the Reflections Clarkes Beach Holiday Park site is split between a Sanctuary Zone to the east and a Habitat Protection Zone to the west (bisecting line near the western end of the eastern seawall), and extends landward as far as the mean high water mark. These two zoning categories have varying permissions and restrictions in place, largely aimed at preserving biodiversity within the Marine Park.

The Marine Park extents (mean high water mark) are mapped in the Kennedy Feature Survey dated 11/09/2019. This shows the plan location of the Reflections seawall being largely out of the Marine Park, except for the western end which extends past the mean high water mark slightly, noting that the mean high water mark plan location may vary with respect to sediment on the beach and that an eroded beach may put the seawall wholly in the Marine Park. Impacts of coastal erosion have been discussed in earlier sections.

5.5.1 Impacts of Retaining Wall

- Impacts on habitats of marine turtles, shorebirds and other fauna may arise from changes to beach morphology in the immediate vicinity of the Seawall. For example, the seawall may prevent turtle access to the dune when the beach is in an eroded state. Changes observed to the wider beach morphology observed to date are very minor. Specifics of fauna impact are out scope for this report.

5.5.2 Impacts of Removing Wall

- The dune will likely erode further potentially allowing building debris, waste and fill of unknow status to enter the marine park.
- Further erosion may impede public access and amenity of the Marine Park.
- To remove the seawall from the beach, vehicles and heavy machinery will require a permit to access to the site (as for the installation of the seawall). This would have been expected by the Department of Primary Industries when provisioning for a 90-day temporary structure, but will have the following effects:

- Increased likelihood of pollutants, pests, disease or other unnatural material to the marine park.
- Driving of these vehicles on the beach and completing required works may impact shorebird, turtle or other fauna habitats.

These impacts are generally mitigated through the development and application of a construction-based environmental management plan.

5.6 Alignment with SEPP

5.6.1 Legislation and Planning Documents

Management of the coastal zone in New South Wales (NSW) is governed by the *Coastal Management Act 2016* (Coastal Act) and the *State Environmental Planning Policy (Coastal Management) 2018* (Coastal SEPP), which applies to the Part 4 development consent process under the *Environmental Planning and Assessment Act 1979* (EP& Act). These legislative instruments set the objectives for management and provide development controls for coastal hazards, coastal wetlands and littoral rainforest areas, coastal environment areas, and coastal use areas of the NSW coastal zone.

An extract from the online Coastal SEPP mapping is provided in (Figure 5-6). The seawalls seaward of the Reflections site (located within Lot 410 on DP729062) are mapped within the Coastal Use Area, the Coastal Environment Area, Littoral Rainforest Area and the Proximity Area for Littoral Rainforests. No mapping has been prepared to date for the Coastal Vulnerability Area. These zones set the applicable elements of the Coastal SEPP that apply in assessing the seawalls.

Note that there is no actual littoral rainforest present in the development (seawall) footprint. All vegetation was removed by coastal erosion prior to the seawall construction (as discussed in Section 5.4).

While the seawalls are already in place, assessment is being undertaken of their development in full, rather than their retention only. This allows a comparison between situations where (a) the wall has theoretically been removed, and where (b) the wall is retained for approximately 5 years, and potentially longer. Impacts of the current wall configuration thus inform the impacts of the wall if it were to be retained.

Table 5-2 provides an assessment of the seawalls against the relevant elements of the Coastal Act and Coastal SEPP. Assessment relates only to objects specifically related to coastal hazards and management. Consideration of changes in drainage and the ecological and environmental values of the coastal zone are outside the scope of this assessment and we understand these aspects are being reviewed by others. It is noted that there are no specific coastal management requirements in federal legislation.

Additionally, Table 5-3 provides an assessment of the seawalls against the principles of ecologically sustainable development (ESD). These principles apply as part of decision-

making under the EP&A Act and therefore will be relevant to the development. The principles of ESD are defined under s6(2) of the *Protection of the Environment Administration Act 1991*.

