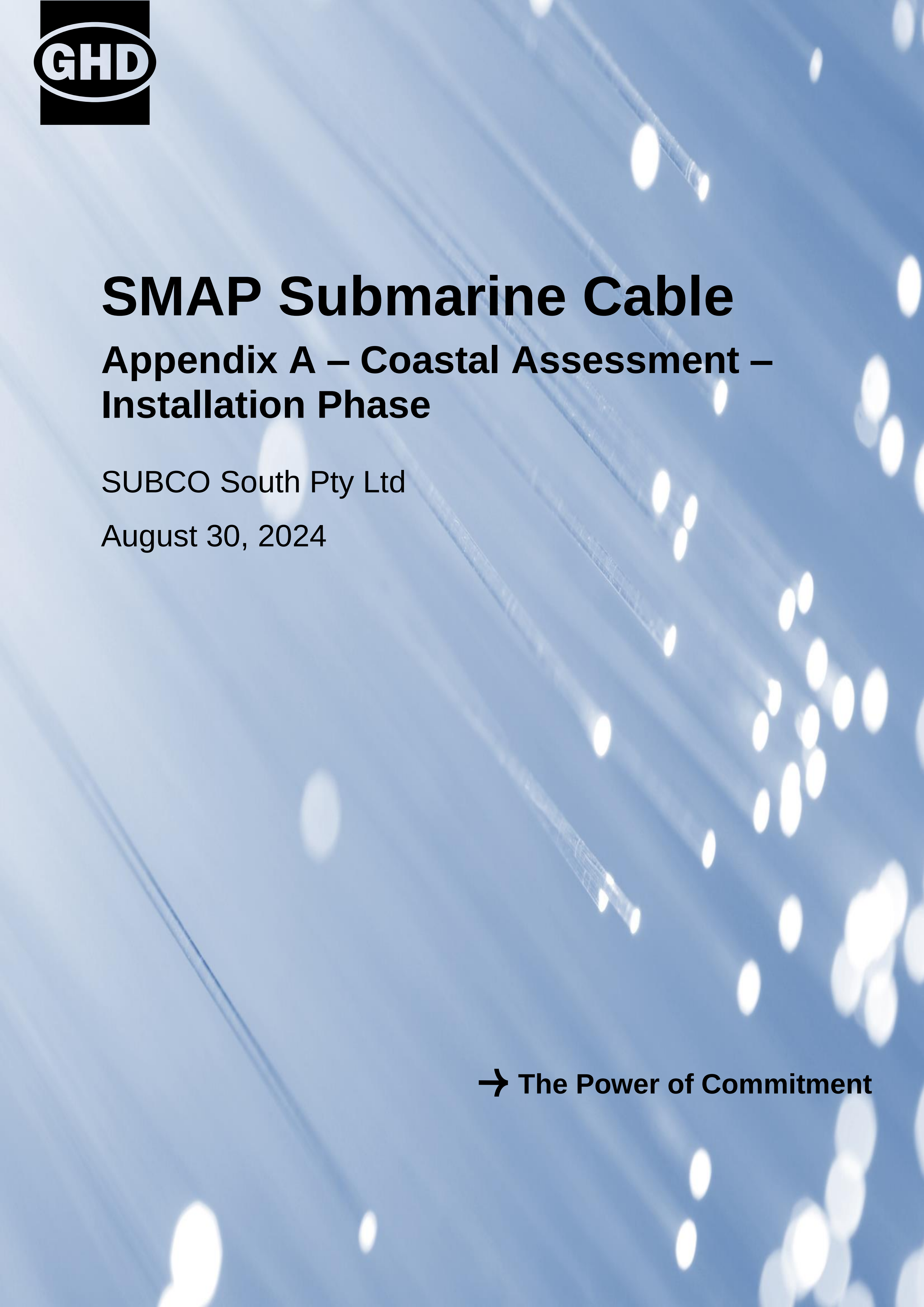

SMAP Submarine Cable

Appendix A – Coastal Assessment – Installation Phase

SUBCO South Pty Ltd

August 30, 2024

→ The Power of Commitment

<table>
<tr><td>Project name</td><td colspan="6">SUBCO South Cable Network (SSCN)</td></tr>
<tr><td>Document title</td><td colspan="6">SMAP Submarine Cable | Appendix A – Coastal Assessment – Installation Phase</td></tr>
<tr><td>Project number</td><td colspan="6">12598885</td></tr>
<tr><td>File name</td><td colspan="6">12598885-SMAP-RPT-Install-EA-CoastalAssessment-RevA.docx</td></tr>
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Status Code	**Revision**	**Author**	**Reviewer**		**Approved for issue**		
			Name	**Signature**	**Name**	**Signature**	**Date**
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Abbreviations

Term	Definition
ACC	Antarctic Circumpolar Current
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Intervals
ASN	Alcatel Submarine Networks
CSICC	Central South Indian Counter Current
CPZ	Cable protection zone
CSW	Continental shelf waves
DEECA	Department of Energy, Environment and Climate Action
DoC	Depth of closure
DoT	Department of Transport
DPIR	Department of Primary Industries and Regions
DPLH	Department of Planning, Lands and Heritage
EA	Environmental Assessment
EAC	East Australian Current
EAC-E	East Australian Current Extension
EEZ	Exclusive Economic Zone
ENSO	El-Nino Southern Oscillation
HAT	Highest Astronomical Tide
HC	Hiri Current
HLC	Holloway Current
ITF	Indonesia Throughflow
IPCC	Intergovernmental Panel on Climate Change
KP	Kilometre Point
LAT	Lowest Astronomical Tide
LC	Leeuwin Current
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MRS	Marine Route Survey
MSL	Mean Sea Level
NECC	North Equatorial Counter Current
NSW	New South Wales
NVJ	North Vanuatu Jet
OMS	Optic Marine Singapore Pte Ltd
RCP	Representative Concentration Pathway
SA	South Australia

Term	Definition
SAC	South Australian Current
SAM	Southern Annual Mode
SARDI	South Australian Research and Development Institute
SEC	South Equatorial Current
SLR	Sea Level Rise
SMAP	Sydney, Melbourne, Adelaide and Perth
SPP	State Planning Policy
SSCPZ	Southern Sydney Cable Protection Zone
SSP	Shared Socioeconomic Pathway
SUBCO	SUBCO South Pty Ltd
TCWC	Tropical Cyclone Warning Centre
WA	Western Australia
ZC	Zeehan Current

1. Introduction

This Coastal Assessment Report is an appendix to the Environmental Assessment Main Report for the SMAP submarine cable installation, and should be read in conjunction with:

- Environmental Assessment (EA) Main Document
- Appendix B – Marine ecology assessment
- Appendix C – Impact assessment
- Appendix D – Other considerations

The purpose of this report is to assess potential environmental impacts of the SMAP submarine cable installation within the Australia Exclusive Economic Zone (EEZ).

1.1 Scope and limitations

This report has been prepared by GHD for SUBCO South Pty Ltd and may only be used and relied on by SUBCO South Pty Ltd for the purpose agreed between GHD and SUBCO South Pty Ltd as set out in section 1.3 of the EA Main Document.

GHD otherwise disclaims responsibility to any person other than SUBCO South Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.2 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

1.2 Assumptions

GHD has prepared this report on the basis of information provided by SUBCO and its partners (ASN/OMS) and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

A list of sources used to inform GHD's understanding of SUBCO's SMAP system includes:

- Route Position Listing and associated geospatial files
- OMS Marine Description for Marine Installation and Marine Survey
- EGS survey information supplied to GHD

A list of broader sources used to inform the EA is provided in section 5.

2. Existing environment

This section provides an overview of the existing environment in regard to physical environmental factors. This is intended to be descriptive of the current situation and potential interactions with the submarine cable installation activities and justifies the assessment summarised in the main body of the report. Mitigation measures or recommendations are included as appropriate.

It should be noted that GHD has not independently verified the information presented and has not undertaken site investigations to inform this assessment.

2.1 Perth Landing – Cable Protection Zone

2.1.1 Bathymetry and seabed conditions

The nearshore coastal environment surrounding City Beach in Perth mainly comprises patches of rocky intertidal and subtidal reefs, as well as extensive sandy habitat areas (as mapped by Lucieer et al. 2023). Primary areas of rocky reef habitats in the region are north surrounding North Reef, and large reef structures in the Marmion Marine Park, which borders the CPZ. The cable route intersects mostly mobile sand (shown in yellow on Figure 2.1), bordering macroalgae-covered reef (shown in dark green on Figure 2.1). While much of the route is unmapped, it is likely to consist of mostly mobile sand in the State and Commonwealth waters segments of the route. The geophysical MRS will fill in gaps in the available data.

There are extensive areas of subtidal rocky reefs in the Perth region (Lucieer et al. 2023). These rocky subtidal reefs typically form linear structures. These linear reefs rise 10–20 m above the seabed, in water depths of around 10–30 m and mostly lie parallel to the shoreline (Brooke et al., 2008). Although there are numerous reef areas such as in Marmion Marine Park, the only recognised significant area of rocky reef within the Perth region occurs around Rottnest Island (Dye, 2009).

The majority of the cable route along the deeper water section is anticipated to be characterised by sands and muds. The bathymetry offshore of the Perth landing is shown in Figure 2.2.

The marine route inshore survey was conducted by EGS Australia on 17th February 2024 and covered the shore end at kilometre point (KP) 0.66 in 8.8m water depth to the Handover Point (HOP) at KP4.21 in 18.9m water depth. The survey identified the route strikes from southwest to west in a moderate to very steep slope up to 23 degrees. The route crosses an area of veneer of loose gravelly sand over medium dense to dense sand with numerous seagrass patches / marine growth. An existing In-Service Oman-Australia (OAC) cable was mapped by side scan sonar at kilometre point (KP) 0.84 in 8.7m water depth to KP1.16 in 9.6m water depth. Low to medium rock outcrops (interpreted as Tamala Limestone) with intermittent sand veneer are present across the whole survey corridor. The proposed route enters two UXO areas at KP1.09 (Scarborough Seaward Firing) and at KP2.11 (Freemantle Seaward Firing).

Figure 2.1 *Nearshore environment of the City Beach landing (SeaMaps) Blue line depicts proposed cable*

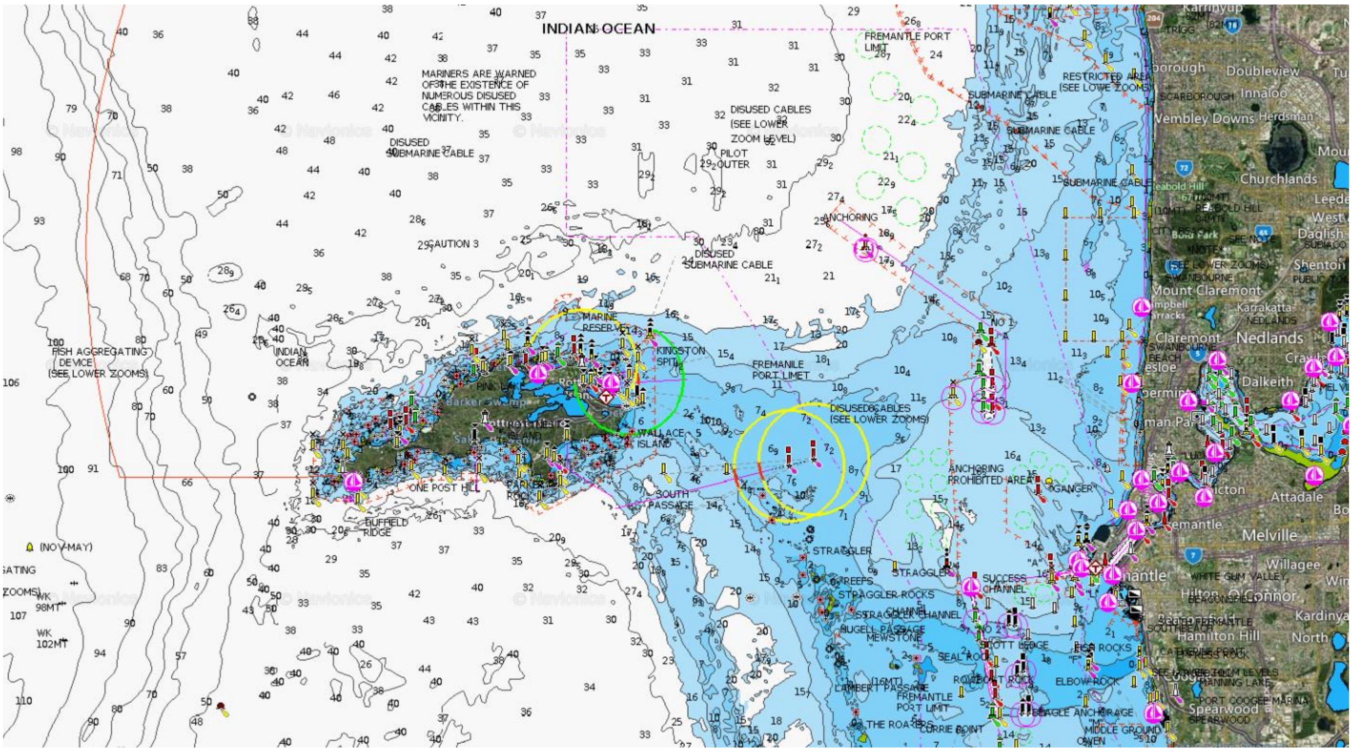


Figure 2.2 *Bathymetry offshore from the Perth landing. Source: Navionics (accessed October 2023)*

2.1.2 Water levels and currents

2.1.2.1 Astronomical tides

Semi-diurnal tides, consisting of part semi-diurnal, but predominantly diurnal occur along City Beach. Tides measured at Hillarys beach are consistent with those measured along the surrounding coastline, including at City Beach (approximately 12 km southeast of Hillarys beach). Due to the proximity of City Beach to Hillarys beach, the Hillarys beach tide gauge is considered to be representative. The tidal planes for Hillarys beach have been extracted from Australian National Tide Tables (2023) and summarised below.

Table 2.1 Tidal planes at Hillary beach (relevant to City Beach landing) (Australian National Tide Tables 2023)

Tidal plane	Water level (m Chart Datum)	Water level (m Australian Height Datum (AHD))
Highest Astronomical Tide (HAT)	1.1	0.5
Mean High Water Springs (MHWS)	0.9	0.3
Mean High Water Neaps (MHWN)	0.8	0.2
Mean Sea Level (MSL)	0.6	0
Mean Low Water Neaps (MLWN)	0.3	-0.3
Mean Low Water Springs (MLWS)	0.2	-0.4
Lowest Astronomical Tide (LAT)	0	-0.6

2.1.2.2 Storm tide (extreme water levels)

Western Australia is characterised by a micro-tidal coastline, heavily influenced by storm surges and mean sea level variation.

Table 2.2 presents extreme water levels for typical Average Recurrence Intervals (ARI) for Burns beach (located approximately 24 km north of the City Beach landing), a representative site for City beach. The ARI used in this instance is in accordance with the Western Australia State Coastal Planning Policy 2.6, which requires an allowance for inundation to be taken as the maximum extent of inundation experienced during a water level event with a 0.2% Annual Encounter Probability, or the 500-year Average Recurrence Interval.

Table 2.2 0.2% AEP storm-tide level (MP Rogers & Associates, 2022)

Location	0.2% AEP Storm-tide levels		
	2047	2072	2097
	(m AHD)	(m AHD)	(m AHD)
Burns Beach	3.1	3.4	3.97

2.1.2.3 Currents

Two primary ocean currents operate offshore off the Western Australian coastline – the Western Australian Current and Leeuwin Current. The Leeuwin Current is seasonally variable, involving a southward flow of warm, low-salinity tropical water along the west and south-west coast of Western Australia. The Leeuwin Current flows year-round but is strongest during winter and non-El-Nino Southern Oscillation (ENSO) years. The Leeuwin Undercurrent is part of the Western Australian Current which forms adjacent to and beneath the Leeuwin Current where highly saline waters and South Indian Central Waters are carried northwards. Interactions between the Leeuwin Current and changes in the bathymetry and offshore water of different densities result in the generation of eddies which move further offshore.

2.1.2.4 Sea level rise

Sea level records measured at Fremantle (located approximately 17 km south of City beach) since 1897 indicate that there has been a mean rate of sea level rise of 1.54 mm per annum along the western coastline of Western Australia. This rate of increase is comparable to the global mean rate of sea level rise which is between 1.1-1.9 mm per annum. The rate of mean seal level changes has varied over time, heavily influenced by inter-annual sea level variability associated with the ENSO phenomenon.

In 2021, the WA Government released the Western Australian Climate Projections Summary. Based on a representative concentration pathway (RCP) of 4.5, the sea level in Fremantle is estimated to rise by approximately 0.07 m to 0.16 m by 2030 (Western Australian Climate Projections, 2021). This can be considered representative of conditions in Western Australia’s Southwestern Flatlands region.

The WA Government’s State Planning Policy 2.6 ‘Coastal Planning’ has allowed for sea level rise to be based on a vertical sea level rise of 0.9 m over a 100-year timeframe to 2110 (SPP 2.6 Coastal Planning, 2013).

2.1.3 Wave climate

Western Australia sits on the eastern border of the Indian Ocean and northern border of the Southern Ocean, which is an area characterised by an energetic wave climate as high latitude strong sustained winds can generate large swells. The offshore wave climate in proximity to the Perth landing is primarily a low to medium wave energy regime characterized by south to southeast swell (Pattiaratchi & Masselink, 2001). During the summer months, mean significant wave height is 1.5 m and 2.5 m in the winter months (Pattiaratchi & Masselink, 2001).

Continental shelf waves (CSW) are active along the Western Australian coast, which are a form of coastally trapped wave that travels parallel to the coast with maximum amplitude at the coast and decreasing offshore. Along the Western Australian coastline, CSWs are produced through the passage of mid-latitude low-pressure systems and tropical cyclones.

Tropical cyclones are a key driver of the wave climate along the west and south coasts of Western Australia, as every tropical cyclone has historically either produced a CSW or southward propagating sea level signal.

There is a strong positive correlation between wave height in the southern Indian Ocean and the Southern Annual Mode (SAM), a low-frequency mode of atmospheric variability of the southern hemisphere and an anti-clockwise rotation of the wave direction associated with the SAM.

2.1.3.1 Winds

The closest weather station in the vicinity of the City Beach landing site that would be relevant is located at Perth Airport (located approximately 20 km east of City beach). Data has been collected from 1944 to 2016 and a wind rose for this location has been provided in Figure 2.3.

The wind rose in Figure 2.3 suggests that City Beach predominantly experiences south-westerly and westerly winds, and less frequently experiences northerly, southerly and easterly winds.

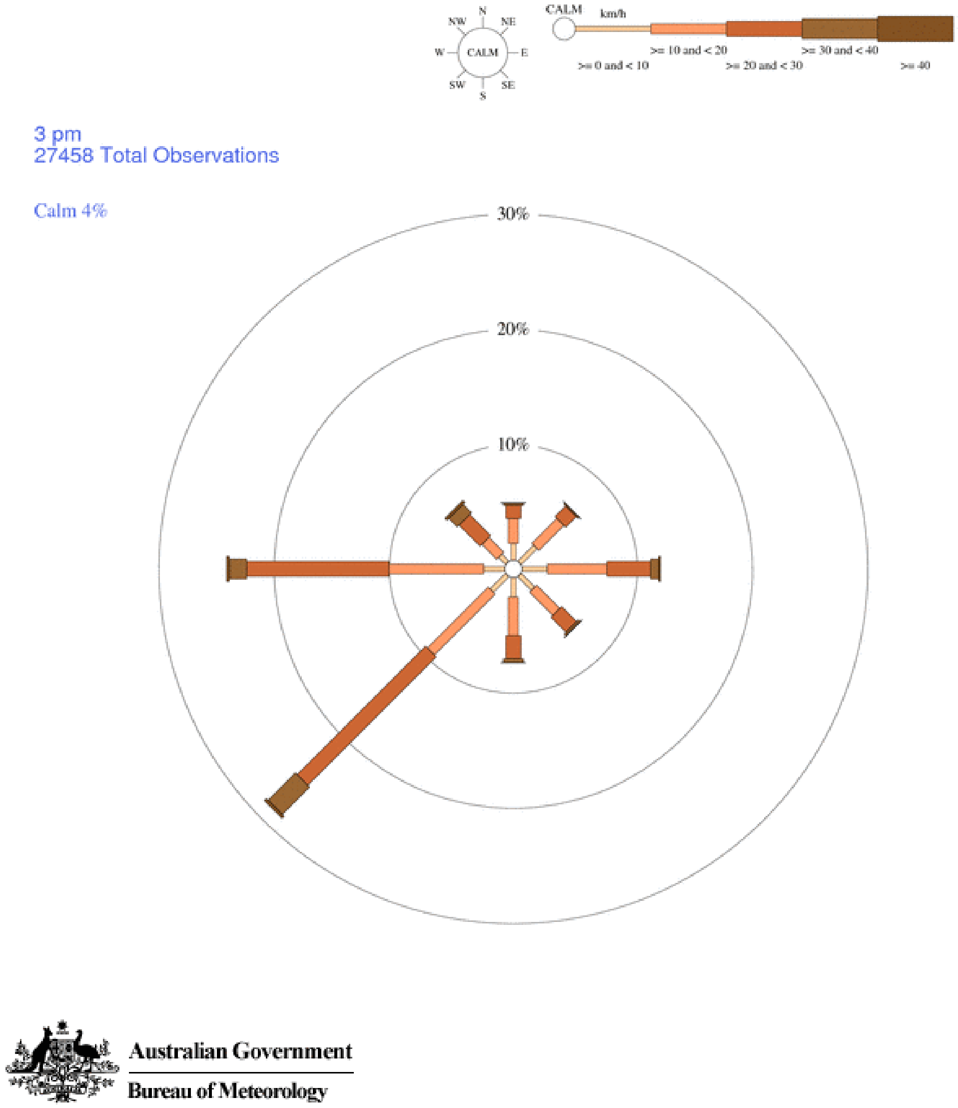


Figure 2.3 *Wind rose of wind direction versus wind speed in km/h at Perth Airport weather station 1944-2016 (BOM, 2023)*

2.1.4 Sediment properties and sediment transport

2.1.4.1 Sediment properties

The Perth coast, which City Beach is a part of, forms the margin of Rottnest Shelf which receives very little terrestrial sediment and is dominated by marine biogenic carbonate sediment (Brooke et al. 2014). Sediments around Rottnest Island (located approximately 25 km southwest of City beach), consist of mainly medium-grained carbon-quartz with 30-96% calcium carbonate. This is characteristic of the aeolianite and shallow-marine deposits in the region.

The marine route inshore survey was conducted by EGS Australia on 17th February 2024 and covered the shore end at kilometre point (KP) 0.66 in 8.8m water depth to the Handover Point (HOP) at KP4.21 in 18.9m water depth. The route crosses an area of veneer of loose gravelly sand over medium dense to dense sand with numerous seagrass patches / marine growth. Low to medium rock outcrops (interpreted as Tamala Limestone) with intermittent sand veneer are present across the whole survey corridor.

2.1.4.2 Geotechnical properties

The north to north-west section of the Perth Basin extends approximately 1300 km along the south-western margin of Australia and is part of the Gondwana rift system (Geoscience Australia, 2023). It contains a thick Permian to Cretaceous succession that is not uniform due to the fracturing of Australia and Greater India in the Early Cretaceous period. The post break-up succession is relatively thin onshore but thickens rapidly offshore and extends to the edge of the continent-ocean boundary.

