5. Coastal exposure – routine high water (2020)

Routine high water

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

Routine high water (2020)

Mud Alley
2020

Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.

The event modelled:

Routine tide	0.80m AHD
Wave set-up	0.20m
Wave run-up	0.50m
Total risk	1.50m AHD

Vulnerable areas likely to flood if the existing foredune is lost has been depicted in Aqua Blue.

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5. Coastal exposure – routine high water (2050)

Routine high water

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

Routine high water (2050)

Mud Alley
2050

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

The event modelled:

Routine tide	0.80m AHD
SLR	0.30
Wave set-up	0.20m
Wave run-up	0.50
Total risk	1.80m AHD

Vulnerable areas likely to flood if the existing foredune is lost has been depicted in Aqua Blue.

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Acknowledgement
The inundation mapping of 2050 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2050. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – routine high water (2100)

Routine high water

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

Routine high water (2100)

Mud Alley
2100

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

The event modelled:

Routine	0.80m AHD
SLR	1.00
Wave set-up	0.20m
Wave run-up	0.50
Total risk	2.50m AHD

Preliminary conclusion: if seas rise as projected, then towards the end of the century it is difficult to see the viability of Foul Bay settlement in its current location.

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Acknowledgement

The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2020)

Storm surge

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

1 in 100 ARI event (2020)

Mud Alley
2020

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.80m AHD.
Wave set-up	0.20m
Wave run-up	0.60m
Risk	2.60m AHD

Comment: this seems to be a long way above historical events but the highest storm surge height on record at Port Giles is **1.84m AHD** which was on 9 May 2016. Whether the weather pattern that produced this tide event can also produce elevated waters at Foul Bay is unknown (no known impact at Foul Bay on 9 May 2016).

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5. Coastal exposure – storm surge (2050)

Storm surge

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

1 in 100 ARI event (2050)

Mud Alley
2050

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.80m AHD.
SLR	0.30m
Wave set-up	0.20m
Wave run-up	0.60m
Risk	2.90m AHD

Note: there is no connectivity to the areas shown as flooded behind the ridge line.

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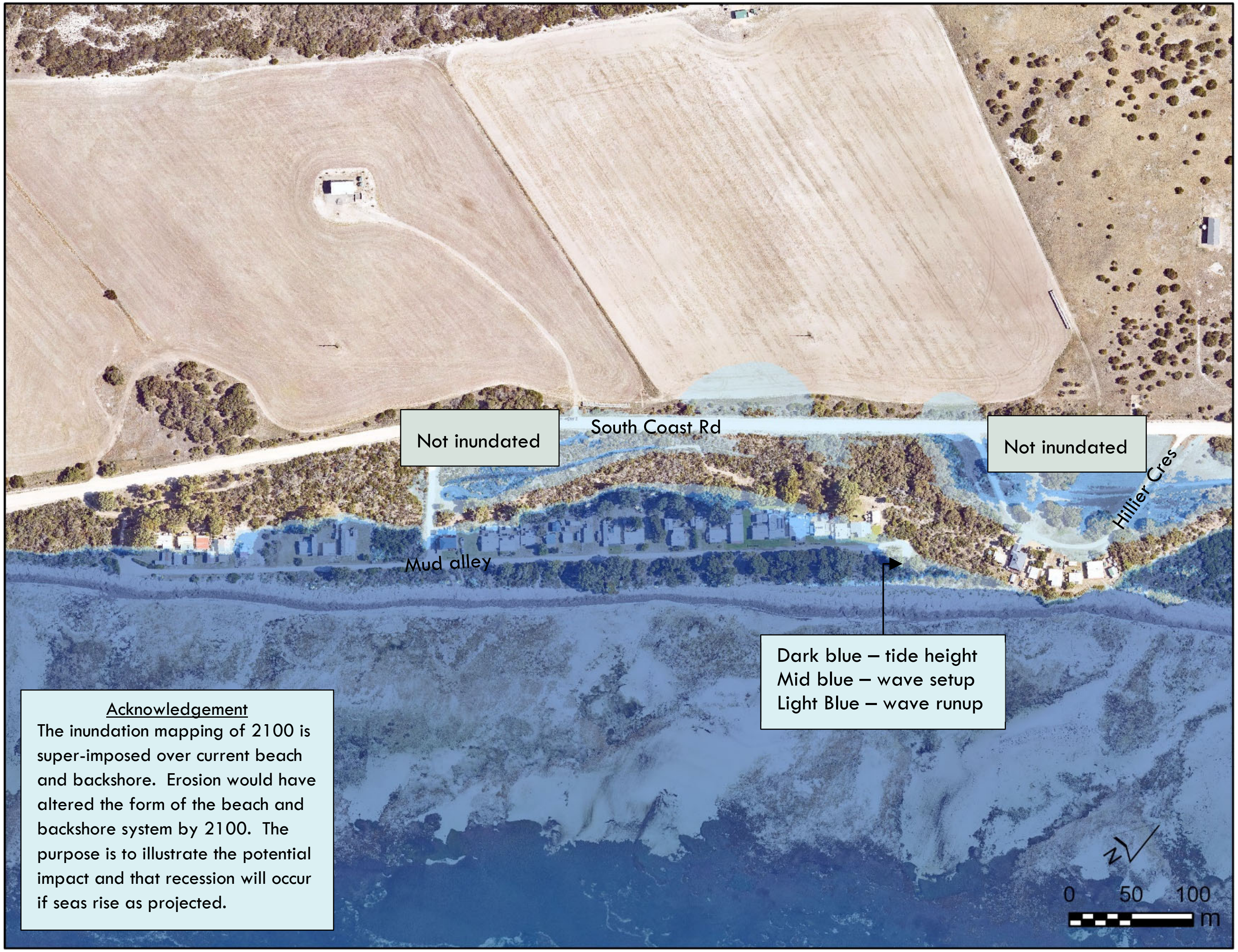

5. Coastal exposure – storm surge (2100)

Storm surge

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

1 in 100 ARI event (2100)

Mud Alley
2100

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.80m AHD.
SLR	1.00m
Wave set-up	0.20m
Wave run-up	0.60m
Risk	3.60m AHD

Note: there is limited connectivity to the areas shown as flooded behind the ridge line. The flood mapping does indicate that the ridge line would be above the 1 in 100-year risk event for 2100 if seas rose as projected. It is important to recognise that this scenario is deemed as worse case for 2100.

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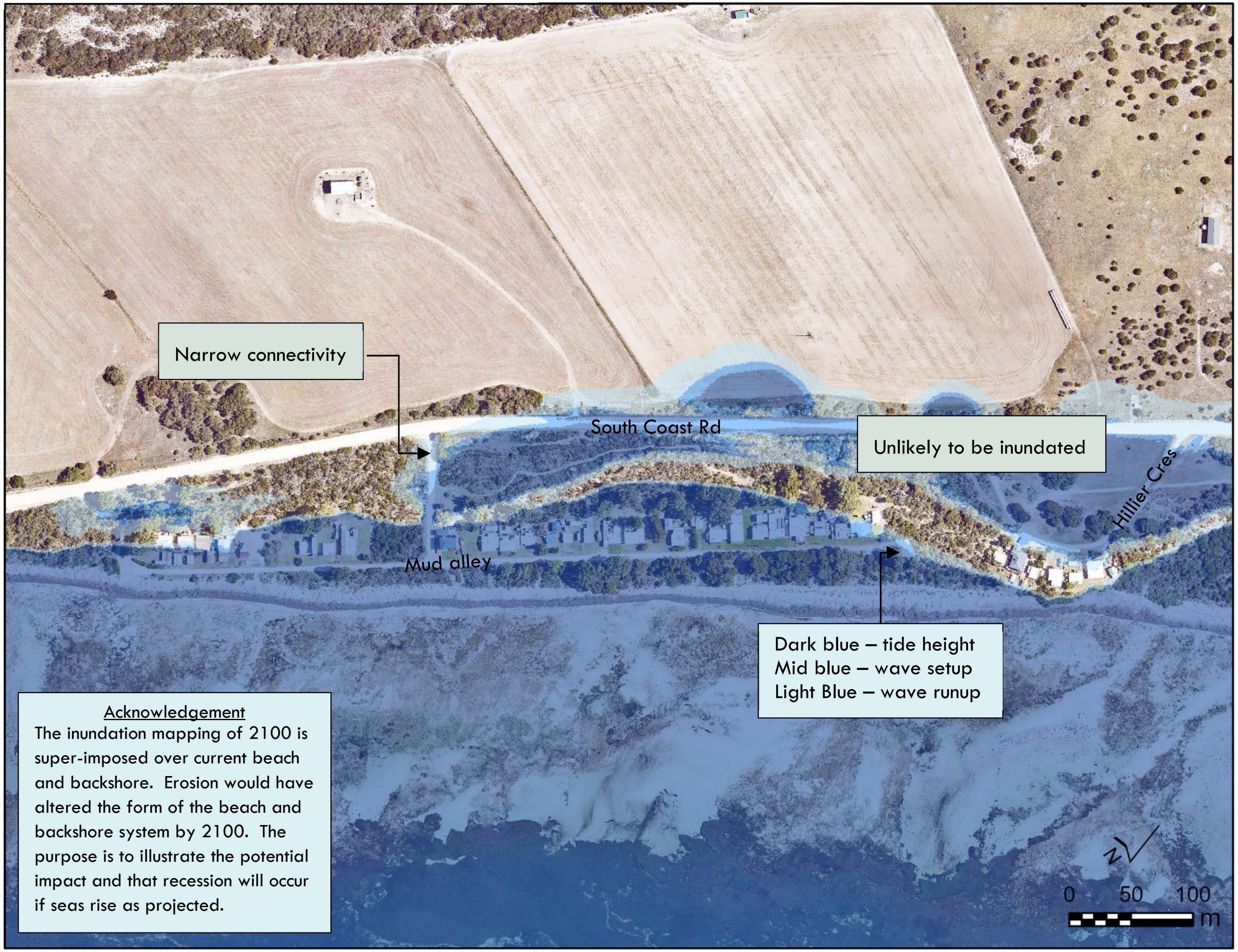

<u>Acknowledgement</u>

The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – summary (Mud Alley)

Summary

Foul Bay (West)

Yorke Peninsula

Cell YP49.1

Summary

Mud Alley

2020-2050

If sea levels rise as projected, then over topping of the embankment would become more frequent, leading to minor inundation of Mud alley and some homes. It is foreseeable that by 2050 larger storm events would flood most homes, some at depths greater than 1.5m.

2050-2100

Sea levels 1m higher than present would cause routine flooding of most homes. Significant storm events would inundate homes by depths up to 2.35m.

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5. Coastal exposure – scenario modelling (Diosma Drive)

Location

Foul Bay (East)

Yorke Peninsula
Cell YP49.2

Location Map

Diosma Drive

The scenarios modelled are:

Routine tide: is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.

1 in 100-year ARI storm surge event (CPB)

The timing of the scenarios:

- Current
- 2050
- 2100

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Viewing instruction:
View the coastal exposure section utilising full screen mode within your PDF software (Control L). Then use arrow keys to navigate.

5. Current exposure – routine high water (2020)

Routine high water

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Event: Routine high water

Diosma Drive
2020

Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.

The event modelled:

Routine tide	0.80m AHD
Wave set-up	0.20m
Wave run-up	0.50m
Total risk	1.50m AHD

Vulnerable areas likely to flood if the existing foredune is lost has been depicted in Aqua Blue.

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5. Coastal exposure – routine high water (2050)

Routine high water

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Event: Routine high water

Diosma Drive
2050

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

The event modelled:

Routine tide	0.80m AHD
SLR	0.30
Wave set-up	0.20m
Wave run-up	0.50
Total risk	1.80m AHD

Vulnerable areas likely to flood if the existing foredune is lost has been depicted in Aqua Blue.

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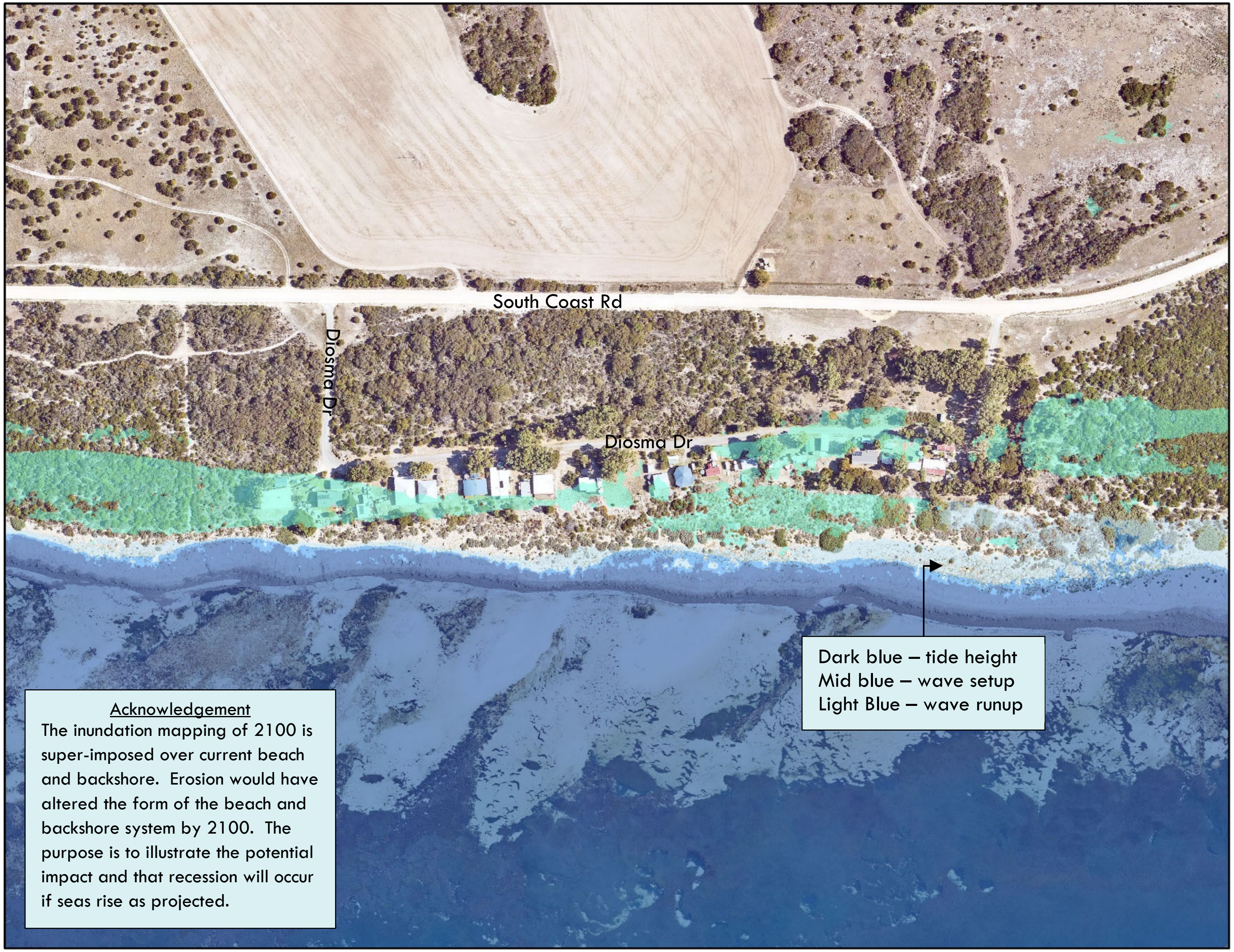

5. Coastal exposure – routine high water (2100)

Routine high water

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Event: Routine high water

Diosma Drive
2100

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

The event modelled:

Routine tide	0.80m AHD
SLR	1.00
Wave set-up	0.20m
Wave run-up	0.50
Total risk	2.50m AHD

Preliminary conclusion: if seas rise as projected, then towards the end of the century the viability of Foul Bay settlement in its current layout.

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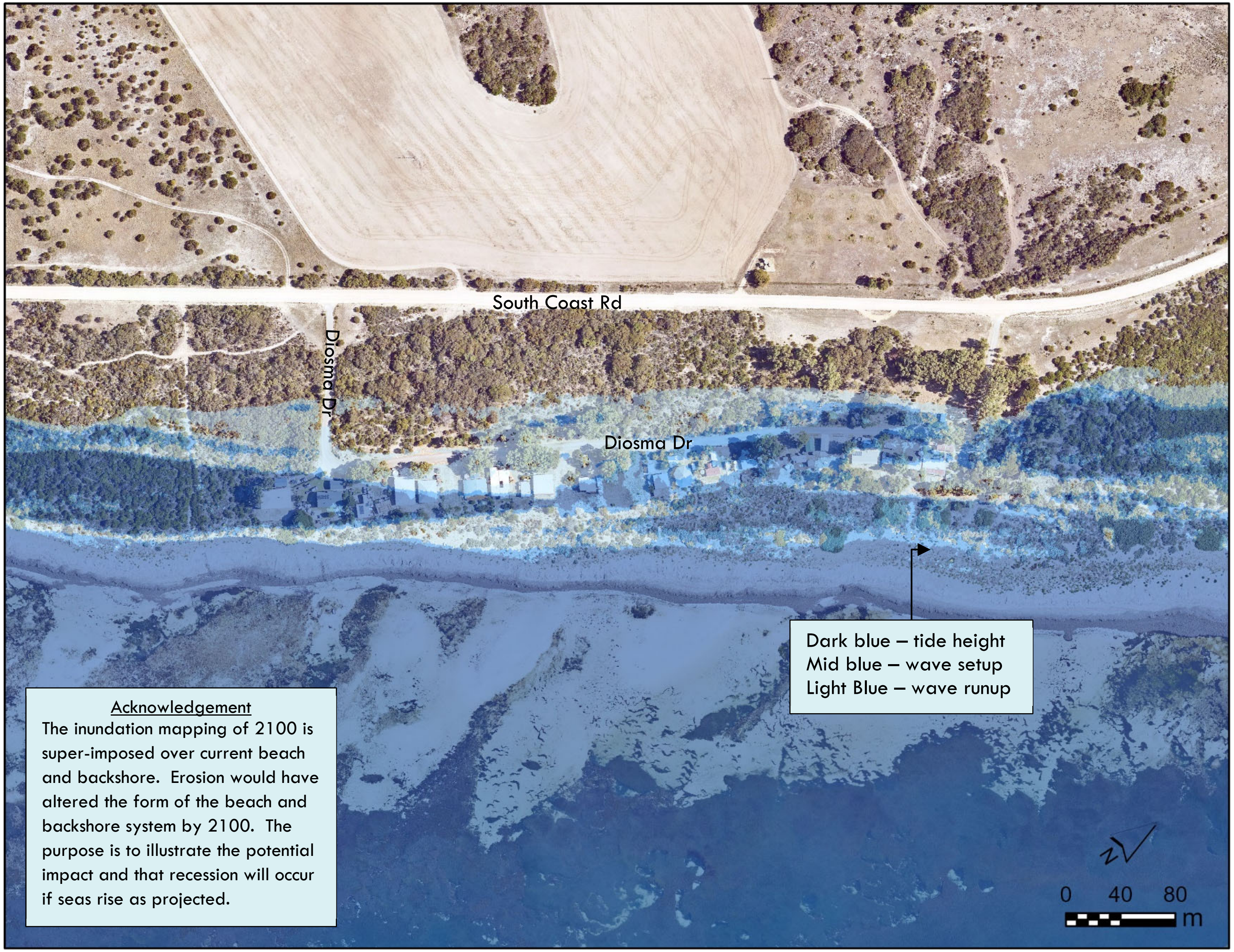

5. Coastal exposure – storm surge (2020)

Storm surge

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Event: 1 in 100 sea-flood risk

Diosma Drive
2020

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.80m AHD.
Wave set-up	0.20m
Wave run-up	0.60m
Risk	2.60m AHD

Comment: this seems to be a long way above historical events but the highest storm surge height on record at Port Giles is **1.84m AHD** which was on 9 May 2016. Whether the weather pattern that produced this tide event can also produce elevated waters at Foul Bay is unknown (there was no known impact at Foul Bay on 9 May 2016).