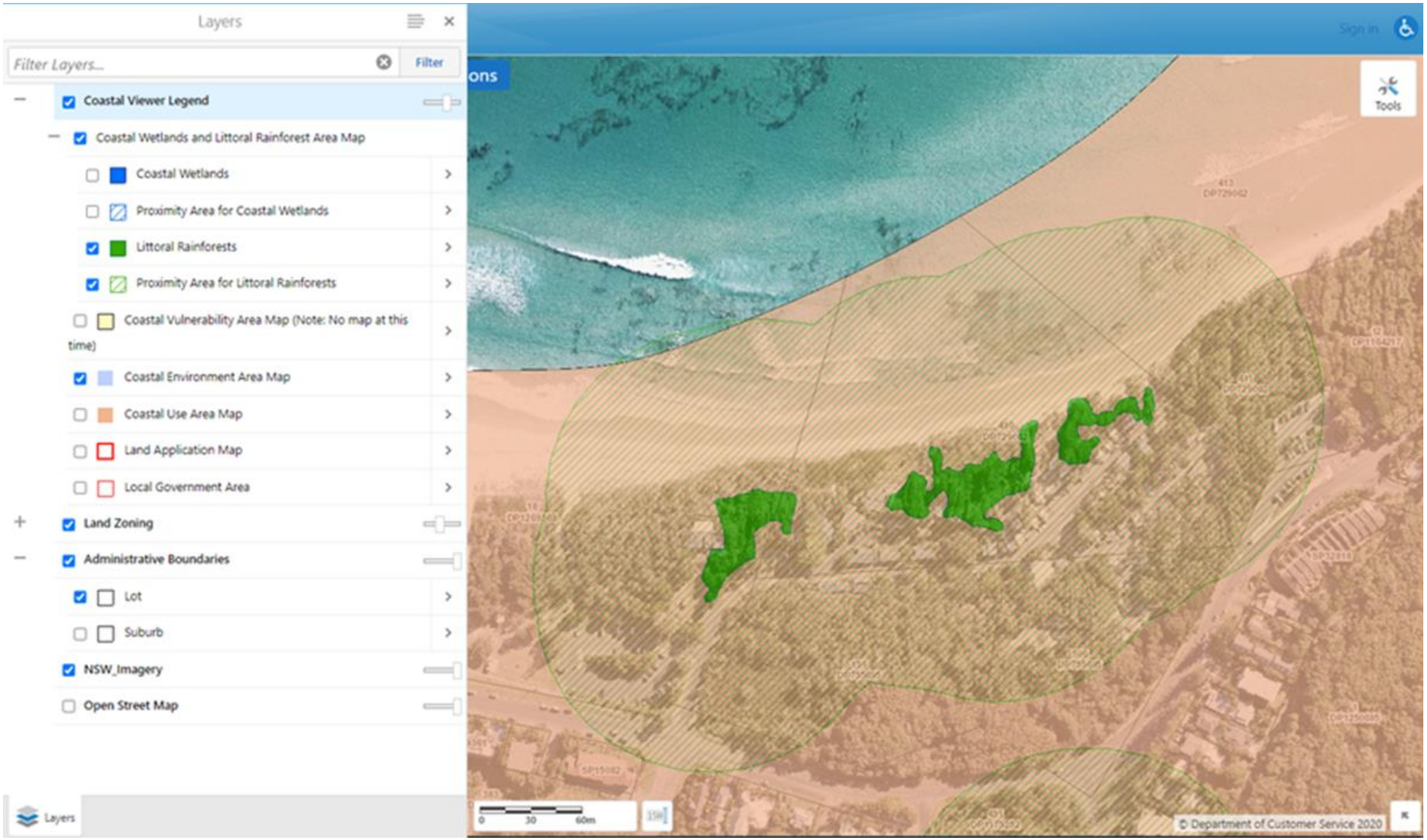

Figure 5-6 Coastal SEPP mapping for Master Site Plan

Table 5-2 Assessment of seawalls against Coastal SEPP and principles of ESD

Provision	Assessment
SEPP (Coastal Management) 2018	
Littoral rainforest	
(4) A consent authority must not grant consent for development referred to in subclause (1) unless the consent authority is satisfied that sufficient measures have been, or will be, taken to protect, and where possible enhance, the biophysical, hydrological and ecological integrity of the coastal wetland or littoral rainforest.	***Compliant*** Development would improve the biophysical integrity of littoral rainforest by stabilising the dune and protecting any remanent littoral rainforest landward of the seawall
Proximity to coastal littoral rainforest	
11(1) Development consent must not be granted to development on land identified as "proximity area for littoral rainforest" unless the consent authority is satisfied that the proposed development will not significantly impact on— (a) the biophysical, hydrological or ecological integrity of the adjacent coastal wetland or littoral rainforest	***Compliant*** Development would improve the biophysical integrity of littoral rainforest by stabilising the dune.
Coastal Environment Area	
13(1) Development consent must not be granted to development on land that is within the coastal environment area unless the consent authority has considered whether the proposed development is likely to cause an adverse impact on the following— (a) the integrity and resilience of the biophysical, hydrological (surface and groundwater) and ecological environment	***Compliant*** Development would improve the biophysical integrity of the environment by stabilising the dune.
13(1) - (b) coastal environmental values and natural coastal processes.	***Compliant*** Development would not appreciably impact coastal processes or environmental values in the area.
13(1) - (e) existing public open space and safe access to and along the foreshore, beach, headland or rock platform for members of the public, including persons with a disability,	***Needs Mitigation*** Development does not impede access to or along beach. High dune scarps developing due to end scour may need to be fenced
13(1) - (f) Aboriginal cultural heritage, practices and places	***Compliant*** Development would protect two midden sites from erosion.
Coastal Use Area	
14(1) - Development consent must not be granted to development on land that is within the coastal use area unless the consent authority— (a) has considered whether the proposed development is likely to cause an adverse impact on the following— (i) existing, safe access to and along the foreshore, beach, headland or rock platform for members of the public, including persons with a disability,	***Needs Mitigation*** Development does not impede access to or along beach or pose risk to beach users. High dune scarps developing due to end scour may need to be fenced

