University of South Australia

School of Natural and Built Environments

Institute for Urban Renewal

Coastal Settlements Adaptation Study- Webb Beach

Framework Report

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GLOSSARY

ADAPTATION

Adaptations are actions taken to help communities and ecosystems cope with actual or expected changes in climate conditions.

AHD

AHD is an acronym for Australian Height Datum. When a measurement is accompanied with the letters AHD it indicates a height above mean sea level. Mean sea level was adopted in 1971 by the National Mapping Council of Australia at 0.00 AHD. For example, 3.2m AHD is 3.2 metres above mean sea level. AHD tide levels are different to the fishing charts which are called Chart Datum (CD). A subtraction of 1.45 metres from tide chart will give the correct AHD height.

ARI

ARI is an acronym for Average Return Interval. ARIs, also known as return periods, are an estimate of the average interval of time between events of a certain magnitude. In relation to severe storm events the longer the interval the higher the storm surge height is predicted to be. For example, a 1 in 100 year ARI storm surge would be higher than a 1 in 50 year or 1 in 10 year ARI storm surge height. It is important to remember that this is just a statistical calculation and represents the long term theoretical average; there is nothing preventing a 1 in 100 year ARI flood happening twice in one week.

DEM

DEM is an acronym for Digital Elevation Model. The digital elevation model used in this study was created from a aircraft that bounced millions of infra-red light beams to the ground and then created a digital topographical map. This digital map is combined with aerial photography and an operator can use a computer to check the height of land features.

EROSION

Erosion is where action of the sea moves sand and vegetation from the shoreline so that the dune system is weakened. When the frontal dune system is significantly weakened it may completely erode away and the shoreline moves inland.

STORM SURGE

A rise in the water level along the coast due to the action of the wind alone or its combination with the reduction of atmospheric pressure accompanying it. The effects of a storm surge are more severe when it occurs in conjunction with high tide.

Introduction

1.1 Background

In May 2013 the District Council of Mallala (DC Mallala) commissioned the University of South Australia, School of Natural & Built Environments to undertake the Coastal Settlements Adaptation Study (CSAS). The aim of the study is to identify and evaluate potential sea level rise adaptation strategies for the coastal settlements of Parham, Webb Beach, Thompson Beach and Middle Beach.

1.2 Investigative framework

This study uses an adaptation of the Coastal Adaptation Pathways Decision Map developed by the Local Government Association of SA and University of South Australia for the Department of Climate Change and Energy Efficiency (Balston et al, 2012) to identify and analyse the threats posed by sea level rise. Each settlement is reviewed within the following framework:

1. Establish settlement history.
2. Analyse existing sea-flood protection.
3. Analyse impact of sea-flood scenarios.
4. Analyse emergency access and egress.
5. Establish profile of the assets at risk.
6. Explore liability issues.
7. Propose adaptation options.

1.3 The stages of the study

The study is conducted in three main stages:

Stage 1: State of Play Report:

The *State of Play Report* contains the findings from steps 1-6 from the investigative framework and was endorsed by the District Council of Mallala at its Ordinary Meeting on 25 November 2013.

Stage 2: Community Consultation:

Subsequent to completion of the draft *State of Play Report* the community was invited to contribute to the report at a public meeting at the Dublin Hotel on 10/09/13 or in writing to DC Mallala. The findings from community consultation were integrated into the State of Play Report and the report was endorsed by the District Council of Mallala at its Ordinary Meeting on 28 October 2013.

Stage 3: Propose adaptation options:

Taking into account the findings of the first two stages, this report represents Step 7 of the Investigative Framework - 'propose adaptation options'. These adaptation options are proposed within the following five categories of adaptation responses:

- **Protect:** use means such as construction of sea walls and levees, beach sand replenishment or installation of drainage swales to protect existing development;
- **Accommodate**[1]: use means such as raising buildings, protecting buildings from flooding, or employ warning and evacuation strategies;
- **Retreat**: abandon settlements and move development inland in the face of rising sea levels. The concept of 'retreat' is also known as 'planned retreat'.
- **Defer:** threats have been assessed and options analysed but there are valid reasons to wait until to a later date to act.
- **Do nothing:** ignore the risks and do nothing.

1.4 Reporting and consultation

While the scope of the Coastal Settlements Adaptation Study (CSAS) covers the four settlements of Parham, Webb Beach, Thompson Beach and Middle Beach, adaptation responses options available to each settlement are reported separately. This report contains the adaptation options for:

Webb Beach.

In preparing the adaptation options in this report the following agencies and individuals were consulted:

- DC Mallala Infrastructure Services Department, on 7th November, 2013.
- Coast Protection Branch, DEWNR, on 12th November, 2013.
- Geoff Fisher, Australian Water Environments (AWE), on 19th November, 2013. Geoff Fisher (AWE) also reviewed the adaptation proposals and offered technical advice.

1.5 Methodology

Adaptation responses in this study take into account: the nature of the threat; the protection of infrastructure, the safety of people; and the appropriate timing of response until 2100.

1.5.1 Adaptation responses that relate to the nature of the threat.

Other than depth of water, additional factors that influence the impact of a flood on a settlement are: the velocity of the water (speed), the duration of the flood (how long it lasts), and the topography of the settlement. How much warning is possible for possible flood is a factor that enables the settlement to prepare for the flood more effectively. The general characteristics of a sea-flood in the Mallala region are shown in **Table 1**.

[1] Protection options in this study relate to the community as a whole and are generally measures that are taken to stop the flow of water into the community at its borders as a first line of defence. Measures that a resident might take to protect the water from entering their own dwelling are classed as accommodation options. The exception to this rule is when dwellings are situated on the shoreline itself.

Table 1: Sea flood characteristics for DC Mallala coastal region.

Flood characteristic	Mallala region
Velocity of water	Low, due to tidal action and ocean terrain
Direction of flow	From the west
Duration of flood	Short 1-2 hours
Warning	Predictable as flood normally relates to tide.

To contextualise the flood risk in the Mallala region, **Table 2** illustrates how insurance companies may discount their flood risk when adequate flood warning can be provided and the community is prepared to deal with a flood. For example, where the community is experienced and there is a greater warning time than 12 hours, the predicted actual cost of damages can be discounted by 0.4 (Victorian Government, 2000).

Table 2: Proposed ratios of actual:potential damages (Victorian Government, 2000)

Warning time	**Experienced community**	**Inexperienced community**
Less than 2 hour	0.8	0.9
2 to 12 hours	Linear reduction from 0.8 at 2 hours to 0.4 at 12 hours	0.8
Greater than 12 hours	0.4	0.7

Historically, storm surges that have threatened settlements in the Mallala coastal region have been in conjunction with the highest astronomic tide (often referred to as a king tide) which would, in the majority of cases, provide a greater than 12 hour warning period. In summary, and based on historical data, the flood threat is normally related to predictions of high tides, likely to be of low intensity in relation to velocity of water, and of short duration.

Finally, adaptation responses are proposed and analysed using the three one in one hundred ARI scenarios provided in the State of Play report (**Table 3**). These scenarios assist in providing the context from which to make decisions that relate to the viability and also the timing of responses.

Table 3: Sea flood scenarios for DC Mallala coastal region.

Flood	**2013**	**2050**	**2100**
Storm surge (at king tide)	2.6m	2.6m	2.6m
Wave set up	0.1m	0.1m	0.1m
Wave run up	0.0m	0.0m	0.0m
Sea level rise	0.1m	0.3m	1.0m
Totals	2.8m AHD	3.0m AHD	3.7m AHD

1.5.2 Adaptation responses that relate to infrastructure and people.

<u>Infrastructure</u>

In proposing adaptation responses, Councils are required to take the long view. For example, a house constructed today is likely to have a life span of 60 to 80 years, so future risks from actions of the sea are required to be taken into account in current planning policies. Councils are also required to adhere to Coast Protection Board policy and advice. Such policy includes being able to demonstrate that development is capable of being protected for the sea-flood risk for the 1 in 100 ARI event adopted for 2050, but also that reasonable steps can be taken to adapt the development to the sea-flood risk for the 1 in 100 ARI event adopted for 2100 (Coast Protection Board, 2004).

People

Adaptation responses are also required to take into account the safety of people in a flood event. These include warning and emergency procedures, the ability of people to be able to move safely away from the flood, and the ability of emergency vehicles and personnel to move into the settlement.

1.5.3 Adaptation responses that take into account time

The *State of Play Report* has already analysed the possible impact of the three 1 in 100 ARI flood scenarios (2013, 2050, 2100) upon the settlements. It is proposed here to draw upon that data and deal with adaptation responses in the following order:

- What level of protection can be realistically provided (at current threat, 2050 threat, 2100 threat).
- Where protection falls short, what accommodation responses can be employed?
- Where protection and accommodation strategies fall short, what longer term retreat options should be employed (if any)?

Finally, responses canvassed within this report may be implemented over the coming decades but also may be contingent on each other. For example, a protection strategy employed now may mean that other accommodation strategies are not required until a later date. The limitation of a protection strategy may mean that accommodation or retreat strategies are required to cater for that shortfall later in the century (**Figure 1**).