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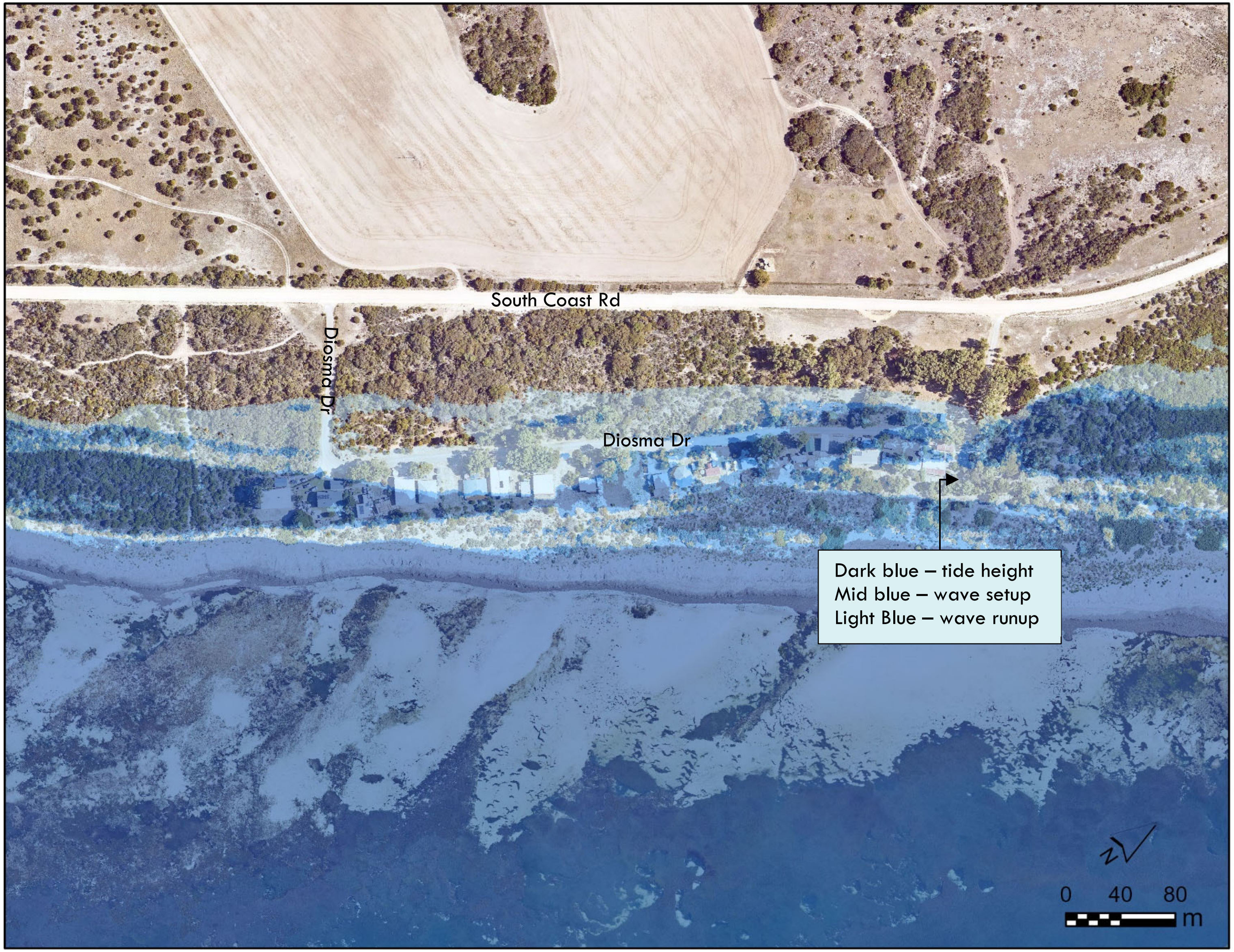

5. Coastal exposure – storm surge (2050)

Storm surge

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Event: 1 in 100 sea-flood risk

Diosma Drive
2050

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.80m AHD.
SLR	0.30m
Wave set-up	0.20m
Wave run-up	0.60m
Risk	2.90m AHD

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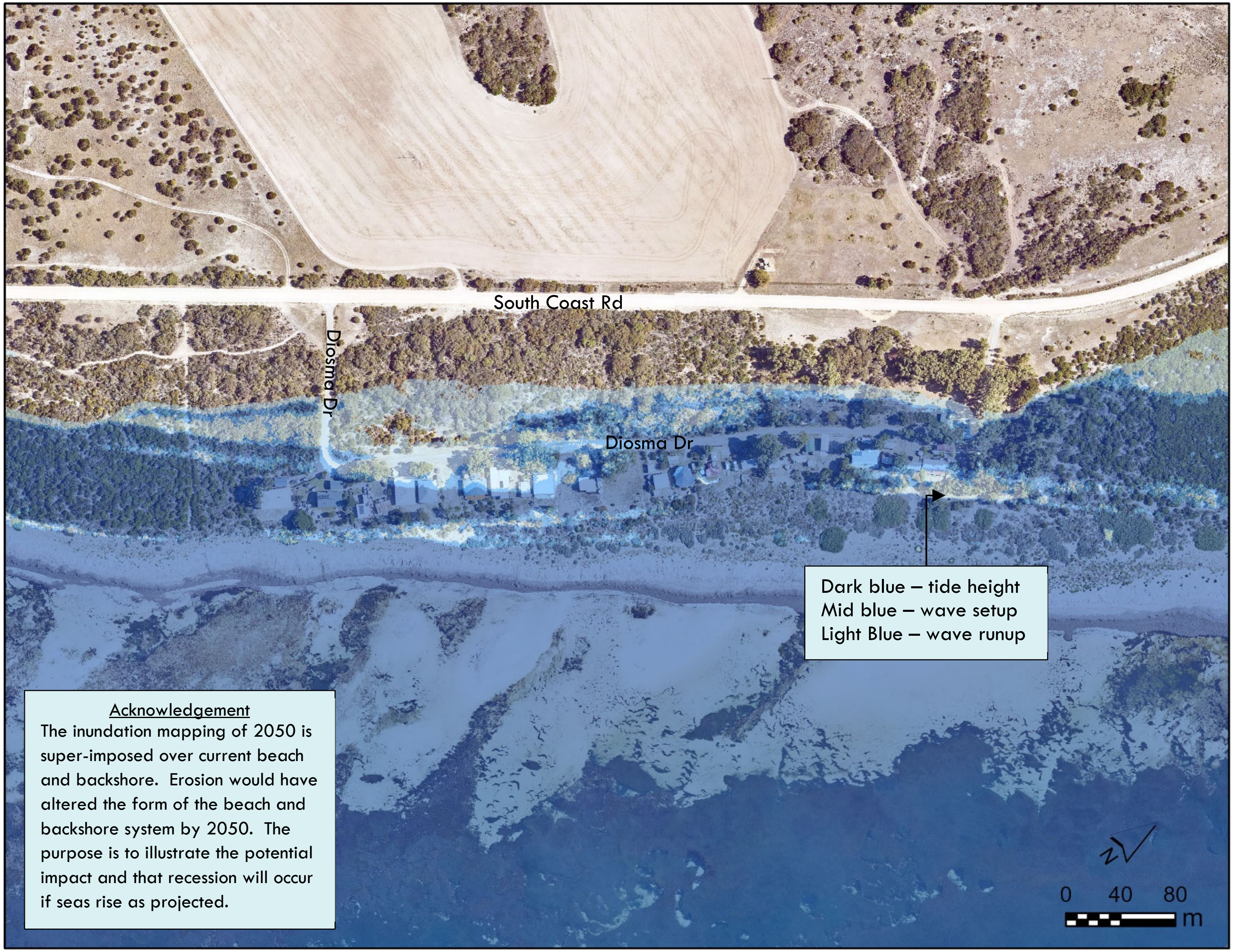

Acknowledgement
The inundation mapping of 2050 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2050. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2100)

Storm surge

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Event: 1 in 100 sea-flood risk

Diosma Drive
2100

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.80m AHD.
SLR	1.00m
Wave set-up	0.20m
Wave run-up	0.00m
Risk	3.60m AHD

Note: there is limited connectivity to the areas shown as flooded behind the ridge line. The flood mapping does indicate that the ridge line would be above the 1 in 100-year risk event for 2100 if seas rose as projected. It is important to recognise that this scenario is deemed as worse case for 2100.

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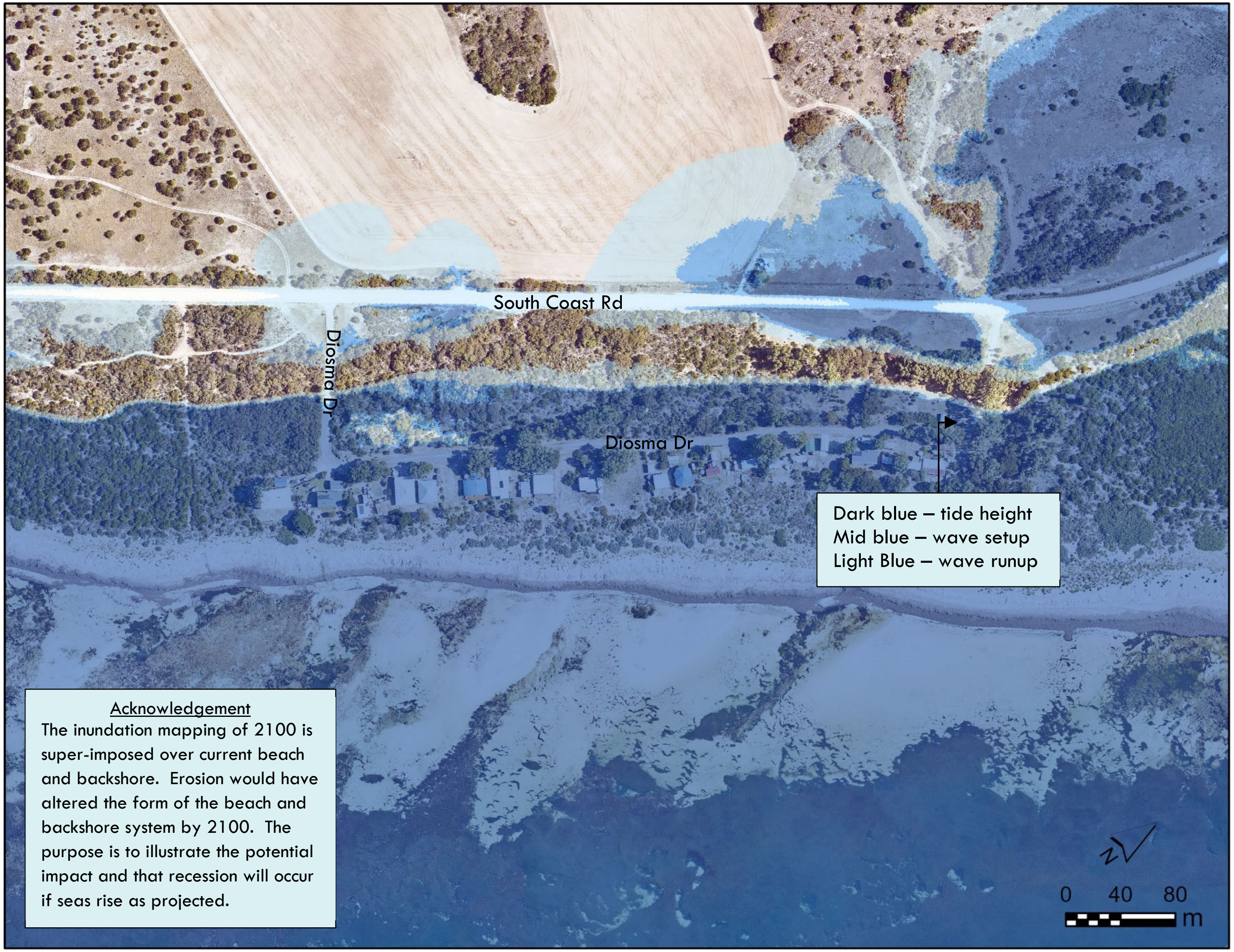

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – summary (Diosma Drive)

Summary

Foul Bay (east)

Yorke Peninsula

Cell YP49.2

Summary

Diosma Drive

2020-2050

The existing foredune is capable of preventing routine inundation; if the foredune was lost routine inundation of low-lying homes is expected. It is foreseeable that by 2050 larger storm events would completely overtop the dune and inundate the entire settlement by depths greater than 1.3m.

2050-2100

Sea levels 1m higher than present would cause routine flooding of most homes. Significant storm events would inundate the settlement by depths up to 2.15m. See also risk assessment section.

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5. Coastal exposure – erosion (introduction)

Erosion trends

Mud Alley
Erosion trends were recounted by landowners in field visits in 2018 and more recently this year[13]. Reports include rapid erosion of the frontal dune and trees that have been uprooted and lost to the sea, some of these remain fallen on the beach. An email report to Council of 10 June 2021 included the following points[14]:

- Erosion of ~5m of 'the bank' has occurred since 2019.
- Recent erosion of ~2m within last few weeks.
- More recent flooding of the 'turn around' at the south end of South Alley.

Hillier Crescent and Diosma Drive
No reports have been received from landowners from the other two residential sections of Foul Bay. Hillier Crescent is situated on a rocky outcrop and a substantial dune has built in front of Diosma Drive.

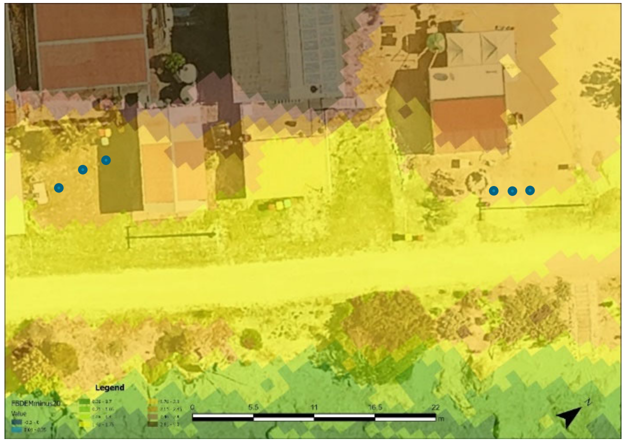

Figure a: Location of seaweed strands and survey points (mean is 1.84m AHD). Note the low elevation of dunes.

Figure b: Evidence of substantial trees lost to the ocean over the last decade or more.

Figure c: Access way to beach in front of 9 Mud Alley where ~5m of recession has occurred since 2019.

Figure d: Recently impacted erosion escarpment is observed along most of Mud Alley.

13 Landowners at 9, 61 and 63 Mud Alley.

14 Landowner at 9 Mud Alley, R Bushell.

5. Coastal exposure – shoreline recession analysis

Shoreline recession due to sea level rise

Methodology

In the following, we attempt to estimate shoreline retreat on the Foul Bay beaches due to sea level rise. This is achieved by two methods, one, utilising the Bruun Rule, which is the standard method to estimate shoreline retreat, but which has several implicit assumptions, and ignores the possibility of dune translation. The second is a method which assumes the beach and dune system can translate upwards and landwards as sea level rises, and estimates shoreline change based on assumptions that the coastal system can actually do this, and that there is sufficient sediment in the system for this to occur.

Assessment context

Backshores of urban and peri-urban/rural environments are often altered from their original states with the installation of protection works in the immediate backshore, or the construction of roads, parks, and buildings further back from the shoreline. It is not possible to factor in these interventions in the assessment of shoreline retreat in any meaningful way. Therefore, this assessment assumes that the coast is in its natural state before interventions took place. The assessment question is, 'if seas rise as projected, what would the coastline naturally do?'. This provides a context to consider what the intensity of the likely impact of sea level rise will be upon settlements and a context to consider appropriate adaptation strategies over time.

Shoreline Change indicated by the Bruun Rule

The Bruun Rule is an equation developed by Per Bruun (1962). While it has subsequently been modified (e.g., Dean and Houston, 2016), the modified equations require more data than available for this coast. The original equation is the most widely used method for determining shoreline response to sea level rise.

S = – S-p (W /dc +B) (1)

Where:

- S is Erosion due to sea level rise
- Sp is Sea level rise projection
- W is Width of the beach profile out to the depth of closure point
- dc is Depth of closure
- B is Foreshore/Dune crest height

The depth of closure is estimated from equation (2) where h is the closure depth in the inner portion of the surfzone-nearshore, and Hs is mean annual significant wave height following Hallermeier (1981) as modified by Houston (1995):

$$h = 8.9Hs \qquad (2)$$

Equation (1) applies to the upper shoreface (Cowell et al., 2003a). It assumes that the upper shoreface keeps the same profile and translates seaward or landward depending on the sediment budget and ignoring alongshore and across-shore changes in sediment supply (Le Cozannet et al., 2016. Obviously, this is a huge assumption in the case of many coastal tracts in South Australia. This is particularly so for the Foul Bay beaches, for three reasons: (i) the surfzone-nearshore is characterised by significant areas of subtidal reef and seagrass beds which may restrict sand movement, and alter the ability of the nearshore-surfzone profile to translate landwards; (ii) there is longshore sand transport from west to east in the region as evidenced by the significant number of relict spits and growth of Point Davenport over time; and, (iii) the small foredunes and dune system present along this coast indicate that it has never had more than a small sediment supply in the past.