(iii) the visual amenity and scenic qualities of the coast, including coastal headlands,	***Needs Mitigation*** Development adversely impacts the desired 'natural sandy beach' scenic quality desired by locals and shire council. May be mitigated by revegetation.
(iv) Aboriginal cultural heritage, practices, and places,	***Compliant*** Development would protect two midden sites from erosion.
General Principles	
15 Development consent must not be granted to development on land within the coastal zone unless the consent authority is satisfied that the proposed development is not likely to cause increased risk of coastal hazards on that land or other land.	***Needs Mitigation*** Development would decrease erosion hazard for Reflections. End scour may cause increased risk to other land for small distance to the west. Could be mitigated by extending the seawall
16 Development consent must not be granted to development on land within the coastal zone unless the consent authority has taken into consideration the relevant provisions of any certified coastal management program that applies to the land.	***Compliant*** No CMP for Byron Bay so compliant.

Table 5-3 Assessment of Proposed Development against relevant Ecologically Sustainable Development Principles

Provision	Assessment
Protection of the Environment Administration Act 1991	
6(2) Ecologically sustainable development requires the effective integration of social, economic and environmental considerations in decision-making processes. Ecologically sustainable development can be achieved through the implementation of the following principles and programs: (a) the precautionary principle—namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.	***Compliant*** There is good understanding of how the proposed development will impact the coastal processes. Development could limit further erosion of littoral rainforest short term. Continued future investigation of wall fitness would increase scientific certainty about impacts of development.
(b) inter-generational equity—namely, that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations	***Does Not Apply*** This is because the development timeframe is only approximately 5 years, not enough time for intergenerational equity issues.
(c) conservation of biological diversity and ecological integrity—namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration	***Does Not Apply*** This is outside the scope of the current report. It is understood this is addressed elsewhere.
(d) improved valuation, pricing and incentive mechanisms—namely, that environmental factors should be included in the valuation of assets and services.	***Does Not Apply*** This is outside of the scope of this report.

6 Recommended Monitoring Program and Mitigation Measures

The Reflections seawall is currently functional, however it is at risk of damage or failure in a severe storm (refer section 4.3) there is also a risk that end scour from the wall could increase erosion hazard to the west (refer section 5.1.3). To mitigate these risks, it is recommended that a monitoring program be implemented to assess the functionality and impacts of the wall. The monitoring program would comprise the following aspects.

6.1 Site Inspections

Continued monthly site inspections, timed to be at low tide following the largest high tide event of the month. Site inspections to include:

- Standardised photography during inspections, documented consistent photo positions and angles so that temporal changes can be reviewed.
    - Photos to have complete coverage of walls and all end points
    - Photograph and document end scour and beach condition further to the west
- Record incidence and location of deflated or displaced bags, new erosion above/below seawall.
- Identify public safety risks, e.g. unstable dune escarpments and notify land managers.

Although month by month inspections will identify any public safety risks, the daily Reflections park site manager can perform this task on a daily basis ensuring the safety of Holiday Park customers.

6.2 Annual Reports

Findings of the monthly site inspections should be collated and reported in an annual report. The report should assess the current condition of the Reflections seawall, it's impact on surrounding areas, in particular end scour to the west and level of risk to structures in this area. This assessment should be supported by:

- Analysis of profile survey and air photo (publicly available data);
- Calculation of recession rates where evident; and
- Review of storm history.

6.3 Actions Available to Land Managers

The recommended monitoring program is set up such that any management issues which could negatively impact for example public safety, wall stability or the surrounding areas will be picked up. In the event that such issues are identified by the monitoring program, management responses may be necessary to maintain the amenity and safety of the area. Potential mitigation measures/responses to several scenarios are listed below. Noting that these suggestions are of a general nature only. Land managers would need to decide the most appropriate response based on the specific circumstances in each case, possibly with further input from coastal engineering professionals.