The stratigraphy of the Perth Basin is primarily fluvial to shallow marine siliciclastic facies (Delle Paine et al. 2013). Geotechnical investigations from cores drilled in the central Perth Basin found porosity varied between a mean of 5% to 16% (Delle Piane et al. 2013). A general trend of decreasing porosity with increasing depth was observed. For different formations, permeability values show a weak trend of reduction with depth and can change by several orders of magnitude within the same stratigraphic formation.

2.1.4.3 Sediment transport

Sea breeze is a key driver of sediment transportation and sediment budget along the Perth Metropolitan coastline as the sea breeze blows predominantly in a shore-parallel rather than a shore-normal direction (Masselink, 1996). As such, the wind waves induced by the sea breeze are larger, persist longer and approach the coast on a larger angle with the shoreline. The alongshore component of the sea breeze and obliquely-incident wind waves generate strong longshore currents and a northward littoral drift.

Sea breeze induces a diurnal cycle of beach change at City Beach by causing erosion of the upper section of the beach which is reversible after cessation of the sea breeze (Masselink, 1996).

At a regional scale, longshore sediment transportation caused by sea breeze is significant and is estimated to drive an annual longshore movement of approximately 100,000 m^3 of sediment along the Perth Metropolitan coastline (Masselink, 1996).

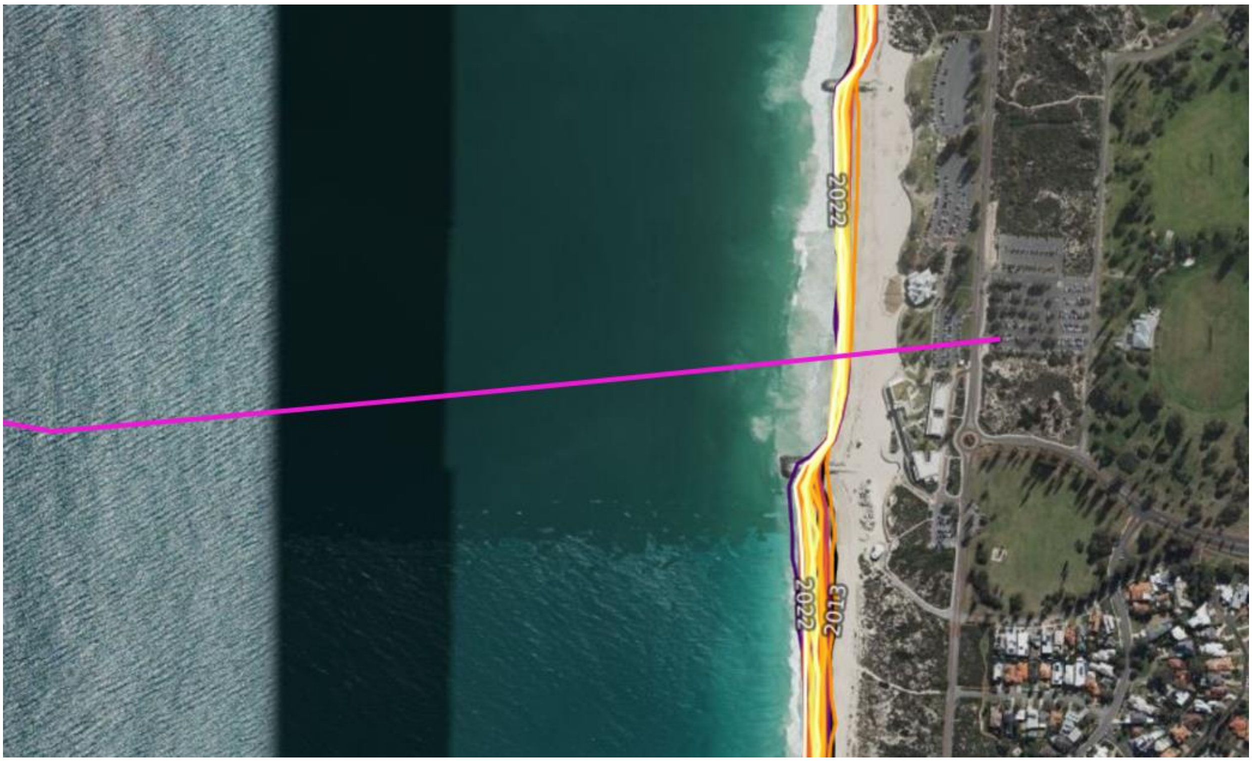


Figure 2.4 *Annual shorelines and rates of coastal change from 1988 – 2021 in the vicinity of City Beach. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:25,000 base map)*

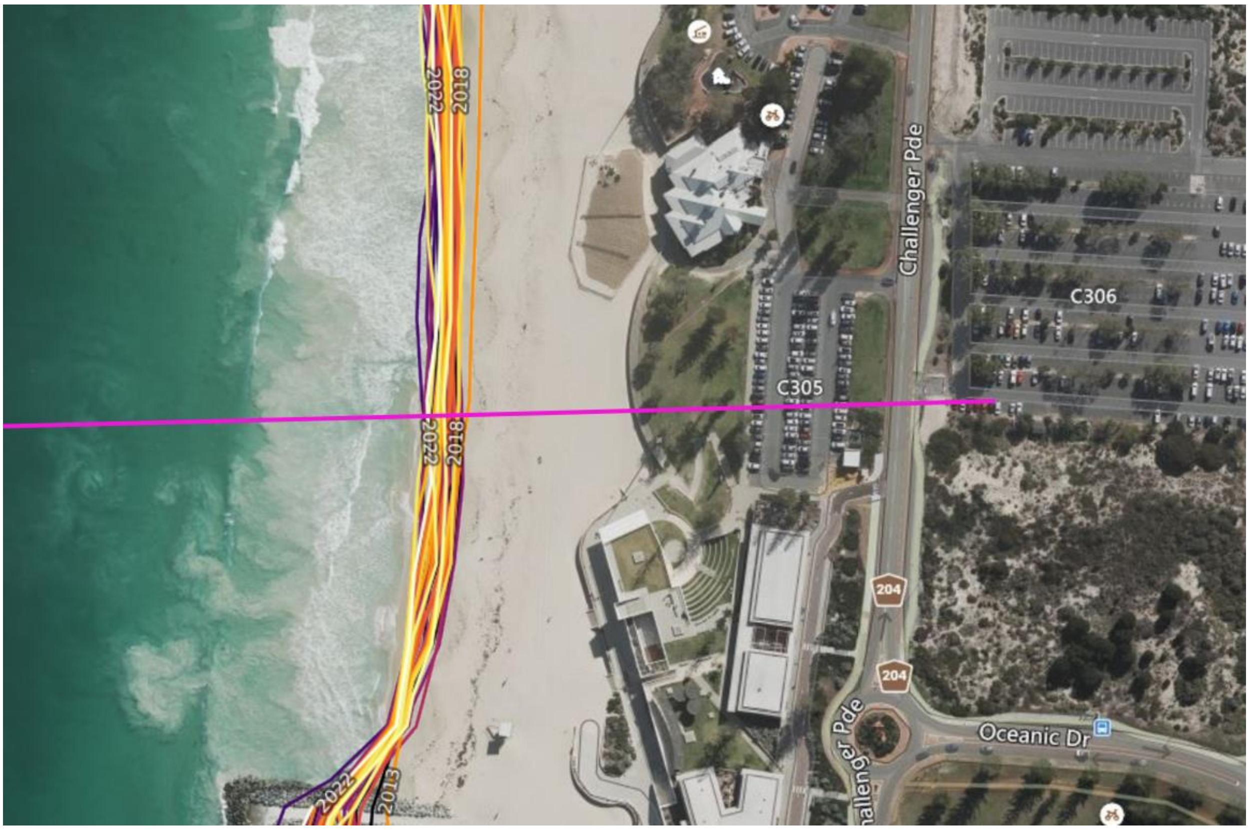


Figure 2.5 *Annual shorelines and rates of coastal change from 1988 – 2021 near the City Beach landing site. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:2500 base map)*

Longshore sediment transport within the vicinity of the City Beach landing has been observed to occur in a northerly direction from September to April and is associated with the prevailing currents that occur during the summer period, which is demonstrated in Figure 2.6. During the winter months (June and July), sediment movement is noted to occur in a southward direction. This results in a net northward movement of sediment material annually (Cardno, 2022). This has been observed at the City Beach landing site with seasonal accretion of the shoreline in the south during the summer months and seasonal erosion of the shoreline in the south during winter (Cardno, 2022).

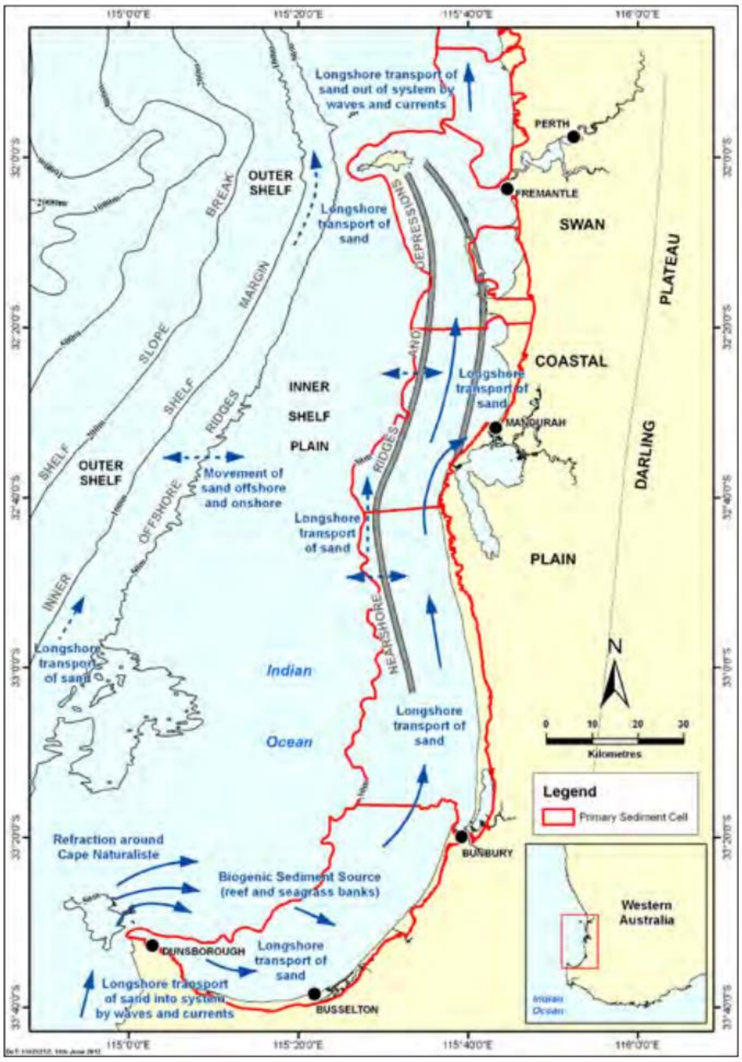


Figure 2.6 *Modelled sediment transport along WA coastline (DoT, 2015)*

2.1.4.4 Erosion potential and depth of sediment mobility

A coastal erosion risk assessment undertaken along the coast of Western Australia identified Floreat beach, which is located immediately to the south of the City Beach landing site, as being of moderate importance in terms of coastal erosion management (DPLH & DoT, 2019).

Cross-shore sediment movement has been noted in the vicinity of the City Beach landing site, with sporadic swell pushing sediment onto the shore and steepening the beach profile. Additionally, during the winter months, winter storms are known to erode the beach face and redeposit the sediment to form offshore sandbars (Cardno, 2022).

Hence, it is important to note that seabed elevations at the time of submarine cable installation may vary from those recorded during the MRS.

2.2 Perth Landing – Garden Island

2.2.1 Bathymetry and seabed conditions

The nearshore environment exhibits certain environmental traits similar to those outlined for the Perth Cable Protection Zone landing in section 2.1. As stated in section 2.1.1 the Perth region, including the Garden Island landing area, features extensive subtidal rocky reefs (Lucieer et al., 2023).

Reefs in the Perth region are typified by elongated formations that extend approximately 10–20 meters above the seafloor, situated at water depths ranging from about 10–30 meters. These formations are predominantly aligned parallel to the shoreline (Brooke et al., 2008).

Five Fathom Bank, stretching from the southern part of Becher Point to Rottnest Island, constitutes the most intricate reef system within the landing vicinity. Additionally, a limestone reef is found in an offshore direction running from the southwest to the northeast of Five Fathom Bank (BMT Oceanica, 2015).

The landing area contains coarse sand within the nearshore environment, while offshore coarse sand can be located within the Five Fathom Banks area. The limestone reef is overlaid with a sand veneer (BMT Oceanica, 2015).

The majority of the cable route along the deeper water section is anticipated to be characterised by sands.

Beyond Five Fathom Bank, the offshore seabed gently slopes to a maximum depth of approximately 35 meters. The offshore habitats primarily comprise bare sandy areas and limestone reefs covered by a sand veneer (BMT Oceanica, 2015). The bathymetry offshore of the Garden Island landing is shown in Figure 2.8.

The marine route inshore survey was conducted by EGS Australia on 16th February 2024 and covered the shore end at kilometre point (KP) 1.84 in 8.2m water depth to the Handover Point (HOP) at KP2.90 in 16.1m water depth. Throughout the surveyed area the route heads west. The seabed is locally rugged with very steep slopes mainly associated with medium to high reflectivity patches interpreted as rock/coral outcrops with marine growth. Intermittent veneers of loose gravelly sand with sand waves (wavelength 50-80m; height >1m) over dense sand can be observed within rock outcrop areas. The route runs within two UXO area at KP1.15 and (Garden Island Ammunition Depot) and KP 1.42 (Rottnest Seaward Firing).

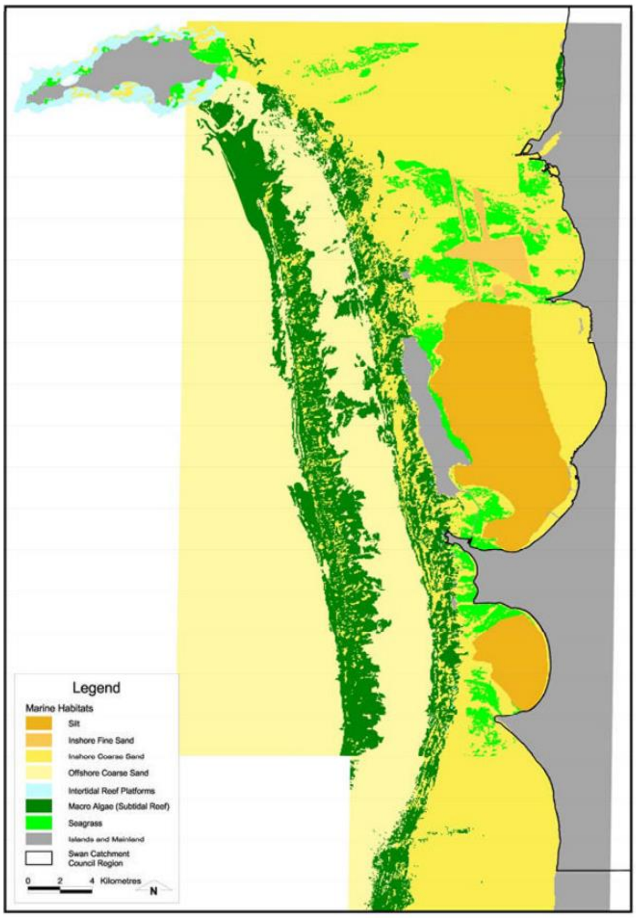


Figure 2.7 *Benthic habitat of the Southern Metropolitan Coastal Waters (Geo Oceans, 2015)*

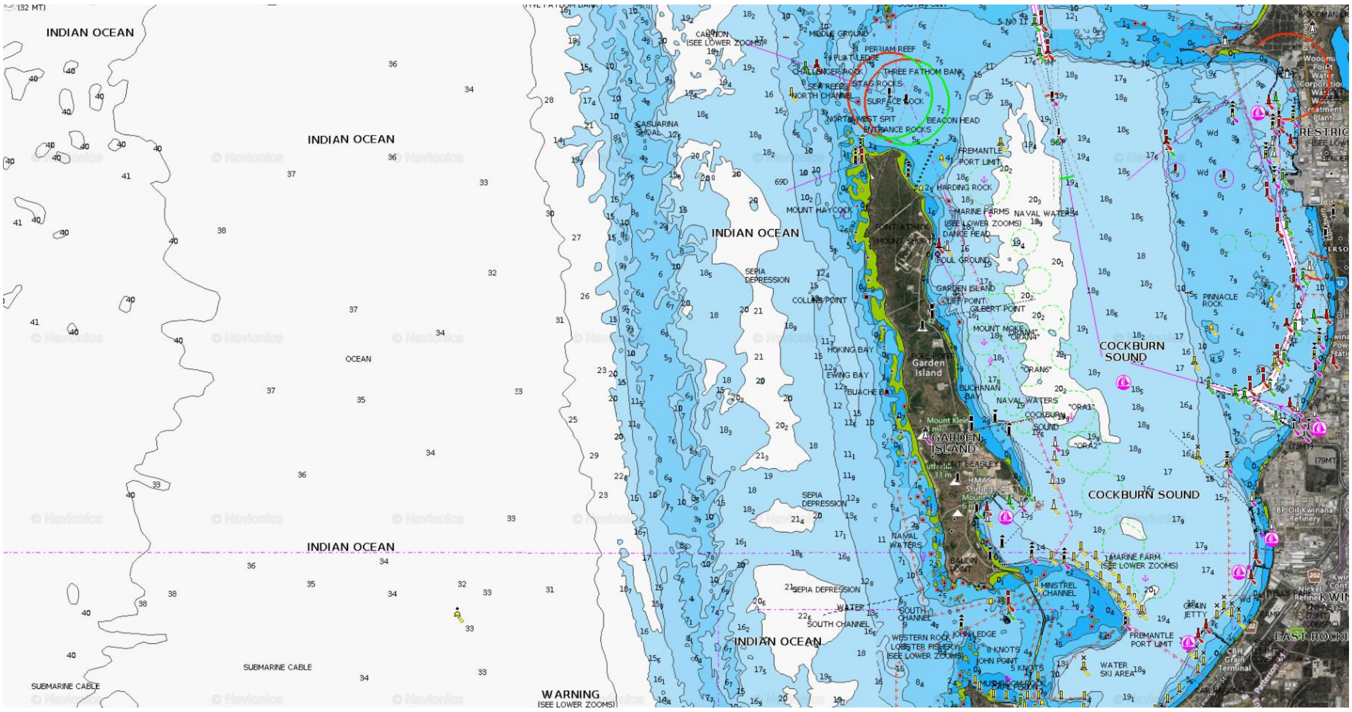


Figure 2.8 *Bathymetry offshore from the Garden Island landing. Source: Navionics (accessed October 2023)*

2.2.2 Water levels and currents

2.2.2.1 Astronomical tides

Tides along the western coast of Western Australia are primarily diurnal. Tides measured at Garden Island are consistent with those measured along the surrounding coastline, including at Fremantle (approximately 40 km north of Garden Island). Due to the proximity of Garden Island to Fremantle, the Fremantle tide gauge is considered to be representative. The tidal planes for Fremantle and have been extracted from Australian National Tide Tables (2023) and summarised below.

Table 2.3 Tidal planes at Fremantle (broadly relevant to Garden Island) (Australian National Tide Tables 2023)

Tidal plane	Water level (m Chart Datum)	Water level (m AHD)
Highest Astronomical Tide (HAT)	1.4	0.6
Mean High Water Springs (MHWS)	1.2	0.4
Mean High Water Neaps (MHWN)	1.0	0.2
Mean Sea Level (MSL)	0.8	0
Mean Low Water Neaps (MLWN)	0.6	-0.2
Mean Low Water Springs (MLWS)	0.5	-0.3
Lowest Astronomical Tide (LAT)	0	-0.8

2.2.2.2 Storm tide (extreme water levels)

Western Australia is characterised by a micro-tidal coastline, heavily influenced by storm surges and mean sea level variation. Storm surges along the Western Australian coastline are driven by tropical cyclones.

Table 2.4 presents extreme water levels for sea level rise estimates at Fremantle, a representative site for Garden Island.

Table 2.4 100-year ARI storm-tide levels sourced from Cockburn Sound Alliance (2013)

Location	Present day (2013)	+0.5m SLR	+1.0m SLR	+1.5m SLR
Freemantle	1.34	1.84	2.24	2.84

2.2.2.3 Currents

Two primary ocean currents operate offshore the Western Australian coastline – the Western Australian Current and Leeuwin Current. The Leeuwin Current is seasonally variable, involving a southward flow of warm, low-salinity tropical water along the west and south-west coast of Western Australia. The Leeuwin Current flows year-round but is strongest during winter and non-El-Nino Southern Oscillation (ENSO) years. The Leeuwin Undercurrent is part of Western Australian Current which forms adjacent to and beneath the Leeuwin Current where highly saline waters and South Indian Central Waters are carried northwards.

2.2.2.4 Sea level rise

Sea level records measured at Fremantle (located approximately 10 km south-west of City Beach) since 1897 indicate that there has been a mean rate of sea level rise of 1.54 mm per annum along the western coastline of Western Australia. This rate of increase is comparable to the global mean rate of sea level rise which is between 1.1-1.9 mm per annum. The rate of mean sea level changes has varied over time, heavily influenced by inter-annual sea level variability associated with the ENSO phenomenon.

Interactions between the Leeuwin Current and changes in the bathymetry and offshore water of different densities result in the generation of eddies which move further offshore.

In 2021, the WA government released the Western Australian Climate Projections Summary. Based on a representative concentration pathway (RCP) of 4.5, the sea levels in Fremantle are estimated to rise by approximately 0.07 m to 0.16 m by 2030 (Western Australian Climate Projections, 2021). This can be considered representative of conditions in Western Australia's Southwestern Flatlands region.

The Western Australian State Government's State Planning Policy 2.6 'Coastal Planning' has allowed for sea level rise to be based on a vertical sea level rise of 0.9 m over a 100-year timeframe to 2110 (SPP 2.6 Coastal).

2.2.3 Wave climate

Western Australia sits on the eastern border of the Indian Ocean and northern border of the Southern Ocean, which is an area characterised by an energetic wave climate as high latitude strong sustained winds can generate large swells. Given the proximity of the Garden Island landing to the Perth landing, the wave climate is as described in section 2.1.3.

2.2.3.1 Winds

Given the proximity of the Garden Island landing to the Perth landing and lack of site-specific wind data for Garden Island, the wind climate is as described in section 2.1.3.1.

2.2.4 Sediment properties and sediment transport

2.2.4.1 Sediment properties

Offshore of the northern coast of Garden Island, there are isolated low profile inshore reefs in a shallow inshore area which give way to a broader area of relatively flat seafloor dominated by medium-grained unconsolidated sediment. The unconsolidated sediments comprise medium-grained to very coarse-grained shelly sand. The unconsolidated sediments then give way to more lithified sediments (i.e., partially calcified sediments, a calcarenite boulder field, and low relief, medium relief and high relief calcarenite reef outcrop), where low relief calcarenite ledges occur.

The marine route inshore survey was conducted by EGS Australia on 16th February 2024 and covered the shore end at kilometre point (KP) 1.84 in 8.2m water depth to the Handover Point (HOP) at KP2.90 in 16.1m water depth. Throughout the surveyed area the route heads west. The seabed is locally rugged with very steep slopes mainly associated with medium to high reflectivity patches interpreted as rock/coral outcrops with marine growth. Intermittent veneers of loose gravelly sand with sand waves (wavelength 50-80m; height >1m) over dense sand can be observed within rock outcrop areas.