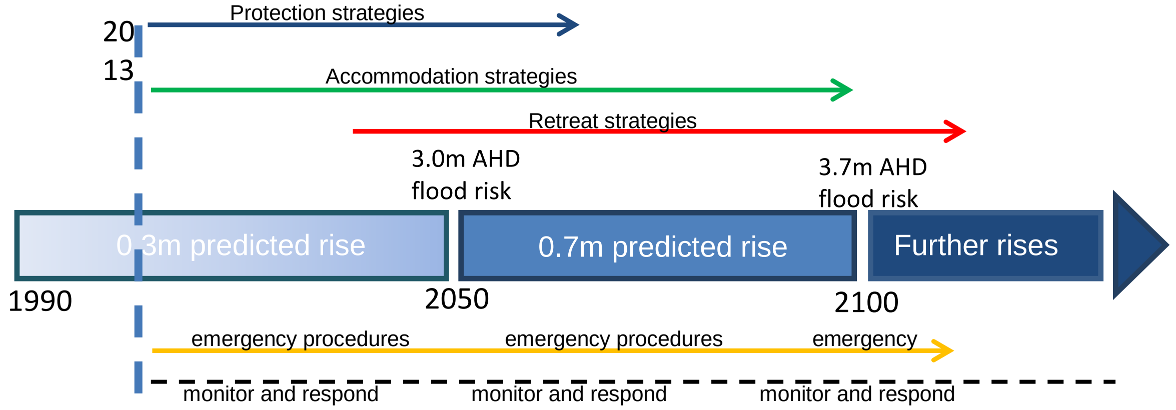


Figure 1: Adaptation responses are time related and sometimes contingent on each other but also contingent on the rate of sea level rise which is to be monitored over time (M. Western, 2013).

1.5.4 Adaptation responses that do not take into consideration:

- The effect of rising sea levels on ground water within Webb Beach.
- The potential for a rain flood event either combined or not combined with a king tide.
- The possibility of a sea-flood event caused by unforeseen event such as a tsunami.

2. Webb Beach Protection Options

2.1 Protection options to cater for sea-flood risk at 2100 (3.7m AHD)

Should the 1 in 100 ARI sea-flood event of 3.7m AHD shown in **Figure 2** occur then:

- The esplanade road would be inundated to depth of 0.8 to 1.0 m;
- Webb Beach Road causeway would be inundated at depth of 1.5m;
- All ground within the settlement would be inundated, from 1.7m depth in the north west corner of the settlement to 0.7m on the eastern end of George Street.

Further, should sea levels rise by 1.0m as predicted, the dunes north and south of Webb Beach, and the dune upon which Webb Beach Road is situated, would likely erode away for two reasons. First, the increase height of water would create new inlets that become wider over time, until the frontal dune system eroded completely away. This is occurring already north and south of Webb Beach (See State of Play Maps, p. 8,10). The second is that the increase height of water may increase the wave 'set up' and 'run up' (see **Table 3**) thereby increasing the amount of erosion to the dunes (Geoff Fisher, AWE, 26.11.13).

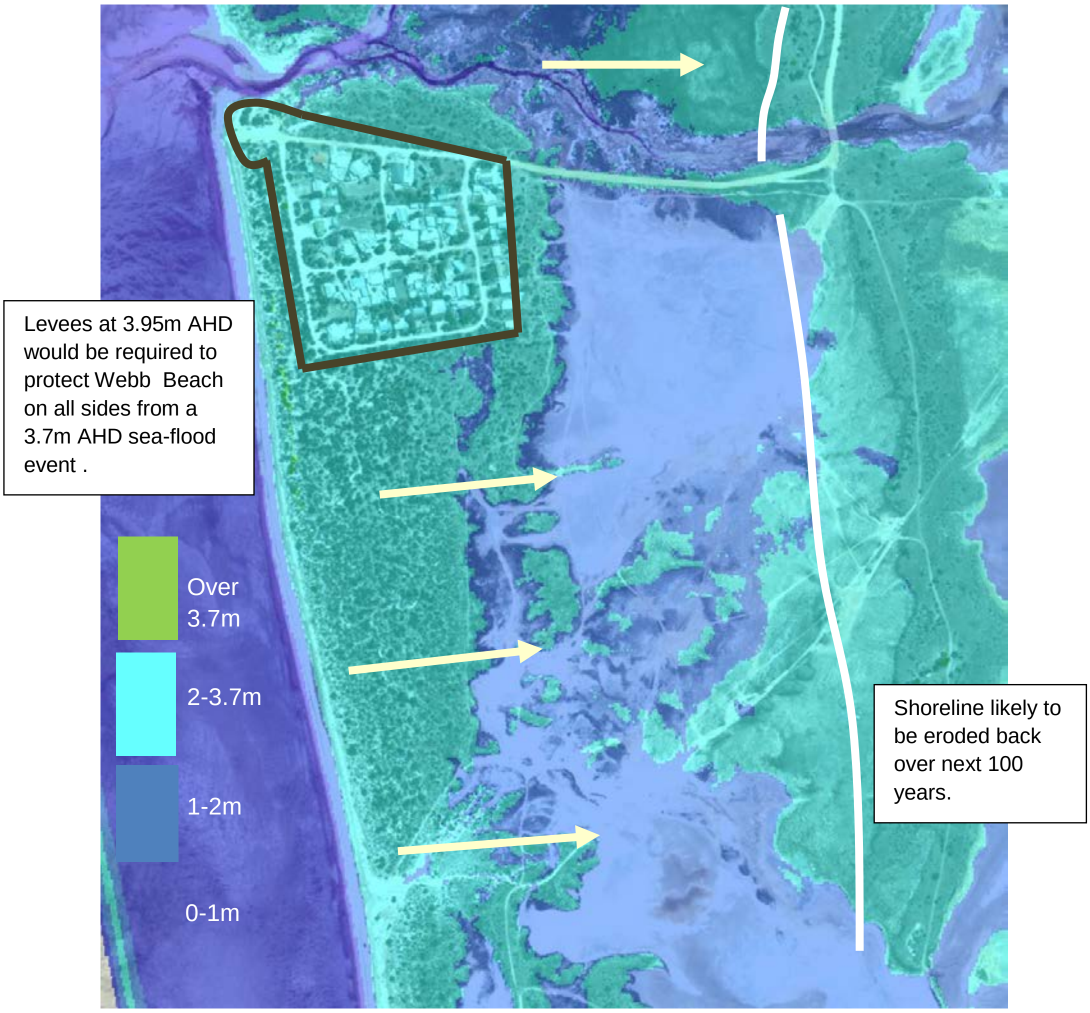


Figure 2: Webb Beach map indicating sea-flood risk at 3.7m AHD and protection requirements at 3.95m.

To provide a contemporary context, if the existing dwellings in Webb Beach were subject to 3.7m inundation, 34 dwellings out of 34 total dwellings would have water over their floor levels (**Figure 3**).

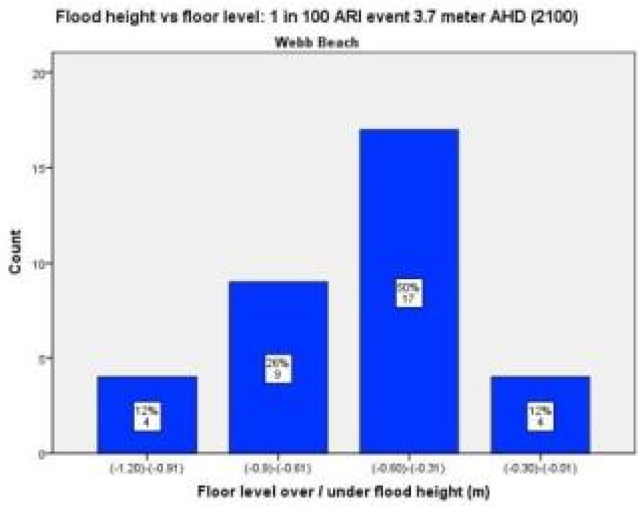


Figure 3: Webb Beach - Flood height vs floor level: 1 in 100 ARI event 3.7m AHD (2100)

While to implement protection levees as illustrated in **Figure 2** is possible in pure engineering terms, the erosion factor makes the proposal untenable as the dunes north and south of the settlement are likely to be eroded away leaving the settlement as a promenade facing increased erosion of its defences as a result. Finally, if the sea level does increase as predicted, then there is nothing to suggest that it won't keep rising past 2100, thereby rendering the defences at 3.7m AHD ineffective.

<u>Conclusion:</u>

To protect Webb Beach with levees to cater for the 1 in 100 ARI event of 3.7m AHD event is not viable and options that utilise protection measures at lower heights, combined with accommodation options should be considered in long term adaptation options for Webb Beach.

2.2 Protection options to cater sea-flood risk at 2050 (3.0m AHD)

In contrast to the 2100 flood scenario, protection options for Webb Beach should be considered for the 2050 1 in 100 ARI flood risk (3.0m AHD) for the following reasons:

- Protection measures are feasible and likely to be effective (see **Figure 4**);
- Protection of development to cater for the 2050 flood scenario (3.0m AHD) is Coast Protection Board policy (Coast Protection Board, 2012);
- Installation of protection measures now will provide a 30-40 year time in which data can be tracked over time to assess the rate of change in sea level.
- Installation of protection measures now will provide a 30-40 year time frame in which accommodation measures can be implemented to cater for predicted sea level rises past 2050.

2.2.1. Protection options for Webb Beach

Figure 4: Webb Beach- 3.0m AHD sea-flood scenario (2050).

Note, the cost estimates provided below have been prepared based on very limited data and without engineering design calculations. They are therefore indicative only and have been prepared to assist council with the priority setting processes. They should not be relied on for budgeting or construction cost management purposes.

1. Remove existing shell grit levee and Install clay levee to height 3.25m AHD on the existing walking trail to join the existing clay levee to the west to the natural ridge line to the East.