- In the event that a site inspection identifies that end scour effects are threatening dune stability or adjacent assets:
  - Erect safety fencing around bottom of erosion scarp to ensure beach users are not in danger from the collapsing/slumping scarp.
  - Erect safety fencing at erosion scarp crest to ensure members of the public do not fall from the erosion scarp.
  - Sand nourishment of the eroded dune area to rebuild the dune profile.
  - Extend the wall to encompass the scour area (this would likely shift the erosion issue further down the beach and could only be undertaken with further advice from coastal engineers).
  - Retreat of at-risk assets from eroding dune scarp.
  - Seek advice from a coastal engineer on further measures.
- If one bag becomes deflated or is displaced from the wall, the overall wall stability may not be significantly affected. Thus, in this case, the following actions may be taken:
  - If possible, the bag should be replaced,
  - The location of the lost bag should be noted.
- If two adjacent bags, or several bags from a small area are lost, wall stability may be impacted and the following actions may be taken:
  - Rebuild a section of the wall
  - Seek further advice from a coastal engineer.
- If undermining of the wall toe or erosion of dune material behind the wall from overtopping occurs, the following actions may be taken:
  - Nourishment of beach at toe,
  - nourishment and revegetation of dune behind wall,
  - Re-build sections of the wall if necessary,
  - Seek advice from coastal engineers about potential further maintenance works.

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Appendix A Beach Profile Comparisons