2.2.4.2 Geotechnical properties

Given the proximity of the Garden Island landing to the Perth landing, the geotechnical properties are as described in section 2.1.4.2.

2.2.4.3 Sediment transport

The western shore of Garden Island is relatively exposed. Sediment transport offshore of Garden Island occurs in the east and northeasterly direction. Medium sand waves are formed from the development of a northerly flowing current between Garden Island and Five Fathom Bank.

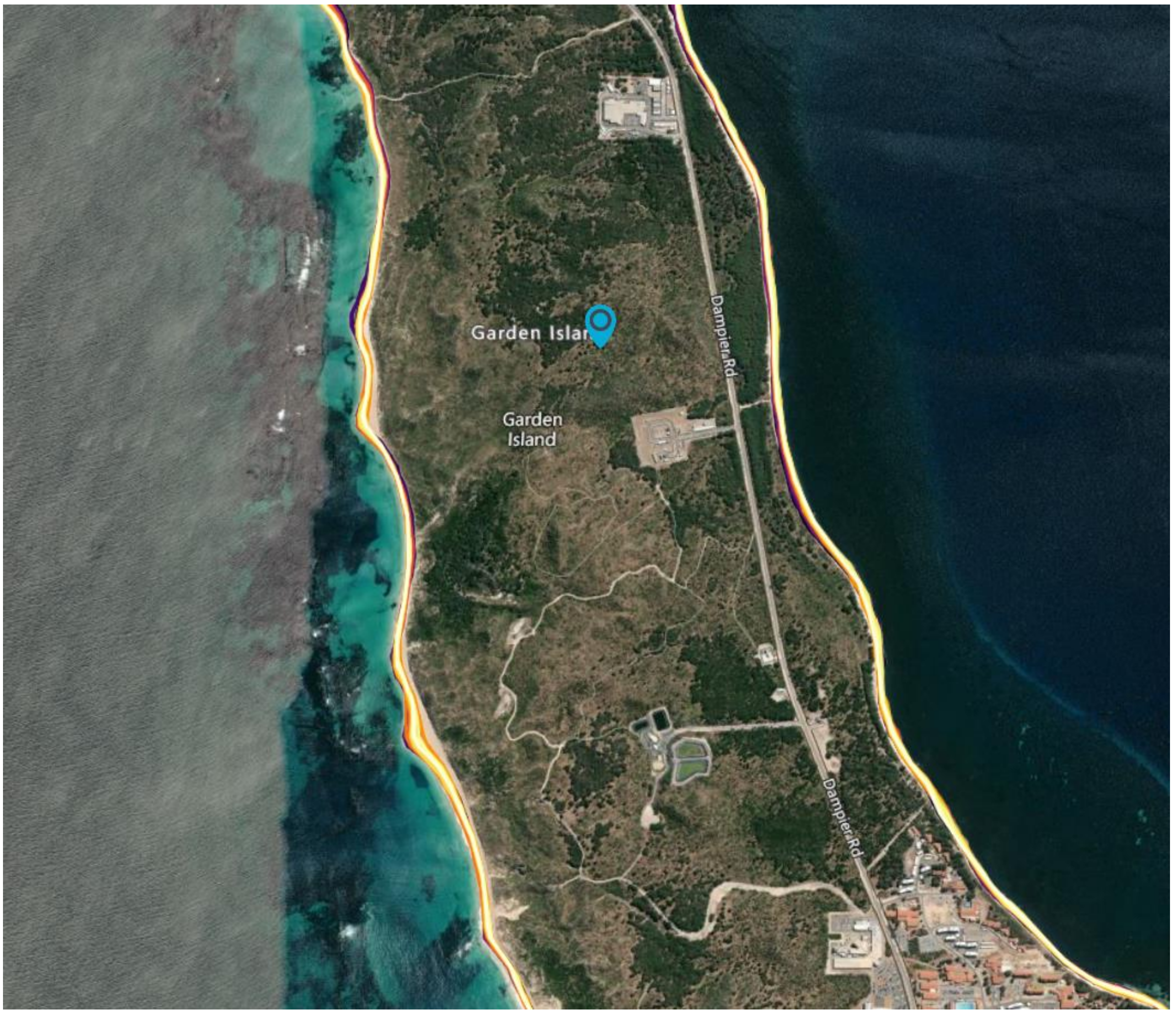


Figure 2.9 *Annual shorelines and rates of coastal change from 1988 – 2021 in the vicinity of the Garden Island landing. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:25,000 base map)*

Figure 2.10 *Annual shorelines and rates of coastal change from 1988 – 2021 near the Garden Island landing site. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:2500 base map)*

2.2.4.4 Erosion potential and depth of sediment mobility

Due to the existing Defence base on Garden Island, there is little publicly available information regarding erosion and sediment mobility on Garden Island, particularly on the western coastline where the Garden Island landing is located. Sediment on the eastern side of Garden Island has been observed occurring in a southward direction towards the southern tip of Cockburn Sound (BMT, 2019). As most of the Garden Island coastline is comprised of sandy beaches, there is a vulnerability to erosion, particularly in the event of future sea level rise.

Hence, it is important to note that seabed elevations at the time of submarine cable installation may vary from those recorded during the MRS.

2.3 Adelaide Landing

2.3.1 Bathymetry and seabed conditions

The nearshore shelf environment in South Australia’s state waters extends out to the 3nm limit from the nearest land mass. The Adelaide landing passes north of Kangaroo Island and south of Yorke Peninsula before landing at West beach (Figure 2.11). Most of the cable route along the offshore section is characterised by soft sediment and interspersed rocky reef. The bathymetry immediately offshore of the South Australian landing is shown in Figure 2.12, and the bathymetry further offshore is shown in Figure 2.13.

The marine route shallow water survey was conducted by EGS Australia on 8th to 21st April 2024 and covered the Landfall Survey Handover Point (HOP) at kilometre point (KP) 4.68 in 12m water depth to the Offshore Survey HOP at KP292.69 in 270m water depth. From the Landfall Survey HOP, the route runs southwest along the seabed with a gentle slope of up to 5°. The seabed composition in this area is primarily low relief rock with intermittent veneers of loose to dense gravelly sand.

Between KP5.70 and KP7.02, the seabed features intercalations of loose to dense slightly gravelly sand over rock and pockets of similar sand with scattered marine growths over rock. From KP7.02 to KP10.76, megaripples and sandwaves are intermittently present under veneers and layers of loose to dense slightly gravelly sand over hardground (indurated clay). The sandwaves have a maximum wavelength and height of 120 m and less than 1.0 m, respectively. Scattered marine growth is reported in this area.

The route crosses one military Firing, Practice and Exercise area R279 from KP97.89 to KP190.78.

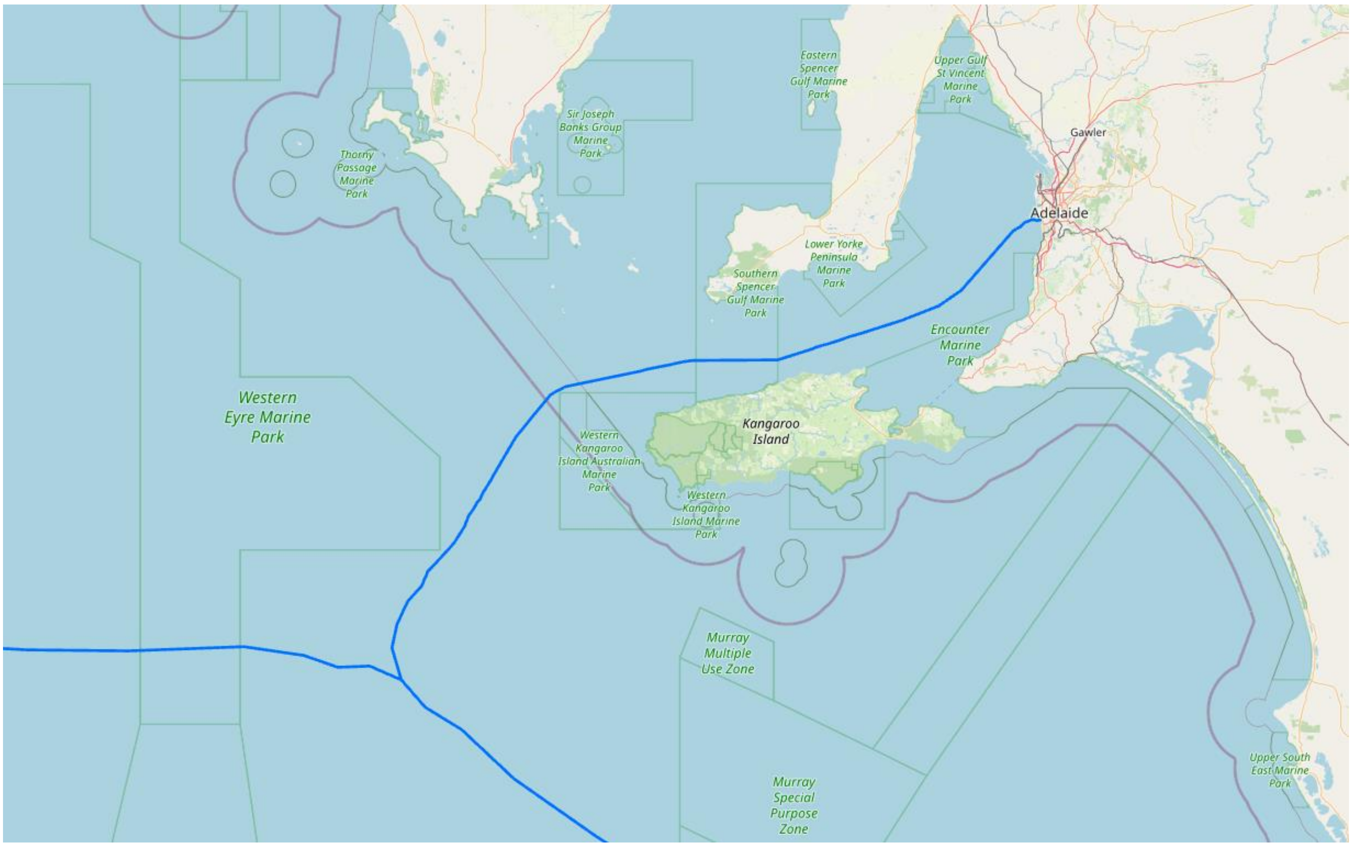


Figure 2.11 *South Australia landing. Purple line depicts indicative proposed cable. Source: GHD Esri maps (base map)*

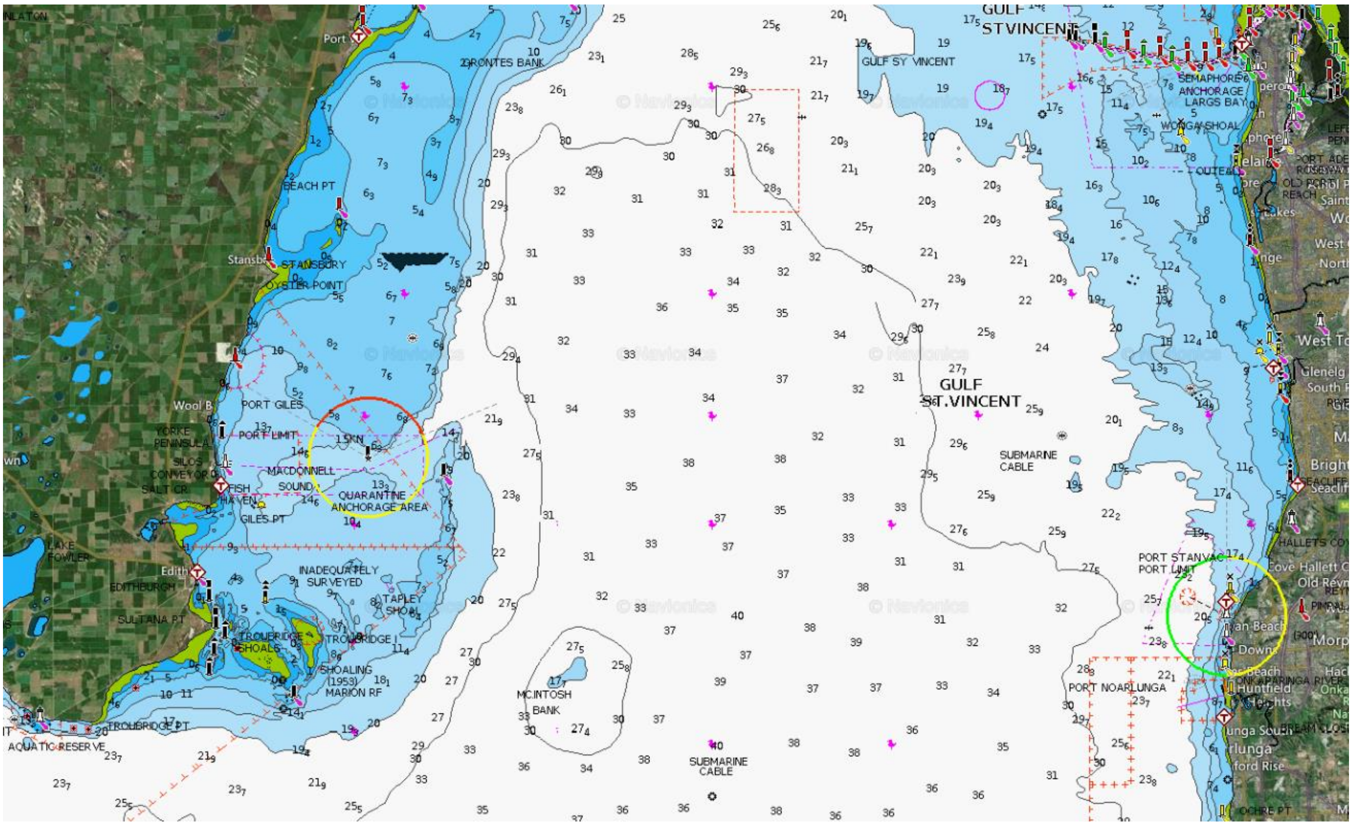


Figure 2.12 *Bathymetry immediately offshore from the South Australia landing. Source: Navionics (accessed October 2023)*

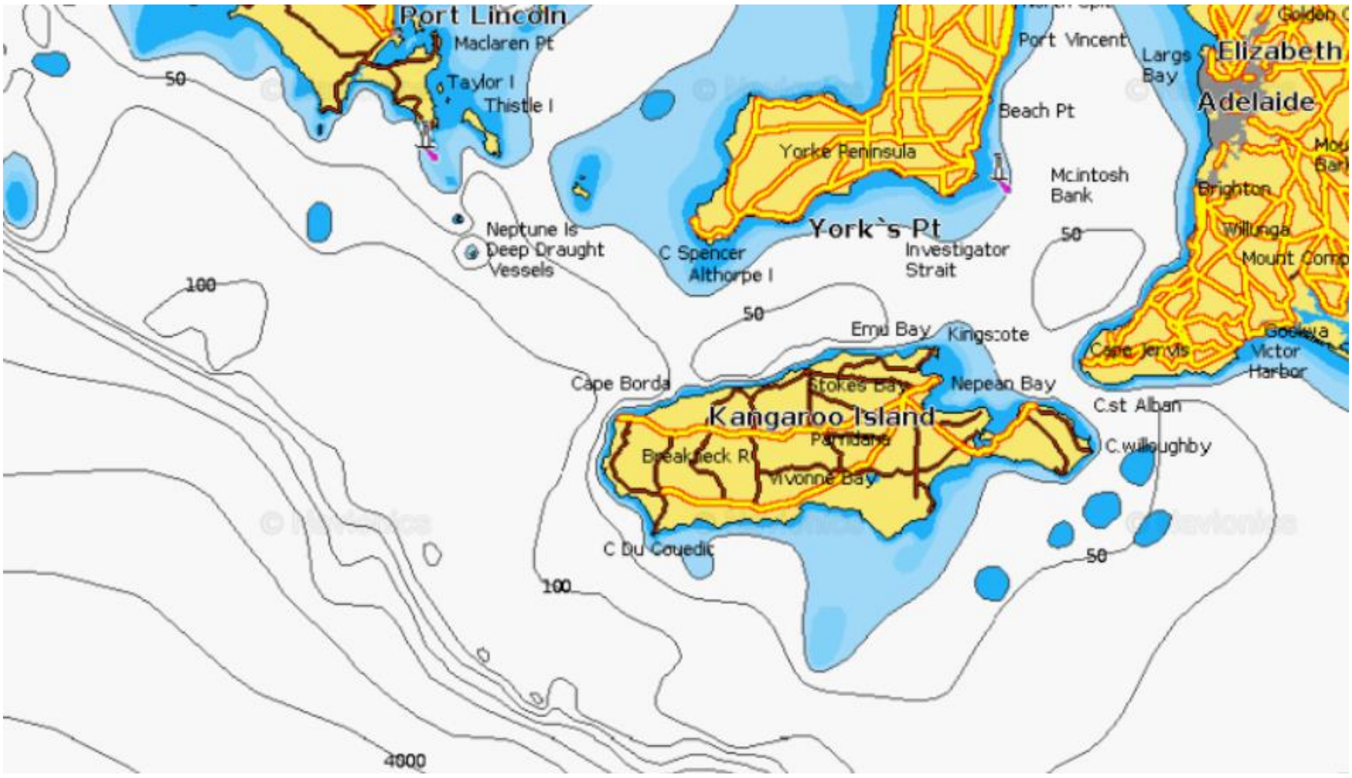


Figure 2.13 ***Bathymetry offshore from the South Australia landing. Source: Navionics (accessed October 2023)***

The South Australian continental shelf is characterised by broad, gently sloping plains covered by relatively shallow water to about 50m in depth and usually extends to a steep slope falling away to a deepwater oceanic plate. In many areas of the South-East Marine Region, the shelf is relatively narrow (10 to 25km wide) except for Bass Strait and much of South Australia, where in places the continental shelf can extend out to 260 km wide. In South Australia, the comparatively wider continental slope incorporates the Great Australian Bight, Spencer Gulf, Gulf of St Vincent, and the waters southeast of Kangaroo Island and west of the Murray River mouth delta.

The South Australian offshore environment spans from the wide shelf area across the Great Australian Bight in the west to the narrow shelf off Port MacDonnell in the east (Geoscience Australia, 2023). This region features notable geological formations with complex topography including submarine canyons along the continental shelf slope. The majority of the cable route along the offshore section is anticipated to be characterised by a sandy seabed.

2.3.2 Water levels and currents

2.3.2.1 Astronomical tides

Tides along the Adelaide coast are primarily semi-diurnal. Tides measured at Brighton beach are consistent with those measured along the surrounding coastline, including at West beach (approximately 9 km north of Brighton). Due to the proximity of West beach to Brighton beach, the Brighton beach tide gauge is considered to be representative. The tidal planes for Brighton beach have been extracted from the Australian National Tide Tables (2023) and summarised below.

Table 2.5 Tidal planes at Brighton beach (relevant to West beach landing) (Australian National Tide Tables 2023)

Tidal plane	**Water level (m Chart Datum)**	**Water level (m AHD)**
Highest Astronomical Tide (HAT)	2.6	1.43
Mean High Water Springs (MHWS)	2.0	0.83
Mean High Water Neaps (MHWN)	1.2	0.03
Mean Sea Level (MSL)	1.17	0
Mean Low Water Neaps (MLWN)	1.2	0.03
Mean Low Water Springs (MLWS)	0.3	-0.87
Lowest Astronomical Tide (LAT)	0.3	-0.87

2.3.2.2 Storm tide (extreme water levels)

Table 2.6 presents extreme water levels for typical Average Recurrence Intervals (ARI), derived from Port Adelaide-inner water level records (University of Western Australia, 2018).

Table 2.6 Extreme Water Levels at Port Adelaide inner harbour

Average Recurrence Interval (years)	Water level (m LAT)	Water level (m AHD)
1	2.36	1.95
50	2.40	2.41
100	2.42	2.58

2.3.2.3 Currents

The South Australian continental shelf waters are adjacent to the only circumpolar ocean and complex meteorological and oceanographic processes. Northwest along the continental slope the Flinders Current traverses year-round and the Leeuwin Current intrudes into surface waters during early winter. During summer and autumn an anticlockwise surface gyre develops over the shelf and during winter shelf currents flow southeast. Seasonal southeasterly winds push upwelled nutrient rich water from the Flinders Current onto the continental shelf mixing the shelf waters.

2.3.2.4 Sea level rise

The South Australian Government has adopted a policy of planning for sea level rise (SLR) of not less than 1.0 m by 2100 (Coastal Adaptation Guidelines, 2020). This is based on the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5, 2014) findings of global SLR projections. The benchmark of 1.0 m by 2100 may be updated in the future as additional scientific data becomes available, or it may be superseded when national vulnerability benchmarks are established.

Using a 25-year design life for the SMAP system, a sea level rise projection for 2050 was estimated based on the IPCC Sixth Assessment Report for Shared Socioeconomic Pathway (SSP) Scenario 8.5.

The relevant projected sea level rise at West beach for 2050 is 0.20 m.