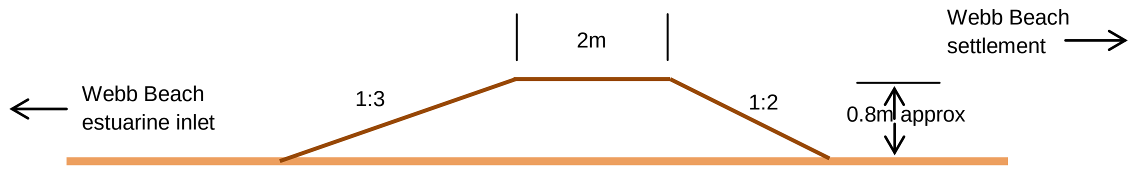


Figure 5: Typical cross section of levee – generally 0.8m height.

1. Preliminary cost calculation: Installation of levee to northern perimeter (Figure 4)							
Location	**Existing road elevation**	**Levee height increase**	**Levee length**	**Area of profile face**	**Volume (approx) m^3**	***Cost per m^3**	**Cost (approx)**
Webb Beach – northern perimeter	2.4 m to 2.5m AHD	0.8m	154m	$3.2m^2$	$500m^3$	$26	$12,900

*Estimate: DC Mallala Infrastructure Services

2. Install rock armoured wall to north-west corner. This section of coastline effectively forms an estuarine inlet with water flowing in at reasonable velocity during an incoming tide. Whilst velocities on the receding tide are likely to be less there are still thought to contribute to erosion at the tow of the north facing bank. This is likely to be an ongoing process even under moderately high tidal events. These forces are likely to be exacerbated under a severe tidal episode. The strategy in this location is to armour this short section of coastal inlet with a rock armoured wall because it is not considered practical to reduce the inlet (and outlet) velocities without impacting significantly on the nearby reserve area and beach access ramp.

Figure 6a: Install rock armour wall between the beach crossover and clay levee to the East (indicated by arrows) (M. Western, 2013)

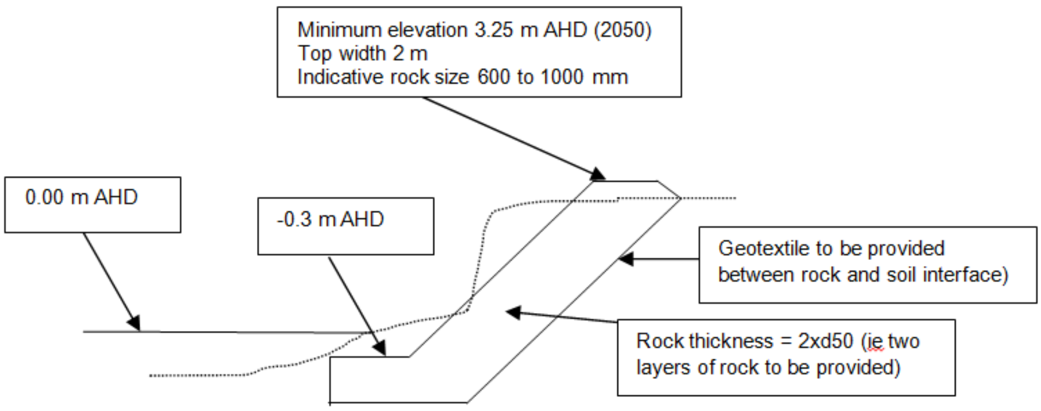


Figure 6b: Rock armour wall concept sketch (G. Fisher, AWE, 2014)

2. Preliminary cost calculation: install rock armour to north-west corner (Figure 4 (2), 6 (a)(b), pp. 9-11)							
Location	**Wall height (approx.)**	**Wall thickness (approx.)**	**Proposed levee length (approx.)**	**Size/ type of rocks**	**Volume of rock beaching m^3**	***Cost per m^3 (approx.)**	**Total Cost (Ex GST)**
Webb – north-west corner	4m	2m	60m	600–1000 mm Hardness Los Angeles Abrasion Test - Abrasive Grading A	500m^3	$150	$75,000

*Estimate: Australian Water Environments

3. Check height of access ramp to beach and raise to 3.25m AHD (**Figure 7**). The existing height is approximately 2.90m AHD, this being sufficient for current 1 in 100 ARI sea-flood event.

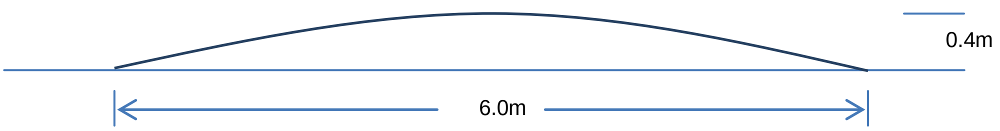


Figure 7: Example of section of beach crossover at end of George Street.

3. Preliminary cost calculation: raise vehicular beach crossovers (Figure 4)							
Location/ section	**Existing height AHD**	**Width of crossover**	**Height of increase**	**Length of curve**	**Volume of fill m^3**	***Unit cost**	**Estimated cost**
End of George Street	2.90m AHD	20m	0.4m	6m	10m^3	$30.00	$300

*Estimate: Mark Western

4. Raise eastern end of Jarmyn Street for a distance of 80 metres (approx.) to height of 3.0m AHD (**Figure 4**) Note: this is a lower priority being a secondary line of defence as water would need to travel behind the dune system either from the north or the south.

4. Preliminary cost calculation: raise section of road to 3.0m AHD (Figure 4)							
Location	**Existing road elevation**	**Raised**	**Length**	**Width (inc batter)**	**Volume/ area**	***Unit cost**	**Estimated cost**
Corner of Jarmyn and Jury St.	2.00m to 2.5m AHD (mostly 2.0m)	0.9 m	80m	6m	430m^3 (Fill)	$20	$8600
			80m	6m	240m^2 (Pavement)	$4	$ 900
*Estimate:	Mallala Infrastructure Services				Total		**$9500**

Note: An alternative option is to install a 40-50m levee at 0.5m high to south on a disused track (**See Figure 4**) but this option requires access through native vegetation.

5. Raise the access road into Webb Beach by completing the following (**Figure 8**):

Figure 8: Proposal to raise Webb Beach Road access.

i) Raise the east-west causeway to 2.8m AHD in accordance with **Figure 9**. Install two fords where indicated at approximately 20 metres in length with compacted rock floor with lowest road height at 2.5m AHD (**Figure 10**). The installation of two fords will provide a predictable pathway for floodwaters as well as a stable roadway for emergency service vehicles at known depths of water.

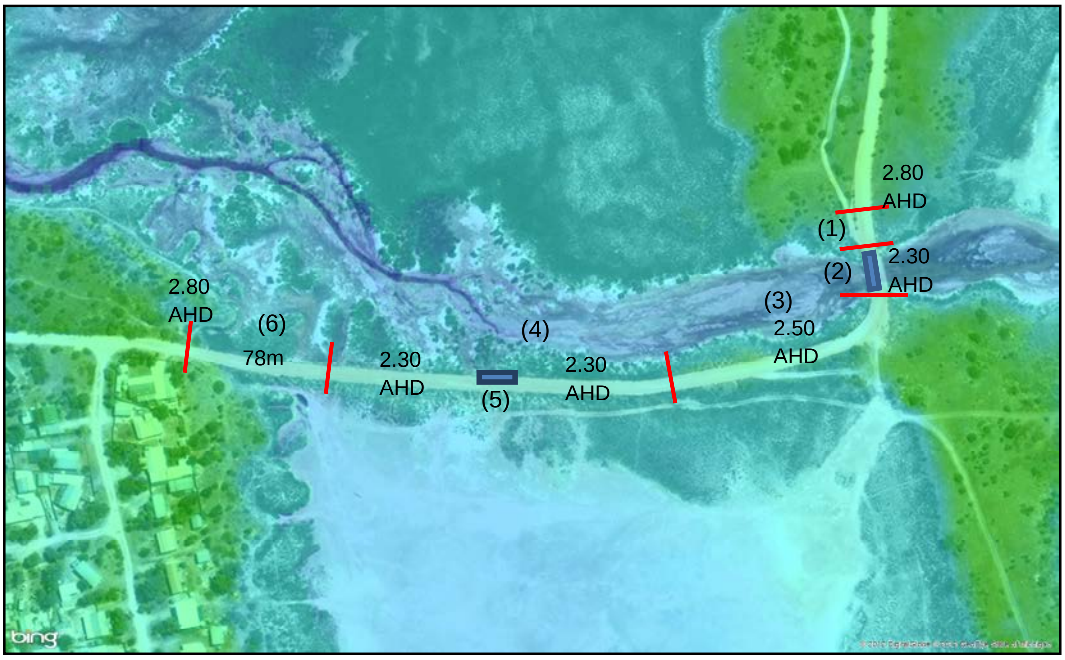


Figure 9: Proposal to raise Webb Beach Road access.

ii) Install two low water fords (concept in **Figure 10**) at locations (2) and (5) in **Figure 9.**

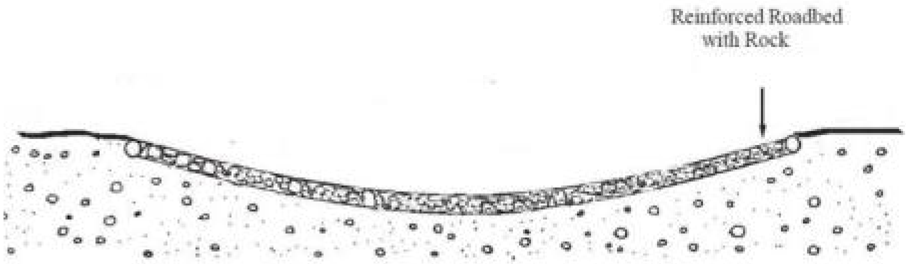


Figure 10: A low water ford to be installed in the east-west causeway (concept only and adapted from Figure 9.1, Low Volume Roads BMP, USA p.93).

