PINE POINT

Seawater Flooding Adaptation Pathways for Yorke Peninsula Settlements

Stage 2: Adaptation Options

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Photograph of Pine Point seafront supplied by Coast Protection Branch.

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Adaptation Options	Draft	14 Sep, 2015	JK 7th Sept 2015	MW 7th Oct 2015

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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 and is a theoretical calculation of the probability of the return of a particular event based on observations of the past. 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 storm surge would be higher than a 1 in 50 year or 1 in 10 year storm surge height. It is important to remember that this is just a theoretical calculation and there is nothing preventing a 1 in 100 year 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 an aircraft that bounced millions of infra-red light beams to the ground and then created a digital topographical map from the reflected beams. This digital map is combined with aerial photography and can be used to display the height of land features. A Digital Terrain Model (DTM) is a type of DEM that has been specifically prepared for flood modelling.

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 storm surge is usually the combination of the highest tide (king tide), the action of the waves, and the height the water is raised when pushed up the beach, especially when driven by a high winds. The combination of these factors is given a height AHD and used by planners to work out at what height buildings and infrastructure should be placed along the shore.

1. Introduction

In February 2015 the Yorke Peninsula Council commissioned Mutual Projects Pty Ltd T/A Integrated Coastal Management to undertake the *Seawater Flooding Adaptation Pathways* study, a project jointly funded by the Commonwealth Natural Disaster Resilience Program, the Coast Protection Board, and the Yorke Peninsula Council. The aim of the project is to identify the seawater flooding risks, assess current flood protection infrastructure and provide recommendations for future action to cater for seawater flooding. The project will also improve community awareness of the risks associated with current and future seawater flooding. The sites under investigation are Clinton, Price, Pine Point (Billy Goat Flat) and Coobowie which are all situated along the eastern coast of the Yorke Peninsula and are considered by Council to be locations of risk.

1.1 Investigative framework

This study utilises the *Local Government Association Coastal Adaptation Decision Pathways Investigative Framework* which was originally developed in 2012, and trialled at Onkaparinga and Mallala Councils. In 2013, the investigative framework was utilised in the *District Council of Mallala's Coastal Settlements Adaptation Study,* and subsequently amended to reflect the findings of that project. Each settlement is reviewed within the following framework:

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

1.2 Staging of the project

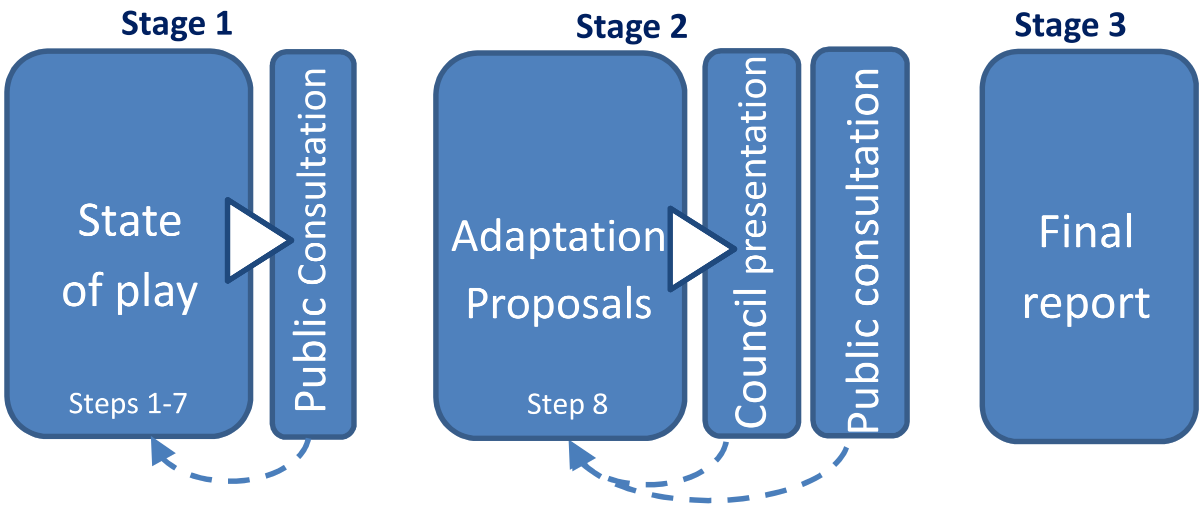
The process is to be undertaken in three main stages (**Figure 1:1**):

Stage 1: State of Play Report (Steps 1 – 7)

Stage 1 evaluates and reports the current and future threat. The community consultation process in Stage 1 reports *to* the community about the potential for sea level rise but also actively requests information *from* the community to create the full 'sea-flood risk picture' (See also Section 3).

Stage 1 is now complete and this report represents the findings of Stage 2.

Figure 1:1 The coastal adaptation study is conducted in three stages[1]



Stage 2: Propose adaptation options (Step 8)

Stage 2 proposes adaptation options in draft form and reports these to the Council, and then to the community by way of a second public meeting. Adaptation proposals are generally framed within the five broad ways human settlements can adapt to rising sea levels:

- **Protect:** use various means such as construction of sea walls, beach sand replenishment or installation of drainage swales to protect existing development;
- **Accommodate:** use means such as raising buildings or protecting buildings from flooding;
- **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 perhaps costs 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.

Stage 3: Final reporting

Responses from the Council and the community from Stage 2 are taken into account for the final report. Stage 3 provides a final report to Council that includes an explanation of the adaptation options, a suggested prioritisation for action, and preliminary engineering solutions and estimated costs (where possible).

[1] Adapted from coastal analysis tool, *Dealing with the impacts of sea level rise on coastal assets (2012) (Western & Kellett)*

1.3 Reporting and consultation

While the scope of the *Seawater flooding adaptation pathways for Yorke Peninsula Cou*ncil covers the four settlements of Clinton, Price, Pine Point (Billy Goat Flat) and Coobowie, adaptation responses options available to each settlement are reported separately. This report contains the adaptation options for:

Pine Point.

Figure 1:2 Location Map: Pine Point, Yorke Peninsula[2]

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

- James Guy, Department of Energy, Water, and Natural Resources,
- Dwayne Werfel, Yorke Peninsula Council, Works Supervisor (North),
- Geoff Fisher, Australian Water Environments (AWE), on 2nd June, 2015 inspected Pine Point settlement and environs, also reviewed the adaptation proposals and offered technical advice on 26th August, 2015,
- Geoff Wilde, Managing Director, Geoff Wilde Earthmoving inspected Pine Point on 10th August, 2015.

[2] http://www.naturemaps.sa.gov.au/maps/viewer.aspx?site=NatureMaps

1.4 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.

1.4.1 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 flooding is a factor that enables the settlement to prepare for the flood more effectively. The general characteristics of a sea-flood in the Pine Point region are shown in **Table 1:1**.

Table 1:1 Sea flood characteristics for Pine Point coastal region.

Flood characteristic	Pine Point region
Depth of water	Shallow (near the coast)
Velocity of water	Low, due to tidal action and ocean terrain
Wave action	Minimal due to depth of water and sheltered from any westerly winds by the land
Direction of water	From the east
Duration of flood	Short 1-2 hours relating to combination of tide and storm surge
Warning	Predictable as flood will relate to tide.

To contextualise the flood risk in the Pine Point region, **Table 1:2** 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 1:2: 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 Pine Point 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 1:3**). These scenarios assist in providing the context from which to make decisions that relate to the viability and also the timing of responses.

Table 1:3 Pine Point - 1 in 100 annual return events, with allowance for sea level rise

	2015	2050	2100
Storm surge (1990 levels)	2.5m	2.5m	2.5m
Wave set up	0.1m	0.1m	0.1m
Wave run up	0.1m	0.1m	0.1m
Sea level rise	0.1m	0.3m	1.0m
Totals (AHD)	**2.8m**	**3.0m**	**3.7m**

1.4.2 Adaptation responses that relate to infrastructure and people.

Infrastructure

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 take into account 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 should also 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.