5. Coastal exposure – shoreline recession analysis

Shoreline change – Bruun Rule (Continued)

There is extremely limited information available for Foul Bay to determine alongshore and across shore sediment exchanges These are the contributions of other processes causing losses or gains of sediments in the active beach profile. However, as Le Cozannet et al. (2016), note, there is currently no better model or "rule" to use. Recent results regarding the global impact of sea-level rise on shoreline change are largely based on the Bruun rule and it is commonly utilised to provide at least a rough estimate of shoreline migration in relation to sea level rise. Alternative approaches exist, but they are more complex, and they require more data.

Shoreline recession estimation due to sea level rise via the Bruun Rule

The 'closure depth' is the depth where most sediment transport due to waves and wave induced currents terminates (Hesp and Hilton, 1996). This closure depth cannot easily be determined in the Foul Bay region due to the fact that the nearshore region is dominated by complex three-dimensional geomorphology and includes sand, possible bedrock outcrop, and extensive reef.

Onshore/offshore sediment transport processes are therefore not operating in a straightforward manner, and application of the Bruun Rule is likely not easily applicable here. Note, in addition, there is no wave data for the region and thus, any estimate of significant wave height (Hs) is also based on local observations, and possibly incorrect.

While extreme caution is urged in using the results provided in this report, for the purposes of obtaining some estimate of shoreline change driven by sea level rise, the Bruun Rule is first utilised.

The depth of closure is estimated at -2.67m for this location using a significant wave height (Hs) of 0.3m (an estimate). The nearshore is characterised by reef which makes an estimation of coastal recession due to sea level rise by the Bruun Rule largely invalid. However, if the profile was all sand and all other issues (open embayment, only sandy surfzone and nearshore, no longshore transport, no reef, no seagrass) were negligible, the Bruun Rule would estimate recession at this location of ~64 (west profile) to 77m (east profile) with a sea level rise of 1m by 2100.

Shoreface-Beach and Dune Translation Model

The utility of the Bruun Rule has been the subject of debate over the last decades, because the "rule" takes no account of longshore sediment transport, the possibility that the foredune or dunes existing behind the beach can translate upwards and landwards with sea level rise, and it is not supposed to be utilised where surfzone-nearshore reefs exist, as they do at Foul Bay.

It is now a known fact that beaches and dunes can easily translate upwards and landwards as either shoreline erosion occurs or sea level rises (Davidson-Arnott, 2005). Therefore, another way to estimate the degree of shoreline retreat due to a given sea level rise is to take the latest topographic profile of the nearshore-beach-dune system and merely translate it entirely upwards and landwards by a given amount of sea level rise (in this case 1.0 m by 2100).

The distance that the profile is translated horizontally is determined by maintaining the distance between two topographic points (i.e. the slope of the beach-backshore) on the original profile in the projected future translated profile. For example, if the distance between zero m or

5. Coastal exposure – shoreline recession analysis

Shoreface-Beach and Dune Translation Model (continued)

AHD on the current profile and the foredune toe is, say, 15m, then that distance between those two points is maintained in the translated 2100 profile (Figure a).

There is considerable shallow reef and sea grass beds existing in the surfzone-nearshore region, and it is impossible to translate this material. It is also virtually impossible to determine what will happen to this reef (and surrounding reefs) as sea level rises. For instance, there may be significant erosion, but there may not.

The translation method shows that the beach-foredune system will translate 80-90 metres by 2100 (Figure 1). This is based on using a depth of -1.0m as the limit of the profile considered due to the presence of the wide reef seawards of -1m water depth. –Note that this assumes there is enough sediment in the system to allow this to occur (a large assumption), and that the nearshore profile can translate adequately given all the reefs present. It also assumes that the very low foredune is maintained as the shoreline retreats and sea level rises and has not been destroyed, in part or fully, due to a significant storm, increased storminess and/or significant jumps in sea level due to meltwater pulses (very rapid rises in sea level due to massive ice retreat or ice shelf collapse) occurring in the next ~80 years.

Note that as future sea level rises over the reef dominated nearshore region, wave energy will increase due to the fact that there will be less dissipation of waves over the reefs as the water depths increase. This will increase wave energy at the beach face and impact several of the factors considered above (storm wave heights and runup, significant wave heights).

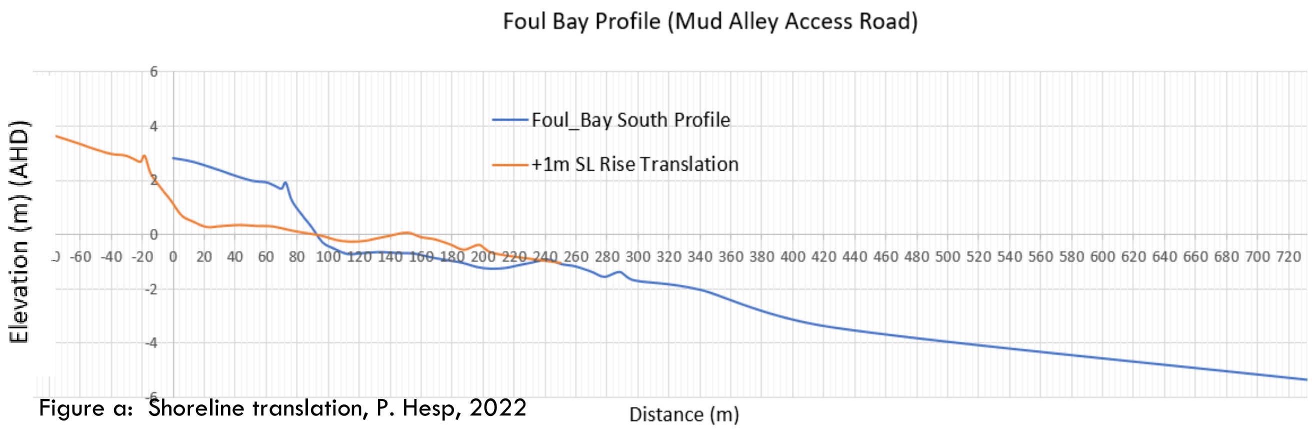

Figure a: Shoreline translation, P. Hesp, 2022

Conclusion

Comments made above about the gross uncertainty of these estimates given the presence of significant reef, the difficulty in determining the depth of closure point or a point on the profile that may be used to define a limit to the nearshore apply. In summary, it is not possible to use normal methods to calculate shoreline retreat due to the Bruun Rule, and likely the translation model also, and these estimates of recession, which range from 64m to 91m depending on the estimation method used, are only ball-park estimates at best.

5. Exposure – erosion projection (2050 & 2100)

Summar

Yorke Peninsula (Foul Bay)

Cell YP49.1

Erosion outlook

Mud Alley

The erosion modelling is conducted as though there is no human infrastructure present. Two methodologies were utilised, but the presence of the offshore reef makes these projections less certain, and the projections of 65m to 91m should be used as a guide only.

Erosion outlook to 2050 will be dependent on the rate of sea level rise, which has not escalated since 1990. However current assessment indicates erosion will continue but may reach equilibrium on the western end due to increased slope in the backshore.

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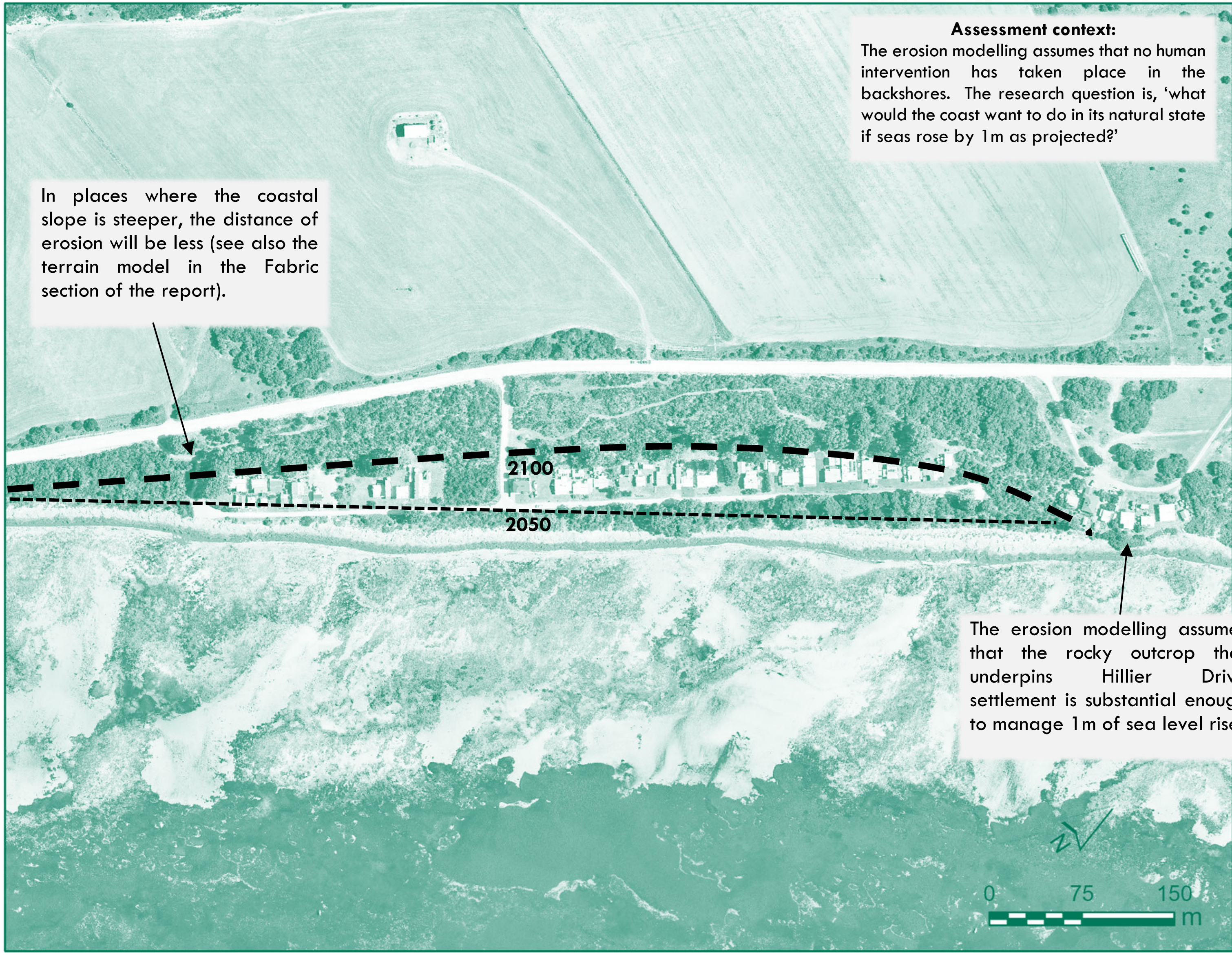

5. Exposure – erosion projection (2050 & 2100)

Summary

Yorke Peninsula (Foul Bay)

Cell YP49.2

Erosion outlook

Diosma Drive

The erosion modelling is conducted as though there is no human infrastructure present. Two methodologies were utilised, but the presence of the offshore reef makes these projections less certain, and the projections of 65m to 91m should be used as a guide only.

Erosion outlook to 2050 will be dependent on the rate of sea level rise and the rate of sand supply from the west. Currently this section of coastline has been accreting, and an erosion trend may be decades away.

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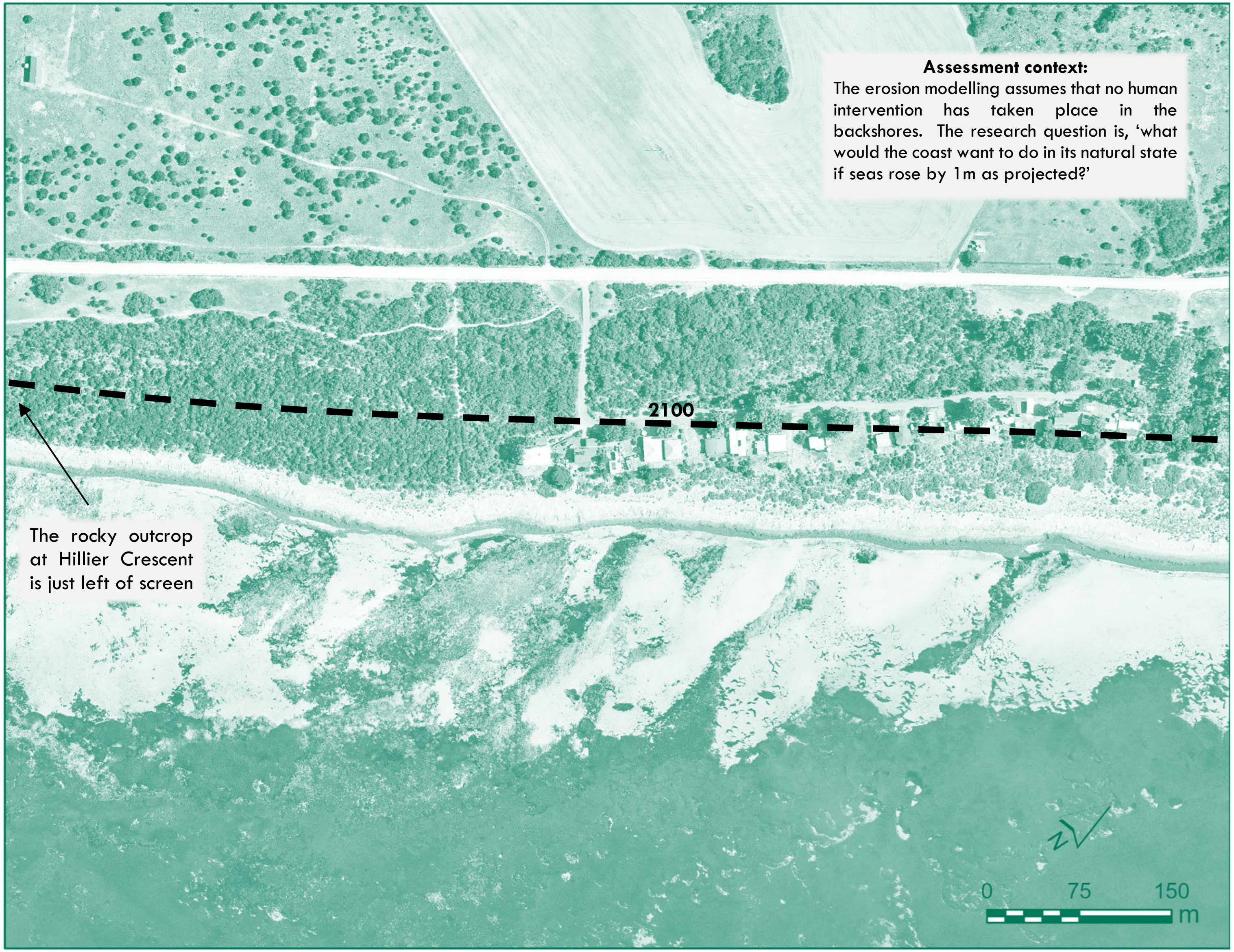


COASTAL EXPOSURE – Summary table

Foul Bay

Foul Bay		Coastal context - natural				Modified	Exposure*	Scenario Modelling	
Cell	**Location**	**Bathymetry**	**Benthic**	**Beach**	**Backshore**	**Human**	**Waves**	**2020 - 2050**	**2050-2100**
47.1	Boat ramp to Hillier Crescent	Slope 1:120 (-5m at 600m offshore).	Nearshore is low profile limestone reef interspersed with sand beds. Offshore - dense seagrass beds.	Fine sand beach. Median grain size was assessed as 0.42mm. (cont. below)	Sandy shore back by low height dunes and sand flat sloping up to South Coast Road at 3-4m AHD. (cont. below)	Interim sandbags have been installed on western end of Mud Alley. Mud Alley imposes a 'hold point' for future erosion.	Sheltered exposure Low energy waves	Erosion of the dune over the 40 years has exposed Mud Alley to increased storm and tidal action. Actions of the sea at 0.30m is likely to erode the remainder of the dune away leaving Mud Alley exposed to frequent tidal inundation.	If seas rise as projected (considering that we are using the worse case scenario of RCP 8.5) then it is difficult to see how Foul Bay settlement would function in its current location. The ridge line behind Mud Alley appears above risk level for 2100.
47.2	Hillier Crescent to Diosma Drive	Slope 1:120 (-5m at 600m offshore).	Same as above, but the reef may diminish in size toward the eastern end of Diosma Drive.	Sand of fine mixed mineral sand with some calcareous material and shells.	At 500m inland from the shoreline, elevation is ~10m AHD	Minor informal protection items now made obsolete by significant shoreline accretion.	Sheltered exposure Low energy waves	This section has accreted in response to the recession of the coast at Mud Alley. The newly formed dune will provide a buffer, provided that erosion does not proceed along the shore.	If seas rise as projected, then the frontal dune will erode away, and be overtopped, flooding the lower lying land behind upon which houses are situated. The ridge line behind Diosma appears above risk level for 2100.

Exposure Rating: Sheltered (2). Assigned by Nature Maps (but not 'very sheltered' due to its proximity to the Southern Ocean).

Foul Bay – Key Points

47.1 Lack of sediment supply and littoral drift eastwards is continuing to erode the coast in front of Mud Alley. Even small Increases in sea level rise are expected to exacerbate this erosion trend and the frontal dune system is likely to be eroded away, leaving Mud Alley at risk of routine inundation. If seas rise as projected after 2050, it is difficult to see how Mud Alley would function in its present layout. (Hillier Drive is more elevated and situated on rocky outcrop).

47.2 The coast in front of Diosma Drive has accreted substantially over the last 40 years which will provide a buffer against sea level rise. However, if the littoral drift continues eastwards, then this dune could go into retreat after 2050.