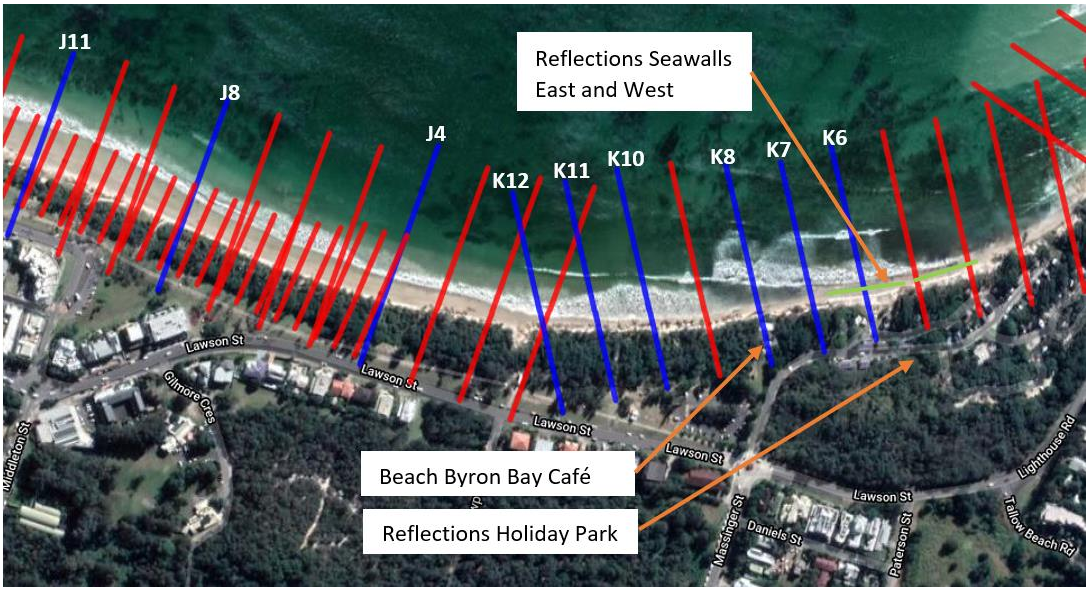

Figure A-1 Location of Profiles

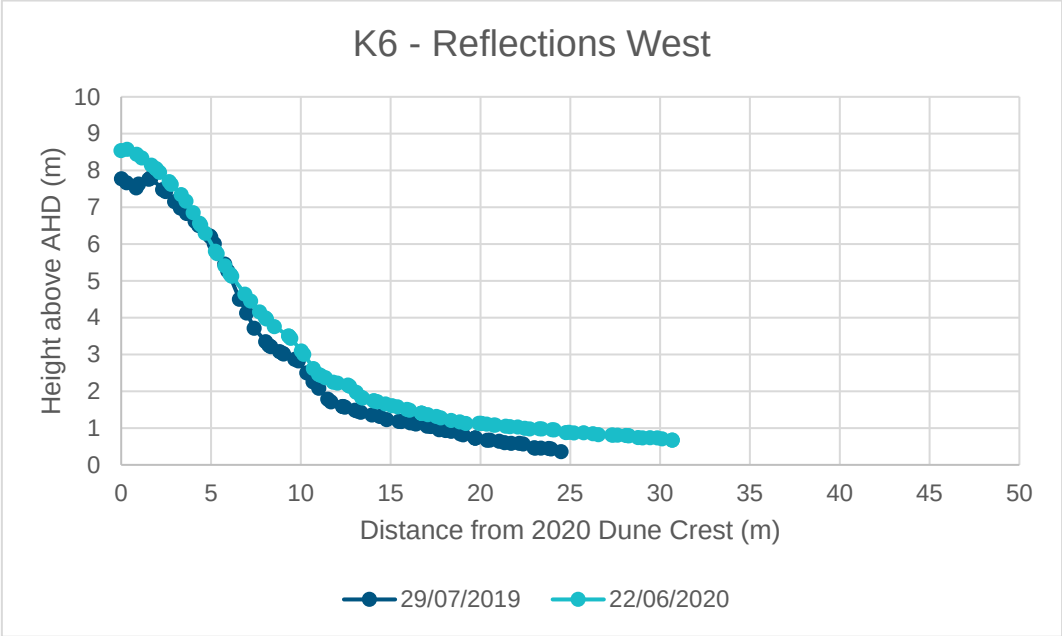

Figure A-2 Section K6 – Through Reflections West

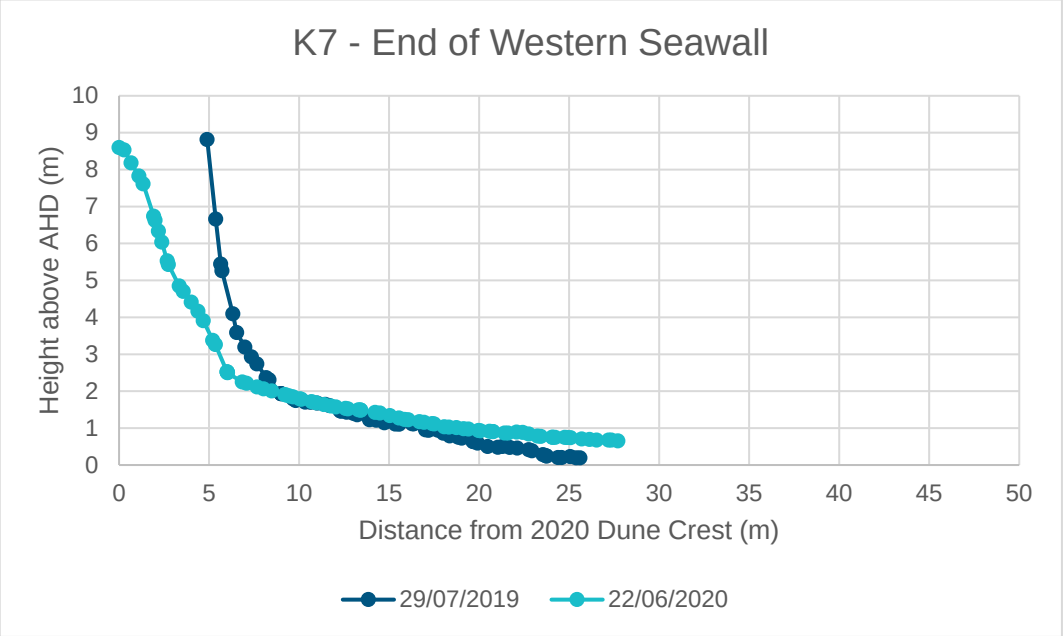

Figure A-3 Section K7 – 15m West of end of Reflections West Wall