1.4.3 Adaptation responses that take into account time

The *State of Play Report* (SOP) has already analysed the possible impact of the three 1 in 100 ARI flood scenarios (2015, 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 1.3** provides a pictorial overview of the adaptation strategy.

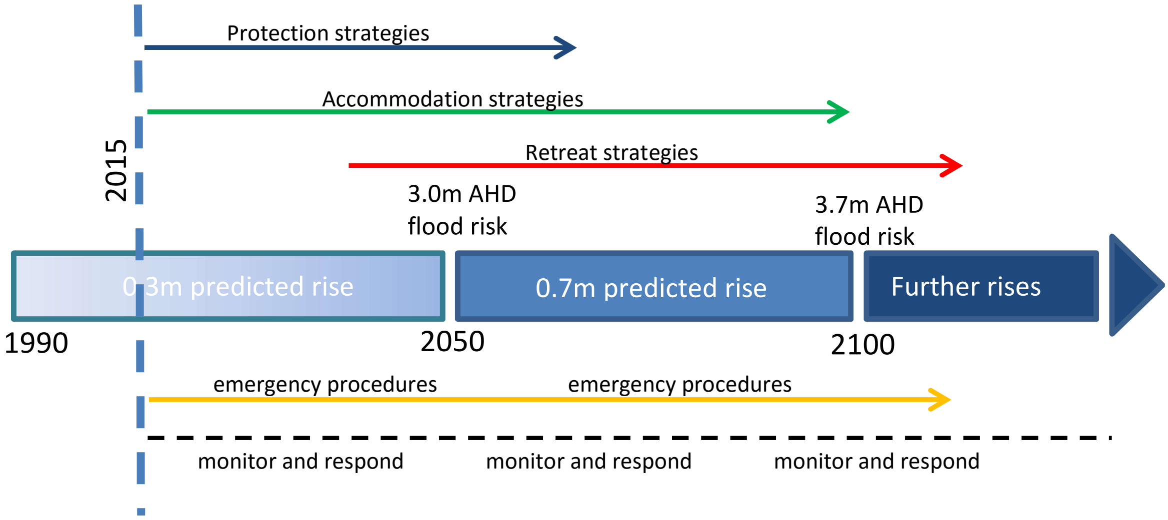


Figure 1:3 Adaptation responses are time related and sometimes contingent on each other but also contingent on the rate of sea level rise which is to be monitored over time (M. Western, 2015).

1.4.4 Adaptation responses that do not take into consideration:

- The effect of rising sea levels on ground water within Pine Point,
- The potential for a rain flood event either combined or not combined with a king tide (although the State of Play report found that there was a low correlation between sea-flooding events and rain flooding events),
- The possibility of a sea-flood event caused by unforeseen event such as a tsunami.

2. Pine Point protection options

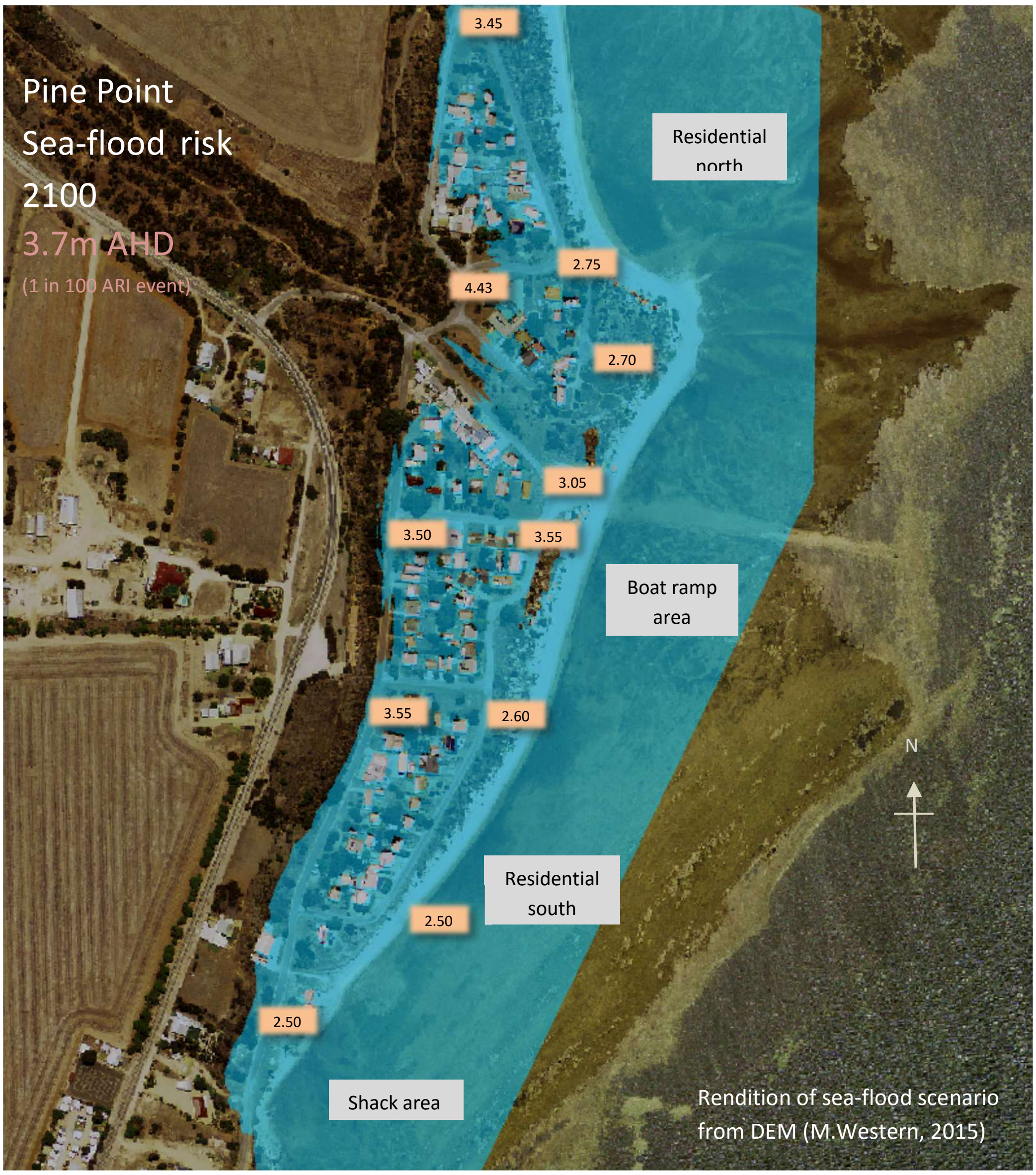
The following preliminary conclusions can be made in relation to the protection system (natural and man-made) at Pine Point (See also State of Play report, pps. 22-32):

- The general topography of Pine Point (Billy Goat Flat) is at 3.0 to 5.0m AHD adjacent the escarpment, and generally at 2.50m AHD along the Esplanade, but with some higher sections around the boat ramp area at 3.50m AHD.
- The highest level of flood water in the last 20 years is likely to have been 2.30m AHD on 25th April, 2009. This correlates with the third highest flood event that occurred in the Gulf St Vincent since 1940 (and only 5cms short of the highest event on 4th July, 2007, which for reasons unknown was not experienced in the Pine Point region).
- The earthen levee in the southern section of the settlement was installed in 2003-2004 at a height of 2.80m. The levee has never been overtopped but water did circumnavigate the levee in the Main Street region in the 2009 sea-flood event.
- A rock revetment wall has been installed to the front of four ‘shack’ sites in the south at height 2.0m AHD but these properties are under land management agreements which assign responsibility for protection to the owners.
- The dune system to the front of the settlement provides general protection at heights 2.40m to 2.50m AHD but some low points exist where water encroached in the 2009 sea-flood event.
- Available evidence suggests that Pine Point was a stable beach from the 1940s to the 1990s, but since then is experiencing erosion south of the boat ramp at increasing rates. The erosion in the south is not far away from threatening Main Street (SOP, p. 27) and the aforementioned levee shows evidence of erosion. In the opinion of Australian Water Environments, the integrity of this levee may be threatened within ten years.
- There was some anecdotal recollection of severe rain events in the 1960s but the general view of those in community consultation was that rain water is adequately drained away within the existing storm water system, despite there being no outlet through the dunes from the storm water channel (SOP, p. 24)

2.1 What level of protection can be realistically provided to cater for the sea-flood risk at 2100 (3.7m AHD)?

In brief, the findings of State of Play report (SOP, p.44) were that should a 3.7m AHD event occur the vast majority of the existing dune system would be overtopped at depths of 1 metre or more and that sixty houses would suffer inundation over floor levels at up to 1.5 metres with a damage cost to dwellings at $1.5 million (in current values).