- **Figure 9 (2)** Attach concrete up-stands to existing culvert on Webb Beach Road to raise height of edges by 300mm (**Figure 11**). Remove existing clay and install compacted rock (200mm) with lowest road height at 2.5m AHD to create a low water ford. Provide 100mm of road pavement on top.

  As a cost saving measure, investigate from an engineering perspective whether installing concrete up-stands to existing culvert *without* the removal of existing clay and installation of compacted rock would act as a stable low water ford.

Figure 11: Existing culvert on Webb Beach Road.

Preliminary cost calculation: install low water ford over existing culvert (Figure 9 (2)).							
Item	**Existing road elevation**	**Proposed height increase**	**Length**	**Width**	**Cubic metres**	***Cost per m^3**	**Total cost**
(2) Install 2 concrete up-stands to height 2.5m AHD	2.2m AHD	0.3m	18m (x2)	0.15m (width of upstand)	1.8m^3 (concrete)	$3000 (including cost to attach to existing culvert)	$5400
(2) Install crushed rock on top of concrete culvert at 300mm deep).	2.2m AHD	0.3m	20m	8m	60m^3 (crushed rock - 200mm)	$80	$4000

*Estimate: Australian Water Environments.

- **Figure 9 (5)** Remove 20m x 0.3m of existing road depth to 'key in' 0.6m of crushed rock (20mm). Provide 100mm road pavement on top.

Preliminary cost calculation: install low water ford to Webb Beach causeway (Figure 9 (5) p.13)							
Item	**Existing road elevation**	**Proposed depth of rock**	**Length of road**	**Width of road**	**Volume m^3**	***Cost per m^3**	**Total Cost**
(5) Webb Beach causeway 'ford'. Cut 0.3m from existing road and install 0.6m of crushed rock.	2.2m AHD	0.6m crushed rock (200mm)	20m	8m	100m^3	$80	$8000

*Estimate: Australian Water Environments

- **Figure 9 (1-6)** raise Webb Beach road.

Preliminary cost calculation: raise access road into Webb Beach (Figure 9)							
Item	**Existing road elevation**	**Proposed height increase**	**Length of road**	**Width of road**	**Volume or area**	***Cost per m^3 or m^2**	**Total Cost**
(1) Webb Beach causeway – raise road level.	2.80m to 2.3m AHD	0.5m/ 2	20m	8m	$40m^3$	$\$20/m^3$	$ 1,600
(3) Webb Beach causeway – raise road level	2.5m AHD	0.3m	128m	8m	$325m^3$	$\$20/m^3$	$ 6,500
(4) Webb Beach causeway – raise road level	2.30m AHD	0.5m	187m	8m	$750m^3$	$\$20/m^3$	$15,000
(6) Webb Beach causeway – raise road level	2.30m – 2.80m AHD	0.5m / 2	76m	8m	$150m^3$	$\$20/m^3$	$ 3,000
(1-6) Install road pavement over fill (total area including fords)			450m	8m	$3600m^2$	$\$4/m^2$	$14,400
*Estimate: DC Mallala Infrastructure Services					Total		**$40,500**

Summary – Cost to raise Webb Beach Road		
Install fill to Webb Beach Road and provide pavement on top.		$40,500
Install Ford (2)		$ 9,400
Install Ford (5)		$ 8,000
	Total	**$57,900**

iii) Review height of road at (5.iii) and raise to 2.8m AHD if required. Evaluate the suitability for a low water ford crossing (**Figure 8**).

2.2.2 Protection options for north and south of Webb Beach.

Maintaining a healthy dune system to the north and south of Webb Beach is vital for the long term viability of the settlement. Small inlets that eventuate as a result of a storm surge are likely to become large inlets over time (See **Figure 2**).

1. Check the dune system north and south of the settlement to identify any new incursions through the dunes. Close any recent inlets in the dune system by:

- Obtaining permission from Coast Protection Board, which permission can be given verbally (Comment, Murray Townsend, CPB, 14th November, 2013)
- Use local materials and fill with sand and brush.
- Revegetate with indigenous species; .
- Additional option: Use geotextile sand bags to improve initial stability of the base (Comment: Geoff Fisher, AWE,20th November, 2013).

Figure 12: Inlet south of Webb Beach created in storm surge of 2007 (M.Western, 2013)

11. Preliminary cost calculation: close incursion in dunes				
Location	**m^3**	**Estimated number of days work**	**Unit cost**	***Estimated cost**
850m south of Webb Beach		3	$1500	$4500

*Estimate: Mark Western

2.2.3. Webb Beach- other protection options

Council to establish a monitoring regime in which levees and dunes are monitored:

- After each inundation event greater than 2.50m AHD
- Annual sight inspections to assess possible weaknesses.
- Higher level engineering inspections once every 5 years (parameters of the inspections yet to be set).
- Aerial photography review and comparison every 5-10 years.

3. Webb Beach Accommodation Options

3.1 Accommodation option - prepare the community to be ‘flood ready’.

As noted above (see p. 4), a community that is prepared to deal with a flood is likely to suffer much less in financial terms, and also less likely to suffer human tragedy. Further, a prudent community prepares for emergency events that may fall outside of its historical context as ‘mother nature’ does not necessarily adhere to ARI tables. The following are ways in which the community could prepare itself to be ‘flood-ready’:

3.1.1 Implement general warnings of general flood risk.

DC Mallala to implement general warnings to residents about the general risk of flood. These warnings may include:

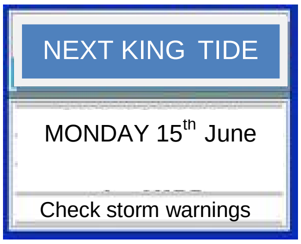
- Flood mapping and floor levels of dwellings made available to residents to allow them to more fully evaluate the flood risk to their property.

- New residents made aware of the risk of flooding in the Form 1 required as part of a real estate contract at time of purchase within the settlement.

3.1.2 Implement warning systems for possible flood events.

Council and the Webb Beach Residents Association (or other appropriate community organisation) to implement flood warning systems such as:

- Community run warning systems to inform residents of upcoming king tides, either by installing a ‘king tide warning’ sign, sending tide charts to all residents, and/or utilising SMS or email to send messages to community members with king tide information.



- Implement systems to warn residents of predicted storms. For example, SMS and email storm warnings are available from the Bureau of Meteorology. It is also possible to receive a SMS warning from a tide gauge in the Port River once it exceeds a predetermined high level[2]. This may give half hour warning of a larger than expected storm surge.

- Install flood depth markers to Webb Beach Road where required.

[2] This gauge is owned by Port Adelaide Enfield Council and there may be a charge associated with this service.

3.1.3 Implement flood emergency procedures.

Council and Webb Beach Residents Association (or similar community body) to establish flood emergency procedures such as:

- Establish an emergency assembly point at the highest point on George Street and mark the spot with a sign.

- Establish emergency evacuation routes that residents can use on foot that lead away from the source of the flood and to the emergency assembly point. In Webb Beach residents can generally move directly away on foot from the flood towards the East and arrive at the emergency assembly point which will provide an area of ground 0.10 above the sea-flood risk level predicted for 2050 (**Figure 13**). However, there are two points of caution:
    - o without the raising of Web Beach Road (see pp. 9,10) residents would not be able to leave Webb Beach settlement.
    - o the assembly point is at 3.10m AHD. Residents relying on the emergency procedures that are caught in a higher than predicted event would be vulnerable.

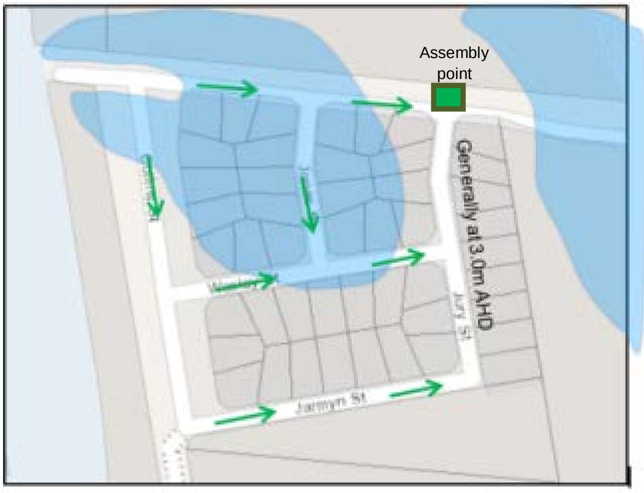


Figure 13: Routes that residents can utilise to move to the emergency assembly point

Most emergency service vehicles would not be able to enter Webb Beach if the sea-flood was higher than 2.5m AHD as water would be over the current level of the road in excess of 300mm. SES vehicles are the exception, but this would be assessed on a case by case basis. SES do have access to water craft but it is unknown how available these are and generally, helicopters are not available to access the area (Comment: Ben Birbeck, SES, 21st November, 2013). The key issue here is not that the flood may cause death or injury but that someone in Webb Beach may need medical attention unrelated to the flood event and emergency vehicles would not be able to enter Webb Beach.