6. HAZARD IMPACTS AND RISKS

The purpose of this section of work is to consider the inputs from the first part of the study and undertake an assessment of hazard impacts and risks on the coast of Foul Bay. We undertake this in three steps:

1. Assign an inherent hazard rating,
2. Describe the likely impacts upon coastal regions,
3. Conduct a risk assessment utilising the risk framework of Yorke Peninsula Council.

6. Hazard impacts and risks

Methodology

South Australian Coast Protection Board considers four main coastal hazards: inundation, erosion, sand drift, and coastal hazard sulfate soils. Only the first two are under consideration in this project as there are no assets at risk from sand drift. The assessment of hazard impacts and risks is undertaken in three main steps.

1. Assign an inherent hazard rating

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk. This reality is most simply understood when considering inundation risk. Whether a coast is at risk from inundation depends entirely on the topography of the coast. If we explain this another way, a low-lying coast is inherently more at risk from flooding whereas an elevated coast is inherently not at risk from flooding.

The assessment of the erosion hazard is more complex, but it is still the relationship of fabric to exposure that determines whether a coast is inherently more at risk from erosion or less at risk. A coastal fabric of granite is less at risk from erosion than a coast backed by sand dunes. In some locations the natural fabric of the coast has been altered by human intervention. For example, the Adelaide metropolitan beaches were once backed by sand dunes, but installation of rock revetment has changed the nature of the fabric to rock.

The application of an inherent risk rating does not suggest that areas rated as 'low' are entirely free from vulnerability, nor conversely that areas rated more highly are necessarily vulnerable now. The aim is to assess the underlying inherent vulnerability of the fabric of the coastal location. This assessment takes into consideration the following elements and has meaning (context) in relation to all South Australian coasts:

- The geological layout
- Sediment supply/ balance
- The erodibility of beach and backshores
- The historical analysis as to how the coastline has performed over time
- The exposure (set by Nature Maps)
- Whether any human intervention has altered the nature of the coastline.

The risk assignments range from 'low' to 'very high' and may include a 'no risk' category. For example, coastal land that is elevated above any inundation risk will be assigned 'no risk'. A dotted circle to the right of the main assignment indicates that the risk assignment requires intensifying due to unique factors, or to indicate a higher risk that does not qualify for an overall higher rating (Example, Figure a).

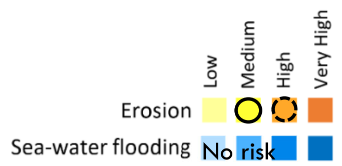


Figure a. Example of inherent risk output

2. Describe hazard impacts upon urban settlements.

In this study we are primarily concerned with the way that coastal hazards may impact urban settlements over the coming century. How inundation and erosion impact human settlement will vary according to location. For example, at Mud Alley a road is positioned between private assets and the shoreline whereas at Diosma Drive private assets are

6. Hazard impacts and risks

Methodology (cont)

directly adjacent the beach. Additionally, if seas rise as projected then seawater may flow further inland changing the ecology. Social disruption relates to issues of public safety and social concern. To evaluate public safety, how easily people may be able to retreat to a safe place is considered. An example of social concern may be the loss of the beach, especially in a larger town where tourism may be impacted.

In summary, while the impact of sea level rise may be somewhat uniform on a coastal region, the impact will be felt differently in the context of human experience. To bring appropriate focus, hazard impacts are described within four main receiving environments:

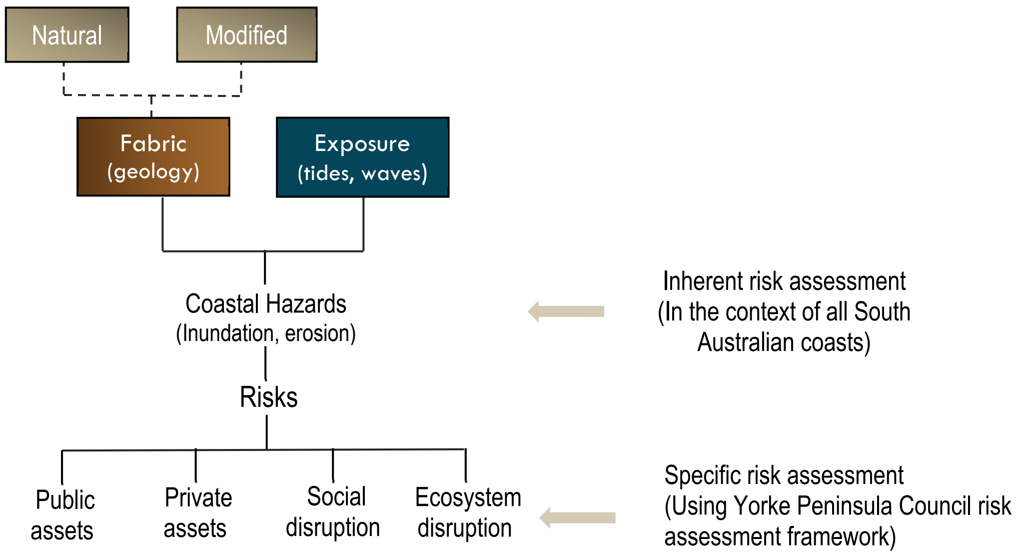
- Public infrastructure
- Private assets
- Public safety
- Ecosystem disruption

Note, the term ecosystem disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes that may threaten to disrupt the entire ecological system, for example seawater flooding into freshwater ecologies.

3. Conduct risk assessment using the risk framework of Yorke Peninsula Council.

This assessment utilises the Council's risk assessment framework and assessment is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. This is a long-term frame, but infrastructure such as houses and roads, have long lifespans.

The risk assessment framework is summarised in the diagram below (Figure a).



6-1 Inherent hazard risk assessment

Coastal setting:

The Foul Bay settlement area has a fine sand beach backed by low height dunes and a sand flat sloping up to South Coast Road at 3-4m AHD. The coastline is backed by a sedimentary plain of Holocene sediments rising to ~8m AHD at 300m inland. Nearshore is dominated by low profile limestone reef interspersed with sand beds. The reef is less prominent towards the eastern end of Diosma Drive. Offshore is dominated by dense seagrass beds. Exposure is categorised as 'sheltered' and wave energy is low.

Historical analysis shows that over the last forty years significant recession (up to 30m) has occurred on the western end of the Foul Bay settlement area and significant accretion has occurred on the eastern end (up to 45m). Hillier Crescent is positioned at about the mid-point and has not undergone any major shoreline changes.

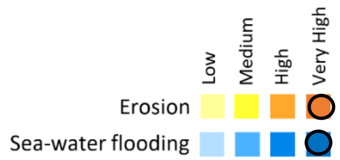
Due to the way that swell waves travel up Investigator Strait and swing around the headland at the boat ramp this erosion trend may have been occurring for a long time, helped along by sea level rise which has been occurring since the ~1850s.

This erosion and accretion trend was noted by Lands Department in 1985 which noted that Foul Bay was an unstable beach subject to littoral sand drift to the east. The prediction was that if sediment supply declined from the west, that Foul Bay coastline would erode in the west and that this erosion could continue towards the east. In other words, the recent accretion in the east (Diosma Drive) could also turn to erosion, but this is likely to take decades to occur.

From a geomorphological perspective it is difficult to envision a change in meteorological conditions that could reverse the flow of sand. It is also difficult to identify the conditions that might increase the sand flow from the west. The best we could hope for is that the trend slows, and a new alignment stabilises. The future rate of sea level rise is likely to be another determining factor in the rate of erosion.

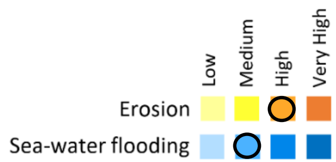
Mud Alley (Cell 47.1)

Erosion of the dune over the 40 years has exposed Mud Alley to increased storm and tidal action. Storms on even moderate tides are flowing over Mud Alley on the western end. If the 1 in 100-year ARI event occurred as set by Coast Protection Board, the frontal dunes of Mud Alley would be overtopped, and significant inundation would occur (see also floor levels assessment below). Unless the current erosion trend reverses, then the frontal dune may be soon eroded, and Mud Alley exposed to frequent tidal inundation. The inherent risk to erosion and inundation is assigned in the diagram below.



Diosma Drive (Cell 47.2)

The coastline in Diosma Drive area has accreted and therefore is currently afforded a buffer from actions of the sea, in particular wave runup. This situation may reverse, but this may take decades to occur.



6-2 Description of hazard impacts

Public assets at risk

Public roads

There are four public roads in the vicinity of the Foul Bay settlement area:

- South Coast Road (unsealed road)
- Mud Alley (unsealed road)
- Hillier Crescent (unsealed road)
- Diosma Drive (sealed road)

Of these, only Mud Alley is likely to be currently at risk. Mud Alley is currently at risk of erosion on the western end. However, if the coastline continues to rotate (I.e. erode on the western end) then this erosion trend can be expected to move eastwards. Mud Alley is also vulnerable to inundation on the western end. In July 2022 sand bags were installed installation as a temporary measure to manage these coastal hazards.

Regarding Mud Alley generally, there is currently a diminishing strip of dunes between the ocean and the road. The strip of dunes is higher than the road and if it erodes, Mud Alley will be more routinely inundated. It is not possible to predict when this erosion may occur. It could occur in the next storm episode or it may be a decade away.

Electrical infrastructure

Additional public assets include the electrical infrastructure which consists of:

- Mud Alley (electrical poles positioned on the landward side)
- Hiller Crescent (electrical poles positioned behind the houses in elevated position)
- Diosma Drive (electrical poles positioned behind the houses on the seaward side at low elevation).

The only electrical infrastructure that is impacted by actions of the sea is tidal flow around the base of some of the poles on the western end of Mud Alley. These are not currently at risk from erosion.

Figure a. The shoreline is rotating (eroding in the west, accreting in the east). The small dune system, which is higher than the road, is being eroded away along Mud Alley. The road is at risk of erosion on the west, and increasing inundation. Two electrical poles are subject to minor inundation at their bases.

6-2 Description of hazard impacts

Private assets at risk

Private assets at risk in the Foul Bay settlement area consist of:

- Dwellings
- Sheds (and associated garden items).

All properties are freehold title except three properties on Diosma Drive which are leasehold. Private assets on Hillier Crescent are unlikely to be at risk.

Inundation

The historical storm analysis showed that no dwellings to date have been impacted from actions of the sea. Several sheds on the western end of Mud Alley have been impacted (see storm analysis in the Exposure section).

However, modelling demonstrates that the 1 in 100-year event would overtop the dunes significantly at Mud Alley and may flow through the dunes at Diosma Drive. The floor levels of dwellings in the settlement areas were surveyed on 21/07/2022. Using the flood levels for the 1 in 100-year storm surge and the historical events of 2016 and 2021 (plus sea level rise projections), the number of houses with flood over floor levels has been estimated (see tables at right).

Erosion

Dwellings are set back behind Mud Alley and in the vicinity of Diosma Drive are set behind the accreting dune system. No private dwellings are likely to be at risk from erosion in the next decade.

	1 in 100-Year Sea flood scenarios (including wave runup)			
Location	Total dwellings	Number of dwellings with flood over floor level		
		2022	2050 (+0.3m)	2100 (+1.0m)
Mud Alley	24	18	19	21
Diosma Drive	22	11[1]	12	20

	Events of 29 September 2016 and 24 July 2021 if the frontal dunes eroded away			
Location	Total dwellings	Number of dwellings with flood over floor level		
		2022	2050 (+0.3m)	2100 (+1.0m)
Mud Alley	24	11	14	19
Diosma Drive	22	6	9	11

[1]The 1 in 100-year sea flood may not overtop the dunes and therefore this number may be zero.

Interpretive notes:

It is recognised that older dwellings will be progressively replaced with floor levels at higher elevations. The purpose of this analysis is to consider the layout of the current settlement in relationship to sea level rise projections.

The purpose of considering the events of 2016 and 2021 as if the dunes had been eroded away is primarily to evaluate Mud Alley dwellings. In this location, the remaining dunes are very narrow and may erode away in the next few storms.

(1) This number may be less because the dunes would dissipate the energy of the waves. However, this analysis does provide a context to consider the current elevation of the houses.

(2) In reality, this number is nil as the existing dunes are accreting and would protect and/or dissipate the energy from waves.

(3) If seas rise as projected by 2050, then this section of coast may go into recession and be more exposed to actions of the sea. However, many of these houses would have been replaced by 2050.

6-2 Description of hazard impacts

Public safety

The assessment conducted within this project is only related to how storms and erosion may increase the risk to people. It is not related to risks that the beach normally poses to the safety of people, such as drowning incidents.

Mud Alley

Some inundation does occur on the western end of Mud Alley, but the depth of water is ~100mm with low energy waves. However, if the 1 in 100-year event occurred, or the dunes eroded away, then risk to people will increase. For example, if the current 1 in 100-year event occurred then sections of Mud Alley would be flooded by up to 1m (including wave runup). An event of this magnitude may pose a risk to the safety of people. However, there are places to which people can easily retreat. Behind all the houses along Mud Alley is a coastal slope up to South Coast Road which is unlikely to be subject to inundation even with 1m of sea level rise.

Hillier Crescent

Hillier Crescent is positioned on a rocky limestone outcrop and inundation and erosion are unlikely to threaten this settlement.

Disoma Drive

It is unlikely that the current 1 in 100-year event would be a risk to people in the Diosma Drive area. All dwellings in the Hillier Crescent section of the coast are above all known flood risk levels.

Ecosystem disruption

The assessment of ecosystem disruption relates primarily to disruption that would occur on a wide scale. For example, sea water flooding through to low lying land that is currently freshwater ecology would be irreversibly disrupted with incursion of saltwater.

There are no apparent risks for ecosystem disruption on a broad scale in this cell. However, it is likely that the small dune system in front of Mud Alley will continue to erode, and vegetation and small habitats will be lost.

If seas rise as projected, then later in this century larger inland seawater flows may disrupt the ecosystems behind the existing houses.

Summary: Hazard Impacts

Public assets: The western end of Mud Alley is currently vulnerable to seawater incursion and erosion. If the small dune system along Mud Alley erodes, then all of Mud Alley will be vulnerable to seawater incursion, possibly two or more times a year.

Private assets: If the 1 in 100-year event occurred, or the dunes in Mud Alley eroded away, 11-18 dwellings would have water over floor levels in moderate storm events. It is unlikely that many houses in Diosma Drive are currently vulnerable to flooding.

Public safety: It is unlikely that public safety is at risk, unless the dunes erode away or the 1 in 100-year event occurs. In any event, the slope up to South Coast Road provides an effective way to retreat from the flood waters.

Ecosystem disruption: Broad ecosystem disruption is unlikely apart from the loss of dunes in front of Mud Alley.

7-3 Risk assessment using Council's risk framework.

Risk identification: Erosion of the foredune is progressively exposing Mud Alley (west) to increased inundation and erosion.

Coastal setting	A fine sand beach backed by low height dunes and a sand flat sloping up to South Coast Road. Nearshore is a low-profile limestone reef interspersed with sand beds. Offshore are dense seagrass beds. Exposure is categorised as 'sheltered'; wave energy is low. Erosion has been occurring in an oblique pattern on the western end at least since 1981 due to the way the waves wrap around the headland and interact with the shore (i.e. obliquely). The shoreline appears to be rotating around Hillier Crescent area which has remained unchanged. The movement of sand is west to east. It is unlikely that this loss of sand will be matched by sand coming into the system from the west and therefore the erosion trend will likely continue. However, an equilibrium in the alignment may eventually slow the rate (but depending on rate of sea level rise).

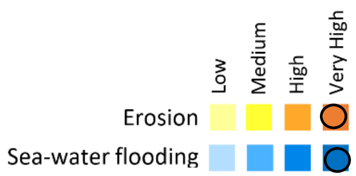
Are any strategies employed to mitigate the risk? Temporary sandbags have been installed to the western end of Mud Alley.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Mud Alley is an unsealed road at a distance of nil from the shoreline on the western end and ~13m at the T-junction. Electrical poles are positioned on landward of Mud Alley. Erosion rate on western end 0.60m per annum.	current	*Likely*	*Moderate*	High
		2100	*Almost Certain*	*Major*	Extreme
Private assets*	Private property is situated on the landward side of Mud Alley. Four sheds are positioned below houses which may be soon subject to erosion. Dwellings are set further back. Lot 208 is 20m from shoreline; at current rate of erosion ~30 years.	current	*Possible*	*Minor*	Moderate
		2100	*Almost Certain*	*Major*	Extreme
Public safety	It is unlikely that erosion will poise a safety risk assuming normal controls are implemented if the road should erode further. The safety risk will increase if the dunes erode away and inundation increases (see inundation assessment below).	current	*Unlikely*	*Minor*	low
		2100	*Unlikely*	*Minor*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. Due to the slope of the backshore in this location, broad scale ecosystem disruption is not envisaged. However, the minor dune ecosystem is likely to be lost.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Minor*	Moderate

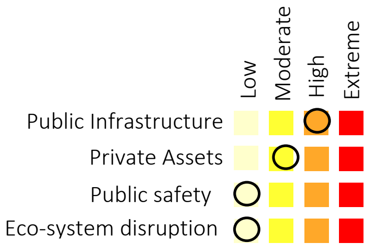
*Council not necessarily liable for private assets

Inherent Hazard Rating

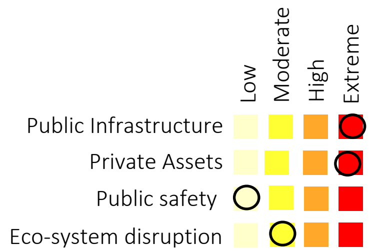
Sandy beach backed by low height dune and sand platform.



Erosion Hazard Rating
(Current outlook 2022)



Erosion Hazard Rating
(Future outlook 2100)



Note: the assignment of future risk assumes seas rise as projected and that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment.

7-3 Risk assessment using Council's risk framework.

Risk identification: Erosion of the foredune is progressively exposing Mud Alley to increased inundation and erosion.

Coastal setting	A fine sand beach backed by low height dunes and a sand flat sloping up to South Coast Road. Nearshore is a low-profile limestone reef interspersed with sand beds. Offshore are dense seagrass beds. Exposure is categorised as 'sheltered', wave energy is low. The shoreline appears to be rotating around Hillier Crescent area which has remained unchanged and therefore the erosion pattern is oblique (much higher rates on the western end of Mud Alley). Since 2008, the shoreline has receded ~8m at the T-Junction and 2m on the eastern end of Mud Alley. The movement of sand is west to east. It is unlikely that this loss of sand will be matched by sand coming into the system from the west and therefore the erosion trend will likely continue. However, an equilibrium in the alignment may eventually slow the rate (but depending on rate of sea level rise).