Figure 2:1 Flood mapping for sea-flood scenario 1 in 100 ARI event of 3.7m AHD (2100 scenario).



Conclusion:
In pure engineering terms it would be possible to construct a levee at heights up to 1.50m high adjacent the Esplanade Rd. However, it is likely that if the predicted rise of sea level occurs, the entire dune system will erode back to the edge of the Esplanade Road and expose the levee to erosion. Furthermore, if the sea level does rise as predicted, there is nothing to suggest that it won't keep rising past 2100, thereby rendering the defences at 3.7m AHD ineffective.

2.2 What level of protection can be realistically provided to cater for the sea-flood risk at 2050 (3.0m AHD)?

In brief, the findings of State of Play report (SOP, p. 38) were:

- Water would completely overtop the levee and dunes and inundate the residential area at depths 0.5m to 0.6m.
- The Esplanade Road would be flooded at depths ranging from 0.4m to 0.7m,
- Main Street would suffer minor inundation (apart from in the southern shack area where inundation would be more significant).

However, before consideration can be given to sea-flood protection options, the increasing rate of erosion in the Pine Point area must be taken into account for the following reasons:

- If the rate of erosion increases, then the entire dune system may erode away and the Esplanade road would become exposed to erosion. If this was to occur then rock revetment would be the likely choice of action.
- If the rate of erosion slowed, or halted, and the dune system remained intact, then a dirt bund would be the likely choice of action to protect Pine Point.

Therefore decisions on how to protect Pine Point more generally should only be made when the nature of the erosion has been quantified more fully. In the first instance, sea-flood protection strategies should focus on the current sea-flood risk of 2.70m AHD[3], and then subject to monitoring over the next ten years, longer term strategies can be employed (if necessary).

Furthermore, the study by Australian Water Environments (SOP, Appendix C) found that the rate of shoreline recession may be attributable to a number of factors either individually or in combination, including:

- Lack of fresh sand supply from the south;
- Increase in sea level
- Vegetation loss due to drought or grazing
- Possible increase in strength and persistence of south-easterly winds

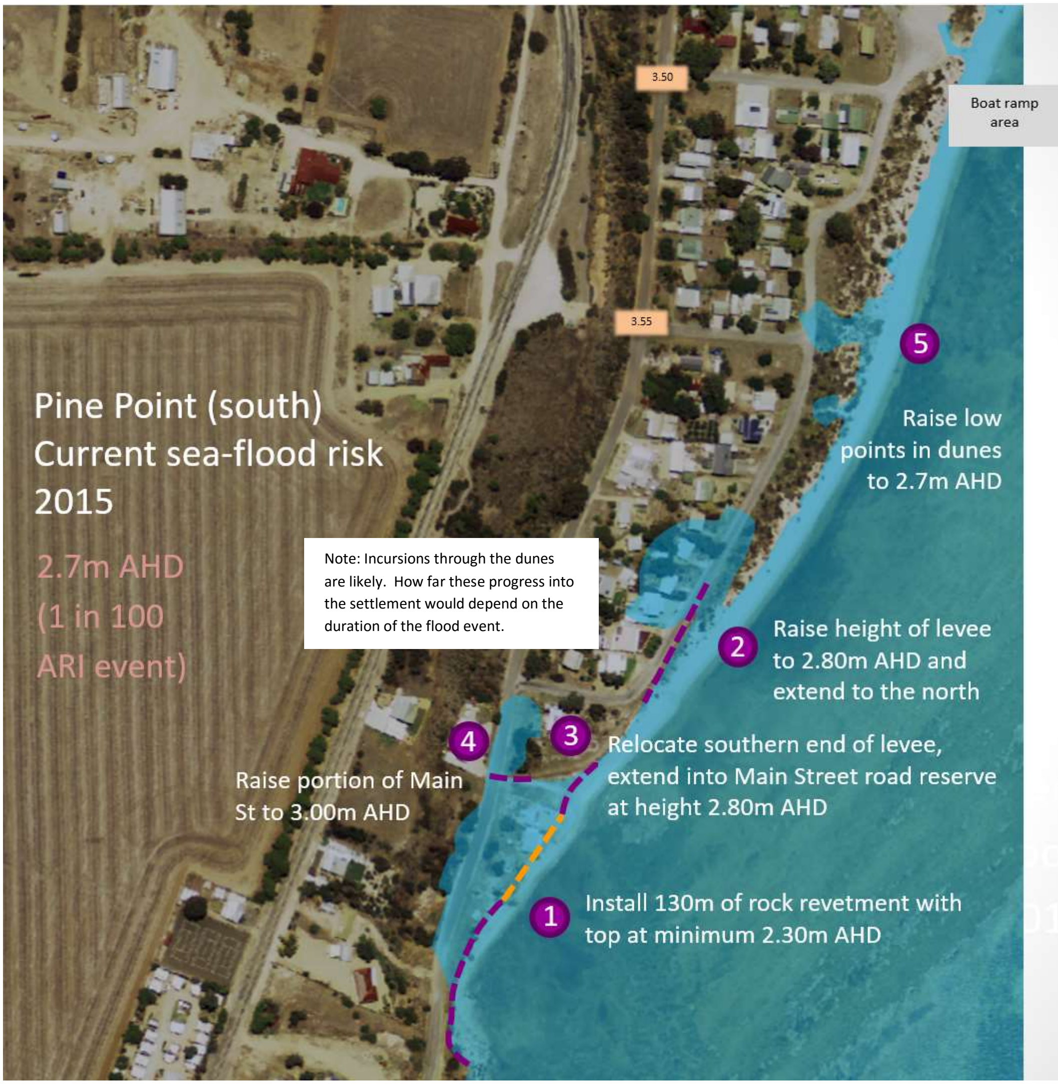
Further study would be required to ascertain which of these (or other factors) is contributing to the accelerated rates of erosion. Without increasing the knowledge base, it is not possible to determine, for example, whether the installation of a groyne would halt the rate of erosion. If the reason was 'lack of fresh supply from the south' then a groyne would be of diminishing assistance over time. Therefore, adaptation options for Pine Point in this study have been limited to those that are defensive rather than options that may address the underlying issues.

[3] In this scenario 'wave run up' has been omitted from the calculations due to the presence of the dune system. To add a contextualisation point, the highest likely level of water into Pine Point over the last twenty years is 2.30m AHD. Wave run up is included in the 2050 sea-flood scenario calculation because it is likely that the dune system would have become more eroded and the settlement more exposed to wave action.

2.3 What level of protection can be realistically provided to cater for the sea-flood risk at 2015 (2.7m AHD)?

Due to the factors outlined in 2.2 above, the approach to Pine Point is to provide sea-flood protection to cater for the current sea-flood risk[4] (2015), monitor the rate of erosion of the dune system over the next ten years, and then make the appropriate decision as to which protection method to employ to cater for the sea-flood risk scenario of 2050. The location of the proposed protection measures are depicted in **Figure 2:2**.

Figure 2:2 Proposed protection works for Pine Point (south).



Rendition of Sea-flood scenario from DEM (M. Western, 2015)

[4] In the 2015 scenario 'wave run up' has been omitted from the calculations due to the presence of the dune system. (To add a contextualisation point, the highest likely level of water into Pine Point over the last twenty years is 2.30m AHD). 'Wave run up' is included in the 2050 sea-flood scenario calculation because it is likely that the dune system would have become more eroded and the settlement more exposed to wave action.