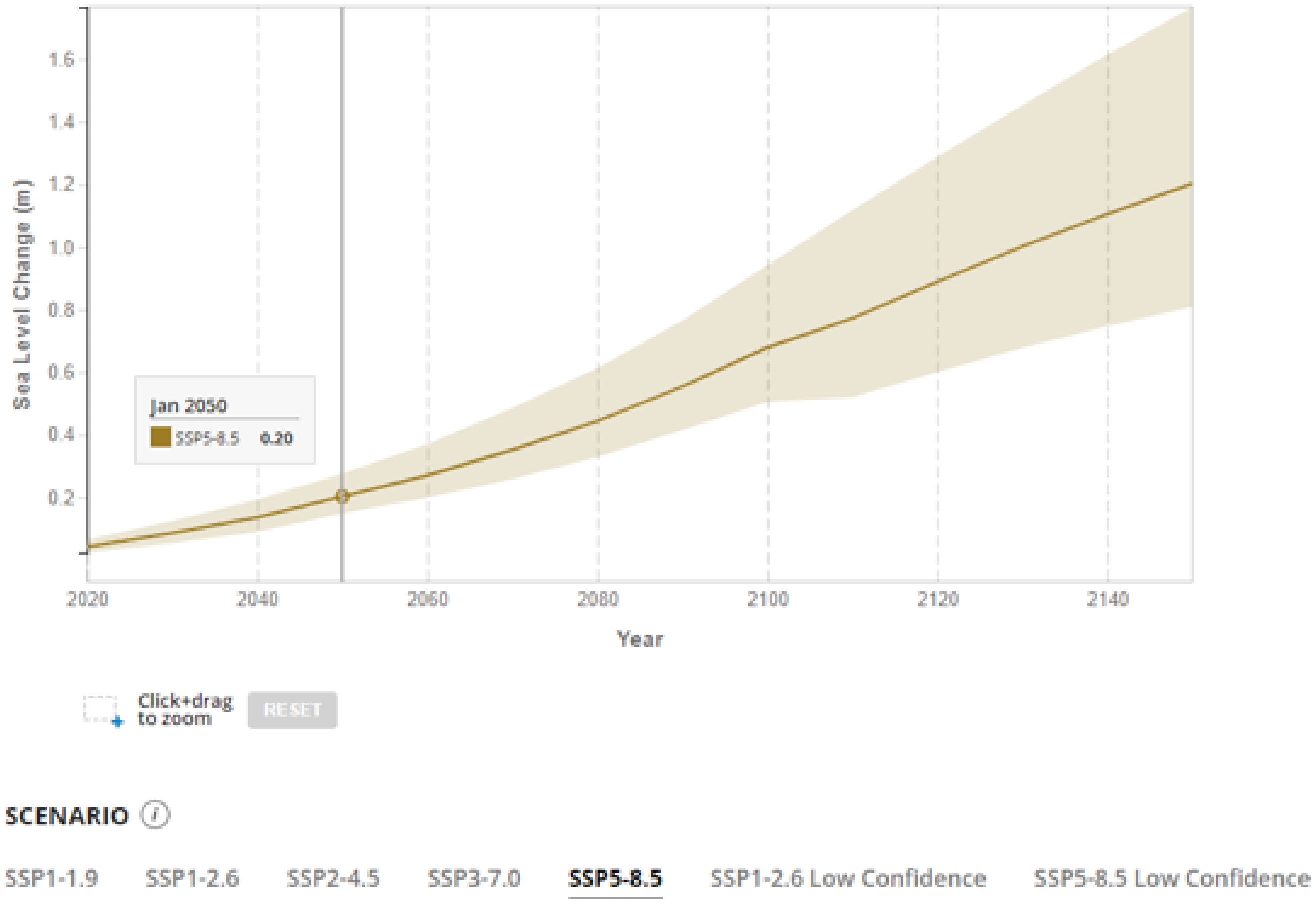


Figure 2.14 Projected sea level rise at West beach using Nasa sea level rise projection tool **[Source:** https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?psmsl_id=1836&data_layer=scenario]

2.3.3 Wave climate

In order to understand the general wave climate of the area, publicly available wave data from the Department of Primary Industries and Regions (DPIR)'s principal research institute (the South Australian Research and Development Institute (SARDI)) can be used. Ocean conditions observed in St Vincent's Gulf are mapped by SARDI using the Two Gulfs Model on a 0.5 km grid, with wave conditions mapped using the AUSWAVE-SVGr wave model. West beach sits within the Gulf of St. Vincent, which is a semi-enclosed, relatively shallow water body with maximum depths rarely exceeding 40 m (South Australian Coastal Protection Board SACPBa, 1993). Waves generated within the Gulf via wind are low to medium energy due to the enclosed nature of the Gulf, however, significant swell wave energy enters into the Gulf from the Southern Ocean (Hemer and Bye, 1999). As such, the wave climate within the Gulf of St. Vincent is heavily influenced by the swell generated from the Southern Ocean, with the dominant swell direction at this location being from the south-west (SARDI, 2023) as demonstrated in the AUSWAVE-SVGr significant wave height map in Figure 2.15, which shows the mean wave direction and significant wave height observed in proximity to West beach at 22:30 on 20/10/23, and the wave rose for the period from 2009 – 2016 provided in Figure 2.16.

A field study using surf zone drifters was undertaken from 3 September to 16 October 2004. Results from the field study during this period included that wave height within the proximity of West beach showed a diurnal variation due to the tide-induced changes in water depth that occur within the Gulf of St. Vincent (Pattiaratchi, 2005). The mean and maximum wave heights recorded nearby to West beach were 0.5 m and 1.7 m respectively, with the wave period ranging from 3 to 12 seconds (Pattiaratchi, 2005).

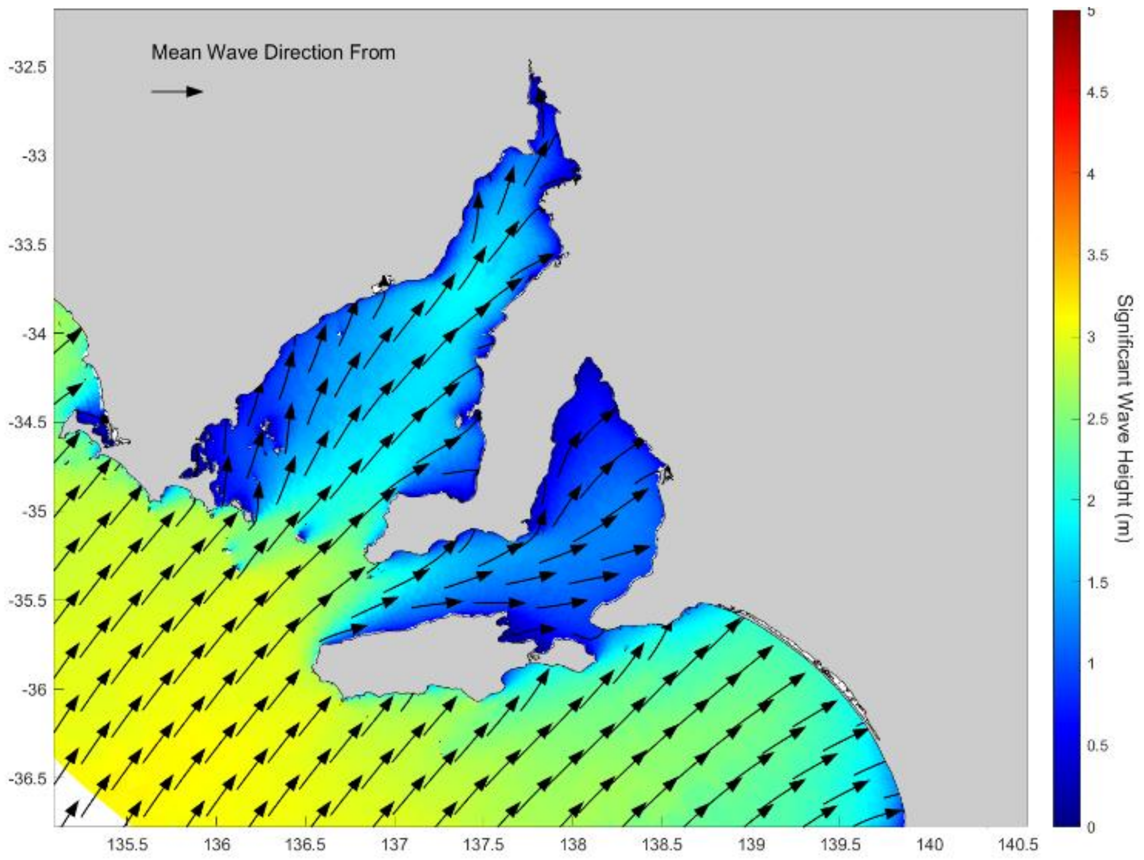


Figure 2.15 Significant wave height and direction taken at 22:30 on 20/10/23 (Source: https://pir.sa.gov.au/research/services/esa_marine/two_gulfs_model/significant_wave_height)

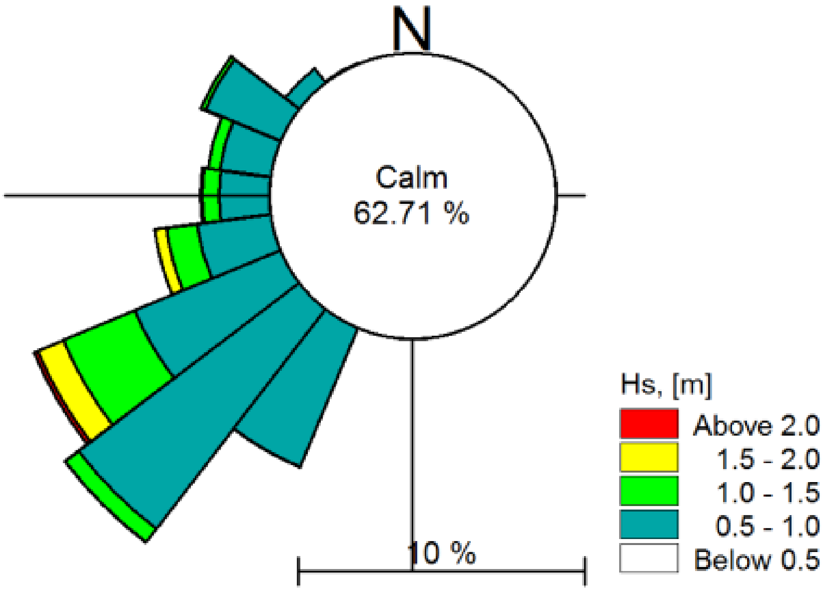


Figure 2.16 Simulated wave rose for West Beach for the period from 2009 - 2016 (DHI, 2018)

2.3.3.1 Winds

The closest weather station in the vicinity of the West beach site that would be relevant is located at Adelaide Airport (located approximately 1.2 km to the east). Wind data has been collected from 1955 to 2019 and a wind rose for this location has been provided in Figure 2.17. The Gulf of St Vincent, and by extension West beach, is dominated by south-easterly winds during summer and south-westerly winds during winter (Powell, 2019).

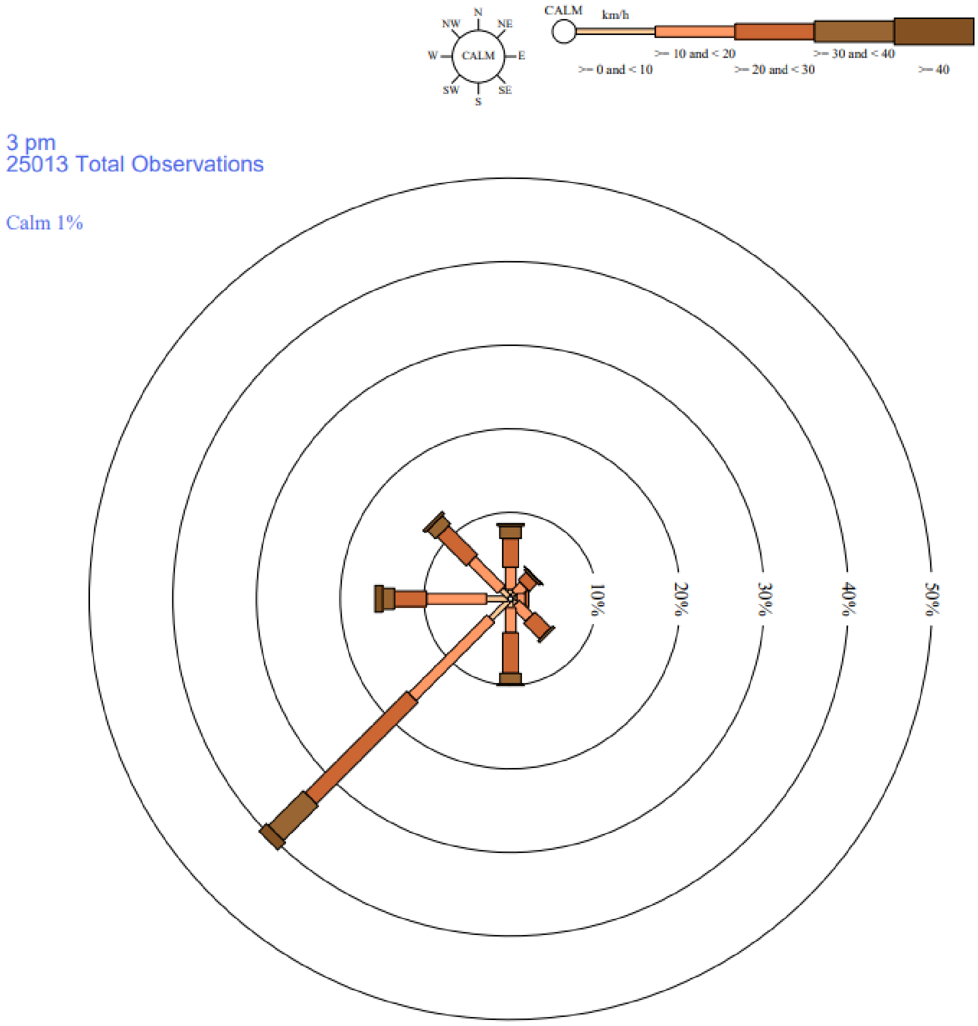


Figure 2.17 Wind rose of wind direction versus wind speed in km/h at Adelaide Airport from 1955-2019 (BOM, 2023)

2.3.4 Sediment properties and sediment transport

2.3.4.1 Sediment properties

Sediments within the vicinity of West beach are comprised primarily of carbonate and quartz grains of varying sizes, in addition to small amounts of clay minerals. The carbonate grains are those produced by marine flora and fauna along Adelaide's coastline whilst the quartz grains are those generated by cliff erosion and scouring of nearby catchment areas (DPI, 2018).

The marine route shallow water survey was conducted by EGS Australia on 8th to 21st April 2024 and covered the Landfall Survey Handover Point (HOP) at kilometre point (KP) 4.68 in 12m water depth to the Offshore Survey HOP at KP292.69 in 270m water depth. From the Landfall Survey HOP, the route runs southwest along the seabed with a gentle slope of up to 5°. The seabed composition in this area is primarily low relief rock with intermittent veneers of loose to dense gravelly sand.

Between KP5.70 and KP7.02, the seabed features intercalations of loose to dense slightly gravelly sand over rock and pockets of similar sand with scattered marine growths over rock. From KP7.02 to KP10.76, megaripples and sandwaves are intermittently present under veneers and layers of loose to dense slightly gravelly sand over hardground (indurated clay). The sandwaves have a maximum wavelength and height of 120 m and less than 1.0 m, respectively. Scattered marine growth is reported in this area.

2.3.4.2 Geotechnical properties

The coastline between West Beach and Point Malcom comprises a Holocene veneer of sediments over Paleogene-Neogene clays, sand and limestones in conjunction with riverine sediments and coastal dunes (Bourman, 2016).

2.3.4.3 Sediment transport

Sediment transport along the coastline of Adelaide is primarily influenced by the wave climate and tidal currents of the area. Wave action is the primary driver of sediment transport in proximity to the shore, whereas outside of the surf zone as the depth of the water increases, the influence of waves on sediment transport lessens (DPI, 2018). Sediment within the vicinity of West beach is moving in a net northerly drift due to wave and current induced shear stresses along the seabed (DPI, 2018).

It is noted that seagrass populations that have been identified offshore from West beach and other nearby beaches are responsible for the slowing of sediment transport in this area. A decline in this seagrass population has been observed within recent years, which may eventually lead to the scouring of the seabed, an increase in the depth of water and the occurrence of higher energy wave action closer to the shoreline (DPI, 2018).

This section of the coast has some natural variability of the shoreline, and has experienced varying levels of shoreline recession as demonstrated in Figure 2.18 and Figure 2.19, where the shoreline has fluctuated within a range of approximately 20 m to 60 m between 1988 – 2021. The coloured lines on Figure 2.18 and Figure 2.19 represent annual shorelines at approximately mean sea level.

Figure 2.18 Annual shorelines and rates of coastal change from 1988 – 2021 in the vicinity of the West beach landing. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:25,000 base map)

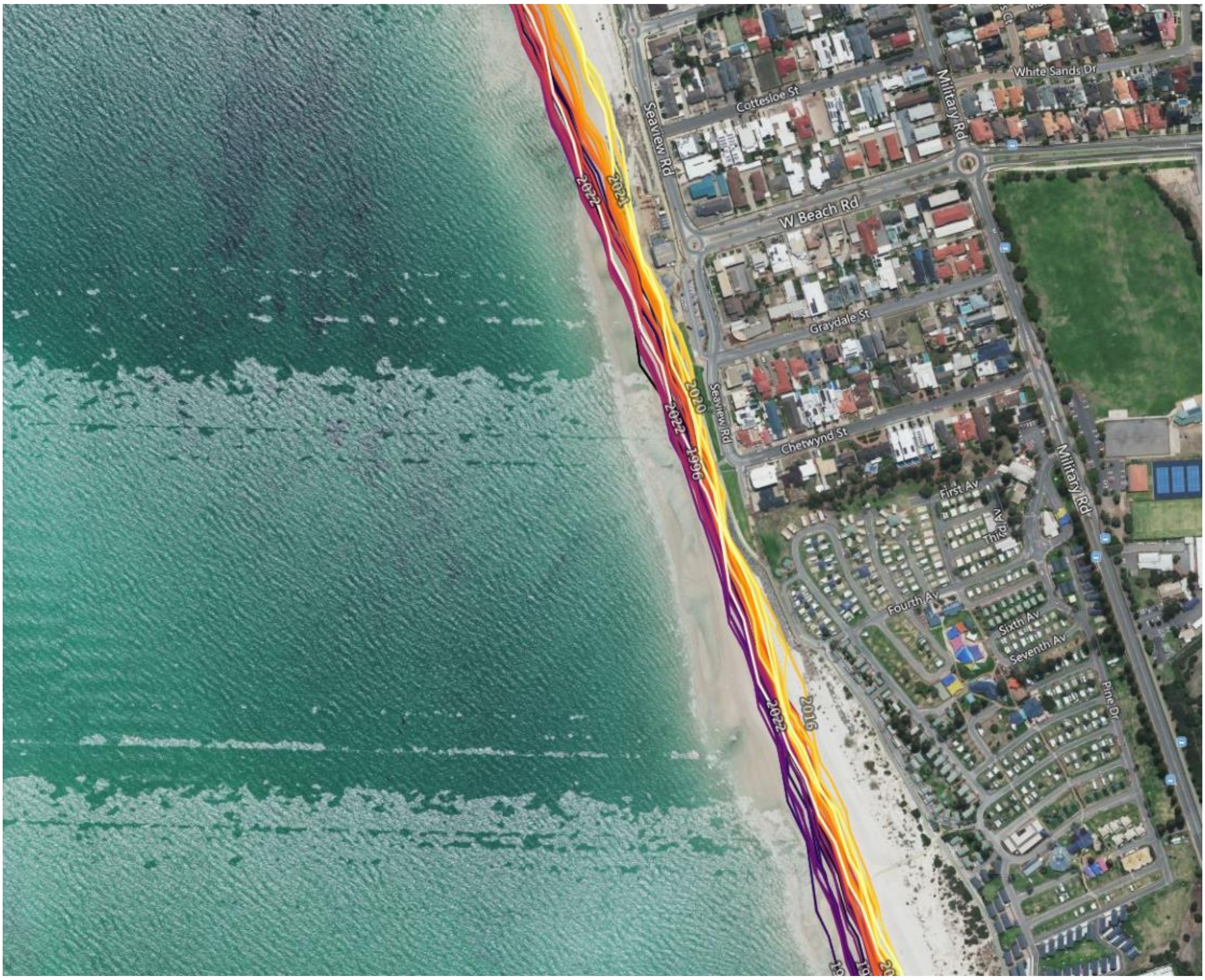


Figure 2.19 Annual shorelines and rates of coastal change from 1988 – 2021 in the vicinity of the West beach landing. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:2500 base map)

2.3.4.4 Erosion potential and depth of sediment mobility

Detailed bathymetric surveys undertaken at West beach from 1990 – 2017 have observed notable changes in the bathymetry at West beach, which are documented below:

- Significant deepening (~-2 m) of the nearshore zone along the length of West beach
- Significant declines in dune volumes both north and south of the seawall present at West beach
- Localised accretion of sediment in the offshore bar feature
- The significant erosion observed nearshore at West beach has steepened the coastal profile

These findings suggest that there is moderate erosion potential in the vicinity of the West Beach landing, influenced by anthropogenic factors which have altered the bathymetry and sediment transport processes. Hence, it is important to note that seabed elevations at the time of submarine cable installation may vary from those recorded during the MRS.

2.4 Voss’ Circuit Landing

2.4.1 Bathymetry and seabed conditions

The proposed cable in Victoria lands at Torquay Surf beach located along the Surf Coast in Victoria. This landing is referred to as Voss’ Circuit. The bathymetry and biotic component (habitats) of the seafloor offshore from the Torquay site is included as Figure 2.20 and Figure 2.21.

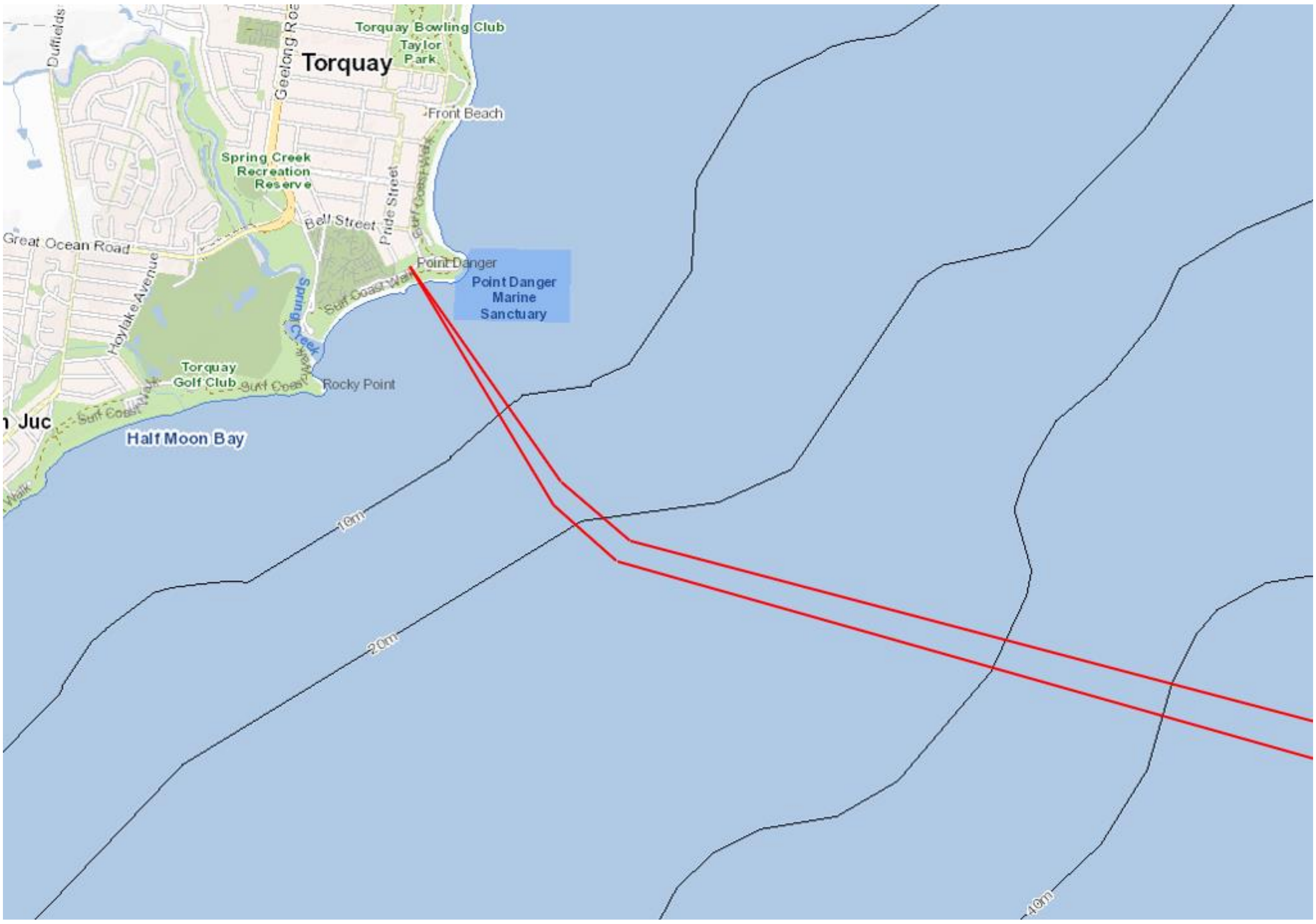


Figure 2.20 Bathymetry immediately offshore from the Voss’ Circuit site. Source: CoastKit, DEECA, accessed February 2024 (base map)