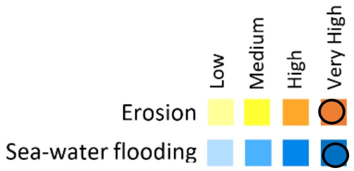
Are any strategies employed to mitigate the risk? Temporary sandbags have been installed to the western end of Mud Alley.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Mud Alley (east) is an unsealed road at a distance of 12m from the shoreline at the T-Junction and 29m from the shoreline on the eastern end. Recession is slower on this end of Mud Alley, but could accelerate if the frontal dune is further eroded.	current	*Unlikely*	*Minor*	Low
		2100	*Almost Certain*	*Major*	Extreme
Private assets*	Private property is situated on the landward side of Mud Alley in excess of 27m from the shoreline. If current rate of erosion at 0.6m was maintained, these would not be impacted for 3 or 4 decades but if seas rose as projected, erosion would be significant.	current	*Rare*	*Insignificant*	Low
		2100	*Likely*	*Major*	Extreme
Public safety	It is unlikely that erosion will poise a safety risk assuming normal controls are implemented if the road should erode further. The safety risk will increase if the dunes erode away and inundation increases (see inundation assessment below).	current	*Unlikely*	*Minor*	low
		2100	*Unlikely*	*Minor*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. Due to the slope of the backshore in this location, broad scale ecosystem disruption is not envisaged. However, the minor dune ecosystem is likely to be lost.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Minor*	Moderate

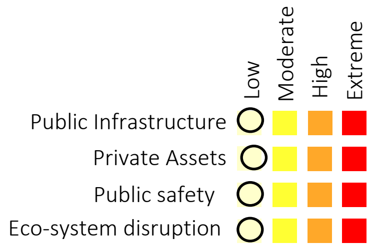
*Council not necessarily liable for private assets

Inherent Hazard Rating

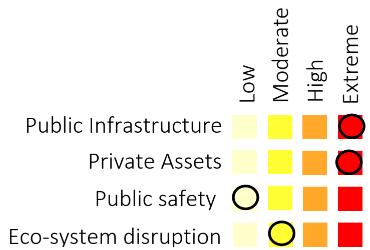
Sandy beach backed by low height dune and sand platform.



Erosion Hazard Rating
(Current outlook 2022)



Erosion Hazard Rating
(Future outlook 2100)



Note: the assignment of future risk assumes seas rise as projected and that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment.

7-3 Risk assessment using Council's risk framework.

Risk identification: Seawater inundates Mud Alley on the western end. If the dunes erode, Mud Alley will suffer general inundation.

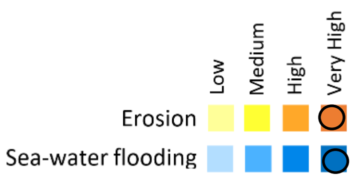
Coastal processes	A fine sand beach backed by low height dunes and a sand flat sloping up to South Coast Road. Nearshore is dominated by low profile limestone reef interspersed with sand beds. Offshore is dominated by dense seagrass beds. Exposure is categorised as 'sheltered' and wave energy is low. Over the last forty years significant recession has occurred on the western end of Mud Alley and storms of 2016 and 2021 caused inundation of this area. Ongoing erosion is causing the dune system in front of Mud Alley to erode. When the narrow strip of dunes that currently protects the road from inundation is removed by erosion, Mud Alley will be exposed to frequent inundation from the sea.

Are any strategies employed to mitigate the risk? No (not for flooding, but sandbags have been installed on the western end of Mud Alley)

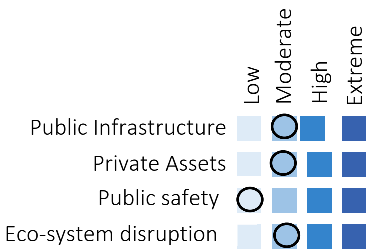
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Mud Alley is an unsealed road and electrical poles are positioned on the landward side. Storms currently cause inundation on the western end of Mud Alley. If the dunes erode further to the east, then Mud Alley will be significantly inundated.	current	*Likely*	*Moderate*	Moderate
		2100	*Almost certain*	*Major*	Extreme
Private assets*	Private property is situated on the landward side of Mud Alley. Some sheds have been inundated. If the dunes erode, then 11 houses will have water over floors in storm events such as 2016 and 2021, and 18 houses in the 1 in 100-year event.	current	*Possible*	*Moderate*	Moderate
		2100	*Almost certain*	*Major*	Extreme
Public safety	Currently sea water flows pose little risk to human safety (at ~100mm deep). However, if the dunes erode, then flood flows could be as deep as 1m in the 1 in 100-year storm event. However, retreat to higher ground behind houses is simple.	current	*Rare*	*Minor*	Low
		2100	*Possible*	*Moderate*	Moderate
Ecosystem disruption	Increasing seawater flows through the dunes will disrupt dune ecologies but this is a relatively small area. Later in the century, if seas rise as projected, then sea-flood flows will penetrate further inland, but flow will be limited by South Coast Road.	current	*Possible*	*Moderate*	Moderate
		2100	*Almost certain*	*Moderate*	High

Inherent Hazard Rating

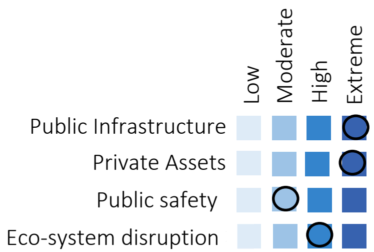
Sandy beach backed by low height dune and sand platform.



Inundation Hazard Rating
(Current outlook 2022)



Inundation Hazard Rating
(Future outlook 2100)



Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Caveat: this assessment is sea-water impact only and does not encompass the possibility of rainwater flooding, nor a combination of both impacts.

*Council not necessarily liable for private assets

7-3 Risk assessment using Council's risk framework.

Risk identification: This section of coast has been accreting but may go into recession in the future (possibly decades).

Coastal setting	A fine sand beach backed by low height dunes and a sand flat sloping up to South Coast Road. Nearshore is low profile limestone reef interspersed with sand beds. Offshore is dense seagrass beds. Exposure is categorised as 'sheltered' and wave energy is low. Significant accretion (up to 45m) has occurred in the Diosma Drive region. The shoreline appears to be rotating around Hillier Crescent area which has remained unchanged. This accretion is a result of sand moving eastwards from Mud Alley. In the longer term, which may be measured in decades, this coast could also go into recession, if no sand supply moves into Foul Bay from the west. Sea level rise will increase the likelihood of a recession trend.

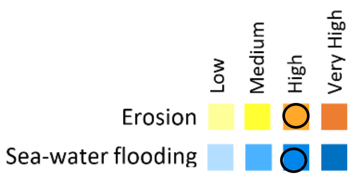
Are any strategies employed to mitigate the risk? Nil (older informal protection is now covered by dunes).

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Diosma Drive is a sealed road set landward of private property at a distance of 60 to 90m. Therefore, it is not at risk from erosion. Electrical poles are situated on the seaward side of Diosma Drive.	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Minor*	Low
Private assets*	Private property is situated behind the dunes that have formed over the last forty years. In the longer term (likely decades) this section of coast may go into recession, especially if seas rise as projected.	current	*No risk*	*No risk*	No risk
		2100	*Possible*	*Major*	High
Public safety	The dunes are currently accreting. Erosion does not generally increase a risk to public safety in a low elevation environment.	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Minor*	Low
Ecosystem disruption	The dunes are currently accreting, and new ecosystems are being established. However, if seas rise as projected, then these dunes may erode again. However, this is likely to be post 2050.	current	*No risk*	*No risk*	No risk
		2100	*Possible*	*Moderate*	Medium

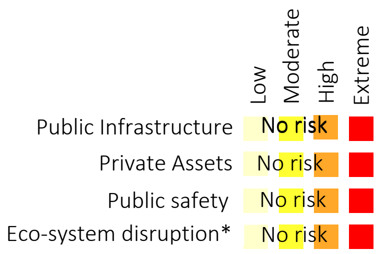
*Council not necessarily liable for private assets

Inherent Hazard Rating

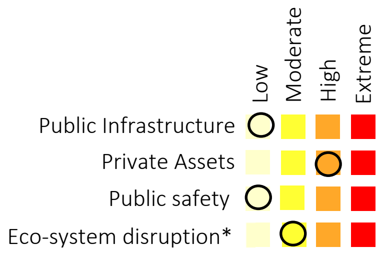
Sandy beach backed by dune system and former marine bench



Erosion Hazard Rating
(Current outlook 2022)



Erosion Hazard Rating
(Future outlook 2100)



Note: the assignment of future risk assumes seas rise as projected and that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment.

7-3 Risk assessment using Council's risk framework.

Risk identification: Modelling shows that the 1 in 100-year event may overtop the dunes and inundate the road and houses.

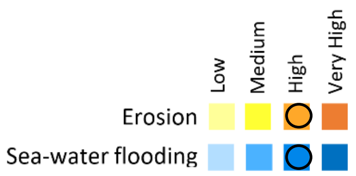
Coastal processes	A fine sand beach backed by low height dunes and a sand flat sloping up to South Coast Road. Nearshore is dominated by low profile limestone reef interspersed with sand beds. Offshore is dominated by dense seagrass beds. Exposure is categorised as 'sheltered' and wave energy is low. Over the last forty years significant accretion has occurred and a dune system has built up in front of the houses. The sea-flood events of 2016 and 2021 did not flow through the dunes. There are historical accounts of sea-floods in 1981 that flowed to some houses. If the 1 in 100-year storm event occurred, then seawater may flow through the dunes to the road and to some houses. Sea level rise will exacerbate the sea-flood risk.

Are any strategies employed to mitigate the risk? No

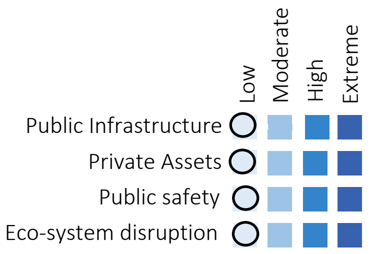
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Diosma Drive is sealed road with electrical poles positioned on the seaward side. The storms of 2016 and 2021 did not impact the road. If the 1 in 100-year storm surge event occurred water may flow to the road (but with minimal impact).	current	*Rare*	*Minor*	Low
		2100	*Likely*	*Major*	Extreme
Private assets*	Private property is situated adjacent the coast. If the 1 in 100-year event occurred some houses MAY be inundated, depending on the rate of flow through the dunes.	current	*Rare*	*Minor*	Low
		2100	*Likely*	*Major*	Extreme
Public safety	Currently there are no obvious safety concerns within Diosma Drive area. However, if the dunes erode again, and sea level rises, increased to people's safety is possible (but this is more likely post-2050).	current	*Rare*	*Minor*	Low
		2100	*Likely*	*Major*	Moderate
Ecosystem disruption	Increasing seawater flows through the dunes will disrupt dune ecologies but this is a relatively small area. Later in the century, if seas rise as projected, then sea-flood flows will penetrate further inland, but flow will be limited by South Coast Road.	current	*Rare*	*Minor*	low
		2100	*Possible*	*Moderate*	Moderate

Inherent Hazard Rating

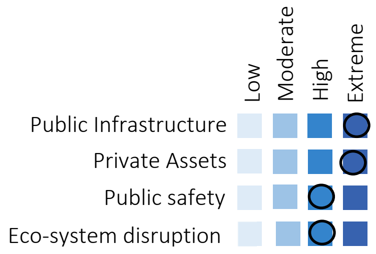
Sandy beach backed by low height dune and sand platform.



Inundation Hazard Rating
(Current outlook 2022)



Inundation Hazard Rating
(Future outlook 2100)



Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Caveat: this assessment is sea-water impact only and does not encompass the possibility of rainwater flooding, nor a combination of both impacts.

*Council not necessarily liable for private assets

Stage 2

Coastal Adaptation Strategy

Project Note: This section of work adopts the framework and understanding of adaptation options and strategies from CoastAdapt. Further reading is available at:

Coastadapt.com.au/understand-adaptation
Coastadapt.com.au/adaptation-options

Adaptation strategy

1. COASTAL ADAPTATION - OVERVIEW

There are generally six categories of adaptation responses in the coastal zone:

1. **Avoidance** – Avoid the impacts of coastal hazards by ensuring that assets are not placed in vulnerable locations.
2. **Hold the line** – Install protection infrastructure that reduces the impact of coastal hazards or use environmental practices to strengthen natural protective forms such as dunes.
3. **Accommodate** – Accept some degree of hazard and conduct limited intervention to manage the hazard (for example, in areas that may be subject to inundation, raise houses on poles).
4. **Managed retreat** – Progressively move assets or services away from areas that could be impacted by coastal hazards now or in the future.
5. **Defer and monitor** – monitor the coast and use the data to form future strategies.
6. **Loss acceptance** - Accept that coastal hazards will cause negative impacts on assets and services and when this occurs, they will not be replaced.

Adaptation responses

Within the adaptation response categories there are a range of potential adaptation responses.

<u>Planning</u>

Planning responses are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. For example, new dwellings being required to be positioned at higher elevation.

<u>Engineering</u>

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation.

<u>Environmental management</u>

Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support growth of habitat such as seagrasses. It may also include sand nourishment to replace sand that has been lost from the beach system.

Adaptation timing

There are two broad ways in which adaptation can occur in relation to timing.

<u>Incremental approach</u>

A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the face of the impacts of climate change. An incremental approach is usually the approach adopted for a location such as Foul Bay.

<u>Transformative approach</u>

In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant that they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term.


MUD ALLEY - EAST
South Coast Road
Diosma Drive
Mud Alley
South Coast Rd

Adaptation strategy

MUD ALLEY – EAST OF THE ACCESS ROAD

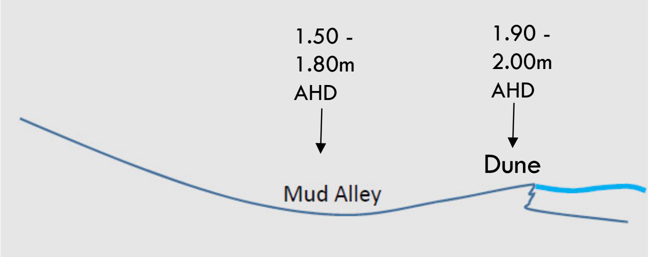
Guiding principles that underpin the strategy.

1. Short term outlook – if the frontal dune erodes, Mud Alley will become immediately vulnerable to sea-water flooding.

Currently, Mud Alley (the road) is not vulnerable to erosion and is not vulnerable to inundation unless a larger storm such as the 1 in 100-year ARI event occurred (p 64). However, if the frontal dune eroded a few metres landward, then even in moderate storm events seawater would flow over Mud Alley and around some of the houses (p 58).

The reason for this rapid increase of vulnerability to flooding is that the height of the dune adjacent the beach is 1.90m to 2.00m AHD, whereas Mud Alley Road is predominantly at heights 1.50m to 1.80m AHD. Furthermore, if the frontal dune erodes away then the rate of erosion is likely to increase but this rate cannot be calculated apart from noting that it is likely to be at least 0.60m per annum (the rate observed on the western end of Mud Alley) but may be faster because tidal action will be more frequent in the lower lying terrain.

Figures: Illustrate the relationship of the height of the frontal dune to lower areas behind.



If erosion escarpment shifts 2-3 metres, the height of the frontal dune will continue to decrease until the settlement is exposed to direct inundation from the sea.

Adaptation strategy

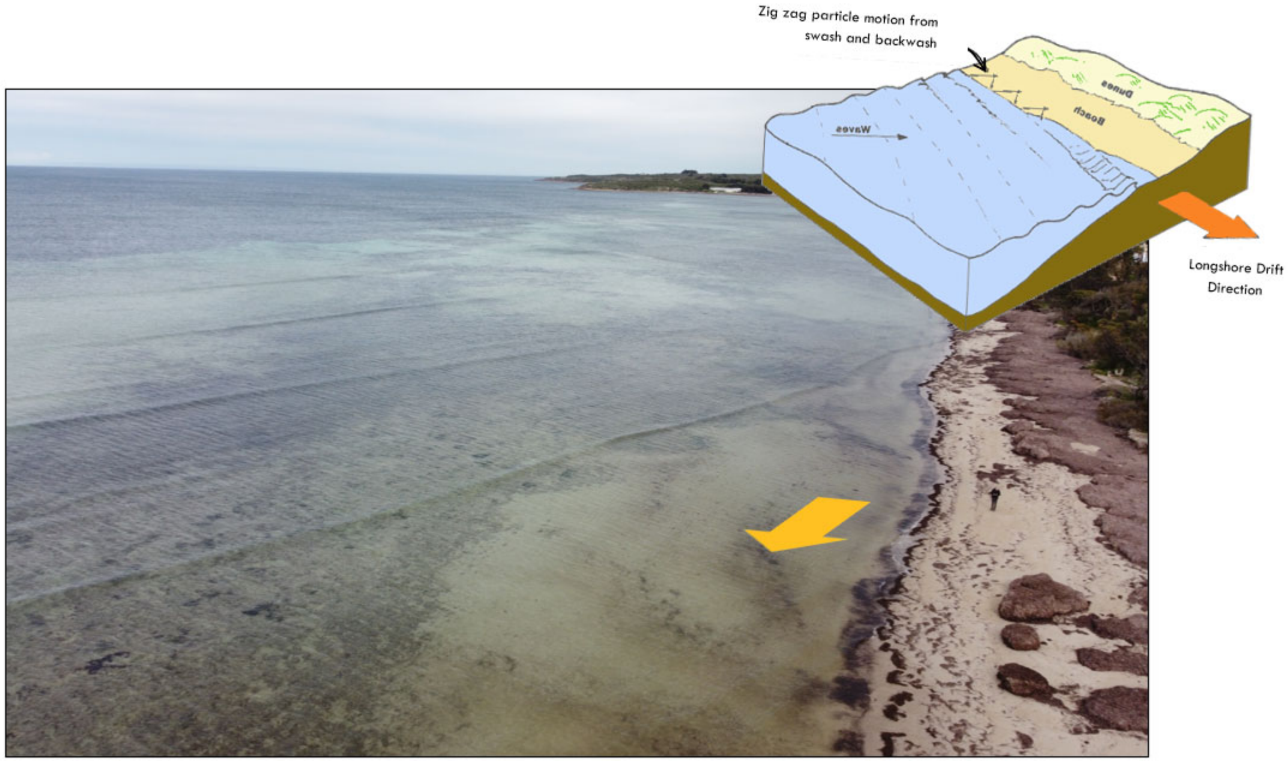
2. Hold the line (protect) is not a viable option to protect the existing foredune.