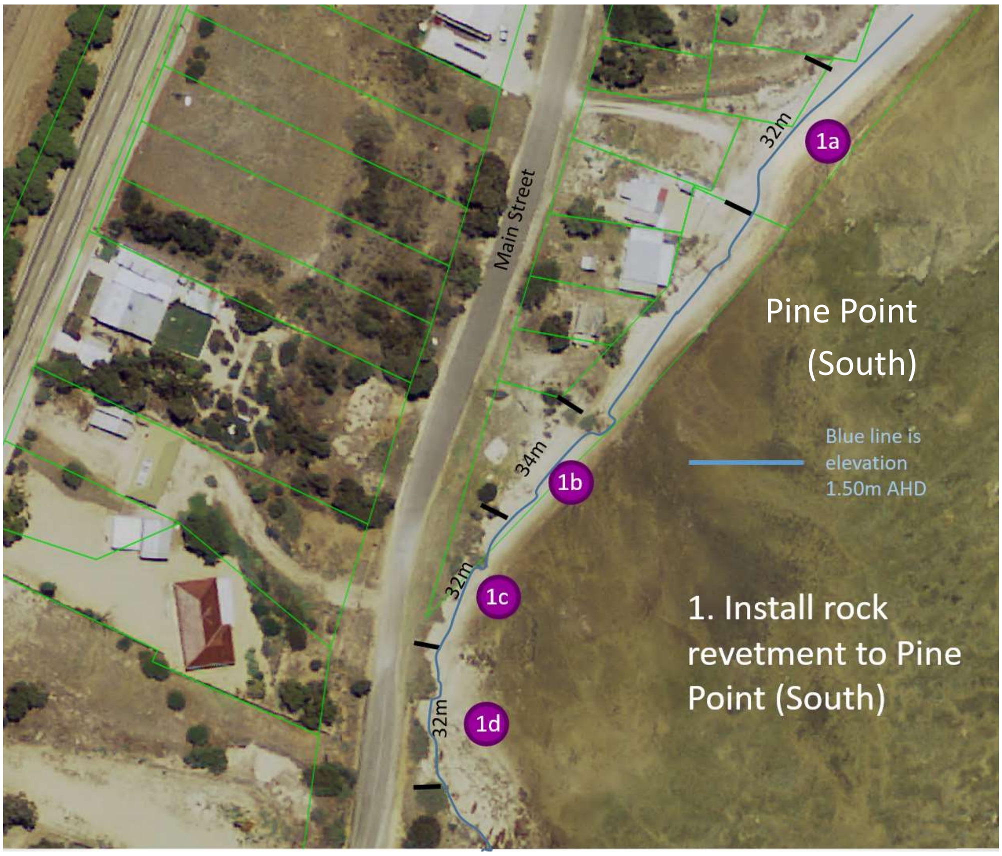
2.4 Protection options for Pine Point

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 setting of priorities. They should not be relied on for budgeting or construction cost management purposes.

1. Install 130m of rock revetment with top at minimum 2.30m AHD.

The prime purpose of these works is to halt the shore line recession that is occurring because of increasing erosion, and are designed to operate over longer time periods (not just to deal with the current risk). If no measures are taken, erosion will soon threaten Main Street and the integrity of the existing earthen levee will be undermined (see SOP, p. 26 and **Figure 2:3** below). The purpose of these works is not to act as flood protection in the longer term, but they will provide increased protection to the southern 'shack' sites. The four properties depicted on the shoreline in **Figure 2:3** are under land management agreements, conditions of which mean that the owners are responsible for their own protection measures. Currently, the owners have installed a rock revetment wall constructed from paddock rocks at a height of 2.0m AHD.

Figure 2:3 Proposed rock revetment sections for Pine Point (south).



Rendition from DEM (M. Western, 2015)

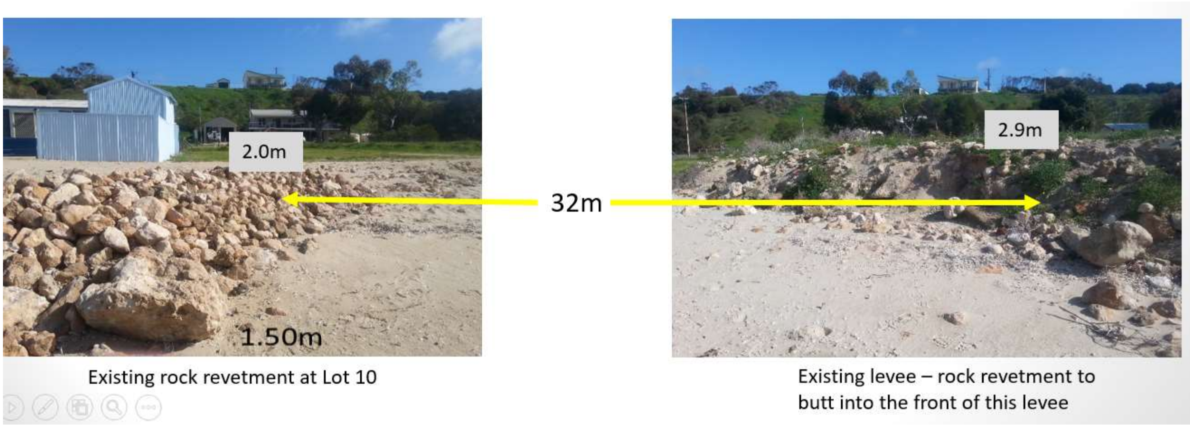
The details of Sections (a) to (d) depicted in **Figure 2:3** are explained further on the following pages.

1.a Install 32m of rock revetment to join existing rock revetment owned by Lot 10 to the existing levee to the north.

Notes:

- Top of existing rock revetment is at 2.0m AHD
- Install rock revetment with top at minimum of 2.30m AHD
- Butt proposed rock revetment into the front of existing levee to the north (to provide increased protection from ongoing erosion)
- Place fill behind rock revetment (see **Figure 2:6**)

Figure 2:4 Location of adaptation strategy 1.a



Photographs: M. Western (2015)

1.b Install 34m of low height rock revetment to join existing rock revetment owned by Lot 273.

Notes:

- Top of existing rock revetment is at 2.0m AHD (to the right of the photograph)
- Install rock revetment with top at minimum of 2.30m AHD
- Place fill behind rock revetment (see **Figure 2:6**)

Figure 2:5 Location of adaptation strategy 1.b

Photographs: M. Western (2015)

Figure 2:6 Backfill behind rock revetment – sections 1.a and 1.b

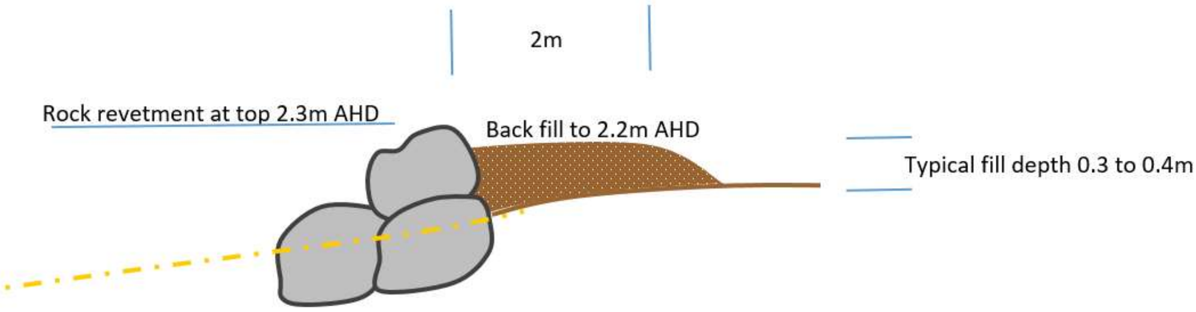


Illustration: M. Western (2015)