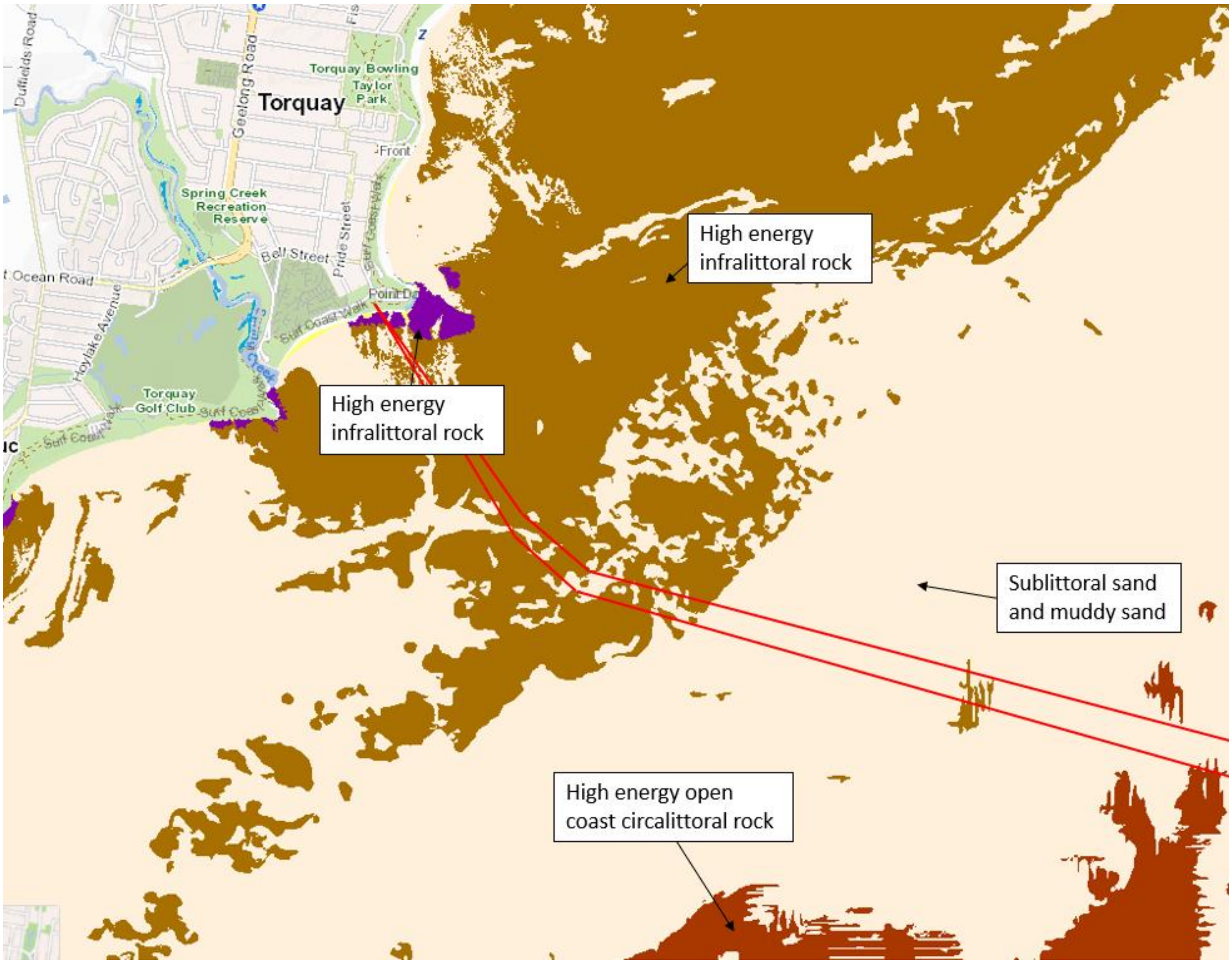


Figure 2.21 Biotope offshore from the Voss' Circuit site. Source: CoastKit, DEECA, accessed February 2024 (base map)

The following information relevant to the coastal assessment:

- Three key benthic habitat types were observed (as per CoastKit) from the landing route through to 3 nm (5.5.km) offshore including sublittoral sand and muddy sand, high energy infralittoral rock and high energy open coast circalittoral rock
- The predominant habitat type of the 5.5 km corridor (3 nm) is that of sublittoral sand and muddy sand
- Located up to 2.6 km from shore, bands of high energy infralittoral rock and high energy open coast circalittoral rock run parallel to the coastline
- The proposed cable route intersects approximately 320m of sublittoral sand and muddy sand from the shoreline between inter-dispersed high energy infralittoral rock, followed by 648 meters of high energy infralittoral rock
- Approximately 2600 m from shore, the cable route intersects approximately 1162 ms of high energy open coast circalittoral rock
- The majority of the cable route crosses sublittoral sand and muddy sand to the limit of state waters, but there may be sections of rocky reef (sublittoral rock) that may require avoidance

The marine route shallow water survey for segment 2.3 was conducted by EGS Australia on 5th to 7th March 2024 and covered the KP 1.86 in 22m water depth to Torquay Branching Unit (BU TQW) KP17.21 in 71m water depth. The route runs southeast along a seabed characterised by low relief rock with intermittent veneers of loose gravelly sand. Subcropping rock at <1m below seabed with local rock outcrops are present up to KP4.91 at 35.7m water depth. From KP4.91 to KP12.92 in 60.6m water depth, the seabed is primarily characterized by a veneer of loose gravelly sand with megaripples (wavelength <5m) over rock and veneer of loose sand over dense to very dense sand. The route runs inside an unspecified restricted area between KP4.55 and KP10.38. The route crosses two UXO potential areas at 369 Point Addis/Torquay in 58.1m water depth and 370 Point Addis/Torquay in 62.0m water depth.

In localised sectors, cable burial may be not feasible or reduced along the route since rock areas are present exposed at seabed and/or within the burial depth. It should be noted that bottom currents can cause abrasion to a cable laid over obstacles such as when having a free-span. In addition, numerous ships were observed in the vicinity of the survey corridor. Cable faults are a risk as they are most common at < 200 m water depth due to fishing and anchoring.

2.4.2 Water levels and currents

The offshore environment along the cable route exhibits a complex interplay of offshore coastal dynamics, shaping its unique oceanographic characteristics and diverse habitats. The area is strongly influenced by wind, tides, waves and weather systems.

2.4.2.1 Astronomical tides

Astronomical tides are the daily rise and fall of sea levels caused by the combined effects of the rotation of the earth and the gravitational attraction between the earth, moon and the sun. Tides along the Victorian coastline in the west are primarily diurnal. The primary tidal harmonic constant is the lunar semi-diurnal component. Tides measured at Torquay Beach are consistent with those measured along the surrounding coastline, including at Lorne (approximately 4 km southwest of Torquay beach). Due to the proximity of Torquay beach to Lorne, the Lorne tide gauge is considered to be representative. The tidal planes for Lorne have been extracted from the Australian National Tide Tables (2023) and summarised below.

Table 2.7 Tidal planes at Lorne (relevant to Voss' Circuit) (Australian National Tide Tables 2023)

Tidal plane	Water level (m Chart Datum)	Water level (m AHD)
Highest Astronomical Tide (HAT)	2.7	1.3
Mean High Water Springs (MHWS)	2.2	0.8
Mean High Water Neaps (MHWN)	1.8	0.4
Mean Sea Level (MSL)	1.36	0
Mean Low Water Neaps (MLWN)	0.9	-0.5
Mean Low Water Springs (MLWS)	0.5	-0.9
Lowest Astronomical Tide (LAT)	0	-1.4

2.4.2.2 Storm tide (extreme water levels)

The sea level also varies at less predictable periods due to storm surges and wave setup. The height of a storm surge is influenced by its timing in relation to astronomical tides. The storm tide is an extreme water level which incorporates astronomical tide, surge and wave setup.

Storm tide levels relevant to the project site were determined in the 2009 CSIRO study "The Effect of Climate Change on Extreme Sea Levels along Victoria's Coast". The storm tide levels were calculated for the 1% annual exceedance probability (AEP) event, where AEP is the likelihood that the given level will be exceeded by the stated probability in any one year (i.e., A 1% AEP storm tide level has a chance of occurrence in any year of 0.01). This report contains results for numerical modelling of a number of different climate change scenarios along Victoria's coastline, including at Lorne which is representative of the Voss' Circuit site, and is included in Table 2.8.

These results are for climate change scenario 2, which comprises a sea level rise of 0.8 m and a 19% increase in wind speed by the year 2100. It should be noted that these reported levels for storm tide do not include an allowance for wave setup or wave runup, and that the tide levels used in the model are based on long term probabilities, rather than reporting to a specific tidal plane. Additional discussion on sea level rise is contained in section 2.4.2.4.

Table 2.8 1% AEP storm-tide level

Location	**1% AEP Storm-tide levels**		
	2030	**2070**	**2100**
	(m AHD)	**(m AHD)**	**(m AHD)**
Lorne	1.91	2.33	2.74

2.4.2.3 Currents

Strong currents push through Bass Strait from the Coral Sea and Southern Ocean. This region is influenced by the East Australian Current, which transports warm waters southward along the coast (Zhai et al., 2022). These currents contribute to upwelling events, where nutrient-rich waters rise to the surface. Offshore waters of the area are primarily comprised of open sandy systems with intermittently distributed small rocky-reef outcrops and high-relief reefs.

2.4.2.4 Sea level rise

The Victorian Government has adopted a policy of planning for sea level rise (SLR) of not less than 0.8 m by 2100 (Marine and Coastal Policy, 2020). This is based on the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5, 2014) findings of global SLR projections of between 0.18-0.59 m by 2090-2099 and additional ice sheet melt of 0.1 – 0.2 m. The IPCC Sixth Assessment Report (AR6, 2021) was released in August 2021 and contains higher SLR projections than AR5. The benchmark of 0.8 m by 2100 may be updated in the future as additional scientific data becomes available, or it may be superseded when national vulnerability benchmarks are established. Global mean sea level will continue to rise over the 21st century and beyond, and global mean SLR above the likely range cannot be ruled out, due to the uncertainty in ice sheet processes.

Using a 25-year design life for the SMAP system, a sea level rise projection for 2050 was estimated based on the IPCC Sixth Assessment Report for Shared Socioeconomic Pathway (SSP) Scenario 8.5.

The relevant projected sea level rise at the Voss’ Circuit landing for 2050 is 0.2 m.

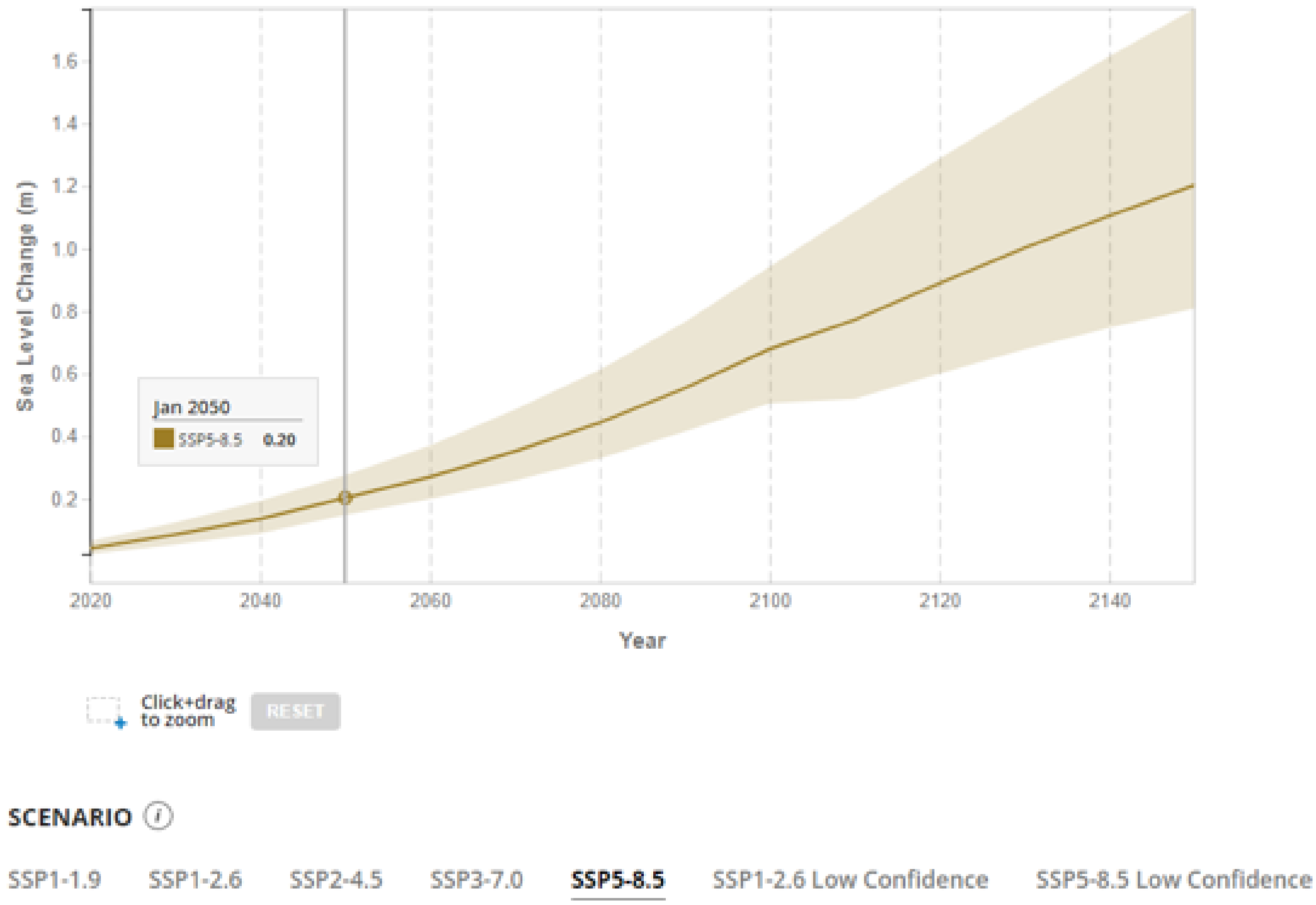
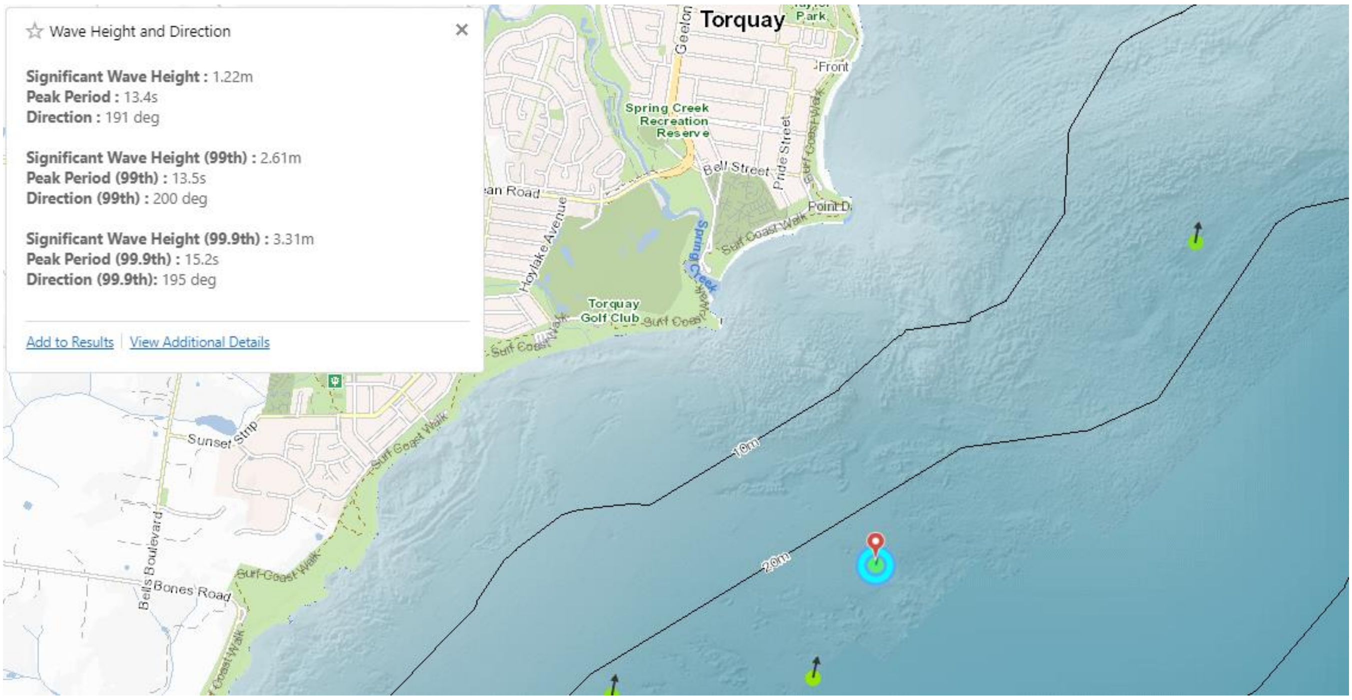


Figure 2.22 Projected sea level rise at Lorne (relevant to Voss' Circuit) using Nasa sea level rise projection tool [Source: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?psmsl_id=1836&data_layer=scenario]

2.4.3 Wave climate

In order to understand the general wave climate of the area, publicly available wave data from the Department of Energy, Environment and Climate Action (DEECA)'s online marine and coastal data tool, CoastKit can be used. The landing at Voss' Circuit is on the open coast of Victoria, which is a high wave energy coastline. The wave climate along the coast of Victoria is heavily influenced by Southern Ocean swell, with the dominant swell direction at this location being from the south-west (CoastKit). The coastline of the area is predominantly open and highly exposed to the wind and wave environment generated in the Southern Ocean and western reaches of the Bass Strait (Clifton et al. 2013)

The significant wave heights given in CoastKit are based on output of a WaveWatch III model. The model is developed by CAWCR and is available on the CSIRO website. The output point which was selected to represent the area is shown on Figure 2.23. This point is located approximately 1.8 km offshore and at a depth of approximately -22 m AHD. The significant wave height (i.e., the average height of the highest one-third of the waves) at this location is 1.22 m, with a corresponding peak period of 13.4 seconds, and direction of 191 degrees (i.e., south-west). The 99th percentile significant wave height (i.e., the significant wave height exceeded 1% of the time) is 2.61 m.



☆ Wave Height and Direction ✕

Significant Wave Height : 1.22m
Peak Period : 13.4s
Direction : 191 deg

Significant Wave Height (99th) : 2.61m
Peak Period (99th) : 13.5s
Direction (99th) : 200 deg

Significant Wave Height (99.9th) : 3.31m
Peak Period (99.9th) : 15.2s
Direction (99.9th): 195 deg

Add to Results | View Additional Details

Figure 2.23 Wave climate output point in vicinity of study area (offshore from the Voss' Circuit site). Source: CoastKit, DEECA, accessed October 2023 (base map)

2.4.3.1 Winds

The closest weather station in the vicinity of the Voss' Circuit site that would be relevant is located at Aireys Inlet (located approximately 30 km south of the Voss' Circuit landing). Data has been collected from 1990 to the present day (2023) and a wind rose for this location has been provided in Figure 2.24.

The wind rose in Figure 2.24 suggests that Torquay beach predominantly experiences southerly winds, and less frequently experiences north-westerly and south-westerly winds. Due to the exposed position of Torquay beach to Bass Strait, Torquay beach is exposed to the southerly/south-westerly winds.

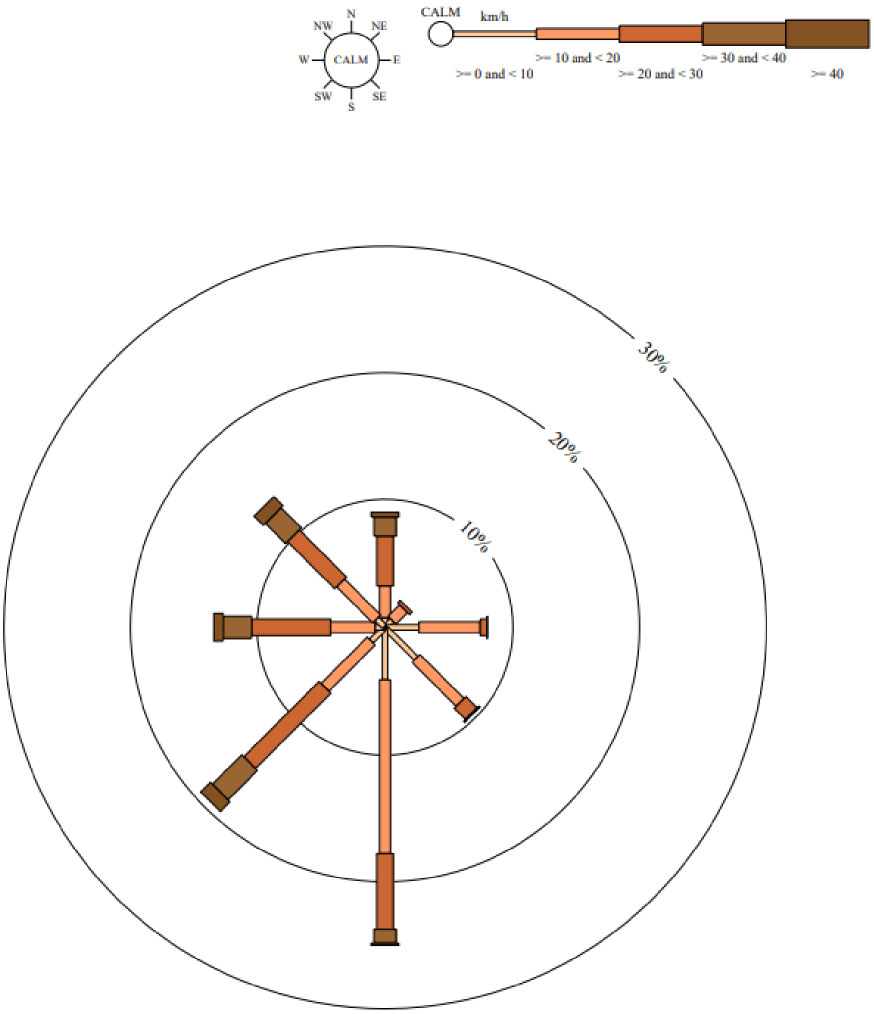


Figure 2.24 Wind rose of wind direction versus wind speed in km/h at Aireys Inlet weather station 1990-2023 (BOM, 2023)

2.4.4 Sediment properties and sediment transport

Geotechnical investigations and sediment sampling has not occurred as part of this study. The following information is based on a desktop study of the site.

2.4.4.1 Sediment properties

Torquay beach lies within the Torquay Basin which is centred in the Anglesea area towards the eastern end of the Otway Basin. It is primarily made up of Cainozoic sediments principally representing the Eastern View, Demons Bluff and Torquay formations (Geological Society of Australia, 2022).

Sediment sampled for a previous study at Torquay beach primarily comprised of very fine sand (< 0.5 mm) (Carvalho et al. 2022).

The marine route shallow water survey for segment 2.3 was conducted by EGS Australia on 5th to 7th March 2024 and covered the KP 1.86 in 22m water depth to Torquay Branching Unit (BU TQW) KP17.21 in 71m water depth. The route runs southeast along a seabed characterised by low relief rock with intermittent veneers of loose gravelly sand. Subcropping rock at <1m below seabed with local rock outcrops are present up to KP4.91 at 35.7m water depth. From KP4.91 to KP12.92 in 60.6m water depth, the seabed is primarily characterized by a veneer of loose gravelly sand with megaripples (wavelength <5m) over rock and veneer of loose sand over dense to very dense sand.