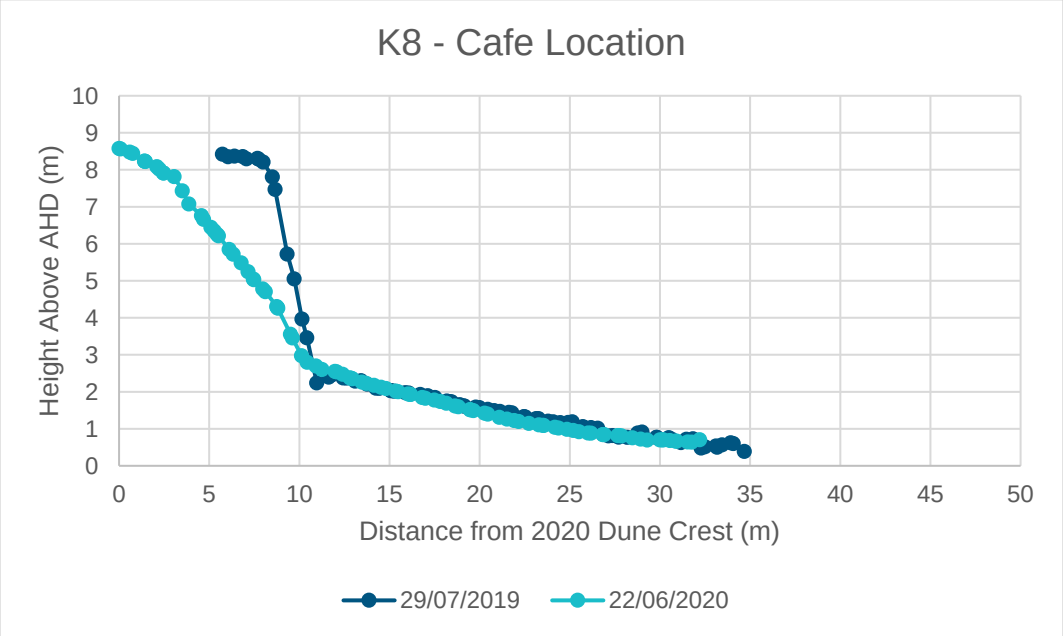

Figure A-4 Section K8 – Café Section – Approx. 65m West of Reflections West

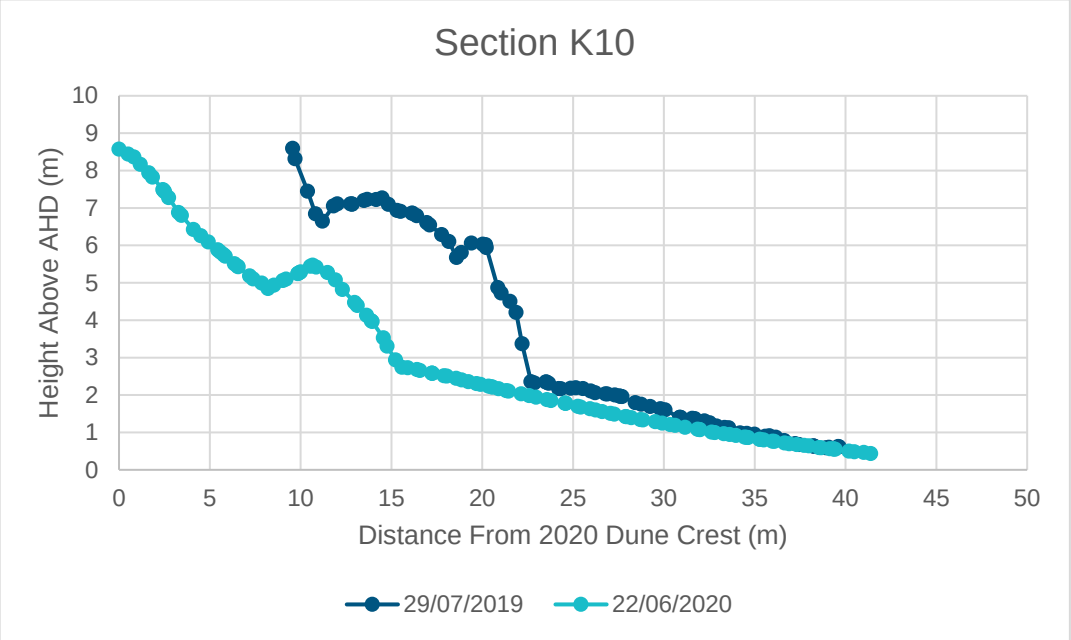

Figure A-5 Section K10 – Approx. 160m West of Reflections West

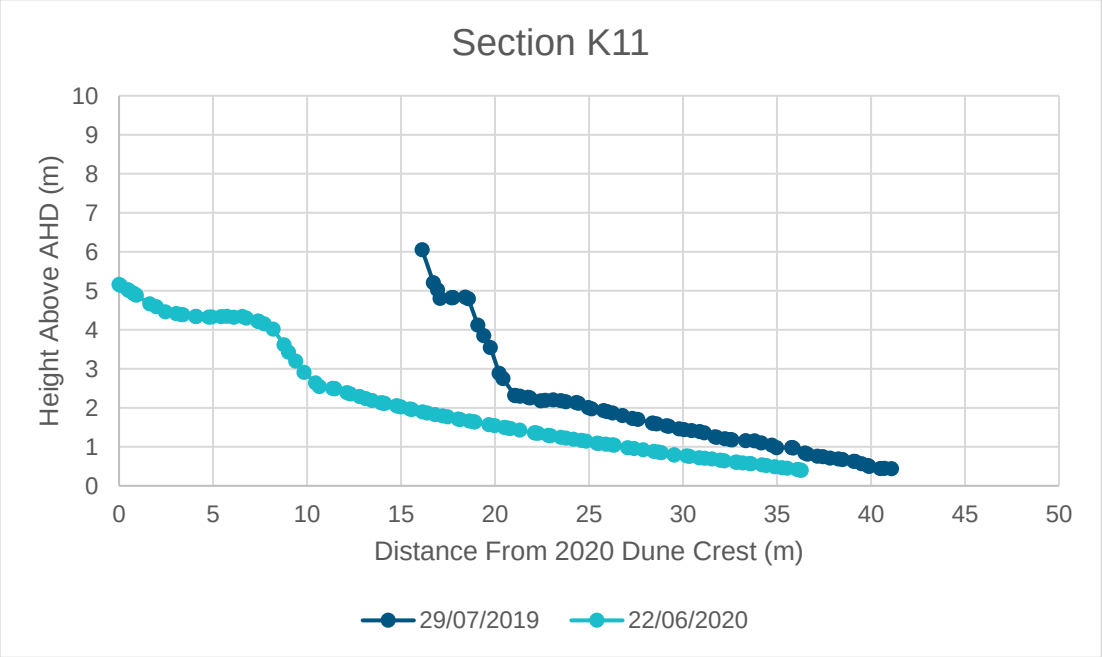