1.c Install 32m of medium height rock revetment

<u>Notes:</u>

- Install rock revetment with top at minimum of 2.30m AHD
- Place fill behind rock revetment (see **Figure 2:10**)

Figure 2:7 Location of adaptation strategy 1.c

Photographs: M. Western (2015)

1.d Install 32m of medium height rock revetment

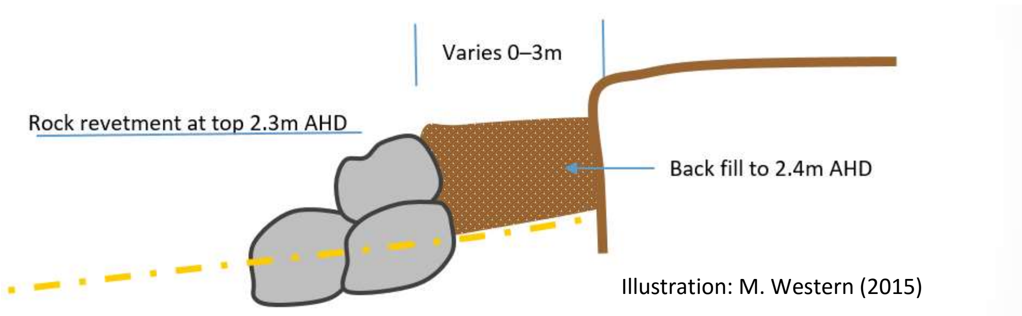
Notes:

- Install rock revetment with top at minimum of 2.30m AHD
- Place fill behind rock revetment (see **Figure 2:9, 2:10**)

Figure 2:8 Location of adaptation strategy 1.d

Figure 2:9 Backfill will be required behind the proposed line of rock revetment

Figure 2:10 Backfill behind rock revetment – sections 1.c and 1.d



Preliminary cost estimate:

$48,250 plus $4,100 for the provision of earthen fill to place behind the rock revetment by Geoff Wilde Earthmoving.

2. Raise height of existing levee to 2.80m (where deficient) and extend 65 m to the north[5].

The purpose of these works is to provide increased protection at current risk levels to the south-west section of the settlement where the existing dunes are the narrowest and under the most threat from being eroded back to the edge of Esplanade Road. Low points in the dunes in this section suggest that water would flow through the dunes should the current risk sea-flood scenario occur. Over the next ten years, ongoing monitoring will establish more clearly the rate of erosion within the dune system, and then what remedies to take to deal with that problem.

Figure 2:11 Raise existing levee and extend to the north

Photograph: M. Western (2015)

[5] 'Wave run up' of 0.1m has been included in the height as this area of Pine Point is the most exposed.

Figure 2:12 Proposed profile for levee adjacent Esplanade Road

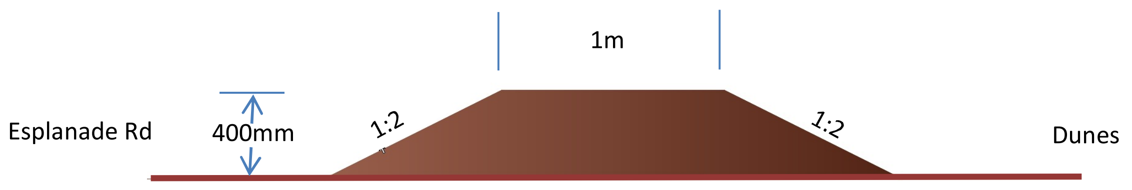


Illustration: M. Western (2015)

Table 2:1 Preliminary cost calculation: raise existing levee to 2.80m AHD and extend							
Location	Existing elevation	Levee height increase	Levee length	Area of profile face	Volume (approx) m^3	*Cost per m^3	Cost (approx)
Adjacent Esplanade Road	2.4 m to 2.5m AHD	0.4m	145m	1.00m^2	145m^3	$45	$6,700

<u>Preliminary cost estimate:</u>

Yorke Peninsula Council estimates the cost of works for Option 2 at $6,700.

3. Relocate the southern end of the existing levee, extend into the road reserve of Main Street, at height 2.80m AHD.

The SOP (p. 29) noted that in 2009 event, water flowed north along Main Street and threatened to circumnavigate the levee. The purpose of these works is to raise this portion of the levee to cope with the current sea-flood risk of 2.80m AHD (including 0.1m wave run up) and extend the levee into the road reserve to prevent water entering the main part of the settlement.

Note: the relocation will need to take into account the private driveway on the west side of Main Street (See **Figure 2:13** and **2:14**).

Figure 2:13 Relocate the southern end of the existing levee and extend into Main Street road reserve.

Photograph: M. Western (2015)

Figure 2:14 Relocate the southern end of the existing levee and extend into Main Street road reserve.

Photograph: M. Western (2015)

Table 2:2 Preliminary cost calculation: relocate existing levee and extend

Location	Existing elevation	Levee height increase	Levee length	Area of profile face	Volume (approx) m^3	Cost per m^3	Cost (approx)
Existing	2.7 m to 2.8m AHD	0.2m	20m	$0.3m^2$	$6m^3$	$45	$800
Relocate portion and extend	2.3m	0.6m	15m	$1.3m^2$	$20m^3$	$45	$2,400
					Total		$3,200

<u>Preliminary cost estimate:</u>

Yorke Peninsula Council estimates the cost of works for Option 3 at $3,200.

Note: Costs associated with works in the road reserve are included at Item 4 below.

4. Raise portion of Main Street to 3.0m AHD[6]

Notes:

- Raise portion of road to 3.00m AHD (5m width road only).
- Create one lane for traffic with appropriate signage
- Remove eastern side of road (see diagram below)

Figure 2:15 Raise portion of Main Street to 3.00m AHD

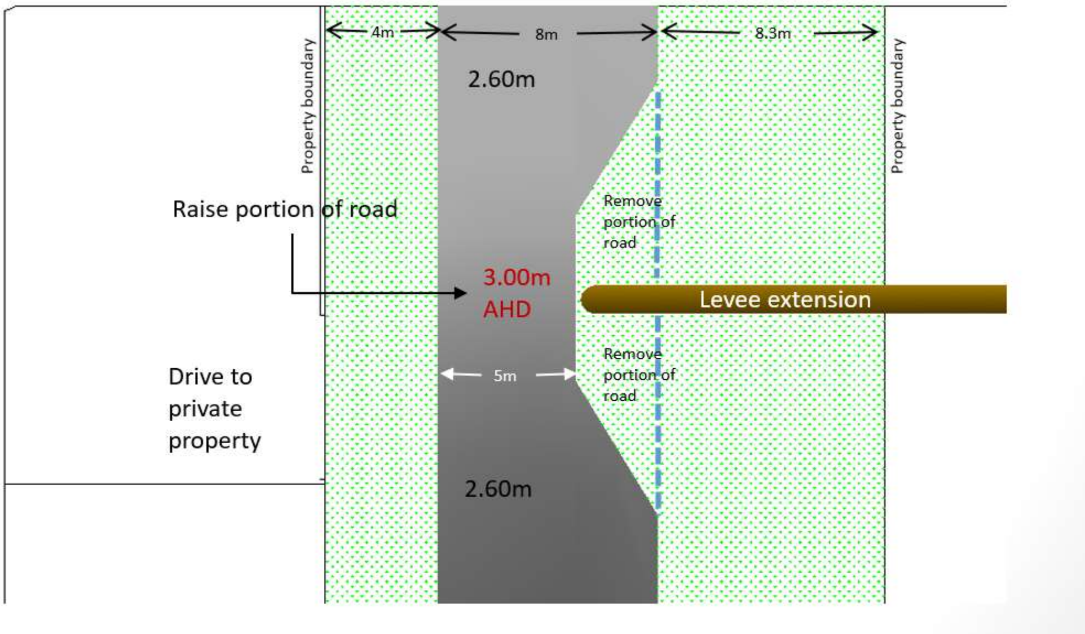


Illustration: M. Western (2015)

Note:

Some community feedback was received that was opposed to reducing the width of the road and therefore the width of the road was expanded from 3m to 5m. This proposal effectively interrelates the levee with the road and also effectively deals with the slope of the road (which slopes down from left to right in **Figure 2:15**). However, if the community was opposed to any narrowing of the road, the entire road could be raised, but this solution would incur greater cost.