2.4.4.2 Geotechnical properties

Torquay beach is located within land mapped as belonging to the Western Plains geomorphological unit and more specifically the geomorphology of the area is classified as sedimentary derived dissected plains (Agriculture Victoria, 2023). The geology of the site is classified as Lower Cretaceous feldspathic sandstone and mudstone (Agriculture Victoria, 2023). The cliffs along the eastern great ocean road have been observed to be primarily comprised of soft rock cliffs, which are cliffs that are highly vulnerable to erosion and are therefore vulnerable to periodic cliff fall events (DEECA, 2023).

2.4.4.3 Sediment transport

The Voss' Circuit site is situated in the Surf Coast sediment compartment which spans from Point Lonsdale to Split Point. This stretch of the coast has been classified with a high coastal erosion rating in the Victorian Coastal Hazard Assessment, 2017. This section of the coast has some natural variability of the shoreline, however, has remained reasonably stable since 1988 as shown in Figure 2.27, where the shoreline has fluctuated within a range of approximately 20 m between 1988 – 2021. The coloured lines on Figure 2.27 represent annual shorelines at approximately mean sea level.

Onshore transport of sand to the beaches between Split Point and Breamlea are likely minimal, however, cross-shore sediment transport is likely due to the ongoing wave-driven transport of sand from the Bass Strait onto the large beaches either side of Barwon Heads (NCCARF, 2019). The sandy beaches within the Surf Coast sediment compartment are losing and gaining sand from alongshore drift from a south-west to north-east direction (NCCARF, 2019), which is illustrated in Figure 2.25.

Figure 2.25 *Surf Coast sediment compartment VIC03.02.01 (relevant to Voss' Circuit landing). Red arrows indicate likely dominant sand transport directions (largely swell driven). Source: (NCCARF, 2019)*

Figure 2.26 *Annual shorelines and rates of coastal change from 1988 – 2021 in the vicinity of the Voss' Circuit landing. Source: DEACoastlines, Geoscience Australia, accessed October 2023 (1:25,000 base map)*

Figure 2.27 Annual shorelines and rates of coastal change from 1988 – 2021 near the Voss' Circuit site. Source: DEACoastlines, Geoscience Australia, accessed December 2023 (1:2500 base map)

2.4.4.4 Erosion potential and depth of sediment mobility

The potential sea level rise discussed in section 2.4.2.4 will result in new areas of low-lying coastal land being exposed to inundation that occur during storm surges and storm tide events. This may contribute to the recession of the erodible coast and in particular cause the retreat of sandy and other unconsolidated coasts (Clifton et al. 2013).

Depth of closure marks the offshore limit of the active coastal zone and indicates the extent of erosion potential. There is little known information on depth of closure in the in the vicinity of the Voss' Circuit landing. Hence, it is important to note that seabed elevations at the time of submarine cable installation may vary from those recorded during the MRS.

2.5 Sydney Landing

2.5.1 Bathymetry and seabed conditions

The proposed Sydney route lands onto Broadarrow Reserve located behind Maroubra Beach. The nearshore bathymetry is shown below in Figure 2.28. For the Maroubra landing, the seabed reaches -50m depths over 2.70 km perpendicular to the shore or 1.8% gradient.

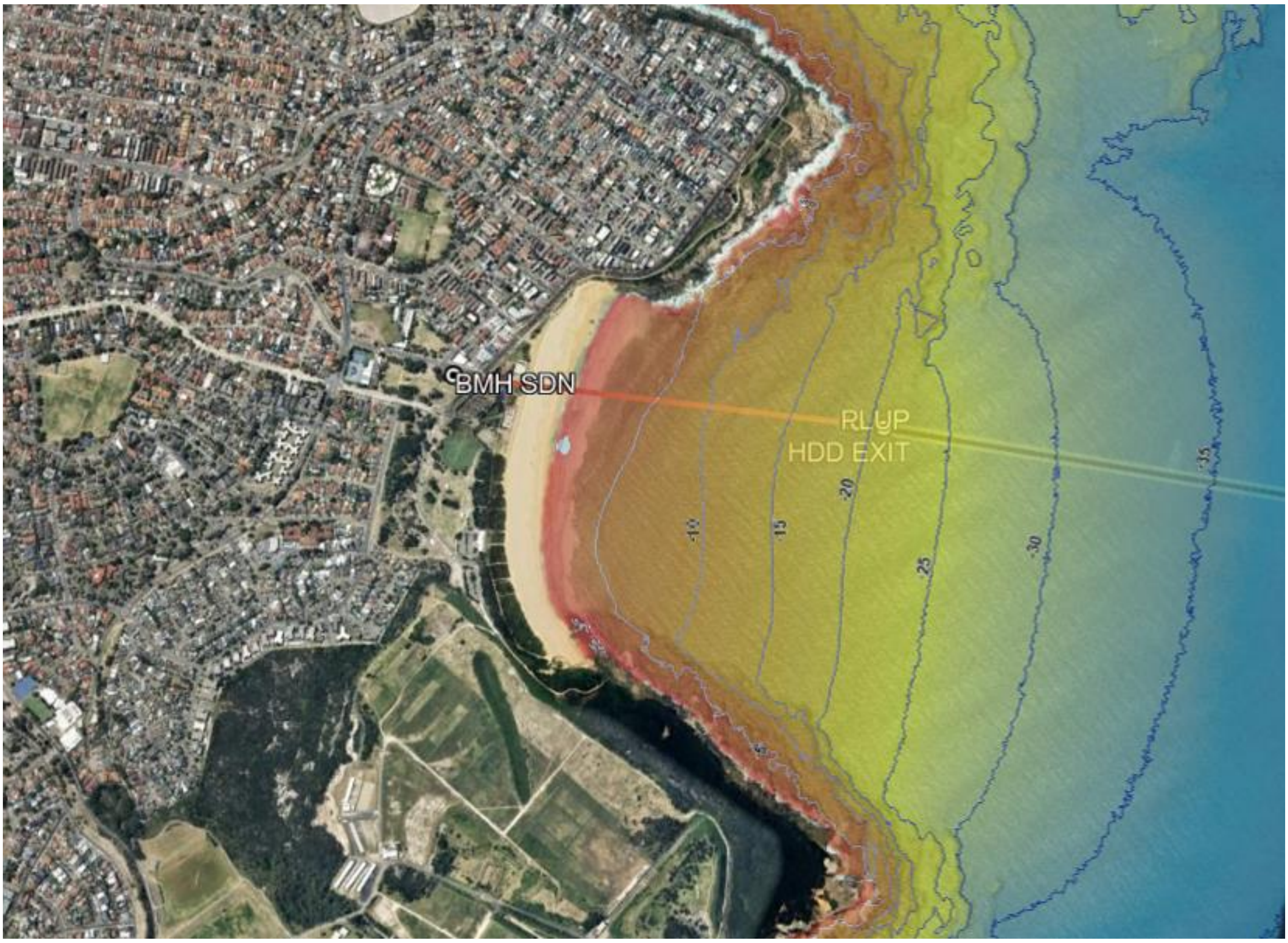


*Figure 2.28 **Bathymetry at Sydney Maroubra landing to -35m contour. Pink line depicts proposed route (GHD Esri maps overlaid with NSW Marine Lidar Bathymetry Data 2018 DEM [SEED, https://www.seed.nsw.gov.au]***

The Sydney landing is currently proposed outside of the SSCPZ due to the congestion within the SSCPZ. The multitude of existing cables within the SSCPZ has meant there is no space for additional submarine cables. As such, the cable proponent has decided to land the cable outside the zone.

The inshore marine survey for segment 2F was conducted by EGS Australia on 24th to 29th March 2024 and covered the KP657.34 in 16m water depth to KP655.68 in 43m water depth (the Handover Point). The route runs along a gentle to moderate slope (6 degrees) with a veneer of loose sand <1m over medium dense to very dense sand. Low to medium relief rock is observed within the marine route corridor, 100m northwards of proposed route, between KP657.00 to KP657.50. Possible seagrass / marine growth may be located at 150m southwards of KP657.36. A grab sample taken at KP657.33 in 19m water depth was observed as loose sandy sediment.

The proposed route does not cross any obstructions. However, it is noted there is a shipwreck located 227 m southward of KP657.88.

2.5.2 Water levels and currents

2.5.2.1 Astronomical tides

Astronomical tides are the daily rise and fall of sea levels caused by the combined effects of the rotation of the earth and the gravitational attraction between the earth, moon and the sun. Tides along the NSW coastline are semi diurnal, with high and low water approximately equally spaced in time and occurring twice daily (meaning on average, there are two high tides and two low tides in a 24-hour period). There is also significant diurnal inequality in NSW coast tides, a difference in height of the two high waters or the two low waters of each tidal day.

The tidal planes of relevance to Maroubra are provided in Table 2.9 below from Australian National Tide Tables 2023 based on the nearest tidal station in Botany Bay.

Table 2.9 Tidal planes at Botany Bay (Australian National Tide Tables 2023)

	Water level (m LAT)	Water level (m AHD)
Highest Astronomical Tide (HAT)	2.1	1.2
Mean Higher High Water (MHHW)	1.6	0.7
Mean Lower High Water (MLHW)	1.4	0.5
Mean Sea Level (MSL)	1.0	0.1
Mean Higher Low Water (MHLW)	0.6	-0.3
Mean Lower Low Water (MLLW)	0.4	-0.5

2.5.2.2 Storm tide (extreme water levels)

Storm surge in NSW occurs as a result of intense low-pressure systems offshore of the NSW coast. Storms originating over the Tasman Sea can produce strong winds and large waves superimposed on elevated water levels. Table 2.10 presents extreme water levels for typical Average Recurrence Intervals (ARI), derived from Fort Denison water level records (Watson & Lord, 2008).

Table 2.10 Extreme Water Levels in Sydney Harbour

Average Recurrence Interval (years)	Water level (m LAT)	Water level (m AHD)
20	2.36	1.38
50	2.40	1.42
100	2.42	1.44

2.5.2.3 Currents

Currents along and off the coast of NSW can be categorised into three main types:

- Tidal currents
- Large scale ocean current – East Australian Current (EAC)
- Wind induced surface currents / storm generated currents

Tidal currents are typically weak and vary between 0.1 to 0.3 m/s along the coastline. However, their magnitude can increase significantly near the entrance to estuaries and in the vicinity of coastal features and coastal headlands. Due to the configuration of Maroubra Bay, with a major headland to the North and South, tidal currents may be influenced to be stronger than the levels stated above.

The EAC is an ocean current that moves warm water from the tropical Coral Sea splitting from the south Equatorial Current down towards the east coast of Australia and meets the temperate waters of the Tasman Sea (Figure 2.29). The powerful flow of the EAC is about 100km wide and 300-500m deep and is typically stronger in summer than winter.

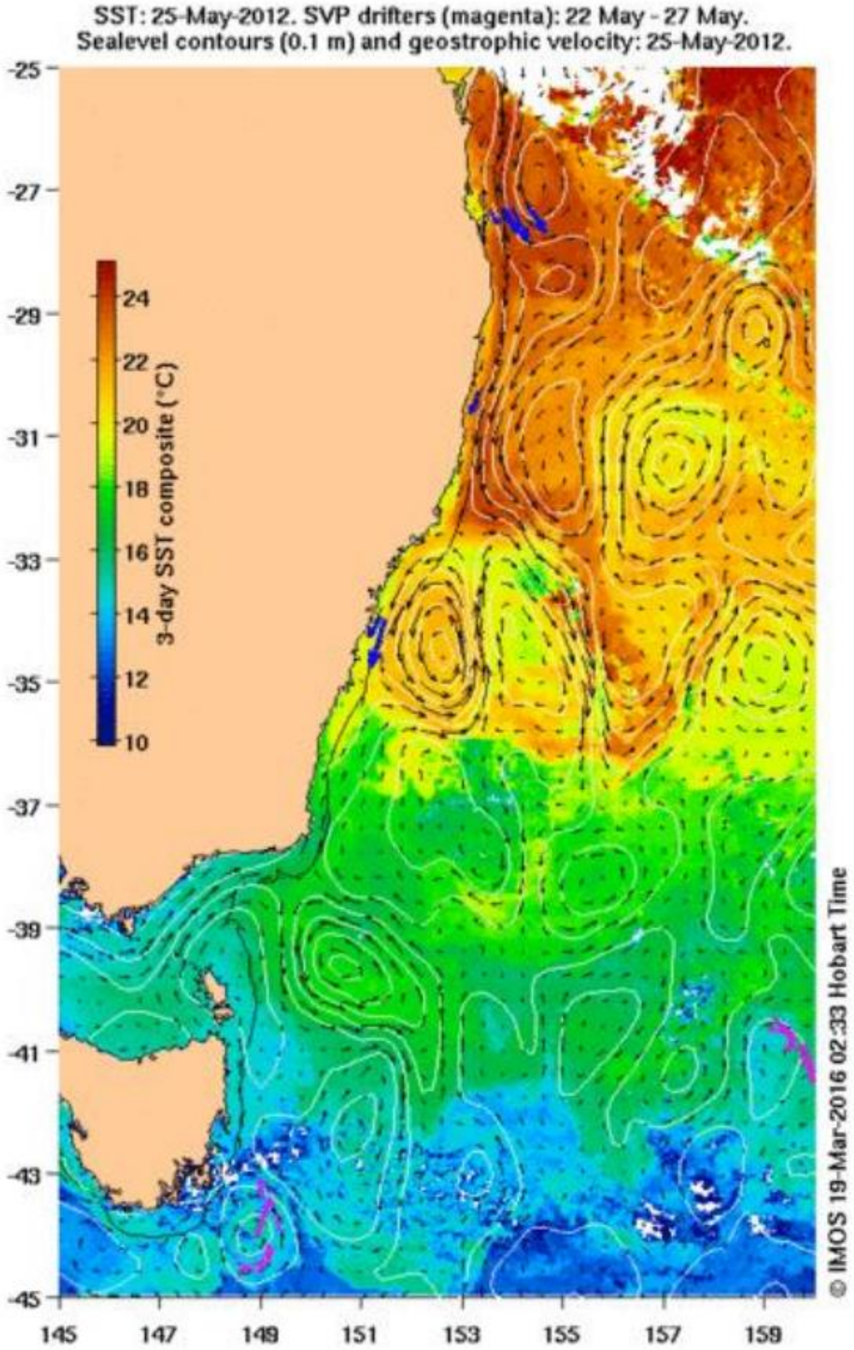


Figure 2.29 East Australian Current (IMOS, 2016)

2.5.2.4 Sea level rise

Using a 25-year design life for the SMAP system, a sea level rise projection for 2050 was estimated based on the IPCC Sixth Assessment Report for Shared Socioeconomic Pathway (SSP) scenario 8.5.

The projected sea level rise allowance for the Sydney landing site for 2050 is 0.23 m.

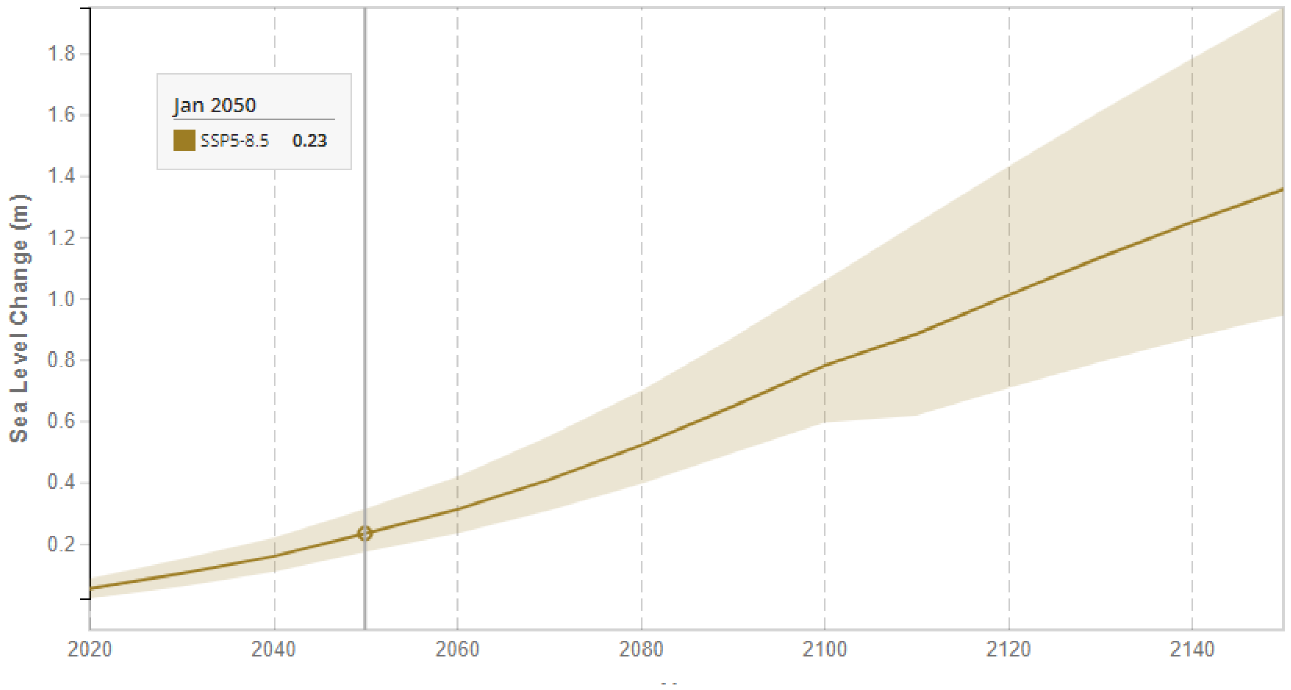


Figure 2.30 ***Projected sea level rise at Port Jackson (nearest to Sydney landing site) using Nasa sea level rise projection tool [Source: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?psmsl_id=216]***

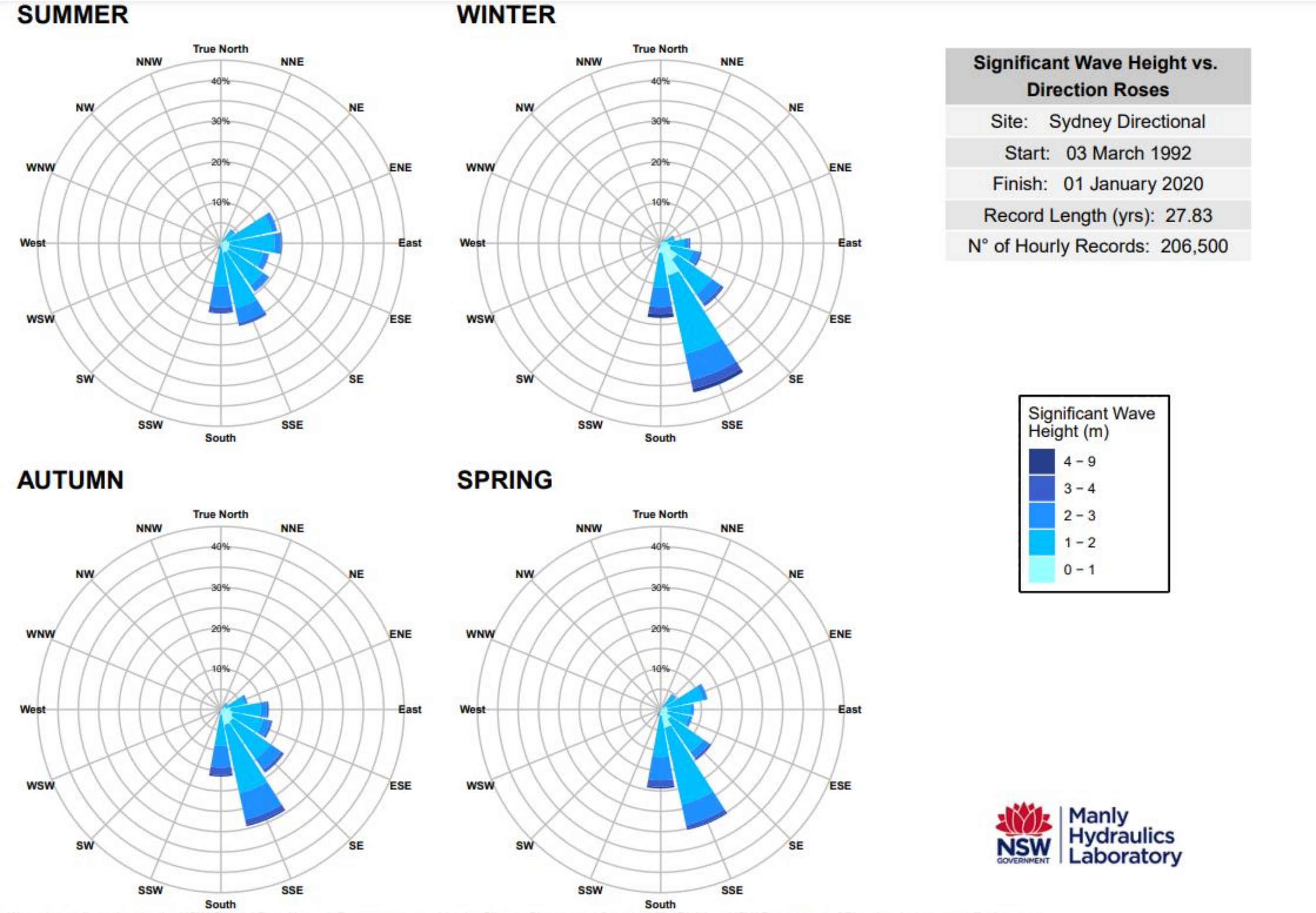
2.5.3 Wave climate

Significant wave heights at the Sydney waverider buoy (82 m – 90 m depth) was collected and analysed by Manly Hydraulics Lab between 1992 to 2019 (27 years of data). Table 2.11 below shows the percentage exceedance for significant wave height (m) at the Sydney waverider buoy. Seasonal wave roses for Sydney are presented in Figure 2.31.