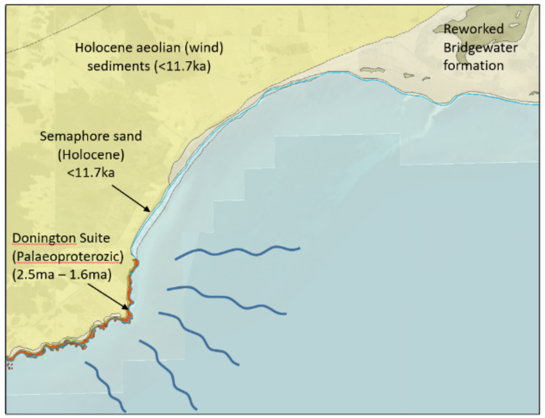
The swell waves that have been swinging around the headland at the boat ramp for thousands of years have formed and reformed the position of the sand platform upon which Mud Alley is located. Over the past few decades sand has moved from the west to the east. If hard protection is implemented to the foredune, the oblique way in which the waves interact with this shoreline is likely to rapidly increase erosion to the east, and also likely to remove sand levels from the beach (p.13).

Furthermore, hard protection items are unlikely to be supported by Coast Protection Board whose policy states, 'Development should not be located where it will create or aggravate coastal erosion or if it will require coast protection works, which will cause or aggravate coastal erosion…' (Policy S5).

Sandbags are not considered a viable option for such a long section of coast, and these are only at best a temporary solution. Sand nourishment will be trialled on the western end of Mud Alley and monitored to evaluate how long sand stays in the local beach system.

Figures: Illustrate the way in which swell waves interact with the beaches of Foul Bay.





Protection problems

The height of the frontal dune is 1.90m to 2.00m AHD. To provide sufficient rock protection to manage storm events projected for 2050 would require a rock wall at 3.00m AHD. There are three main problems with this strategy. First, rock protection at this height would spoil the natural beach. Second, the way waves interact obliquely with this beach is likely to cause rapid erosion to the east of the rock wall. Third, rock walling would prevent the dune from receding and then sand would likely be lost from the beach.

Adaptation strategy

3. If seas rise as projected in the second half of this century, the current layout of Foul Bay is unlikely to be viable.

Sea flood modelling

The sea-flood modelling in this project uses sea level rise projections of 0.30m by 2050 and 1.00m by 2100 which correlates to the most pessimistic scenario from the IPCC (RCP 8.5) (p. 46-47). The sea flood map on this page depicts a routine high tide event that is projected to occur once or twice a month in winter months with the addition of 1.00m sea level rise projection for 2100. This event would routinely overtop the current road level of Mud Alley by 0.70m- 1.00m. The 1 in 100-year ARI event would overtop the current road level of Mud Alley by 1.80 to 2.10m (p.66). On the other hand, we need to take into consideration that current rates of sea level rises are relatively small[1] and there is minimal evidence of acceleration in the rate of rise[2].

Erosion modelling

The erosion modelling was conducted as though no human infrastructure was present as a way to envisage how the coast may erode (p. 76-81).

Figure a: Routine high-water event (1-3 times per month) with 1.00m sea level rise projected for 2100.

Shoreline recession was estimated at 65m to 91m, but this should be used as a guide only. Using the average at 78m, the projected rate of erosion is 1m/year or 30m by 2050 and 80m by 2100. As a comparison, the rate of erosion on the western end has been calculated at 0.6m/year. However, rates of erosion will not not be uniform and will be controlled by the rocky outcrop at Hillier Crescent and the upward slope toward the ridgeline and South Coast Rd.

Summary

If seas rise as projected in the second half of this century, the current layout of Foul Bay is unlikely to be viable.

[1] Average sea level rise rate since 1990: Port Lincoln 2.14mm, Port Giles 2.58mm, Victor Harbor 2.48mm.

[2] Watson, P. 2020, Updated Mean Sea Level rise, including analysis of Outer Harbor tide gauge.

Adaptation strategy

4. Managed retreat is a long-term option, but not an option in this current era.

To implement a retreat strategy in this current era is not warranted due to relatively low rates of sea level rise and the uncertainty of sea level rise projections. Furthermore, new dwellings have been recently approved and constructed, and changes of property ownership would have occurred without due warning about such a significant policy implementation. On the other hand, knowing that a retreat strategy is possible is an advantage in that it provides long term certainty for the community irrespective of future sea level rises. By contrast, other locations around Gulf St Vincent, such as the lower lying areas in the Mallala region, do not have easily identifiable retreat options.

The ridgeline behind Mud Alley (eastern end) is predominantly at elevations 3.60 to 4.90 (Figure a). The 1 in 100-year risk at 2100 is 3.60m AHD. South Coast Road is predominantly 2.80 to 2.90, rising to 4.25 on western end. Therefore, the settlement could retreat to the ridgeline in the second half of this century if the larger sea level rise projections were realised. It is important to recognise that this proposal is not under consideration in this present time.

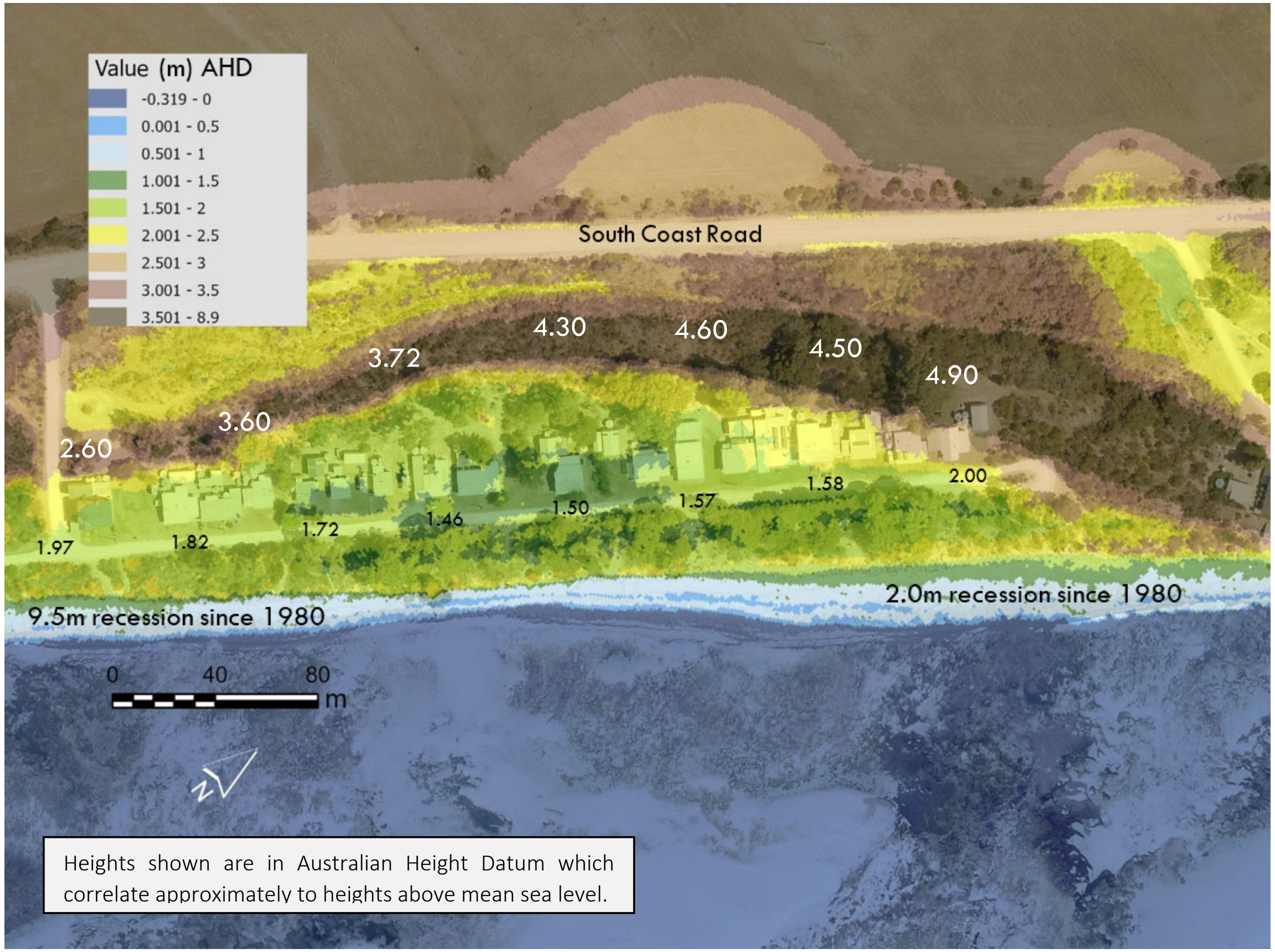


Figure a: Terrain model depicting the geological layout of Mud Alley (east of the access road). The ridgeline behind Mud Alley settlement is at higher elevations than the projected sea-flood risk for 2100, allowing for 1m of sea level rise. The exception is where the ridgeline intersects the Mud Alley access road which would need to be raised by 1m. Note, the current proposal is not to retreat the settlement.

Adaptation strategy

5. Raising floor levels of new dwellings will accommodate future sea-flood flows.

A tension exists between the uncertainty of the sea level rise projections, the low rate of sea level rise, and the need for Council to demonstrate that new dwellings can be appropriately managed in the context of Coast Protection Board Policy. Housing constructed now is likely to have a 60 - 80 year life span and Council is required to demonstrate how these dwellings can be managed over time.

In 2016, SA Coast Protection Board amended its policy to manage coastal layouts such as Foul Bay more effectively[3]. It was recognised that raising site levels is not always advisable in low lying areas as these will need to be protected if seas rise as projected and new erosion problems could emerge with seawater flow paths altered by various site level configurations.

Key points from the policy

- Elevated floor levels may be considered as an alternative option to raising site levels.
- The finished floor level is to be no lower than added 1.25m to the 1 in 100-year ARI sea-flood level.
- The underside areas are not enclosed (to allow for the potential flow of inundation).
- Adjacent land is uniformly low lying and is not compromised with scouring.
- Service facilities vulnerable to flooding are raised above the finished floor levels.

It is recognised that landowners may wish to moderately raise site levels to provide better amenity for their housing proposals. As seen in the next section, moderately raising site levels may be useful in the context of managing Foul Bay over the longer term if seas rise as projected.

The reason SA Coast Protection Board implemented this policy (i.e. raising floor levels but not site levels) was the recognition that some settlements may be situated in inappropriate locations in regard to coastal hazards. The policy also recognises that elevated floor levels may not alleviate long term coastal hazard risks, nor lessen the requirement for whole of settlement coastal adaptation strategies. In other words, the adoption of a policy of raised floor levels should be seen as an interim measure, and that longer term adaptation strategies are likely to be required.

On the other hand, the ability to raise floor levels provides some certainty in dwelling approvals.

Policy implementation at Foul Bay

This strategy is already in place at Foul Bay with the planning requirement that new dwellings have finished floor levels at 3.85m AHD which correlates to the 1 in 100-year ARI event with the inclusion of 1m sea level rise projected for 2100.

Additional adaptation strategies

Raising floor levels of dwellings deals effectively with sea-flooding risk to new dwellings but other hazard factors are required to be managed:

- Secure vehicle and pedestrian access to private properties along Mud Alley.
- Potential sea-flood issues for existing housing.
- Erosion issues, which may increase in the future if the frontal dune is eroded.

An adaptation strategy to deal with these three factors is proposed on the following pages.

[3] SA Coast Protection Board Policy, 2016, p. 41. Foul Bay is specifically mentioned in the policy as an example.

Adaptation strategy

Adaptation Proposals – short to medium term

1. Proposal to manage interim sea-flood risk to Mud Alley road and to existing houses.

As noted in the Guiding Principle 1 (p. 98) only a narrow strip of elevated dune now protects Mud Alley road and the houses behind from being routinely flooded from the sea. It is unknown if this strip of dune will erode away in the next few storms, or if it will last another 10 years or more. Therefore, interim measures will be required to provide certainty for vehicle access along Mud Alley and to limit flooding of housing allotments. The term 'interim' is not intended to be interpreted as 'temporary' but rather reflects the conclusions in (3) above.

<u>Two Options Considered</u>

1. Raise Mud Alley road surface to 2.20m AHD to reduce potential sea-flood hazard if the frontal dune erodes away based on the following inputs:

- The events of 29 September 2016 and 21 July 2021 that overtopped the western end of Mud Alley were surveyed at 1.85m AHD.
- A hypothetical event that combines higher wave effects (29 September 2016) with higher tide (21 July 2021) produces an event at 2.15m AHD.
- The 1 in 100-year ARI event is assigned by SA Coast Protection Board at 1.80m (storm tide height) and 0.20m (wave setup). As the road is setback 15m to 25m from the dune escarpment, wave runup of 0.70m could be validly omitted.

The proposal to raise the road to 2.20m AHD would mean an increase in height of the road of 0.20m at the Mud Alley access road junction, 0.70m in the middle section and 0.20m on the eastern end. See also road elevations on page 101 above.

2. Install an earthen levee to the seaward side of Mud Alley Road. Several designs were considered for an earthen levee to the seaward side of Mud Alley Road. However, this option was discounted based on the following:

- As a protection item the levee may require a height 3.15m AHD to meet sea level rise projections for 2050 and would require a base 6.7m wide. By way of contrast, the road width of Mud Alley is generally at 4m.
- The footprint required for a levee of any height would mean substantial clearing of the vegetation along Mud Alley (Figure a).
- The installation of the levee reduces the distance between the levee and erosion escarpment (for example by 6-7m) and therefore reduces the erosion buffer, and therefore also decreases the time buffer.

It is important to note, that the road ***or*** the earthen levee would not be engineered to manage regular interaction with the sea and are therefore to be regarded as interim flood protection devices rather than an erosion management strategy.

The next stage of this project would be to produce a road design which may include a 3m wide top, strategic passing bays, and how the road would interrelate with private properties (see also a discussion regarding site levels below).

Figure a: Mud Alley is bordered by vegetation, is approximately 4m wide, and at elevations 1.50m AHD in the middle, and approximately 2.00m AHD at either end .

Adaptation strategy

2. Proposals to manage potential erosion.

It is hoped that the above strategy will provide a time buffer before erosion impacts the road. Considering the rate of erosion from the western end, which has been at a higher rate than the eastern end at 0.6m/yr, and that the road is set back 15m to 25m from the frontal dune then this strategy may provide a time buffer of 25 – 40 years. Furthermore, the coast may eventually find equilibrium and the rate of erosion slow, or halt, but there is no way to assess when, or if, this may occur.

Coastal Monitoring

Therefore, subsequent to the raising of the road, monitoring should be undertaken of:

- The rate of erosion of the frontal dune.
- The impact of storms to identify weak points in the dune system.
- If the frontal escarpment is eroded away, the rate of erosion/recession of the land between the receding dune and the road.
- The impact and frequency of sea-flooding on the edge of the road.
- Any escalation in the rate of sea level rise (this will be undertaken by entities other than Council or landowners).

Coastal Management

While the fact that hard protection is not desirable for the frontal dune escarpment does not discount the possibility of employing techniques to slow the rate of erosion. For example, a trial to sand nourish the western end of Mud Alley will provide a case study to understand how sand moves along the coast and whether this strategy could be employed more generally. in some places sandbags could be placed, but this is not an advisable strategy for the entire length of the coast. If the frontal dune eroded away completely, a new dune may be able to be formed adjacent the road with the importation of sand from local sources and the installation of vegetation to provide consolidation. The monitoring program mentioned previously will provide the data from which to make these decisions.

Rock protection

If erosion recedes back to the road, then the road may require interim rock protection while an alternative coastal adaptation strategy could be designed and employed. Rock protection is to be regarded as in interim measure because if seas rise as projected in the second half of the century, then the current layout is unlikely to be viable. The rock protection is a means to provide a time buffer for further monitoring and to prepare an alternative strategy (see next page).

Proposed setback for new dwellings

The length of the allotments is relatively small at 24m and therefore a significant setback cannot be imposed. However, a policy for a setback of 6m will increase the erosion buffer between dwellings and the frontal dune.

3. Proposed site levels and drainage

Generally, the policy of raising houses is coupled with the policy not to raise sites excessively. However, in the context of raising the road 2.20m AHD, landowners could be permitted to raise their allotments to the same height as the road (or slightly higher). At worst, site levels in the mid-section of Mud Alley are as low as 1.30m AHD which would require 1m of fill. A policy is required to set all site levels at the same height. Additionally, if site levels are not raised, then a means to drain rainwater (or sea-flooding if this occurs in the future) through the road, such as pipes through the road with valves on the seaward side that could be opened to drain the water away quickly after the flood event.

Adaptation strategy

Adaptation Proposals – longer term (post 2050)

As noted in Guiding Principle 4 (p. 101), long term retreat is a viable option for Mud Alley settlement as there is a ridgeline behind the houses that is higher than the projected risk for 2100. However, any long-term retreat strategy would be staged due to the existence of the houses that will be constructed over the next 30-40 years in the current alignment to Mud Alley (with 6m setback). As noted previously, all new dwellings will be required to be constructed at 3.85m AHD which is above the sea-flood risk projected for 2100.

Retreat Strategy - Stage 1

The factors that will trigger the need to employ a retreat strategy (Stage 1) will come from the monitoring of the coast as described on the previous page. These triggers are likely to include:

- Accelerated rate of erosion towards Mud Alley road or overtopping of the road.
- The need to install rock adjacent to the road to slow the rate of erosion.
- An escalation observed by others in the rate of sea level rise.

The first stage of retreat is to close Mud Alley to vehicular traffic and provide access to properties from South Coast Rd. These access ways may service several properties to limit the impact on the natural vegetation currently situated in the road reserve and Allotment 21 which is Crown Land. Mud Alley could be reformed into a pedestrian walkway at increased height. If it is recognised that Stage 1 of the retreat strategy is required, planning and policy implementation should be undertaken for Stage 2.