<u>Preliminary cost estimate:</u>

Yorke Peninsula Council estimates the cost of works within the road reserve depicted in **Figure 2:15** at $8,500 including relaying new bitumen and signage.

Geoff Wilde Earthmoving estimated the cost of raising the road for its entire width with a 10 metre length of rise on each side (probably not warranted) at $16,000.

[6] The logic of raising the road to meet the 2050 sea-flood level of 3.0m AHD is that it is cost effective to do this work now, and the increased height is only 0.4m to 0.5m above the existing road level.

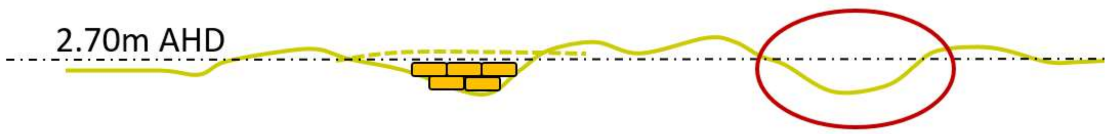
5. Identify low points in dunes and raise to 2.70 m AHD.

The purpose of these works is to strengthen and add height to the dunes in locations that are lower than 2.70m AHD. In the sea-flood event of 25th April, 2009, which was approximately 2.30m AHD in height, water flowed through the dunes at the end of First Street, and almost overtopped the dunes at the end of Earl Street. If a flood event of 2.70m AHD occurred significant inundation through the dunes is likely.

Notes:

- Surveyor to locate low spots in dunes (half day)
- Install sandbagging to low spot location (obtain sand from south of the wharf)
- Cover with sand (obtain sand from south of the wharf)
- Encourage revegetation
- The height of sand dunes vary. It may not be possible to provide protection in dunes higher than 2.70m with this approach.

Figure 2:16 Concept: Low points in dunes to be located and strengthened and raised with sand



Preliminary cost estimate:

It is not possible to estimate the cost due to the unknown number of locations to be filled but a contingency sum of 10k to 20k is suggested.

6. Monitor rate of erosion over the next ten years

A monitoring system should be employed to ascertain the nature of the erosion with key indicators to be designed by an engineer. Subsequent to monitoring, protection measures for areas of Pine Point north of the existing levee should be considered for the following reasons:

- Protection measures are feasible and are likely to be effective (although if rock revetment is required the costs will be high),
- Protection of development to cater for the 2050 sea-flood scenario (3.0m AHD) is Coast Protection Board policy,
- Installation of protection measures will provide a 30-40 year time in which data can be tracked to assess the rate of change in sea level rise,
- Installation of protection measures will provide a 30-40 year time frame in which accommodation measures can be implemented to cater for predicted sea level rises past 2050 (see next section).

Note: The original list of proposals included the option to ‘install mechanism to cater for storm water flows and limit sea water from entering’. However, the general feedback in community consultation was that storm water was adequately drained away in the current system.

3. Pine Point Accommodation Options

Accommodation options are necessary when sites and buildings are not able to be protected by reasonably practical means to cater for the 1 in 100 ARI event for the 2100 sea-flood scenario. Infrastructure and buildings implemented in the present time will have life spans in excess of eighty years and thus are likely to be in existence around 2100. This study has found that protection options are only viable to cater for the 2050 sea-flood scenario and therefore, other accommodation options should be implemented.

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

As noted above (see p. 5), a community that is prepared to deal with a flood is likely to suffer much less in financial terms, and also likely to face lower risk of injury to humans. 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.

Yorke Peninsula Council 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. It is noted here that two community work shops have been held, and the State of Play reports containing flood mapping have been posted on the Council website. All land owners were notified of the meetings and where to find the State of Play report.

- 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.

Pine Point Progress Association (or other appropriate community organisation) to implement flood warning systems such as:

- Community run warning systems to inform residents of upcoming king tides. Examples of warning systems include: 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 and could be forwarded to residents. The SES or CFS may also have other ways in which to warn residents.
- Install flood depth markers to Main Street where required[7].

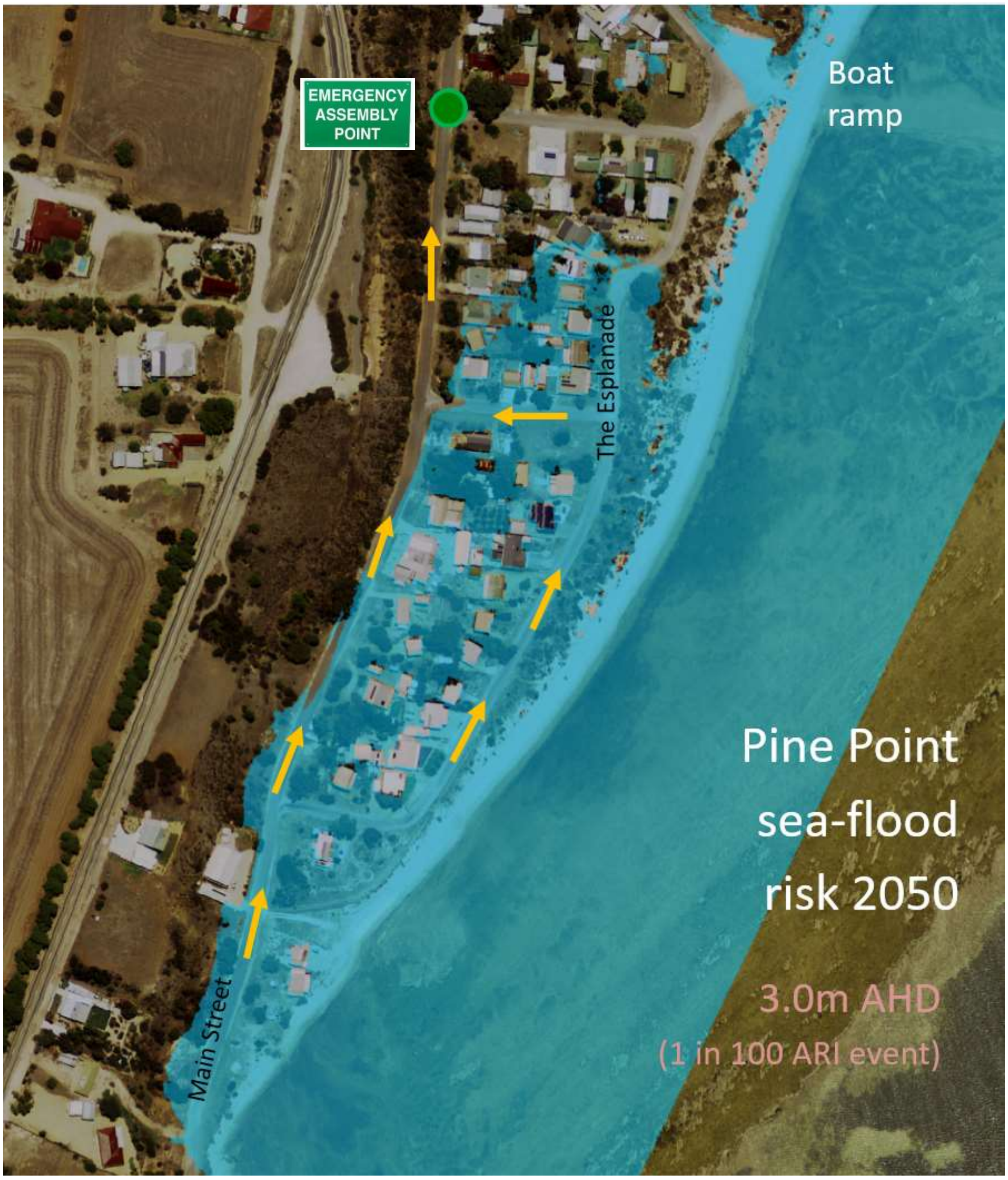
[7] Unit cost $150, approximate labour cost $250, installation $400 per flood depth marker.