Figure A-6 Section K11 – Approx. 200m West of Reflections West

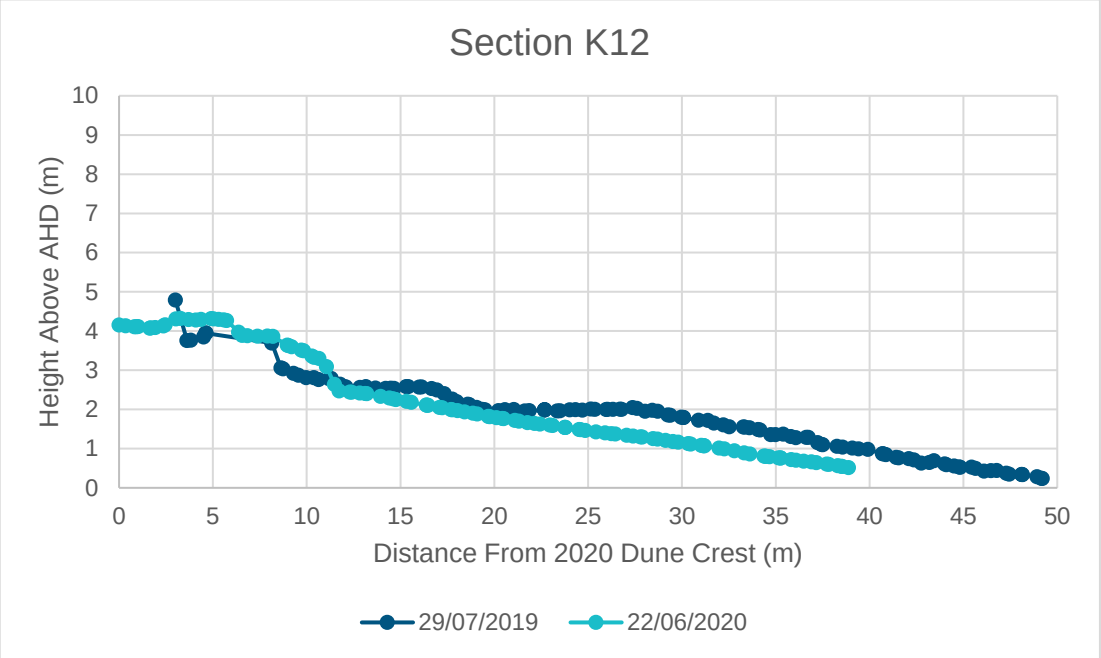

Figure A-7 Section K12 – Approx. 250m West of Reflections West

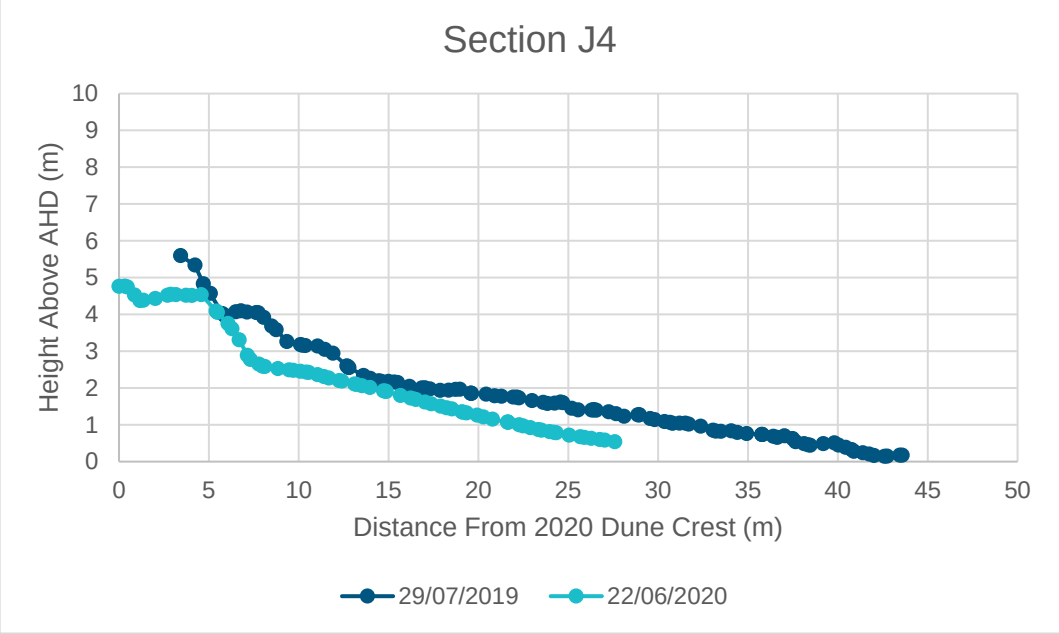

Figure A-8 Profile Section J4–Main Beach, Byron Bay ~400m from end of Reflections West