- In light of the above, and if the access road into Webb Beach is not raised, the residents may be advised to adopt emergency procedures that include scenarios where evacuation from the settlement precedes the storm event, especially in cases where residents are already known to sometimes require medical attention.

- Install flood depth markers to Webb Beach Road. Note, check road height at 5(iii) on **Figure 8** and install marker if the road is less than 2.50m AHD.

Preliminary cost calculation: install flood depth markers				
Location	**Quantity**	**Estimated labour cost**	**Unit cost**	**Estimated cost**
Webb Beach Road at 100m intervals where road height is less than 2.50m AHD	4	*$230	**$150.00	$2000

*Estimated: DC Mallala Infrastructure Services

**Unit available from http://www.advancedroadsigns.com.au/Flood-Height-Marker-2m-lengths-p/g9-22-2.htm

Important note: these emergency procedures are only relevant to sea-flood risk of 3.0m AHD (2050 levels).

3.1.4 Prepare written Flood Emergency Action Plans.

Webb Beach Residents Association (or other appropriate community body) to prepare a guide to assist residents to prepare Flood Emergency Action Plans and to educate new and existing residents of its contents. The Guide should include evacuation policies based on the level of warning, what each member of the household should do if flood waters enter the dwelling, and describe how each member will access the emergency assembly point. Webb Beach Residents Association (or other appropriate community body) to encourage households to prepare Flood Emergency Action Plans and provide assistance if required.

3.2 Accommodation Option- amend Development Plan policy.

Planning policy should ensure that:

- All new buildings (apart from minor structures such as sheds) to be capable of being raised to 3.95m AHD (and not that they are capable of being raised to 1.25m above the standard sea-flood level);

- Site levels to be no longer required to be ‘protected’ from standard sea-flood risk level, and sites should no longer be required to be 0.3m above the standard sea-flood risk. Substitute clauses should have the sense of ‘managing’ the site in relation to sea-flood risk;

- The requirement that practical measures are available to ‘protect’ new development against additional sea level rise of 0.7 metres is removed and replaced with a clause that has the sense of ‘accommodating’ additional sea level rise.

Review the specifications of septic systems to be installed with new dwellings at Webb Beach to ensure that these are adequate to cater for potential sea flood scenarios later in the century.

3.3 Accommodation Option - adapt existing buildings

3.3.1. Raise the floor level of dwellings.

The predominant housing construction in Webb Beach is either light weight or transportable[3] and constructed on stumps or poles (**Figure 14**). Many of these dwellings would be capable of being raised if they are subject to inundation.

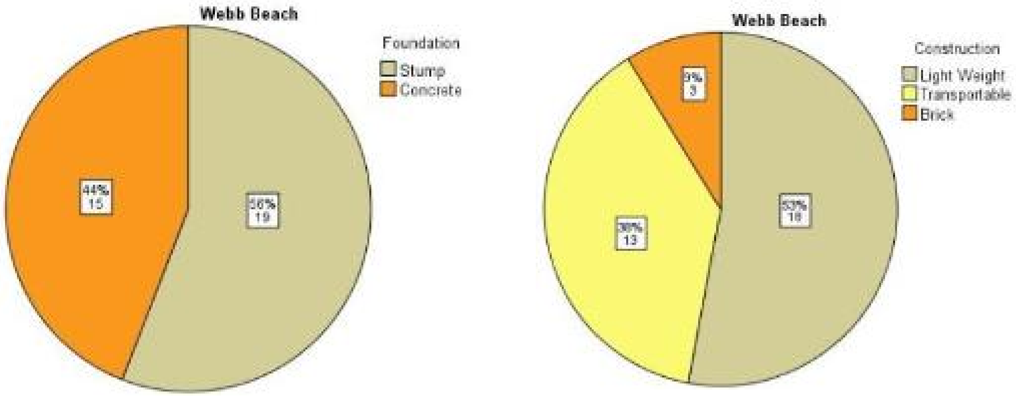


Figure 14: Construction types in Webb Beach

The number of existing dwellings subject to inundation at the current predicted 1 in 100 ARI event of 2.8m AHD is 4 (**Figure 15**) with a likely damage bill to private property in current dollars at $24,500 (*State of Play Report*, p. 60). If a decision is made to do nothing about the protection options outlined above (p.7-9) or a decision is made to defer for any length of time, then residents may choose to raise their dwellings. However, as the number of houses affected is small and the water depth shallow, residents may choose to wait until sea levels have risen further before raising their dwellings.

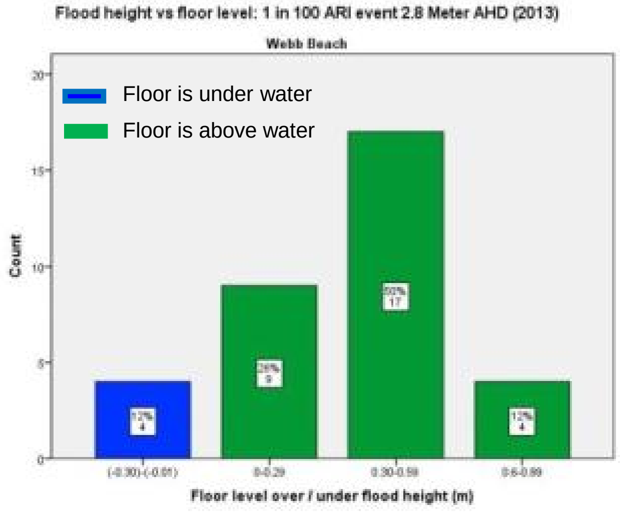


Figure 15: Webb Beach - Flood height versus floor level in 1 in 100 ARI event 2.8m AHD (2013)

[3] It is likely that in collection of data that 'lightweight' has been over applied rather than the 'transportable' category but this is of little consequence to the accommodation strategy proposed here.

It is anticipated over the next 30-40 years that many of the existing dwellings in Webb Beach will be replaced. If the proposed protection options outlined above (p. 9-11) are implemented then it is conceivable that a number will still remain with floor levels lower than the sea-flood risk. Residents could raise their dwellings to deal with the sea-flood threat subsequent to 2050 when the proposed protection options may not always protect the settlement from the sea-flood risk.

3.3.2 Water proof dwellings

Other flood accommodation options that residents could employ are:

- To internally water proof buildings and raise electrical outlets above the predicted flood levels.

- To provide temporary flood barriers to the outside of dwellings when tides are predicted to be high. Examples from Blobel Flood Protections Systems are shown in **Figure 16** and **Figure 17** (Blobel Environmental Engineering, 2013)

Figure 16: Flood protection wall to divert water away from the house

Figure 17: Flood protection barrier to stop water entering the house

4. Webb Beach Retreat Options:

The data from tide gauges at Port Stanvac and Thevernard have shown that sea has been rising in the region at an average of 4.3mm per year over the past 20 years. For the sea to rise 0.7m in the second half of this century as predicted would require an average rate of rise at 14mm per year. In reality this rate would be much lower than 14mm at 2050, and a much higher rate at 2100. Therefore, in decades of 2020s, 2030s, and 2040s it should be possible to monitor the rate of increase and adjust predictions accordingly. There are two possible scenarios that will emerge from the monitoring in this time frame:

- If the rate of change of sea level rise does not increase and the predictions for 2100 are proven to be inaccurate, then at the very least as a result of implementing the adaptation strategies above, Webb Beach would have become a far more resilient community and prepared for any unforeseen flood event.

- If the rate of change of sea level rise does accelerate and the predictions are likely to be accurate, then Webb Beach can expect to be inundated far more frequently as the century approaches its close. Even though planning changes foreshadowed above mean that the floor levels of dwellings are above the flood levels, roads are likely to be frequently cut off and damaged, emergency vehicles frequently would not be able to enter the settlement, evacuation procedures may become part of life in Webb Beach, and the safety of people may be at risk.

If such a situation eventuated, to provide some context from a planning perspective, the DC Mallala current Development Plan already currently states:

> 'Development should not occur where essential services cannot be economically provided and maintained having regard to flood risk and sea level rise, or where emergency vehicle access would be prevented by a 1-in-100 year average return interval flood event, adjusted for 100 years of sea level rise'. Control 26 (p.33)

Therefore, it monitoring of sea level rise in the 2020s, 2030s and 2040s indicates that the rate of change is accelerating, then planning policy should devised and implemented to ensure that all new buildings are capable of being removed. Policy should be developed so that a predetermined event triggers the removal of buildings, for example, when a certain sea level height is reached, residents may have 5 years (for example) to remove dwellings. It is important to note that this study is not recommending that such a change be made now, but that sea level rise be monitored over the coming decades and the change made when:

- It is recognised that the rate of sea level rise is accelerating[4]
- In time so that dwellings constructed now will be reaching the end of their life span when sea levels reach levels that may not be properly accommodated.

In conclusion, such a policy would allow residents the liberty to continue to develop their properties, but with the knowledge that the development may have limited life span and plan accordingly.

[4] Caution: the rate of sea level rise is not constant and thus longer term trends should be employed to ascertain whether the rate of change is accelerating.

5. Webb Beach Risk Analysis

Using the National Emergency Risk Assessment Guidelines (NERAG) (Australian Government, 2010) four risk statements have been generated for the Webb Beach settlement. The risk assessment is completed taking into account existing protection and emergency procedures and for a sea-flood height that exceeds 2.5m AHD but less than 2.8m AHD, the latter being the current 1 in 100 ARI sea-flood event (See **Appendix 1** for full analysis).