3.1.3 Implement flood emergency procedures.

Pine Point Progress 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 location 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 Pine Point residents can generally move directly away on foot from the flood towards the west and find higher ground at Main Street (apart from south of the levee).

Figure 3:1 Routes that residents can utilise to move to the emergency assembly point (Example Only)



Flood mapping from DTM: M. Western (2015)

Emergency service vehicles would be able to enter Pine Point from the northern entry point to Billy Goat Flat, but not the southern entry. Main Street is predominantly at heights well above the sea-flood risk level for 2050 and thus acts as a 'spine' to the settlement upon which emergency vehicles can safely travel with reasonably close access into all parts of the settlement apart from the southern 'shack' area.

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.

Pine Point Progress 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.

3.2 Accommodation Option- amend Development Plan policy.

Planning policy should ensure that:

- All new buildings (apart from minor structures such as sheds) are 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 in accordance with current policy);

- 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 Pine Point 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 number of existing dwellings subject to inundation at the current predicted 1 in 100 ARI event of 2.7m AHD is 16, with a likely damage bill to private property in current dollars at $198,000 (SOP, p. 48). The predominant housing construction in Pine Point is either light weight or transportable[8] but foundation types are evenly split between concrete and stumps or poles. Those dwellings on stumps could be raised if required. If a decision is made to 'do nothing' about the protection options outlined above (p.12-21) or a decision is made to defer for any length of time, then residents may choose to raise their dwellings if the rates and heights of inundation increase[9]. (However note, dwellings constructed over the last two decades are likely to be above the sea-flood risk for 2050).

Figure 3:2 Building construction types (Pine Point)

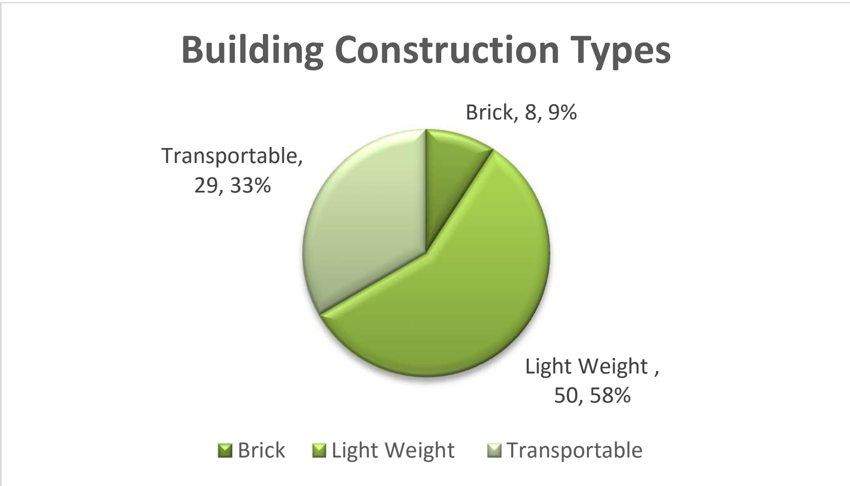
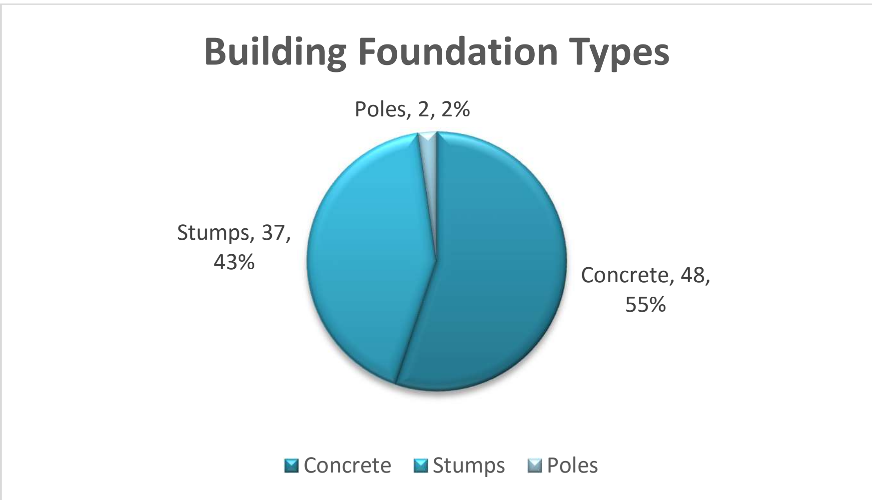


Figure 3:3 Foundation construction types (Pine Point)



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[8] 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.

[9] Note: Any dwelling constructed over the last decade or so is likely to be at height for 2050 sea-flood scenario.

It is anticipated over the next 30-40 years that many of the existing older dwellings in Pine Point will be replaced. If the proposed protection options outlined above (p. 12-21) 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.

3.3.2 Water proof dwellings

Other flood accommodation options that residents could employ should the threat of inundation increase are:

- Internally water proof buildings and raise electrical outlets above the predicted flood levels.
- Provide temporary flood barriers to the outside of dwellings when tides are predicted to be high[10].

Figure 3:4 Flood diversion/ protection method for dwellings

Figure 3:5 Flood diversion/ protection method for dwellings

[10] Examples from Blobel Flood Protections Systems (Blobel Environmental Engineering, 2013)

4. Pine Point Retreat Options

The data from tide gauges at Port Stanvac and Thevernard have shown that sea level in the region has been rising at an average of 4.3mm per year over the past 20 years. For the mean sea level to rise by 0.7m in the second half of this century as predicted, would require an average rate of rise of 14mm per year. In reality this rate would be less than 14mm at 2050, and a much higher than 14mm per year by 2100. Therefore, from now until 2050-2060 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, Pine Point would have become a far more resilient community and be prepared for any unforeseen flood event.

- If the rate of change of sea level rise does accelerate and the predictions prove to be accurate, then Pine Point can expect to be inundated far more frequently as the century approaches its close. Furthermore, the associated increased erosion may also see the demise of the entire dune system. Even though planning changes foreshadowed above mean that the floor levels of dwellings are above the flood levels, roads are likely to be more frequently cut off and damaged, emergency vehicles may not be able to enter the settlement, and the safety of people may be increasingly at risk.

Therefore, if monitoring of sea level rise in the over the coming decades indicates that the rate of change is accelerating, then planning policy should be devised 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[11]
- Dwellings constructed now will be reaching the end of their life span. This may coincide with sea levels reaching a position where they may not be properly accommodated.

In summary, such a policy would allow residents the liberty to continue to develop their properties, but with the knowledge that the development may have a limited life span and plan accordingly. Additionally, within this strategy is the assumption that should sea level rise as predicted and coastal properties become increasingly threatened by inundation or erosion, people's attitudes will change to living in certain coastal areas. It is also likely that this changing attitude will be reflected as reduced values of some coastal properties.

[11] 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.

In regard to Council owned infrastructure it is anticipated that:

- Any new buildings or infrastructure would be implemented taking into account the flood mapping provided by this study,
- Council will increasingly make decision not to upgrade infrastructure if it has become obvious that in the longer term a settlement cannot be protected,
- Should a retreat strategy be implemented, Council would need to implement its own retreat strategy for its own assets.

In conclusion, using the strategy outlined above, the Council will not be in the position of needing to implement a retreat strategy until it is obvious that such a strategy is required, and that fair warning had been given to all residents with the establishment of a pre-determined trigger a few decades prior.

5. Pine Point 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 5:1** is a summary of the adaptation options for Pine Point grouped according to the categories of *protect, accommodate, or retreat*.