Retreat Strategy – Stage 2

Even if seas rise as projected, Stage 2 is unlikely to be required until later in this century (perhaps post 2070). It is important to recognise that by this stage current dwellings would have been replaced with floor levels at 3.85m AHD which could still be accessed from South Coast Road. Stage 2 of the retreat strategy would retreat allotments to the ridgeline upon which new dwellings would be constructed.

Figure a: Cadastral layout of Mud Alley (east of the access road). Arrows are only schematic representations of possible access ways to private property.

Adaptation strategy - Summary

MUD ALLEY – EAST OF THE ACCESS ROAD | COASTAL ADAPTATION STRATEGY

Adaptation Context	Mud Alley is set at lower elevation than the foredune which has been eroding for at least 40 years. If the frontal dune erodes a few more metres, then Mud Alley will be exposed to routine flooding. However, the timing of this erosion is unknown. It may be a few storms away or the dune may remain intact for a decade or more. The erosion is likely to continue towards Mud Alley road unless an equilibrium is reached between actions of the sea and the shoreline. If the rate of erosion is similar to that of the western end (0.6m/year), then it may take 25 to 40 years before erosion interacts with the road, but the rate may be faster. Taking into account the longer-term view, if seas rise as projected in the second half of this century, then it is unlikely that the current layout of Mud Alley would be viable. Sea-flooding would regularly flow across the current height of Mud Alley at depths 1m or more. It is acknowledged that recently implemented planning policy requires all new dwellings to be installed at 3.85m AHD which will ensure that dwellings are placed above sea level rise of 1m projected for 2100.

Adaptation Item	Description	Next steps	Timing
1. Raise Mud Alley			
Raise the surface of Mud Alley to 2.20m AHD	Mud Alley is approximately 4m wide and set at heights 1.50m AHD (mid-section) to 2.00m AHD (at either end). Raising the road to 2.20m AHD will provide access for vehicles in the event the road becomes subject to inundation and interim protection for houses situated behind.	Obtain engineering design and costing. Consider whether sites should be raised to 2.20m AHD.	Raise the road as soon as practicable.

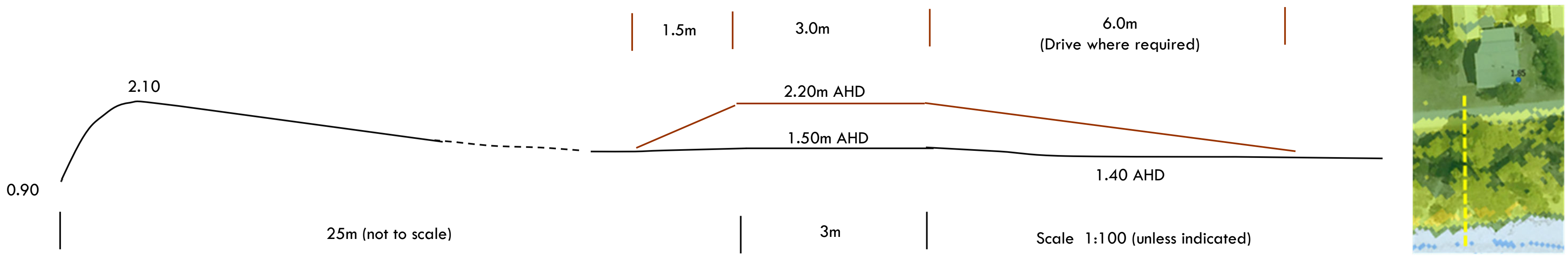


Figure: Example of existing profile at 49 Mud Alley, with proposed road and drive modification. If no drive, then similar profile to the left-hand side of the diagram.

Adaptation strategy - Summary

Adaptation item	Description	Next steps	Timing
2. Monitor the coast			
Implement a monitoring program to monitor the shoreline position and the impact of storms.	Monitor the shoreline position using aerial photography within GIS software. Monitor the impact of storm events. A citizen science approach through the Foul Bay Area Progress Association may be an effective way to monitor storm impacts.	Design a monitoring program.	Implement monitoring program within 1-2 years.
3. Coastal management			
The main aim of coastal management would be to slow the rate of erosion toward the road.	The monitoring program will identify weak points in the current dune system and residents could be encouraged to make these points more resilient. If the frontal dune escarpment erodes away, then sand could be imported, and a dune established and vegetated closer to the newly raised road. Furthermore, a trial for sand nourishment on the western end of Mud Alley will be used to ascertain effectiveness.	Design a coastal management system (based on inputs from the monitoring) and use a 'citizen science' approach where appropriate.	Implement coastal management within 1-2 years.
4. Provide protection to the road			
The aim is to provide interim protection to prevent erosion of the road, not to provide protection from long term inundation.	If the shoreline erodes back to the road, low height rock protection may be required to protect the integrity of the road. It will depend on the rate of sea level rise at the time, whether this strategy will provide longer term protection, or whether access should be provided for vehicles from South Coast Road (refer to 5 below).	Nil.	Based on current erosion rates, 25-40 years, but may be sooner.
5. Retreat vehicular access			
If seas rise as projected, then Mud Alley road may not be viable.	If seas rise as projected or if erosion is more significant than anticipated, provide access to dwellings from South Coast Road. Mud Alley could be reconstructed into walking trail. If the rate of sea level rise had escalated, then Item 6 should be planned at this time also.	NIl	30-40 years.
6. Retreat the settlement			
If seas rise as projected in the second half of this century, then Mud Alley settlement may not be viable in its current layout.	It is important to remember that new dwellings constructed from this era forward will be set at 3.85m AHD above projected sea flood risk for 2100. The issue considered here is increased erosion that will be brought about if seas rise as project	Nil	50+ years

MUD ALLEY - WEST

Adaptation strategy

MUD ALLEY – WEST OF THE ACCESS ROAD

Guiding principles that underpin the strategy.

The guiding principles that underpin the coastal adaptation strategy are similar as for Mud Alley – east (see section above). In summary these are:

1. Mud Alley (west) already suffers from sea-flood inundation in storm events. If the frontal dune erodes further, then Mud Alley will be increasingly vulnerable to sea-water flooding.

2. Hold the line (protect) is not a viable option to protect the foredune or the road (see p.99). Sandbags have been installed as an interim measure, but these are not a long-term solution.

3. If seas rise as projected in the second half of this century, the current layout of Foul Bay is unlikely to be viable (see p. 100).

4. Managed retreat is a long-term option, but not an option in this current era (p. 101).

5. The current planning policy of raising floor levels of new dwellings to 3.85m AHD will accommodate future sea-flood flows (p. 102).

Figures: The pattern of erosion is oblique, Mud Alley in storm event 29 September 2016, Sandbags installed on western end in 2022.

Over the last 40 years, the dune has receded in an oblique pattern resulting in 20m recession at the end of Mud Alley and 8.5m at the Mud Alley access road.

Adaptation strategy

Land tenure and layout

The adaptation strategy for the western end of Mud Alley will need to be planned at the property level and take into account issues relating to access, site levels, vegetation and distance from the erosion.

- Lots 204-207. Houses are set above sea-flood risk. The sheds and other structures are set at the same level as Mud Alley and were flooded in previous two events.
- Lot 208. Recently renovated with Development Approval. Site level 1.90 (front) to 2.80 (rear), dwelling at 2.16m AHD.
- Lot 211. House constructed prior to 1992. Site level 1.80 (front), 2.30 (rear). Dwelling at 1.82m AHD.
- Lot 212. House constructed prior to 1992. Site level 1.80 (front) to 2.30 (rear) Dwelling and garages at 1.98m AHD.
- Lot 213. House constructed prior to 1992. Site level 1.75 (front), 2.30 (rear). Dwelling at 2.49m AHD.

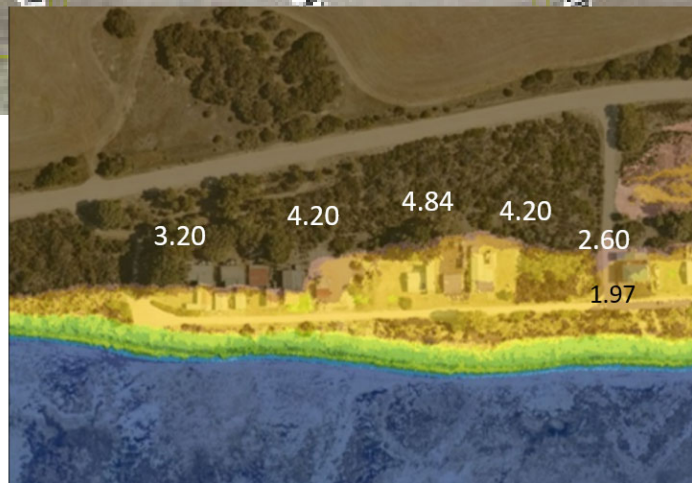
Lots 241, 209, 210, 214, 215, 216 are owned by the Crown.

Figures: Land tenure, terrain layout showing ridgeline behind existing houses.

Future flooding problem:

If seas rise by 0.30m (projected for 2050) then Mud Alley will be routinely (~monthly) inundated at depth 0.50m.

If seas rise by 1.00m (worst case scenario projected for 2100), then Mud Alley will be routinely inundated at 1.20m (~monthly)



Adaptation strategy

Adaptation context

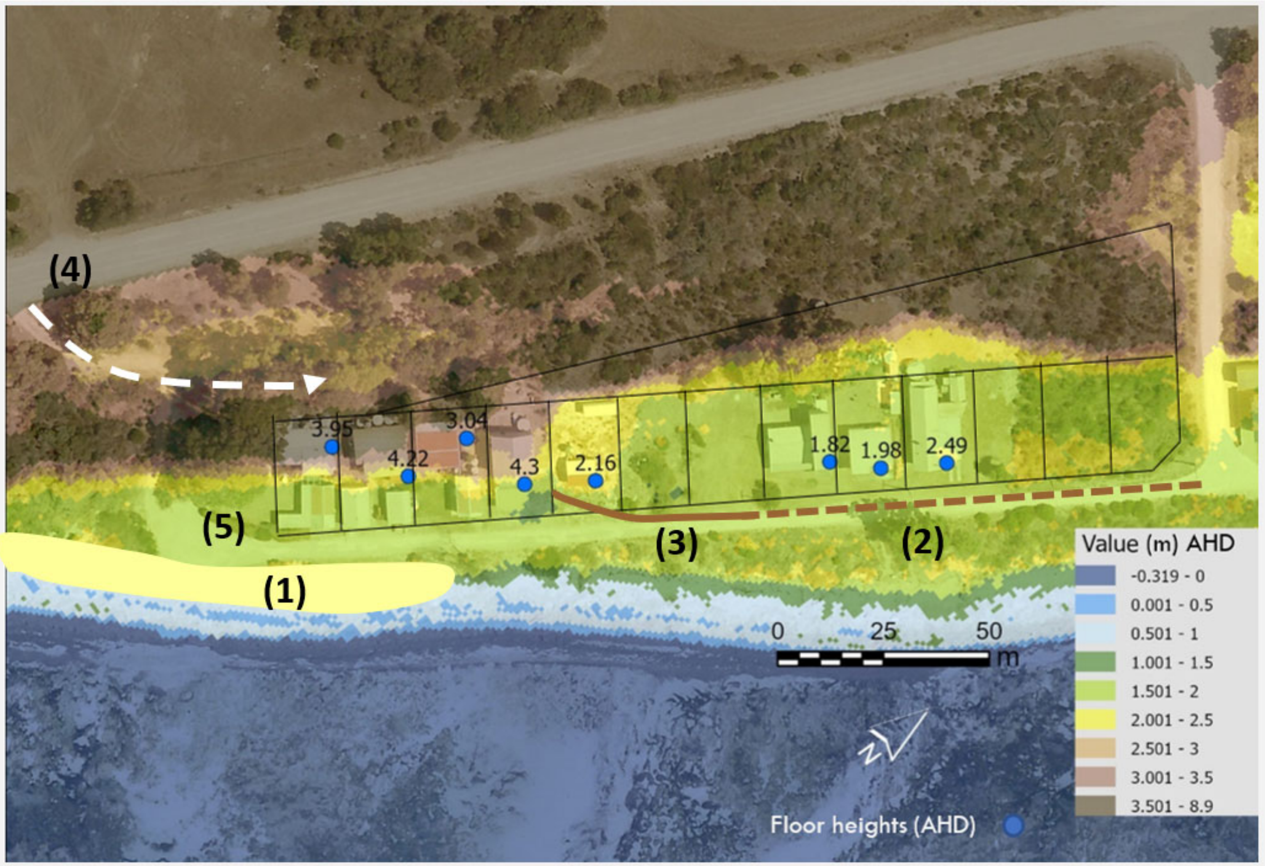
The following adaptation strategy is regarded as preliminary, requiring engineering review and consultation with the community. The proposals take into account that hard protection is not advisable for Foul Bay (see section above), and that inundation of Mud Alley cannot be easily controlled because it is at low elevation. This section of coast may continue to erode, or an equilibrium may be reached and the rate slow.

Adaptation strategy – short to medium term

Adaptation tasks

1. Import sand for installation west of Mud Alley road and to 'wrap around' the existing sand bags. The following items are recommended:

- Source ~720m^3 sand from the northern end of Foul Bay, vegetate and attempt to re-establish the dune in this location.
- Monitor the rate of movement of sand to the east to ascertain if the strategy may work in other locations along the beach.
- Note, the installation of a sand dune is unlikely to prevent inundation of Mud Alley in higher storm events and is not designed as a long-term sea-flood control strategy in the context of sea level rise.



2. Raise Mud Alley road to 2.20m AHD. See previous section for the rationale for the height and for an example of how the road could be raised (p.103,106). Raising Mud Alley will ensure that vehicle access is secure in current flood events and this strategy will also provide interim protection to the dwellings behind. The word 'interim' is used to note that if seas rise as projected, that this strategy will not manage sea level rises projected for 2050 and beyond.

Adaptation strategy

Adaptation – short to medium term (cont.)

3. Install a low height earthen levee (2.20m AHD) from the end of the road to the elevated section of land on the western end of Mud Alley to act as an interim sea-flood protection measure. The reason that the raised road is not extended any further to the west is to allow an erosion buffer of ~12m between the current shoreline and private property. The sand nourishment strategy (1) may increase that erosion buffer. At the worst case if the sand nourishment has no benefit, it may take another 10-20 years before the erosion impacts the earthen levee[4].

4. Provide vehicle access to the rear to the five dwellings on the western end of Mud Alley. It is recognised that design and planning will be required at the individual property level and several issues will need to be worked through:

- vegetation removal.
- space for new garaging and access.
- boundaries and right of way access.

This strategy could be employed immediately or delayed to ascertain the effectiveness of the sand nourishment and dune stabilisation (1).

5. If the sand nourishment strategy (1) is not effective at managing erosion and the shoreline continues to recede (the sandbags may provide a time buffer), close Mud Alley to vehicle traffic on western end. Consider retaining a public pedestrian path at narrower width.

Coastal Monitoring

After installation of the sand and dune creation, monitoring should be undertaken of:

- The rate of erosion of the frontal dune.
- The impact of storms to identify weak points in the dune system.
- If the frontal escarpment is eroded away, the rate of erosion/recession of the land between the receding dune and the road.
- The impact and frequency of sea-flooding on the road edge or road surface.
- Any escalation in the rate of sea level rise (this will be undertaken by others).

Coastal Management

While the fact that hard protection is not desirable for the frontal dune escarpment does not discount the possibility of employing coastal management techniques along all the western end of Mud Alley to slow the rate of erosion. These techniques may include use of additional sand nourishment, localised use of sandbags, and maintaining vegetation.

Rock protection

If erosion recedes back to the road or earthen levee, then these may require interim rock protection while an alternative coastal adaptation strategy could be designed and employed. Rock protection is to be regarded as an interim measure because if seas rise as projected in the second half of the century, then the current layout is unlikely to be viable. The rock protection is a means to provide a time buffer for further monitoring and to prepare an alternative strategy (see next page).

Proposed setback for new dwellings

The length of the allotments is relatively small at 24m and therefore a significant setback cannot be imposed. However, a policy for a setback of 6m will increase the erosion buffer between dwellings and the frontal dune. Current planning policy will ensure that all new dwellings have floor levels at 3.85m AHD (projected risk, 2100).

[4] Estimation based on 0.60m/yr rate of erosion over 40 yrs.

Adaptation strategy

Adaptation Proposals – longer term (post 2050)

As noted in Guiding Principle 4 (p. 101), long term retreat is a viable option for Mud Alley settlement as there is a ridgeline behind the houses that is higher than the projected risk for 2100. However, any long-term retreat strategy would be staged due to the existence of the houses that will be constructed over the next 30-40 years in the current alignment to Mud Alley. As noted previously, all new dwellings will be required to be constructed at 3.85m AHD which is above the sea-flood risk projected for 2100.

Retreat Strategy - Stage 1

The factors that will trigger the need to employ a retreat strategy (Stage 1) will come from the monitoring of the coast as described on the previous page. These triggers are likely to include:

- Accelerated rate of erosion towards Mud Alley road or the earthen levee and/or increased overtopping of the road surface.
- The need to install rock adjacent to the road and/or the levee to slow the rate of erosion.
- An escalation observed by others in the rate of sea level rise.

The first stage of retreat is to close the remainder of Mud Alley to vehicular traffic and provide access to properties from the rear. These access ways may service several properties to limit the impact on the natural vegetation. Mud Alley could be reformed into a pedestrian walkway at increased height. If it is recognised that Stage 1 of the retreat strategy is required, planning and policy implementation should be undertaken for Stage 2.

Retreat Strategy – Stage 2

Even if seas rise as projected, Stage 2 is unlikely to be required until later in this century (perhaps post 2070). It is important to recognise that by this stage current dwellings would have been replaced with floor levels at 3.85m AHD. Stage 2 of the retreat strategy would retreat allotments to the ridgeline upon which new dwellings would be constructed.

Figure a: Schematic representation of Retreat Strategy 1 for possible access ways if erosion removes the road. If seas rise as projected post 2050, then, Retreat Strategy 2 may be required which relocates allotments and new dwellings to the ridge line.