5.1 Risks to people

Risk statement 1

There is the potential that a storm surge exceeding 2.5m AHD but less than 2.8m AHD resulting from a south easterly to north-westerly wind combined with a king tide will cause floods to Webb Beach, which in turn will cause impact on the residents (but not taking into account Risk Statement 2).

The analysis in **Appendix 1** resulted in a risk category assigned as ALARP 5 which is 'broadly acceptable' (see **Figure 18**). With implementation of warning and emergency procedures, the risk will be even more effectively managed. Should protection measures be installed at 3.0m AHD the risk would be well within the 'broadly acceptable' category for risk to human life.

Risk statement 2

There is the potential that a storm surge that exceeds 2.5m AHD but less than 2.8m AHD resulting from a south easterly to north-westerly wind combined with a king tide will inundate the cause way to a depth of 0.3m to 0.6m, which in turn will cause impact on the residents.

Risk category is ALARP 4-5 which is tending toward 'broadly acceptable'. The probability of a medical emergency occurring within a two hour time frame when water crossed the road in a sea-flood event exceeding 2.5m AHD but less than 2.8m AHD is remote (no formal probability calculation completed). The risk could be improved if residents were warned of impending king tides and those with medical conditions could remove themselves prior to the event.

5.2 Risks to infrastructure

Risk statement 3

There is the potential that a storm surge exceeding 2.5m AHD but less than 2.8m AHD resulting from a south-easterly to north-westerly wind combined with a king tide will cause floods to Webb Beach, which in turn will cause damage to private infrastructure.

The analysis in **Appendix 1** resulted in a risk category assigned as ALARP 5 which is in the 'broadly acceptable region'. Only four dwellings are predicted to have water over floor levels. Installation of the protection works described above would improve this rating further

Risk statement 4

There is the potential that a storm surge exceeding 2.5m AHD but less than 2.8m AHD resulting from a south-easterly to north-westerly wind combined with a king tide will cause floods to Webb Beach, which in turn will cause damage to public infrastructure.

The analysis in **Appendix 1** resulted in a risk category assigned as ALARP 4-5 which is in the 'tolerable region' trending towards the 'broadly acceptable region'. The main public infrastructure in Webb Beach would be mainly confined to 'roads'. As the duration of the flood is short lived and the velocity normally low, damage to roads is likely to be low. There is no way to reduce the risk without implementing protection to the foreshore or by raising roads (the latter being not cost effective).

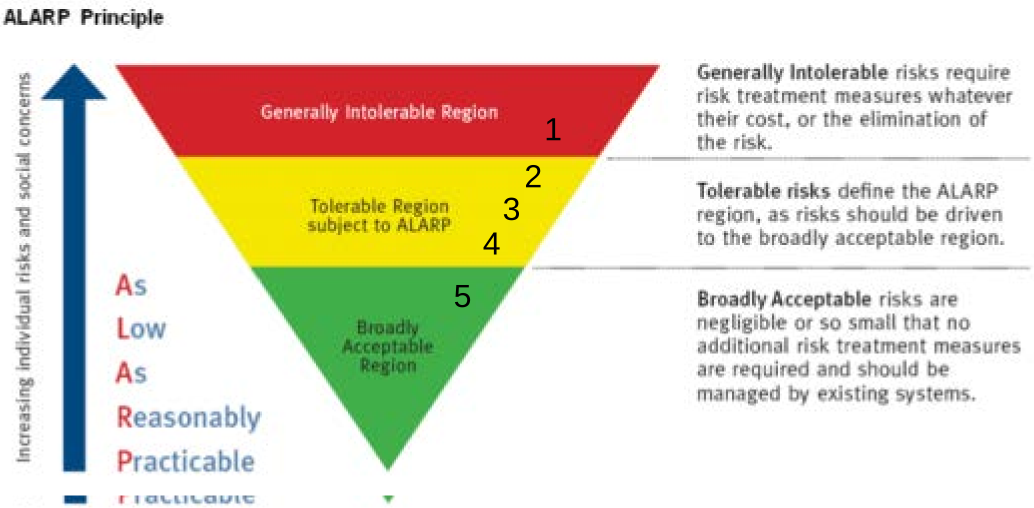


Figure 18: National Emergency Risk Assessment Guidelines – ALARP assessment.

6. Webb Beach Adaptation Costs (preliminary)

The cost estimates provided below have been prepared based on very limited data and without engineering design calculations. They are therefore indicative only and have been prepared to assist council with the priority setting processes. They should not be relied on for budgeting or construction cost management purposes. **Table 4** is a summary of the adaptation options for Webb Beach grouped according to the categories of *protect, accommodate, or retreat*.

Table 4: Summary of adaptation options for Webb Beach

	Adaptation option		Approximate cost	Reference pp.
Protect	1.	Remove shell grit levee and install 170m approx. of clay levee at height 3.25m AHD to northern perimeter.	$12,900	10
	2.	Install rock armoured wall to north-west corner.	$75,000	11
	3.	Check height of ramp and raise to 3.25m AHD. (DEM approximates current height at 2.90m AHD which is sufficient for current flood-risk).	$ 300	11
	4.	Raise eastern end of Jarmyn Street for distance of 80LM to height 3.0m AHD (this is a secondary defence).	$ 9,500	12
	5.	Raise Webb Beach east-west causeway by 0.6m to 2.80m AHD for distance of 350 m. Install two 20 m compacted rock fords – one on the cause way, one on existing culvert (running north-south) at height 2.50m AHD.	$57,900	13-15
	6.	Implement monitoring regime to check dune system north and south of Webb Beach. Fill recent incursion 950m south of Webb Beach to prevent further erosion of the dune system.	$ 4,500	16
Accommodate	7.	Implement emergency procedures – establish warning systems; establish emergency assembly point; establish evacuation policies; establish community and households emergency action plans.	Not costed	17-19
		Install flood depth markers to Webb Beach Road.	$2000	19
	8.	Devise and implement planning policy that ensures: new dwellings are capable of being raised to 3.95m AHD; and site levels are not required to be raised.	Not costed.	19
	9.	Adapt existing dwellings – residents to raise floor levels; utilise internal waterproofing; or temporary protection mechanisms.	Not costed.	20
Retreat	10.	Subject to monitoring that demonstrates that the rate of sea level rise is accelerating, devise and implement planning policy that ensures that new dwellings are capable of being removed (once a predetermined trigger point has been reached, for example a particular AHD height).	Not costed.	22

Within all of these adaptation options is the option to ‘defer’ or ‘do nothing’. For example, cost may prohibit the implementation of a protection measure and therefore the project is deferred. In other cases, the risk might be deemed so minor that ‘do nothing’ is adopted. For example, there is a very small probability that a medical emergency develops within Webb Beach at the same time there is a king tide and a storm. Therefore, the cost of raising the road to cater for this low probability risk may not be warranted, and then ‘do nothing’ is the appropriate response. Conversely, such a scenario could be ‘deferred’ to be reviewed at a later date, or when funding might come to hand.

7. Webb Beach - Timing and Prioritisation

7.1 Timing of adaptation options

Figure 19 illustrates how the different protection, accommodation, and retreat options interrelate over time. Sea level rise and erosion are monitored over time and response made accordingly. Emergency procedures are always in place and amended according to the conditions. When protection measures become inadequate, accommodation options mitigate the risk. Subject to ongoing monitoring longer term decisions are made in relation to the viability of the settlement itself.

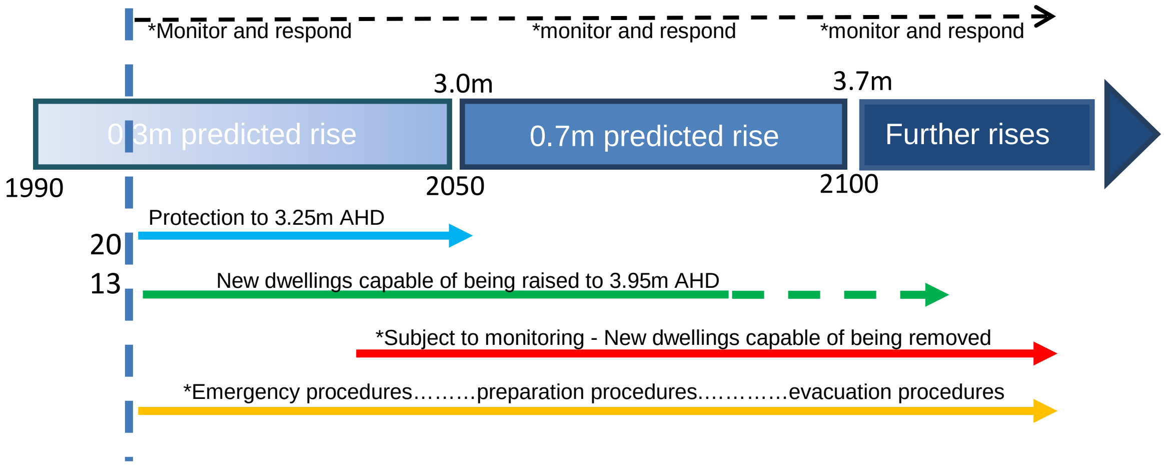


Figure 19: The relationship of decision making on options to time

7.2 Prioritisation of adaptation options

Prioritisation of adaptation options is based on the following criteria:

- First, warning and emergency procedures to ensure people are safe.
- Second, begin changes to planning policy as this process takes time, and the life span of infrastructure is long.
- Third, implement monitoring systems because these are not onerous, and the Council may be liable without them.
- Fourth, install protection works to protect Webb Beach for the current sea-flood risk.
- Fifth, protection works to protect Webb Beach for the sea-flood risk for 2050.