Table 2.11 Percentage exceedance for significant wave height (m) sourced from Manly Hydraulics Lab

Monthly exceedance probability													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Hsig													
0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	**100.00**
0.50	99.97	99.99	100.00	99.89	99.57	99.68	99.63	99.43	99.96	99.84	99.94	99.94	**99.825**
1.00	87.91	90.03	89.94	83.91	77.68	81.04	76.73	75.33	81.32	86.39	86.24	85.74	**83.520**
1.50	44.70	49.14	50.53	46.79	48.06	51.81	44.89	42.00	42.79	47.03	45.25	44.21	**46.554**
2.00	17.22	21.82	24.59	24.62	27.31	30.26	24.35	21.57	19.77	20.62	20.10	17.81	**22.657**
2.50	6.67	9.45	11.64	10.90	13.11	17.45	13.27	11.23	9.10	9.28	9.00	6.74	**10.761**
3.00	3.15	3.59	5.85	5.46	6.47	10.27	6.98	6.09	4.02	4.58	4.35	2.67	**5.359**
3.50	1.36	1.21	2.78	2.87	2.45	5.99	3.69	3.23	1.74	2.12	2.26	1.00	**2.603**
4.00	0.49	0.43	0.93	1.45	1.06	3.33	2.15	1.99	0.83	0.96	1.01	0.37	**1.280**
4.50	0.14	0.17	0.38	0.74	0.57	1.74	1.19	0.97	0.41	0.39	0.50	0.11	**0.624**
5.00	0.00	0.03	0.21	0.38	0.42	1.01	0.52	0.46	0.11	0.16	0.23	0.02	**0.305**
5.50	0.00	0.01	0.12	0.23	0.24	0.64	0.24	0.18	0.05	0.10	0.10	0.00	**0.165**
6.00	0.00	0.00	0.05	0.16	0.12	0.32	0.12	0.04	0.01	0.02	0.02	0.00	**0.074**
6.50	0.00	0.00	0.01	0.10	0.09	0.09	0.04	0.00	0.00	0.00	0.00	0.00	**0.028**
7.00	0.00	0.00	0.00	0.00	0.07	0.07	0.05	0.00	0.00	0.00	0.00	0.00	**0.015**
7.50	0.00	0.00	0.00	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.006**
8.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.002**
8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.000**
Monthly statistics													
Minimum	0.48	0.50	0.52	0.38	0.38	0.39	0.39	0.40	0.45	0.40	0.38	0.42	**0.38**
Average	1.56	1.63	1.69	1.64	1.64	1.64	1.77	1.62	1.56	1.55	1.60	1.54	**1.62**
Maximum	4.95	5.53	6.61	8.06	8.43	7.76	6.96	6.41	6.18	6.17	6.22	5.49	**8.43**
Number of data points used for statistical analysis													
No. points	15,826	14,506	16,913	17,188	17,573	17,385	18,976	17,941	17,480	18,221	16,927	17,571	**206,507**
Percent capture based on nominated start finish													
% capture	82.21	82.74	83.84	88.14	87.01	87.87	92.78	87.62	88.62	90.78	87.22	87.78	**87.28**

As waves approach the shore they may be transformed by the processes of refraction, shoaling, diffraction, attenuation, reflection and breaking. Therefore, the wave height and wave direction of the nearshore wave climate differs from the offshore wave climate, with wave period generally remaining constant. An online tool has been developed on behalf of the NSW Government which transfers the offshore wave height into 30m and 10m contours and is accessible via **www.nswaves.com.au**. It is recommended that this tool be used to monitor forecast conditions at the time of submarine cable installation.



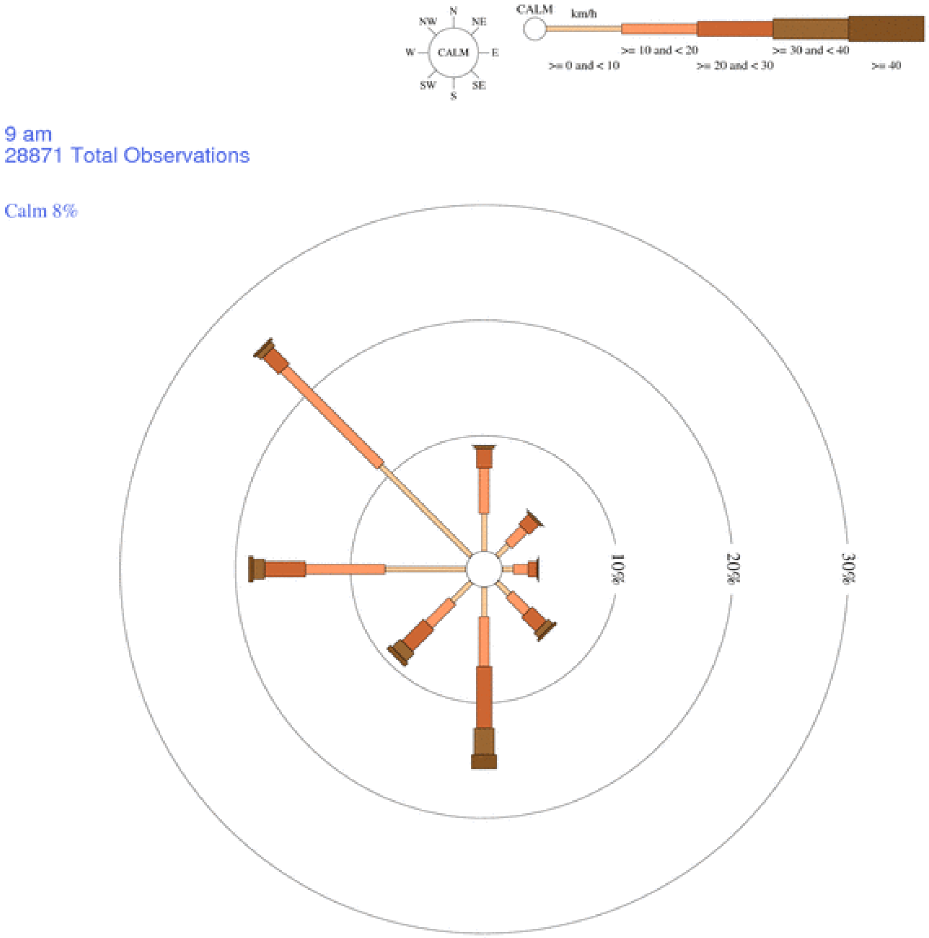
Significant Wave Height vs. Direction Roses	
Site:	Sydney Directional
Start:	03 March 1992
Finish:	01 January 2020
Record Length (yrs):	27.83
N° of Hourly Records:	206,500

Wave data collected under the NSW Coastal Data Network Program managed by the Climate Change and Sustainability Division, NSW Department of Planning, Industry and Environment

Figure 2.31 Seasonal significant wave heights and direction sourced from Manly Hydraulics Lab

2.5.3.1 Winds

The nearest wind rose relevant to the Sydney site is Sydney airport (4.4km distance) weather station. The wind rose in Figure 2.32 suggests that Maroubra Beach predominantly experiences north-westerly winds. Maroubra beach also receives some protection from southerly/south-easterly winds due to the presence of Headlands immediately to the southeast of the beach.



Australian Government
Bureau of Meteorology

Figure 2.32 *Windrose data from Sydney airport weather station from 1939 to 2019 (Source: Bureau of Meteorology)*

2.5.4 Sediment properties and sediment transport

2.5.4.1 Sediment properties

The Sydney coastline is dominated by prominent Triassic sandstone cliffs (Hawkesbury sandstone) that cut into deeply embayed pocket beaches like at the Sydney landing site at Maroubra beach. Maroubra beach is a deeply embayed beach set back between two headlands, 1500m from Magic Point and Boora Point to the south and 500m from Mistral Point to the north (Geomarine, 1993). Maroubra beach comprise of medium, quartzose-rich beach sands.

The inshore marine survey for segment 2F was conducted by EGS Australia on 24th to 29th March 2024 and covered the KP657.34 in 16m water depth to KP655.68 in 43m water depth (the Handover Point). The route runs along a gentle to moderate slope (6 degrees) with a veneer of loose sand <1m over medium dense to very dense sand. Low to medium relief rock is observed within the marine route corridor, 100m northwards of proposed route, between KP657.00 to KP657.50. Possible seagrass / marine growth may be located at 150m southwards of KP657.36. A grab sample taken at KP657.33 in 19m water depth was observed as loose sandy sediment.

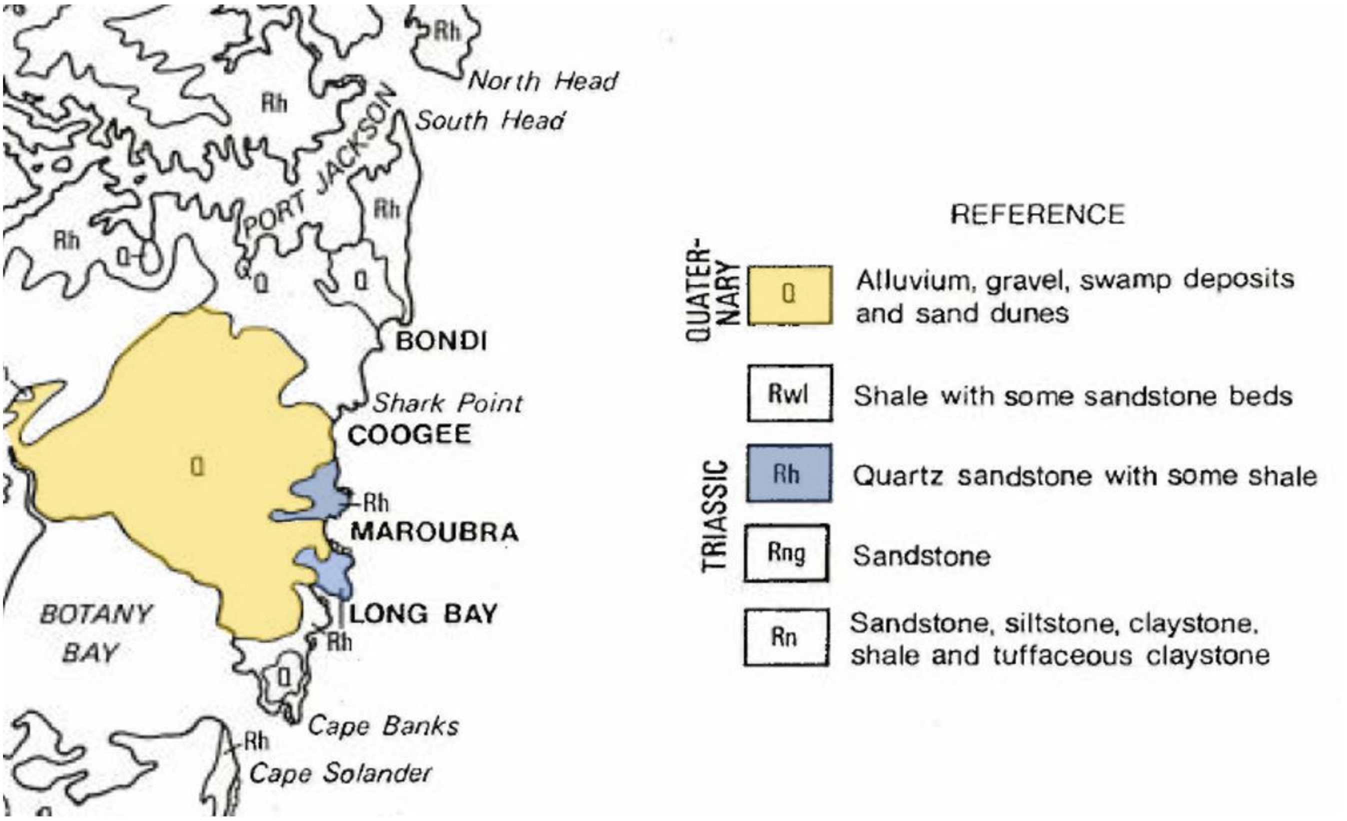


Figure 2.33 Geology of Sydney landing site in Maroubra [Source: Geomarine 1993]

2.5.4.2 Sediment transport

Maroubra foredune is quite large at 1100m in length compared to other beaches along this section of coast. It is a moderate energy intermediate beach with medium, quartzose-rich beach sands. With major sandstone headlands to the north and south the overall configuration of Maroubra suggest it is a closed system. Generally, there are no net long term losses or gains to the sand supply of the system, and that the quantity of sand available for onshore and offshore movement is fixed. The beach and foredune system form a stationary barrier (Geomarine, 1993).

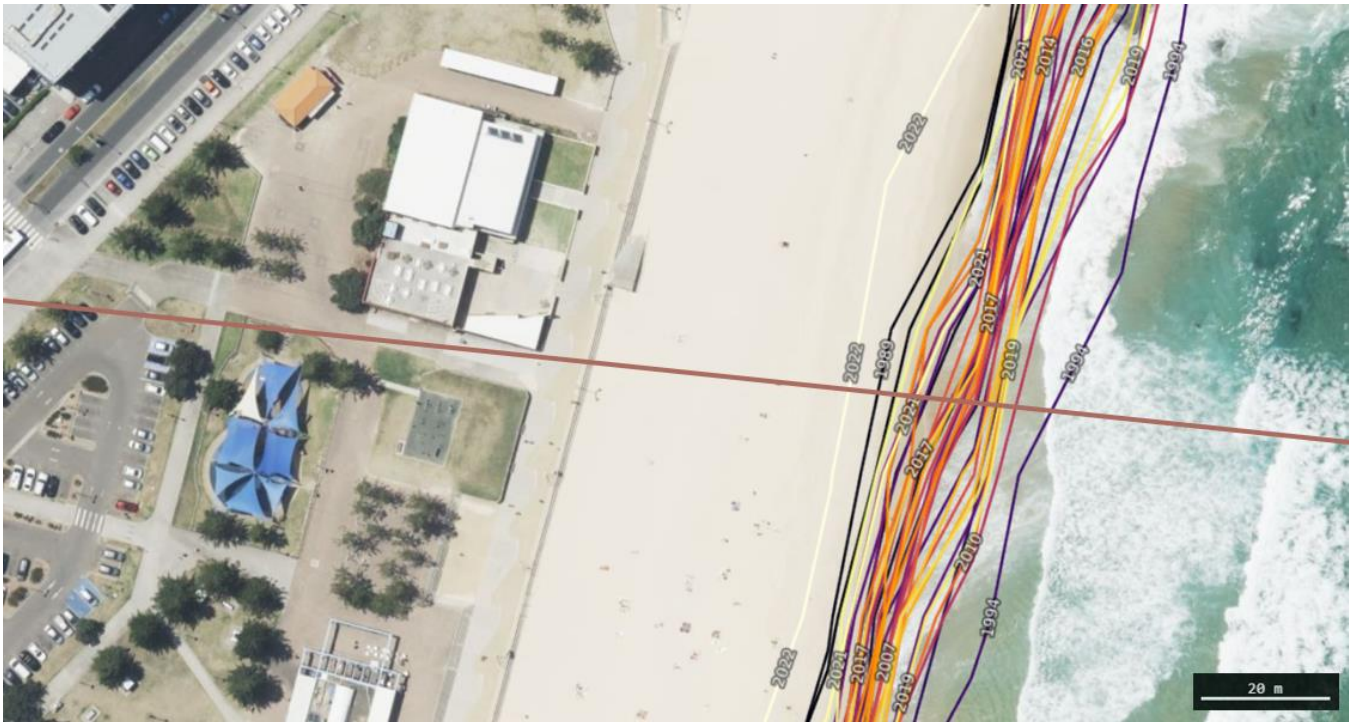


Figure 2.34 ***Annual shorelines and rates of coastal change from 1988-2022 near Broadarrow Reserve landing site with cable route overlaid. Source: DEACoastlines, Geoscience Australia, accessed October 2023***

2.5.4.3 Erosion potential and depth of sediment mobility

The nearshore portion of the seabed is potential prone to erosion and accretion within the Depth of Closure (DoC) which marks the offshore limit of the active coastal zone. It is important to note that the depth of closure does not define the absolute limit of sediment movement rather the seaward point at which there is no significant movement of sediment in relation to beach erosion and accretion cycles.

Gordon (1987) summarised beach erosion in terms of storm recurrence for different beach types in NSW. Although over 30 years old, this information still captures a large NSW dataset which remains useful and applicable. Gordon (1987) determined the maximum vertical movement in sandy nearshore profiles for the NSW coast based on 10 years of survey, seabed data and Hallermeier’s depth of closure. The results of this study are presented in Table 2.12.

Nielsen (1984 a, b) has undertaken a similar investigation based on the measurements of beach profiles and identified the maximum seabed variation expected for selected water depth, which is described in Table 2.13.

Both Gordon and Nielsen indicate that the limit of change in seabed level due to storm events is in the order of 30m below man sea level.

Based on further analysis, Nielsen (1994) defined the offshore limit of significant wave breaking and significant beach fluctuations for south-east Australia as -12m AHD (+/- 4m).

Hence, it is important to note that seabed elevations at the time of submarine cable installation may vary from those recorded during the MRS.

Table 2.12 Estimated maximum vertical movement in a sandy nearshore seabed profile along NSW Coastline (Gordon, 1987)

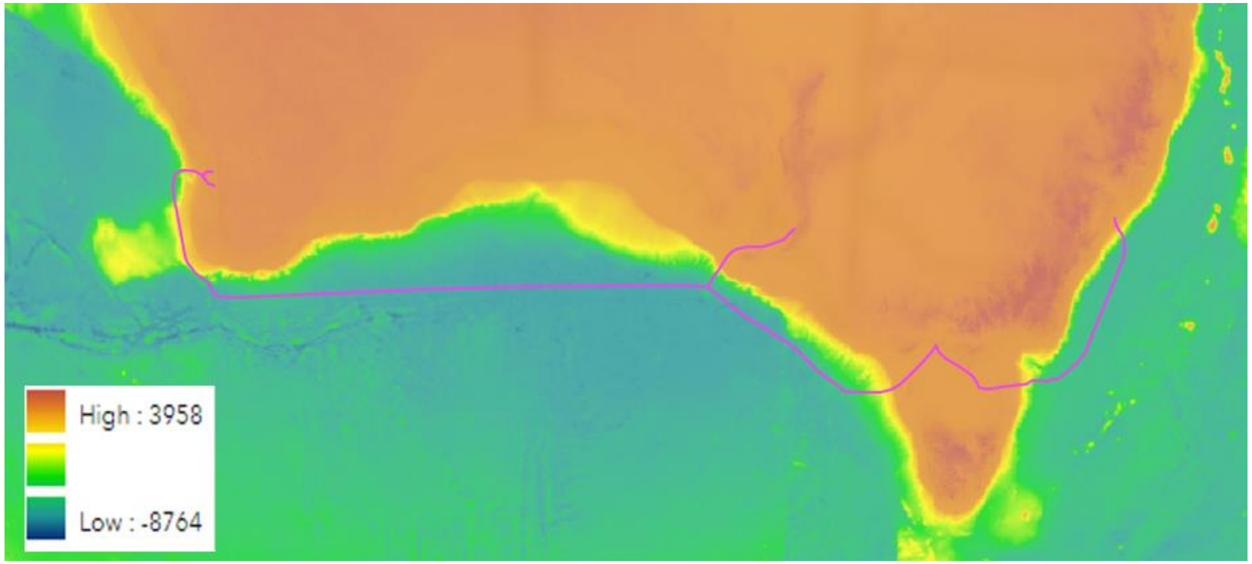
Seabed Level (m AHD)	Maximum vertical movement of profile (m)
+5	5
0	4
-5	2.5
-10	1.7
-20	0.6
-30	0.25

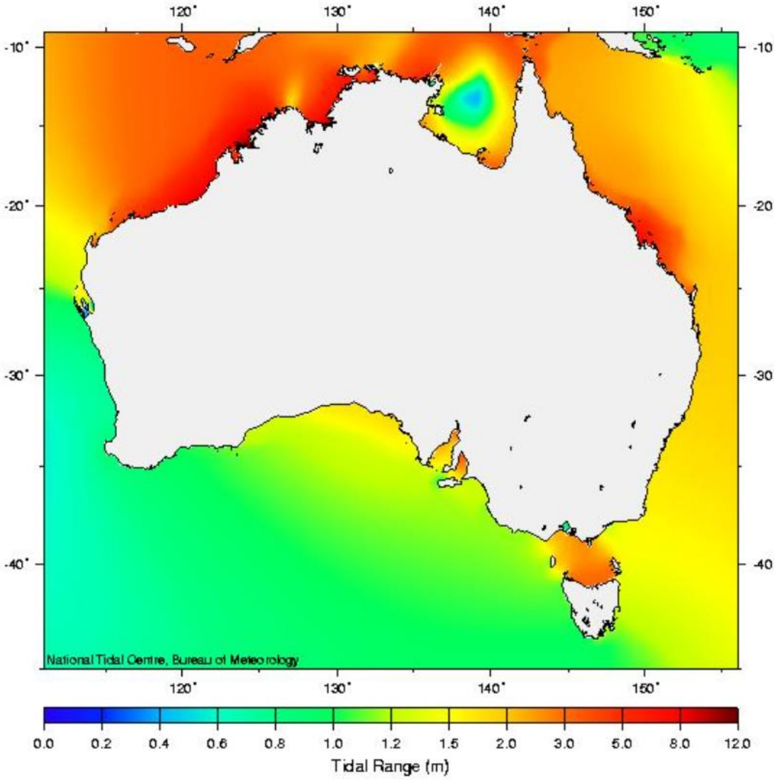
Table 2.13 Maximum Seabed Variation at NSW Beaches (Nielsen 1984a, b)

Water Depth (m)	Maximum vertical movement of profile (m)
5	>3.5
10	3.5
15	0.2
20	0.15
25	0.1

2.6 Deep water

The physical environments within the vicinity of the landings are described in sections 2.1 to 2.5. This section describes the physical environment in the deeper water of the proposed cable route.

Coastal Factors	Perth (CPZ) landing to Perth Garden Island landing	Perth (CPZ) landing to South Australia	South Australia landing to Victoria landing	Victoria landing to Sydney landing
Bathymetry and seabed conditions				
Bathymetry	 *Figure 2.35 Bathymetry for deep water sections of the cable. Purple line depicts proposed route (GHD Esri maps overlaid with Geosciences 2009 Bathymetry Data) Australian bathymetry mapping (Source: Geosciences, 2016)* The proposed cable route lies in water depths up to 5,000 m. The route crosses the Australian continental shelf, with the edge of the continental shelf being marked by an abrupt slope over a distance of approximately 25 km where the depth changes from approximately 60 m to approximately 2,000 metres.			
Seabed conditions	The marine geomorphic features that the route traverses include shelf and slope.	The marine geomorphic features that the route traverses include deep hole/valley, basin, shelf, canyon, slope, deep ocean floor and continental rise.	The marine geomorphic features that the route traverses include escarpment, deep hole/valley, canyon, slope, deep ocean floor, shelf and basin.	The marine geomorphic features that the route traverses include shelf, deep hole/valley, escarpment, basin, plateau, tidal sandbank, apron, canyon, and deep ocean floor.

Coastal Factors	Perth (CPZ) landing to Perth Garden Island landing	Perth (CPZ) landing to South Australia	South Australia landing to Victoria landing	Victoria landing to Sydney landing
Water levels and currents				
Tidal Range	 *Figure 2.36 Average tidal range at spring tides around Australia (BoM 2018)*		There are numerous sources that contribute to the variation in tidal range, including the response of the ocean to astronomical tides, and the shape and depth of the seabed.	
	Due to the proximity of the Garden Island and Perth landing, the tidal range along the route does not have a high degree of variability and remains relatively stable.	The average tidal range varies along this length of the route, with the largest tidal range for this section being within the Gulf of St Vincent and some parts of the Great Australian Bite.	The average tidal range varies along this length of the route, with the largest tidal range for this section being within the Gulf of St Vincent.	The average tidal range varies along this length of the route, with the largest tidal range for this section being in Bass Strait.