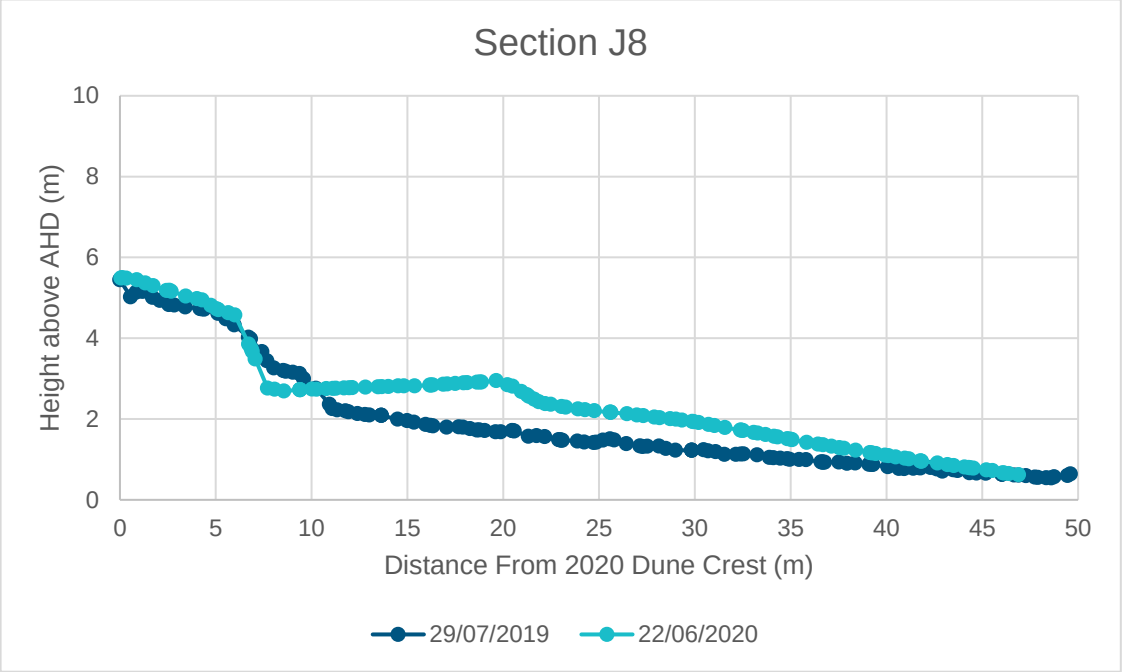

Figure A-9 Profile Section J8 – Main Beach, Byron Bay

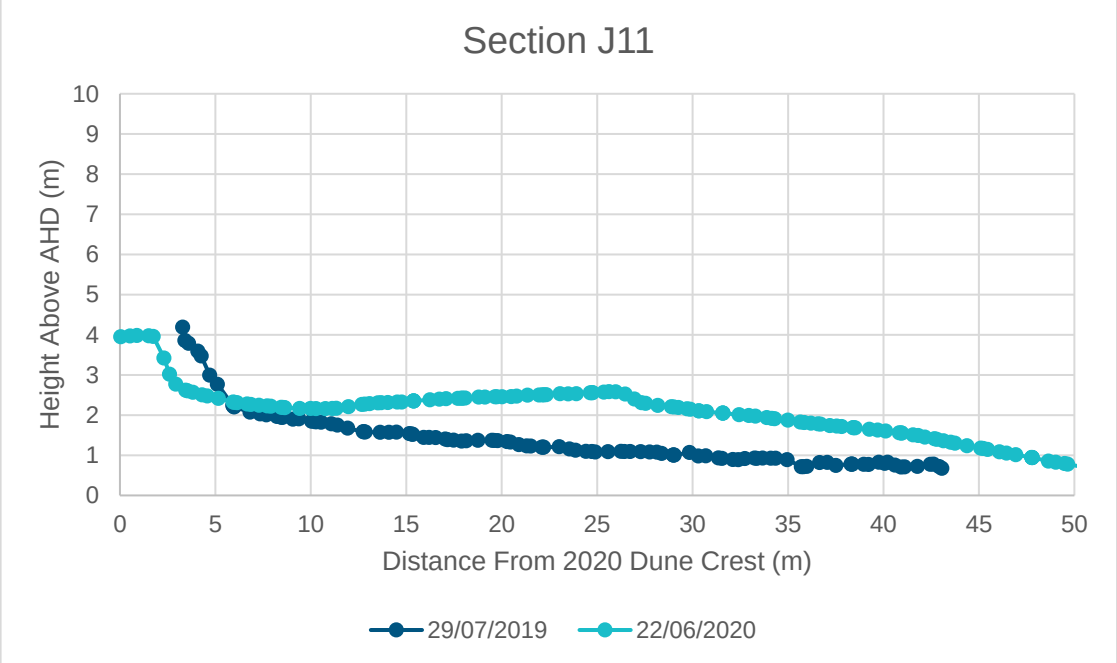

Figure A-10 Profile Section J11 – Main Beach, Byron Bay – 800m from end of Reflections West

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