Subject to Council and community input the following prioritisation in **Table 5** is recommended for Webb Beach:

Table 5: Prioritisation and responsible entities for adaptations at Webb Beach

	Adaptation response	Risk rating and other priority factors	Response time	Entity responsible
1.	Implement emergency procedures which should be maintained even if protection options are implemented.	Such procedures are a wise response to living adjacent to an unpredictable threat as well as a way to educate the community about the potential for the threat to be increased.	Within 1 year	Council and Webb Beach community
2.	Install flood depth markers to Webb Beach Road	Flood depth markers will increase awareness and safety of drivers.	Within 1 year	Council
3.	Devise and implement planning policy that ensures all new buildings are capable of being raised to 3.95m AHD and sites are not required to be raised (check adequacy of sewer system specifications).	Some dwellings constructed now may still be in use in 2080-90 when the 1 in 100 ARI flood risk is 3.7m AHD.	Within 1 year	Council
4.	Implement monitoring systems to assess the state of levees (within the settlement and dunes to the north and south)	A duty of care for levees, and provides information about dune system so that breaches can be closed.	Within 1 year	Council
5.	Install protection levee to the northern side of Webb Beach foreshore to provide protection at 3.25m AHD.	Webb Beach is likely to be significantly flooded in a 2.8m AHD event, although the predicted impact to private dwellings is small. The required levee is only 170m and 0.8m high to provide 3.25m AHD protection. If the Parham levee was to proceed as recommended there would be economies of scale that would warrant the installation of this levee at the same time. ALARP risk rating is 4 – tolerable risks.	1-2 years	Council
6.	Raise the ramp access to the beach to 3.3m AHD (check height now – 2.90m?)	While the height of the ramp is sufficient for the current sea-flood risk, the work should be carried out at the same time as (5).	1-2 years	Council
7.	Reinstate sand and revegetate the inlet in the dunes south of Webb Beach	Should sea-flood events higher than 2.3 m (approx.) occur, this inlet will be enlarged encouraging the erosion of the dune system.	1-2 years.	Council
8.	Install rock armoured wall to north-west corner of Webb Beach	A storm event can cut the existing shell grit levee very rapidly, but currently this	2-5 years	Council

		section of Webb Beach is protected.		
9.	Raise 80m of Jarmyn Street to a height approaching 3.0m AHD (an increase of 0.3m to 0.5m in height)	This is a secondary defence and water would need to travel through the dunes (or over the causeway) to enter this section of Webb Beach.	5-10 years	Council
10.	Raise the causeway to a level of 2.8m AHD, and include two sections of rock armoured road at 2.5m AHD to act as fords (also check height of road indicated as 3.iii on Figure 7)	The risk rating relating to the inundation of the causeway causing impact to human life is calculated at ALARP 4-5 which is broadly acceptable. However, increase in sea level will increase the incidents and therefore in the longer term raising Webb Beach Road should be considered.	5-10 years	Council
11.	Subject to monitoring from the present until the 2020s- 2030s, should sea level rise accelerate to indicate more rapid rise, devise and implement planning policy that ensures new dwellings are capable of being able to be removed once predetermined triggers have been realised.		15-20 years or sooner if the data warrants.	Council
12.	Dwellings raised, or water proofed internally, or temporary protection strategies employed.	Community protection has become insufficient.	As required.	Residents

8. References

Balston, J.M., Western, M.D., Kellett, J., Wells, G., Li, S., Gray, A, 2012, *Climate change decision framework and software for coastal councils*, Local Government of Association of South Australia, Adelaide, SA.

Coast Protection Board (SA), 2014, *Coast Protection Board Policy Document: Revised 22 May 2012.*

District Council of Mallala Development Plan (consolidate 31/01/2013)

Blobel Environmental Engineering, 2013, *Flood protection – manual and automatic flood defence*, viewed at http://www.blobel.com/e_html/02-02e-flood-protection.html, on 12th December, 2013.

National Emergency Management Committee, 2010, *National Emergency Risk Assessment Guidelines*, Tasmanian State Emergency Service, Hobart.

Victorian Government, 2000, *Rapid Appraisal Method (RAM) for floodplain management*.

9. Appendix 1: Risk analysis utilising NERAG

1. Risk statement:

There is the potential that a storm surge that exceeds 2.5m AHD but less than 2.8m AHD resulting from the combination of a king tide and south easterly or north-westerly storm will cause floods to Webb Beach, which in turn will cause impact on the residents (but not taking into account risk statement 2).

Risk identification:

Source of threat	Storm surge entering community from the north (also over beach ramp)
Impact category	People
Prevention controls	Shell grit levees to north-west corner of settlement
Preparedness controls	No emergency procedures
Response	SES, ambulance, fire, police
Recovery	Pumping, draining water away. Repair of houses and roads.

Credible consequence level to people:

'Insignificant' – near misses or minor injuries

Likelihood of the event occuring:

'Likely'- two one in 20 ARI events in previous decade which is at 2.5m AHD. The current 1 in 100 ARI event is 2.8m AHD .

Consequence Level:

Qualitative Risk Matrix

	Consequence Level				
Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium
Very Rare	Low	Low	Low	Low	Medium
Almost Incredible	Low	Low	Low	Low	Low

Degree of confidence in the above assessment:

High confidence – extensive study conducted, historical data known, hazard known, and comprehensive knowledge of the receiving environment.

Confidence Table

Confidence Criteria	Low Confidence	Moderate Confidence	High Confidence
Data/Information	Neither community nor hazard specific; anecdotal only	Community or hazard specific; validated historical or scientific	Community and hazard specific; validated historical and scientific
Team knowledge	Neither hazard nor process (risk assessment) specific	Hazard or process specific	Hazard and process specific
Agreement	Neither on interpretations nor on ratings	On interpretations or ratings	On interpretations and ratings

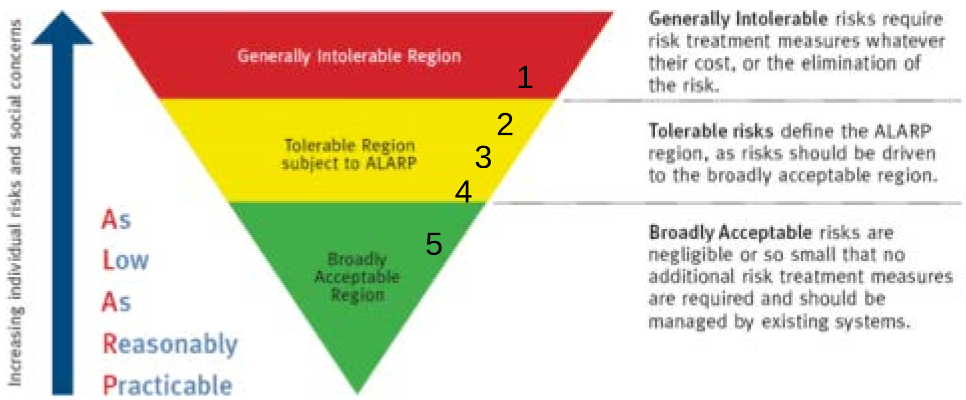
Classification of risk tolerability:

Risk Tolerability Tables

High Confidence Level

Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	4	3	2	1	1
Likely	5	4	3	2	1
Possible	5	5	4	3	2
Unlikely	5	5	4	3	3
Rare	5	5	5	4	3
Very Rare	5	5	5	5	4
Almost Incredible	5	5	5	5	5

ALARP Principle



Conclusion:

Risk category is ALARP 5 which is ‘broadly acceptable’. With implementation of warning and emergency procedures, the risk will be even more effectively managed. Should protection measures be installed at 3.0m AHD the risk would be well within the ‘broadly acceptable’ category for risk to human life.

2. Risk statement:

There is the potential that a storm surge that exceeds 2.5m AHD but less than 2.8m AHD resulting from a south easterly or north-westerly storm will inundate the causeway to a depth of 0.3m to 0.6m, which in turn will cause impact on the residents.

Risk identification:

Source of threat	Sea-flood entering from north or south of Webb Beach and crossing the causeway.
Impact category	People
Prevention controls	None.
Preparedness controls	No emergency procedures
Response	SES, ambulance, fire, police
Recovery	Waiting for water to subside, repair road if necessary.

Credible consequence level to people:

'Minor' – 'insignificant' - there is no direct impact of this event on the people, only if there was a medical emergency at the same time that the causeway was cut for up to two hours.

Likelihood of the event occuring:

'Likely'- two 2.5m AHD events in the last six years. The current 1 in 100 ARI event is 2.8m AHD .

Consequence Level:

Qualitative Risk Matrix

	Consequence Level				
Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium
Very Rare	Low	Low	Low	Low	Medium
Almost Incredible	Low	Low	Low	Low	Low

Degree of confidence in the above assessment:

High confidence – extensive study conducted, historical data known, hazard known, and comprehensive knowledge of the receiving environment.