Adaptation strategy - Summary

Adaptation Context	The dune in front of Mud Alley (west of the access road) has been eroding for at least 40 years in an oblique pattern which reflects the way that swell waves wrap around the rocky headland at the boat ramp. The rate of erosion has been 0.6m/year and the erosion escarpment has recently interacted with the western end of Mud Alley. This section of road has been subject to inundation in two recent storm events. The erosion is likely to continue towards Mud Alley road unless an equilibrium is reached between actions of the sea and the shoreline. Sandbags have been recently installed as an interim erosion control measure. Taking into account the longer-term view, if seas rise as projected in the second half of this century, then it is unlikely that the current layout of Mud Alley would be viable. Sea-flooding would regularly flow across the current height of Mud Alley at depths 1m or more. It is acknowledged that recently implemented planning policy requires all new dwellings to be installed at 3.85m AHD which will ensure that dwellings are placed above sea level rise of 1m projected for 2100.

Adaptation Item	Description	Next steps	Timing
1. Sand nourishment			
Import ~720m^3 sand and install on western end	Import ~720m^3 of sand from local sources (possibly north end of Foul Bay). Install to the western end of Mud Alley and wrap around the existing sandbags. Consolidate the dune with vegetation.	Obtain engineering design and costing. Source sand.	Install as soon as practicable.
2. Raise Mud Alley road			
Raise the surface of ~100m of Mud Alley to 2.20m AHD	Mud Alley is approximately 4m wide and set at heights 1.70m AHD to 1.80m AHD. Raising 100m of the road to 2.20m AHD from the Mud Alley access road to Lot 211 will provide access for vehicles in the event the road becomes subject to inundation and interim protection for houses situated behind (also taking into account item 2).	Obtain engineering design and costing. Consider whether sites should be raised to 2.20m AHD.	Raise the road as soon as practicable.
3. Install earthen levee			
Install ~110m of earthen levee at 2.20m AHD.	Install low height levee to connect the raised road to the elevated portion of land at Lot 207. The purpose of the levee is to act as an interim measure to manage current sea-flood risk. If seas rise as projected post 2050, then this area of Mud Alley is unlikely to be viable.	Obtain engineering design and costing.	Install as soon as practicable.

Adaptation strategy - Summary

Adaptation item	Description	Next steps	Timing
4. Monitor the coast			
Implement a monitoring program to monitor the shoreline position and the impact of storms.	Monitor the shoreline position using aerial photography within GIS software. Monitor the impact of storm events. A citizen science approach through the Foul Bay Area Progress Association may be an effective way to monitor storm impacts.	Design a monitoring program.	Implement monitoring program at same time of sand nourishment.
5. Coastal management			
The main aim of coastal management would be to slow the rate of erosion toward the road.	The monitoring program will identify how the imported sand moves along the coast and/or how well the dune can be established. Interim management techniques such as sandbags at key locations, additional sand nourishment and vegetation will assist in slowing the rate of erosion towards Mud Alley road.	Design a coastal management system.	Implement coastal management within 1-2 years.
6. Provide vehicle access from rear (Part A)			
Assumes that the dune creation on the western end is not effective, or inundation continues of the western end of Mud Alley.	If the installation of the dune fails to offer protection from erosion and the road continues to be inundated, provide vehicular access to the rear for the five dwellings on the western end. It is recognised if the road continues to be inundated, the private sheds and other structures will also continue to suffer inundation.	Conduct planning and design at the property level to ensure viability.	1-2 years.
7. Provide protection to the road/levee			
The aim is to provide interim protection to prevent erosion of the road, not to provide protection from long term inundation.	If the shoreline erodes back to the road or the levee, low height rock protection may be required to protect from erosion. It will depend on the rate of sea level rise at the time, whether this strategy will provide longer term protection, or whether access should be provided for vehicles from behind the remaining dwellings (refer to 8 below).	Nil.	Based on current erosion rates, 10-20 years, but may be sooner.

Adaptation strategy - Summary

8. Provide vehicle access from the rear (Part B)			
If seas rise as projected, then Mud Alley road may not be viable.	If seas rise as projected or if erosion is more significant than anticipated, provide access to dwellings from behind the remainder of the settlement. Mud Alley could be reconstructed into walking trail. If the rate of sea level rise had escalated, then Item 9 should be planned at this time also.	NIl	30-40 years.
9. Retreat the settlement			
If seas rise as projected in the second half of this century, then Mud Alley settlement may not be viable in its current layout.	It is important to remember that new dwellings constructed from this era forward will be set at 3.85m AHD above projected sea flood risk for 2100. The issue considered here is increased erosion that will be brought about if seas rise as project	Nil	50+ years


HILLIER CRESCENT
South Coast Road
Diosma Drive
Mud Alley
South Coast Rd

Adaptation strategy

HILLIER CRESCENT

Adaptation considerations:

The six houses at Hillier Drive are positioned on a rocky outcrop of limestone. The terrain upon which the houses are situated is at heights 3.70m to 5.00m AHD.

The land behind is at lower elevation but the ridgeline will protect from any seawater flowing into this region.

The 1 in 100 year sea flood risk set by Coast Protection Board for 2100 in this region is 2.80m AHD storm tide height, 0.20m wave setup, and 0.60m wave run up (total, 3.60m AHD).

Therefore, Hillier Drive is at no risk from sea level rise based on current projections to 2100.

Adaptation proposal:

Monitor the impact of storms and erosion on the base of the rocky outcrop to ensure that it is not breaking down (unlikely to occur).

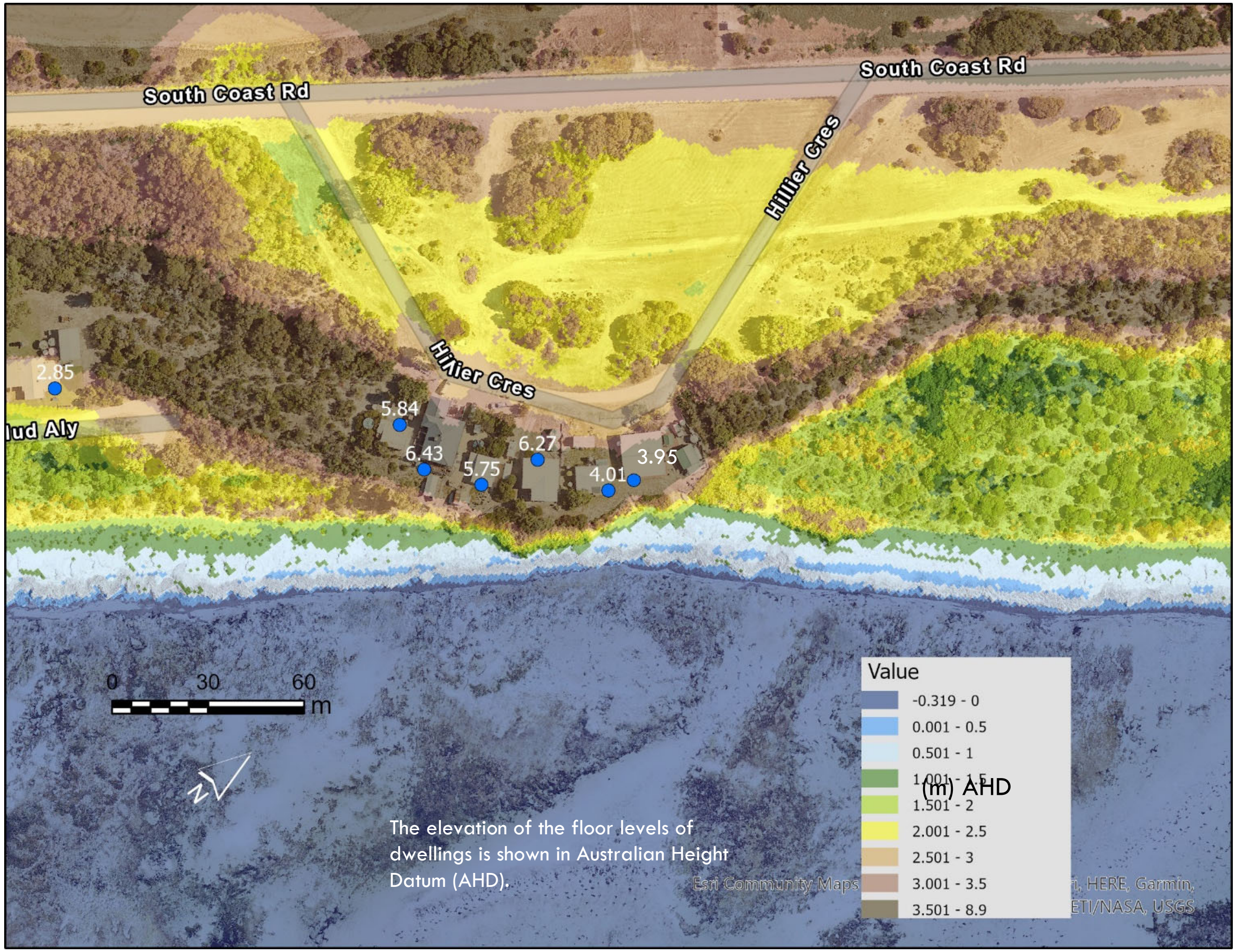


Figure a. The houses at Hillier Drive are set on terrain at heights 3.70m AHD to 5.00m AHD.

Adaptation strategy - Summary

Adaptation Context	The houses on Hillier Crescent are positioned on top of a rocky limestone outcrop above sea level rise risk to 2100. The exact nature of the outcrop is unknown and therefore the impact of storms and whether any recession is evident could be periodically monitored over time .

Adaptation item	Description	Next steps	Timing
1. Monitor			
Monitor coastal processes that impact the rocky outcrop.	Monitor the impact of storm events and ascertain if the rocky outcrop to ensure it remains stable. This should be a simple monitoring strategy based on observation of storm impact which could be managed/reported through the Foul Bay Area Progress Association.	Design a simple monitoring strategy.	1-2 years (but this is a low priority item)


DIOSMA DRIVE
Diosma Drive
South Coast Road
South Coast Rd
Mud Alley

Adaptation strategy

DIOSMA DRIVE

Adaptation considerations:

Due to the way swells rotate around the rocky headland to the west, the shoreline along Mud Alley has been receding and the shoreline along Diosma Drive has been accreting.

The alignment of the shoreline has rotated clockwise, the effect of which is more accretion in the east (62m) than the west of Diosma Drive (11m) over the last forty years.

Diosma Drive settlement is positioned on a low-lying sandy bench that was likely formed when sea level dropped by ~1m about 4,000 - 6,000 years ago. The terrain model indicates the possible location of this former shoreline (Figure a).

Sea level rise of ~1m is projected over the course of this century. However, in this present time the rate of sea level rise remains relatively low (2.40mm)[1].

Considering the macro view, a retreat strategy would be theoretically possible to the ridgeline behind Diosma Drive which is position above 3.50m AHD (pictured in dark brown) if seas rose as projected by 2100.

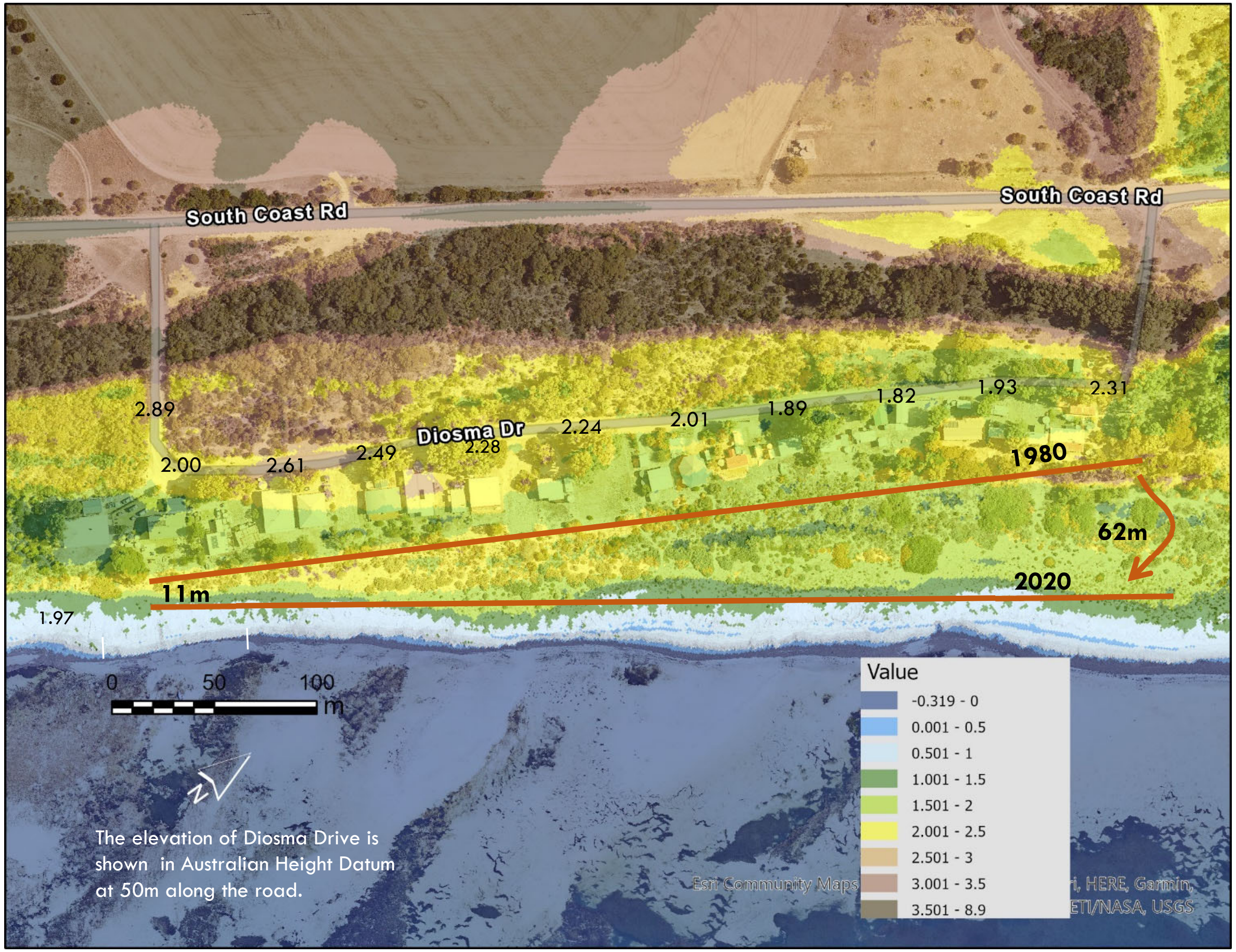


Figure a. Consideration of terrain layout and erosion trends. Mud Alley is predominantly at 1.50m to 1.80m.

[1]Tide gauges, since 1990: Victor Harbor (2.48mm), Port Giles (2.58mm), Port Lincoln (2.14mm) is average 2.40mm. Thevenard (3.66mm)

Adaptation strategy

DIOSMA DRIVE

Adaptation considerations (cont):

Two storm events (2016, 2021) inundated the western end of Mud Alley but Disoma Drive was not impacted due to the dune system that has built over the past 40 years.

The sea-flood map at the right depicts the 1 in 100-year storm surge event assigned by CPB at 1.80m AHD (tide height) and 0.20m (wave setup), no wave runup due to the dunes). Factors for long term planning:

- The coastal processes that moved the sand from the east and built this dune, may eventually act on this section of coast, and cause it to go into recession, but this is likely to be decades away.
- The current 1 in 100-year storm surge event (without wave runup) appears as though it may penetrate the dunes and cause inland flooding, but this would depend on the duration of the event.
- If this event did penetrate the dunes in any significant manner, eight dwellings would have flood over floor levels.
- Hard protection items are not recommended for a sandy location such as Diosma Drive.

Figure a. Storm modelling for the event 1 in 100-year ARI storm surge event for current risk. Wave runup has not been included so as to evaluate the likelihood that this event would penetrate through the dune system. Depending on the duration of the flood event, sea-flooding may penetrate through the dunes and cause inland flooding.

Adaptation strategy

DIOSMA DRIVE

Policy considerations

Diosma Drive is a difficult location at which to apply coastal policy:

- In the 1980s this location was exposed to actions of the sea because there was no foredune.
- The coastal processes that built the existing dune over the last forty years may also remove it, but this may be decades away.
- The location may be currently at risk from flooding from the 1 in 100-year storm surge event but this is difficult to determine in the context of a vegetated dune system.
- Hard protection items are not compatible with the coastal location and not in accordance with Coast Protection Board Policy (S5).
- Council has already implemented development policy that requires all new dwellings to have a finished floor level of 3.85m AHD (which is above sea-flood projections for 2100).

Figure a. The various policy and land tenure considerations. Lot 22 is owned by the Crown and land between Allotment 22 and South Coast Road is designated as 'road reserve'.

Adaptation strategy - Summary

Adaptation Context	Diosma Drive varies in height, with low sections at 1.80m to 1.90m AHD in the east and a higher section in the west at 2.30m to 2.60m AHD. In 1980s there was no foredune, and archives held at Department of Environment and Water reveal that there was ongoing concern about erosion and potential inundation. Since the 1980s, the dune has accreted seaward by 11m on the western and 62m on the eastern end. However, the processes that caused the accretion may also eventually move the sand further eastward and the site could enter an erosion phase (but this is likely decades away). The site may be at risk from the current 1 in 100-year storm surge event, but the risk is difficult to quantify due to the width and varying height of the dune. However, for context, if this event did overtop the dunes, then 8 houses may have sea-flood over floor levels. Yorke Peninsula Council has already implemented planning policy that requires new dwellings to have finished floor levels of 3.85m AHD which would put dwellings above sea-flood risk level projected for 2100 with 1m of sea level rise.

Adaptation item	Description	Next steps	Timing
1. Monitor			
Monitor coastal processes and rates of sea level rise.	Monitor the shoreline position to ascertain whether the coast is in accretion or erosion cycle. Shoreline monitoring is best achieved using aerial photography within Geographical Information Systems (GIS) software. Monitor and record the impact of storm events, especially those that come close to penetrating the dunes. This will provide warning whether events of a higher magnitude might flow through the dunes. A citizen science approach through the Foul Bay Area Progress Association would be the most effective way to manage this task.	Design a monitoring program. Use aerial photography and a ‘citizen science’ approach to monitor storm impacts.	Within 1-2 years.
2. Coastal management			
The aim of the coastal management would be to maintain the dunes.	Using the inputs from the monitoring program, maintain the height and integrity of the dune system. This would be best achieved through maintaining vegetation (which is occurring naturally) and if necessary, importing sand into lower vulnerable areas. However, if the oblique pattern of the erosion continues, the loss of these dunes may be unavoidable, but this is likely to be decades away.	Design a coastal management program that maintains dune integrity.	Within 1-2 years.