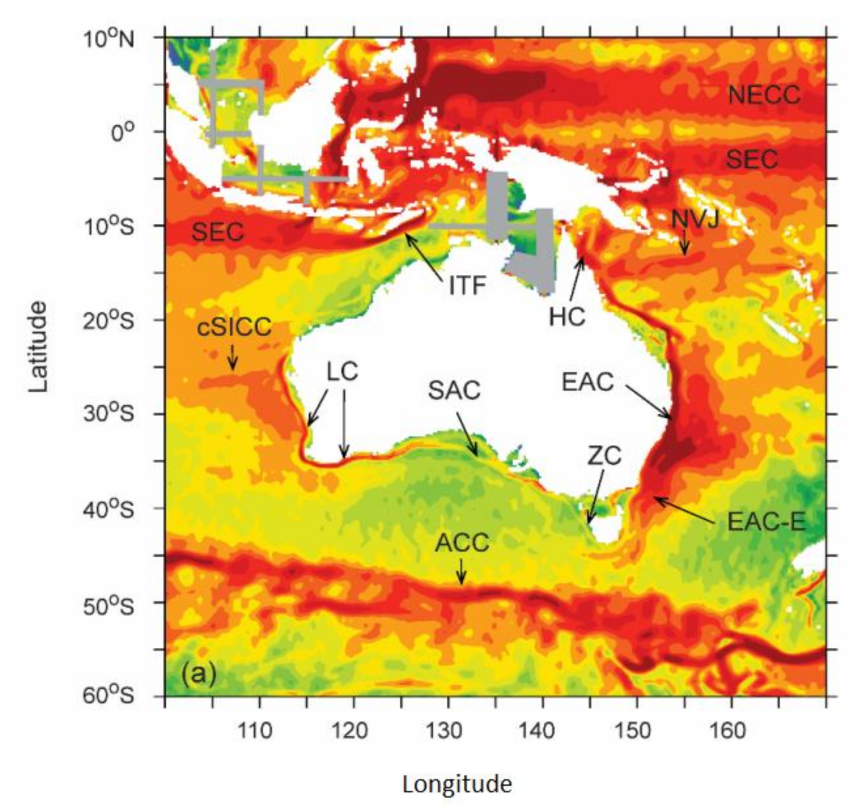
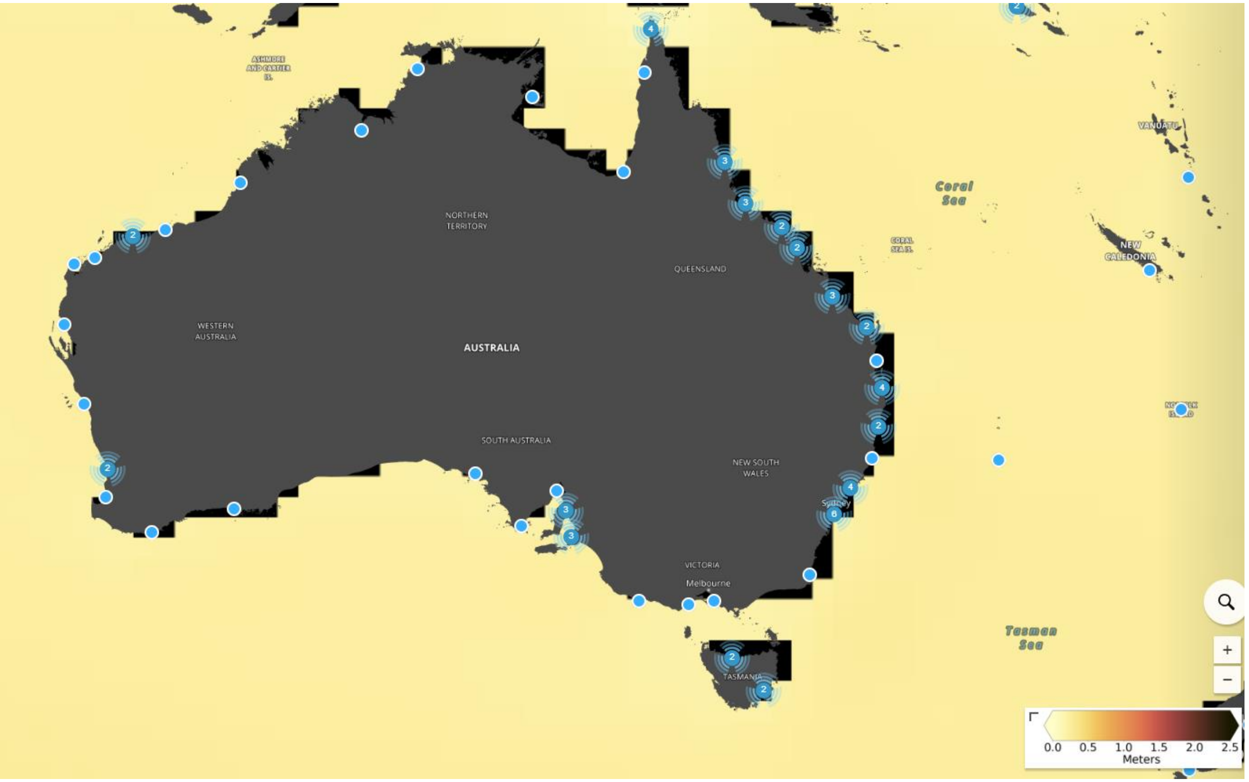
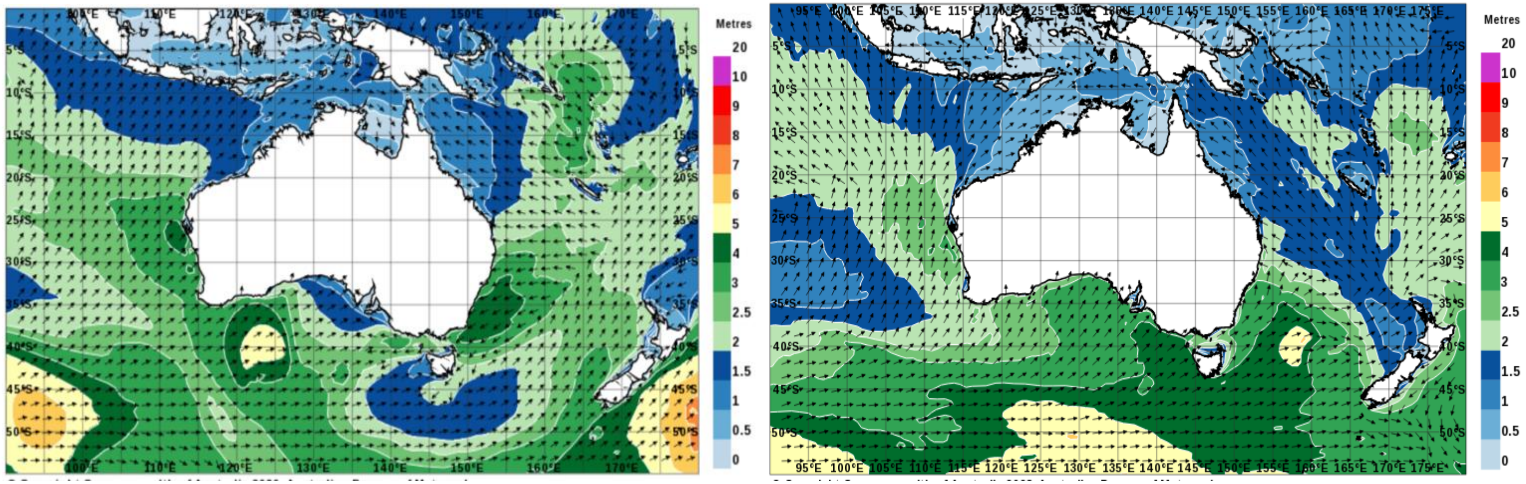
<table>
<tr><th>Coastal Factors</th><th>Perth (CPZ) landing to Perth Garden Island landing</th><th>Perth (CPZ) landing to South Australia</th><th>South Australia landing to Victoria landing</th><th>Victoria landing to Sydney landing</th></tr>
<tr><td rowspan="2">Currents</td><td colspan="2">

Figure 2.37 Mean kinetic energy for oceans around Australia 1993-2018 (Pattriaratchi & Siji, 2020)</td><td colspan="2">Mean kinetic energy for the oceans around Australia over the period 1993-2018 are included in Figure 2.37. The current systems shown in Figure 2.37:
– ITF= Indonesian Throughflow
– SEC=South Equatorial Current
– HLC=Holloway Current
– LC=Leeuwin Current
– cSICC= central South Indian Counter Current
– ACC=Antarctic Circumpolar Current
– SAC=South Australian Current
– EAC=East Australian Current
– EAC-E=East Australian Current Extension
– NVJ=North Vanuatu Jet
– HC=Hiri Current
– NECC=North Equatorial Counter Current
– ZC = Zeehan Current.</td></tr>
<tr><td>The large-scale ocean current that will have the biggest effect along this route is the Leeuwin Current (LC).</td><td>The large-scale ocean current that will have the biggest effect along this route is the South Australian Current (SAC) and the Leeuwin Current (LC).</td><td>The large-scale ocean current that will have the biggest effect along this route is the South Australian Current (SAC) and the Zeehan Current (ZC).</td><td>The large-scale ocean current that will have the biggest effect along this route is the East Australian Current (EAC).</td></tr>
</table>

Coastal Factors	Perth (CPZ) landing to Perth Garden Island landing	Perth (CPZ) landing to South Australia	South Australia landing to Victoria landing	Victoria landing to Sydney landing
Sea level rise	 *Figure 2.38 Projected sea level rise between landing sites using Nasa sea level rise projection tool [Source: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool]* The projected sea level rise along the cable route is 0.23 m (all other landings).			

<table>
<tr><th>Coastal Factors</th><th>Perth (CPZ) landing to Perth Garden Island landing</th><th>Perth (CPZ) landing to South Australia</th><th>South Australia landing to Victoria landing</th><th>Victoria landing to Sydney landing</th></tr>
<tr><td colspan="5">Waves</td></tr>
<tr><td rowspan="2">Wave Climate</td><td colspan="4">
***Figure 2.39** (LEFT) National total wave height and direction taken during summer months & (RIGHT) National total wave height and direction taking during winter months (BoM, 2022).*</td></tr>
<tr><td>Continental shelf waves (CSW) are active along the Western Australian coast, which are a form of coastally trapped wave that travels parallel to the coast with maximum amplitude at the coast and decreasing offshore. Along the Western Australian coastline, CSWs are produced through the passage of mid-latitude low-pressure systems and tropical cyclones.
Tropical cyclones are a key driver of the wave climate along the west and south coasts of Western Australia, as every tropical cyclone has historically either produce a CSW or southward propagating sea level signal.</td><td colspan="2">Waves generated in proximity to the Gulf to St Vincent via wind are low to medium energy due to the enclosed nature of the Gulf, however, significant wave energy is able to enter into the Gulf from the Southern Ocean (Hemer and Bye, 1999). The wave climate within the Gulf of St. Vincent is heavily influenced by the swell generated from the Southern Ocean, with the dominant swell direction at this location being from the south-west (SARDI, 2023).
The wave climate within the Bass Strait is driven primarily by the dominant Southern Ocean swell. Peak wave direction has been observed to shift from south-westerly in the winter months to south-easterly in the summary months (Liu et al., 2022).</td><td>The south-eastern Australian continental shelf predominantly experiences a marginal sea wave climate driven by weather systems in or near to the Tasman Sea (Mortlock & Goodwin, 2015). Swells, such as those generated in the Southern Ocean, are largely not felt. Along the south-eastern continental shelf, five to six synoptic-scale wave climates prevail, including Tropical Cyclones, Tropical Lows, Anti-cyclonic Intensification, East Coast Lows, Southern Tasman Lows and Southern Secondary Lows.</td></tr>
</table>

Coastal Factors	Perth (CPZ) landing to Perth Garden Island landing	Perth (CPZ) landing to South Australia	South Australia landing to Victoria landing	Victoria landing to Sydney landing
Sediment properties and sediment transport				
Sediment properties	The characteristics of sediments in deep water regions of the Australian continental shelf which experience minimal sediment mobility are contended. Porter-Smith et al. (2004) describe these sediments as coarse-grained, calcareous and having a low mud content, but this contradicts the conventional graded shelf model which suggests that sediment mud content increases seaward.			
Geotechnical properties	For the cable route, the Bassian Rise is a notable metamorphic and crystalline underwater plateau which sits on the eastern margin of the Bass Strait (Murray-Wallace, 2014). The Bass Canyon is another important geological feature that lies southward off the East Gippsland coastline – it is 60 km long, 10-15 km wide and has canyon head walls 1000 m high.			
Sediment transport	Waves in deep water (depths greater than 5,000 m) in the Tasman Sea rapidly shoal to approximately 100 m at the East Australian shelf (Mortlock & Goodwin, 2015). This process creates a high-energy nearshore wave climate and wave-dominated sediment transport as offshore wave energy is preserved throughout movement across the shelf. The combined influences of wave and tidal current can mobilise and transport quartz grains in deep water (Porter-Smith et al., 2004). Sea level variations also influence absolute sediment transport intensity under combined flows. Tidal currents are strong enough to mobilise finer sediments, such as silt and fine sand, over northern and north-eastern sections of the shelf, including Bass Strait. Taking into account wave height, wave period and tidal current speed over a semi-lunar cycle, mobilisation of unconsolidated sediment on the Australian continental shelf from tidal currents is estimated to occur on 41% of the shelf. Approximately 27% of the Australian continental shelf experiences minimal sediment mobility, which may be low-energy depositional zones.			

2.7 Natural hazards

2.7.1 Cyclones

An average of approximately 11 tropical cyclones form or move over Australia every year, with around four of these systems making landfall. The frequency of tropical cyclones varies year-on-year due to naturally occurring climate drivers, such as El Nino Southern Oscillation.

While tropical cyclones do not impact NSW very often, they have caused flooding, destructive winds, storm surges and loss of life. When a tropical cyclone is in effect in NSW, the Tropical Cyclone Warning Centre (TCWC) will issue a Tropical Cyclone Advice for NSW and a Tropical Cyclone Forecast Track Map will be issued by the BoM.

Like NSW, tropical cyclones do not impact Victoria very often. Trends on the climatological characteristics of tropical cyclones from 1980 to 2009 for Australia's eastern basin (in which Victoria lies), suggest that there is an average of 2.9 cyclones per season (Chand et al., 2019). Over the past two climatological periods, the eastern basin has experienced a decrease in the overall cyclone days, mainly due to a decrease in the number of cyclones which have occurred. Out of the cyclones which have occurred, the proportion of severe cyclones has increased substantially.

The northern coastal region of WA, particularly Broome to Exmouth, is a notably cyclone-prone region of Australia. The area between Whim Creek and Marie is an area of high risk. Tropical cyclones which impact WA often generate strong winds, large and swell, and severe flooding from heavy rainfall and high storm surges. The Indian Ocean Dipole and Southern Annular Mode have significant influence on the occurrence of strong tropical cyclones over WA.

Projections suggest that in the future, the number of tropical cyclones experienced over Australia per year may decrease by 2100 due to climate change. However, the intensity of cyclones which do occur are expected to increase. Tropical cyclones may also track further south.

In contrast with WA, South Australia (SA) is more likely to experience a mid-latitude cyclone (Burns et al., 2016) compared to the tropical cyclones that regularly impact northern Australia and the eastern coast of the continent. The most recent mid-latitude cyclone that hit South Australia, Adelaide included, was in September 2016 and caused statewide power outages (Burns et al., 2016, BoM 2016). The damage from these mid-latitude cyclones are caused by sever super cell thunderstorm outbreaks which can also result in the formation of tornados (BoM 2016). Worsening impacts resulting from these weather systems has been potentially attributed to increased ocean temperatures resulting from climate change (Pepler 2015).

2.7.2 Earthquakes

Lines of earthquakes to the south and west of Australia occur along the mid-ocean ridges, which are centres of seafloor spreading. Earthquakes to the east and north of Australia are at destructive plate boundaries, where subduction of the sea floor occurs. NSW is far removed from any tectonic plate boundaries. However, there is a pocket of intra-plate earthquake activity.

Earthquakes have historically occurred predominantly along the convergent plate boundaries in the region, while earthquakes within the Australian Plate are very rare and with shallow focal depths.

Although Victoria experiences earthquakes periodically, they are typically relatively low in magnitude. No earthquakes of a magnitude of 6 or above have occurred in Victoria since the early 1800s (McCue, 2015). A 5.9 magnitude earthquake was recorded in September 2021 with an epicentre north of Rawson, which is approximately 190 km north-east of the Voss' Circuit landing. Historically, two of the most destructive Victorian earthquakes occurred in April and July 1903 near Warrnambool which is over 210 km west of the Voss' Circuit landing. These earthquakes were of magnitudes of 4.9 and 5.3, respectively. Victoria records approximately 100 small earthquakes per year, excluding aftershocks. This may be partially attributable to comprehensive recording as Victoria has the highest density of seismographs of any state or territory in Australia.

Certain regions of WA exhibit notably high levels of seismic activity compared to most other regions in Australia. Earthquakes which have occurred in the wheat-belt region of WA, such as the Meckering Earthquake of 1968 and Cadoux Earthquake of 1979 are examples of this. In WA, earthquakes typically form spatial clusters which do not seem to be correlated to rock type or geology. Trends of historical earthquakes which have occurred between 1990-2016 in southwestern WA suggest that earthquake occurrence has clustered in an area west of Burakin, approximately 250 km northeast of Perth. More broadly, earthquake clusters have historically occurred within the Yilgarn Craton which is a region between Yandanooka and Cape Riche.

Earthquakes within SA have been observed since European settlement of the state, with hundreds of earthquake events recorded both before and after the first seismograph was installed in Adelaide in 1909 (McCue 2012). Southeast Australia and the Flinders Ranges have the highest rates of seismicity within the Australian continent (King, 2019), with the largest earthquake recorded in SA 1897 reaching a magnitude of 6.5. The main seismic zone within SA has been noted to extend from Kangaroo Island northward through the Mt Lofty and Flinders Ranges with lateral branches south-west along the Eyre Peninsula (Love et al., 2011). The SA landing is located within this seismic zone and may be impacted by the occurrence of future earthquakes.

2.7.3 Tsunami

Tsunamis are large waves produced by an earthquake or a submarine landslide. They can travel thousands of kilometres across open ocean and cause destruction on distant coastlines hours after the earthquake has passed.

Somerville et al. (2009) has undertaken a study on the Tsunami risk assessment along the NSW coast which has led to the following conclusions:

- At short return periods (500 years or less), the tsunami hazard along the NSW coast is dominated by earthquake sources
- The coast of NSW has a moderate tsunami hazard level with direct exposure to subduction zones in the Pacific Ocean. The hazard is relatively uniform along the NSW coast, with near shore wave amplitude values for and ARI of 500 years ranging from about 0.5 to 1.1m, reaching approximately 0.8m off Sydney. The main contributors to the hazard at this return period come from earthquakes on the Vanuatu, Kermadec, and Puysegur trenches.
- The tsunami wave amplitude hazard level increases gradually with return period, but the vulnerability increases rapidly with return period since small increases in wave amplitude will expose large numbers of additional properties to inundation
- At low probability levels (ARI much longer than 500 years), it is expected that tsunami sources other than earthquakes would potentially have the greatest impact. In this case local landslides, large scale collapse of volcanic islands at regional distances, and asteroid impacts could produce tsunamis much larger than those caused by earthquakes. The impacts from landslides would be local, but those from the low-likelihood large scale collapse of volcanic islands or from asteroid impacts would be widespread.

Since European settlement, the BoM has only recorded four tsunami events which have affected Victoria. These occurred in 1868, 1960, 2004 and 2006.

The northwest coast of WA is more likely than the east or southwest coast to experience a tsunami event due to its proximity to the Indonesia tectonic plate boundary which has a long seismically active fault line. Relative to other regions of Australia, WA experiences a high frequency of tsunamis from earthquakes along the Sunda Arc, south of Indonesia. A notable example is the 2004 Indian Ocean earthquake-tsunami event where the western Sunda Arc generated a magnitude 9.1 undersea earthquake and tsunami that created significant tidal surges and strong currents that caused localised inundation along towns on the WA coastline.

Based on a global analysis of Tsunami risk, the location of the SA landing has been assigned a medium hazard level in relation to potential impacts from a Tsunami (Løvholt et al., 2015). This means that within the next 50 years there is more than a 10% chance of a potentially damaging Tsunami occurring at the SA landing. According to past tsunami events recorded by BoM (BoM, 2023), only 4 tsunamis have impacted SA since European settlement. The geographic nature of the Gulf of St Vincent affords the SA landing a significant amount of shelter from potential future tsunamis as the coastal areas of Adelaide are not exposed to the open ocean. In order for future tsunami events to impact the proposed SA landing, waves coming from the west would have to get through the Yorke Peninsula and Kangaroo Island, and similarly anything coming from the south would need to get past Victor Harbor and Kangaroo Island. As such, the likelihood of future tsunamis impacting the proposed SA landing are not high.

2.7.4 Geological features

Geological features such as submarine volcanoes, seamounts and fault lines may be encountered along the submarine cable installation route. One of the objectives of the MRS was to reveal any of these, in order for these to be avoided by the future cable route.

Following review of the MRS findings for Sydney, Torquay, Perth, and Adelaide, no significant geological features were identified that would require realignment of the cable route.

3. Potential impacts and mitigation measures

The potential physical environment impacts from submarine cable installation are provided in the table below, along with applicable mitigation measures. Potential impacts and mitigation measures associated with commercial fisheries, shipping and anchorage, dumping, dredging and reclamation, shipwrecks and aircraft wrecks and other cable projects are described in Appendix C (Other Environmental Issues). In addition, Appendix D (Impact Assessment) addresses impacts and mitigation measures associated with artificial noise emissions.

Table 3.1 Potential impacts and mitigation measures

Consideration	Potential impacts	Mitigation measures	Outcome
Bathymetry and seabed conditions	Disturbance to the seabed and benthic habitats	Survey data has been used to align the cable to avoid sensitive marine habitats such as hard coral, seagrass and rocky reef wherever possible. The area of disturbance would be a narrow linear corridor which spans a wide geography, with any affected habitat well represented in the region. In addition, ploughing operations to bury the cable are generally conducted at very low speeds, typically less than 1.5 knots. This low energy movement reduces the sediment suspension in the water column.	The seabed disturbance from the submarine cable installation are likely to recover quickly and not likely to be detrimental due to the localised and temporary nature of the impacts. Once the cable has been installed, further disturbance or damage to soft sediment habitats and benthic communities is not anticipated. Changes to seabed bathymetry are not expected to occur from the presence of the cable due to the small footprint area and size of the cable.
Water levels and currents	Variation in water levels and currents negligible	Due to the cable level and footprint compared to the existing seabed, the cable would not be anticipated to influence currents or water levels. Does not require mitigation.	The installation and presence of the cable would not be expected to influence currents or affect water level variation.
Wave climate	Changes to wave climate	Due to the level and footprint compared to the existing seabed, the submarine cable installation would not be anticipated to affect wave processes or wave propagation. Does not require mitigation.	The installation and presence of the cable would not be expected to increase or have any influence over the wave climate of the surrounding area.
Sediment properties and sediment transport	Large volumes of sediment being mobilised or dunes being destabilised Increased accretion or erosion	HDD is proposed for all landing sites. It is not expected that nearshore mobility of sediment under storm conditions would impact the cable. The cable is not expected to be exposed under extreme storm erosion events.	Sediment transport is negligible beyond the punch out point at a water depth of approximately 30m. In addition, the small footprint and size of the cable once installed would not be expected to have any significant effects on sediment transport. Risk of cable exposure at landing sites is considered low.
Natural hazards	Tsunami, earthquake, cyclone event	As a general rule, when there are natural hazards forecast in the area (e.g., tsunami) such that safety of life at sea is a concern, marine activities are to be avoided.	Project activities, including the submarine cable installation will not affect climatic processes, including natural hazards.

4. Conclusion

The existing conditions and potential impacts to hydrodynamics and coastal processes from submarine cable installation has been described in this report.

Due to the small footprint area, it is anticipated the submarine cable installation activities and long term presence of the cable will have negligible effects on bathymetry, water levels, wave climate and currents. Project activities related to submarine cable installation will not affect climatic processes (such as sea level rise and cyclones). The small footprint area and size of the cable is also not expected to have any significant effect on natural sediment transport processes.

Localised disturbance to the seabed during submarine cable installation is expected to occur; however, is likely to recover quickly and not likely to be significant due to the localised and temporary nature of the impact. Survey data obtained from the MRS will be used to align the cable to avoid sensitive marine habitats such as hard coral, seagrass and rocky reef wherever possible.

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