Confidence Table

Confidence Criteria	Low Confidence	Moderate Confidence	High Confidence
Data/Information	Neither community nor hazard specific; anecdotal only	Community or hazard specific; validated historical or scientific	Community and hazard specific; validated historical and scientific
Team knowledge	Neither hazard nor process (risk assessment) specific	Hazard or process specific	Hazard and process specific
Agreement	Neither on interpretations nor on ratings	On interpretations or ratings	On interpretations and ratings

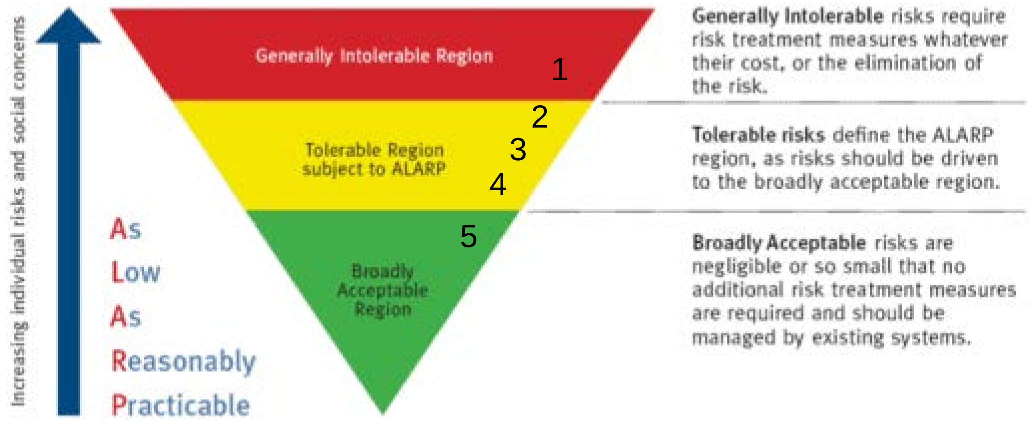
<u>Classification of risk tolerability:</u>

Risk Tolerability Tables

<u>**High Confidence Level**</u>

<u>Likelihood Level</u>	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	4	3	2	1	1
Likely	5	4	3	2	1
Possible	5	5	4	3	2
Unlikely	5	5	4	3	3
Rare	5	5	5	4	3
Very Rare	5	5	5	5	4
Almost Incredible	5	5	5	5	5

ALARP Principle



<u>**Conclusion:**</u>

Risk category is ALARP 4-5 which is tending toward ‘broadly acceptable’. The probability of a medical emergency occurring within a two hour time frame when water crossed the road in a sea-flood event exceeding 2.5m AHD but less than 2.8m AHD is remote (no formal probability calculation completed). The risk could be improved if residents were warned of impending king tides and those with medical conditions could remove themselves prior to the event.

3. Risk statement:

There is the potential that a storm surge greater than 2.5m AHD and less than 2.8m AHD resulting from a south-easterly or north-westerly storm will cause floods to Webb Beach, which in turn will cause damage to private infrastructure.

Risk identification:

Source of threat	Storm surge
Impact category	Infrastructure – dwellings/sheds
Prevention controls	Shell grit levees provided to north west corner and part way along the northern boundary. Frontal dune assessed as being of suitable height.
Preparedness controls	None relating to infrastructure.
Response	SES, ambulance, fire, police
Recovery	Pumping, draining water away. Repair of houses.

Credible consequence level:

Private Infrastructure – 'insignificant'. Only four houses are predicted to have water over floor levels and the depth is limited to 300mm or less.

Likelihood:

Likely (maybe possible) – two events in last decade have approached 2.5m AHD. One in one hundred is 2.8m AHD.

Consequence Level:

Qualitative Risk Matrix

	Consequence Level				
Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium
Very Rare	Low	Low	Low	Low	Medium
Almost Incredible	Low	Low	Low	Low	Low

Degree of confidence in the above assessment:

High confidence

Confidence Table

Confidence Criteria	Low Confidence	Moderate Confidence	High Confidence
Data/Information	Neither community nor hazard specific; anecdotal only	Community or hazard specific; validated historical or scientific	Community and hazard specific; validated historical and scientific
Team knowledge	Neither hazard nor process (risk assessment) specific	Hazard or process specific	Hazard and process specific
Agreement	Neither on interpretations nor on ratings	On interpretations or ratings	On interpretations and ratings

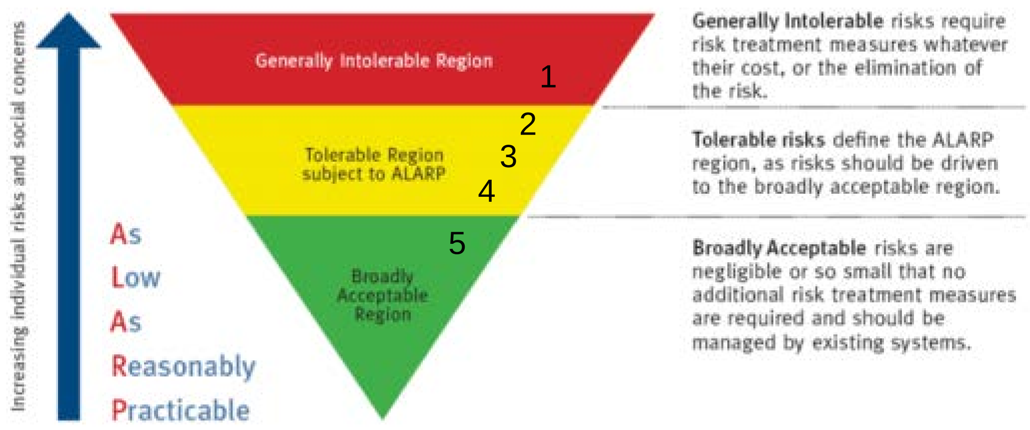
<u>Classification of risk tolerability:</u>

Risk Tolerability Tables

<u>**High Confidence Level**</u>

Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	4	3	2	1	1
Likely	5	4	3	2	1
Possible	5	5	4	3	2
Unlikely	5	5	4	3	3
Rare	5	5	5	4	3
Very Rare	5	5	5	5	4
Almost Incredible	5	5	5	5	5

ALARP Principle



<u>Conclusion:</u>

Risk category is ALARP 5 which is in the ‘broadly acceptable region’. Only four dwellings are predicted to have water over floor levels. Installation of the protection works described above would improve this rating further.

4. Risk statement

There is the potential that a storm surge exceeding 2.5m AHD but less than 2.8m AHD resulting from a south-easterly or north-westerly storm will cause floods to Webb Beach, which in turn will cause failure or damage to public infrastructure.

<u>Risk identification:</u>

Source of threat	Storm surge
Impact category	Infrastructure – primarily roads. Other infrastructure likely to remain unaffected. Power lines above ground.
Prevention controls	Shell grit levees provided to north west corner and part way along the northern boundary. Frontal dune assessed as being of suitable height.
Preparedness controls	None relating to infrastructure
Response	SES, ambulance, fire, police
Recovery	Pumping, draining water away. Repair of roads.

<u>Credible consequence level:</u>

Private Infrastructure – 'minor' to 'insignificant'

<u>Likelihood:</u>

Likely (maybe possible) – two events in last decade have approached 2.5m AHD. One in one hundred is 2.8m AHD.

<u>Consequence Level:</u>

Qualitative Risk Matrix

	Consequence Level				
Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium
Very Rare	Low	Low	Low	Low	Medium
Almost Incredible	Low	Low	Low	Low	Low

<u>Degree of confidence in the above assessment:</u>

High confidence

Confidence Table

Confidence Criteria	Low Confidence	Moderate Confidence	High Confidence
Data/Information	Neither community nor hazard specific; anecdotal only	Community or hazard specific; validated historical or scientific	Community and hazard specific; validated historical and scientific
Team knowledge	Neither hazard nor process (risk assessment) specific	Hazard or process specific	Hazard and process specific
Agreement	Neither on interpretations nor on ratings	On interpretations or ratings	On interpretations and ratings

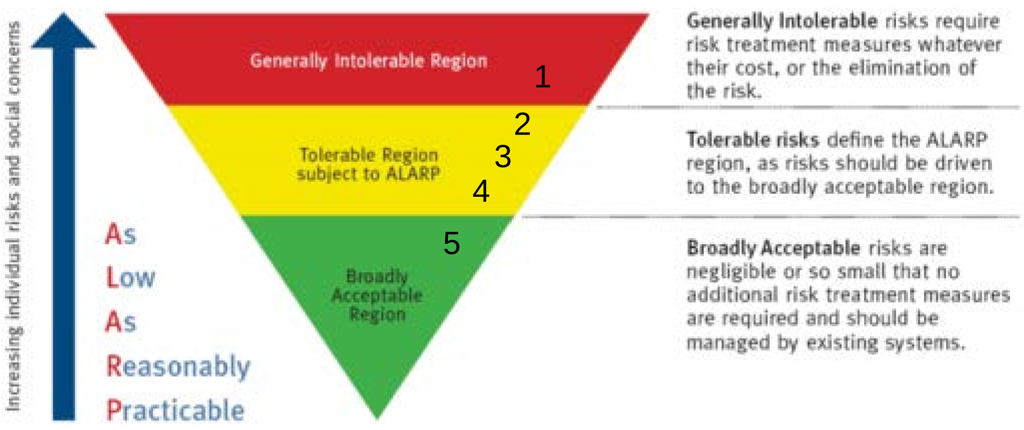
<u>Classification of risk tolerability:</u>

Risk Tolerability Tables

<u>**High Confidence Level**</u>

Likelihood Level	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	4	3	2	1	1
Likely	5	4	3	2	1
Possible	5	5	4	3	2
Unlikely	5	5	4	3	3
Rare	5	5	5	4	3
Very Rare	5	5	5	5	4
Almost Incredible	5	5	5	5	5

ALARP Principle



<u>Conclusion:</u>

Risk category is ALARP 5 which is in the ‘tolerable region’ and should be driven further to the ‘broadly acceptable region’. There is no way to reduce the risk without implementing protection to the foreshore or by raising roads (not cost effective).