Table 5:1 Summary of adaptation options for Pine Point

	Adaptation options	Approximate cost	Reference pp.
Protect	Install 135 LM of rock revetment with top at 2.30m AHD to southern 'shack' area.	$52,450	12
	Raise the existing levee to 2.80m AHD (where deficient) and extend 65m further north	$6,700	16
	Relocate the southern end of the existing levee and raise to 2.80m AHD	$3,200	18
	Raise portion of Main Street to 3.0m AHD	$8,500	20
	Identify low points in dunes and raise to 2.70 m AHD (not able to be costed - contingency sum)	$15,000	21
	Monitor rate of erosion over ten year period and then implement protection works to cater for 2050 sea-flood risk (where not already implemented)	not costed	21
Accommodate	Implement emergency procedures – establish warning systems; establish emergency assembly point; establish evacuation policies; establish community emergency action plans.	Progress Association	22
	Install flood depth markers to Main Street (in southern 'shack' area).	$1000	22
	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	24
	Adapt existing dwellings (if required) – residents to raise floor levels; utilise internal waterproofing; or temporary protection mechanisms.	Residents cost	25
Retreat	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.	27

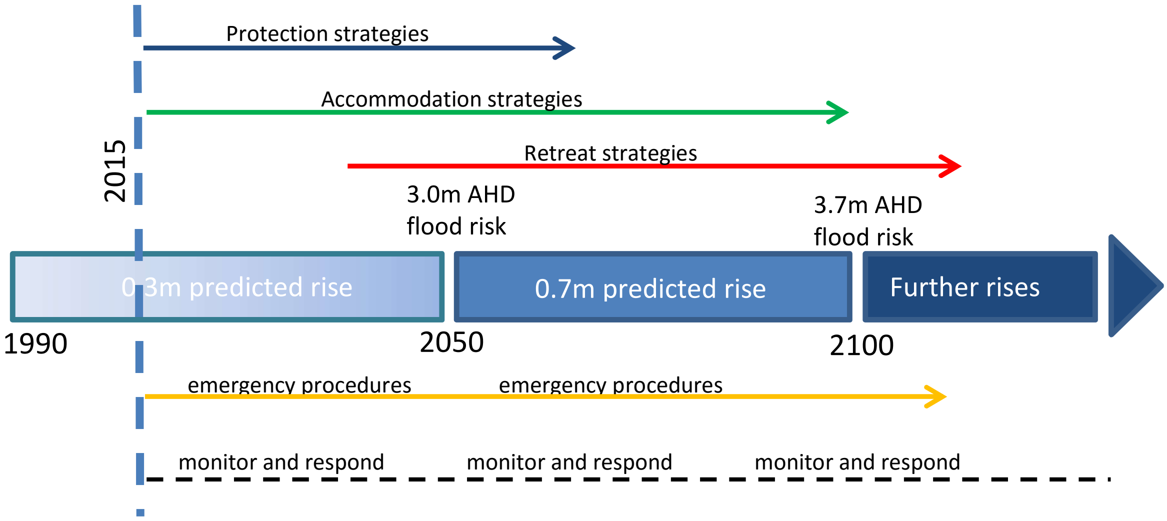
Within all of these adaptation options is the option to 'defer' or 'do nothing'. For example, cost may prohibit the implementation of a protection measure and therefore the project is deferred. In other cases, the risk might be deemed so minor that 'do nothing' is adopted.

6. Pine Point – Timing and prioritisation

6.1 Timing of adaptation options

In general, **Figure 6:1** illustrates how the different protection, accommodation, and retreat options interrelate over time. Sea level rise and erosion are monitored over time and responses 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 6:1 The interrelationship of adaptation options over time



6.2 Prioritisation of adaptation options

The prioritisation of adaptation options is based on the following criteria:

- First, warning and emergency procedures to ensure people are safe.
- Second, implement monitoring systems because these are not onerous, and the Council may be liable without them.
- Third, begin changes to planning policy as this process takes time, and the life span of infrastructure is long.
- Fourth, implement protection works to protect Pine Point for the current sea-flood risk (apart from southern and northern shack areas).
- Fifth, subject to monitoring of the rate and impact of beach erosion, implement protection works to protect Pine Point for the sea-flood risk for 2050 (apart from southern and northern shack areas)[12].

[12] Contextual note: Pine Point is the only settlement of the four settlements under review in this study where protection works are provided for current sea-flood risk only and not 2050 sea-flood risk.

Subject to Council and community input the following prioritisation in **Table 6:1** is recommended for Pine Point.

Table 6:1 Prioritisation and responsible entities for adaptations at Pine Point

	Adaptation response	Risk rating and other priority factors	Response time	Map reference
1.	Implement emergency procedures – establish warning systems; establish emergency assembly point; establish evacuation policies; establish community emergency action plans.	Such procedures are a wise response to living adjacent to an unpredictable threat.	Within 1 year	NA
2.	Implement monitoring systems to assess the state of protection bunds (annual) and rate of erosion of the dunes according to	A duty of care exists for the condition of bunds/ monitoring of the beach will assist in determining future actions	Within 1 year	NA
3.	Install flood depth markers to Main Street.	Flood depth markers will increase awareness and safety of drivers.	1-2 years	NA
4.	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.	Some dwellings constructed now may still be in use in 2080-90 when the 1 in 100 ARI flood risk is 3.7m AHD.	1-2 years	
5.	Install 135 LM of rock revetment with top at 2.30m AHD to southern ‘shack’ area.	Erosion is not far away from threatening Main Street and the existing levee is breaking down in places.	1-2 years	1
6.	Raise the existing levee to 2.80m AHD (where deficient) and extend 65m further north	The levee is as low as 2.40m AHD on the northern end, the dunes are at their narrowest point in this region, and water would flow through the dunes if the current sea-flood risk occurred.	1-2 years	2
7.	Relocate the southern end of the existing levee, extend, and raise to 2.80m AHD (to be completed at the same time as (7).	Increased flood protection will be obtained from (5) but should the current sea-flood scenario occur, water is likely to flow north past the existing levee	1-2 years	3

8.	Raise portion of Main Street to 3.0m AHD (To be completed the same time as (6)	Increased flood protection will be obtained from (5) but should the current sea-flood scenario occur, water is likely to flow north past the existing levee	1-2 years.	4
9.	Identify low points in dunes and raise to 2.70 m AHD	There are several low spots in the dune system that were inundated at 2.30m AHD. If an event at 2.80m occurred inundation is likely to be significant. It is unknown how successful this approach will be.	1-2 years	5
10.	Subject to monitoring of erosion over next ten years, implement protection works to protect settlement to 2050 sea-flood risk levels.	Monitoring will determine whether earthen bunds will be sufficient protection, or whether harder options are required.	10-12 years	
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 removed once predetermined triggers have been realised.		30-40 years	
12.	Adapt existing dwellings (if required) – residents to raise floor levels; utilise internal waterproofing; or temporary protection mechanisms.	Residents responsibility	30-40 years	NA

Note: The initial proposals for protection works included map reference (6) which was a proposal for the installation of a mechanism to cater for storm water flows out to sea and limit sea water from entering. However, initial general feedback from participants in community consultation meeting of 19th August was that storm water was currently being adequately drained away.

7. Pine Point - Community consultation

7.1 Consultation methodology

All land owners were mailed an invitation to attend a community workshop on 19th August 2015 at 1.30pm. The invitation included the summary table from the State of Play Report (p. 61) and notification that the State of Play report had been uploaded to the Council website.

Mark Western gave a formal presentation in which a review was undertaken of the State of Play report and then the adaptation options were presented. At the conclusion of the formal presentation, maps showing the location of the proposed adaptation options and two feedback sheets were positioned on tables and participants were invited by the facilitators to answer questions. The facilitators of the meeting were Mark Western (Integrated Coastal Management), Natasha Hall (Central Region Climate Change Officer), Stephen Goldsworthy (Yorke Peninsula Council). Twenty six people attended the meeting.

Feedback Sheet 1 related to the issue of becoming 'flood ready', and included the questions:

- Do you think it necessary to be flood ready?
- What type of warning systems could be implemented?
- What emergency procedures could be implemented?

Feedback sheet 2 and associated maps listed the protection adaptation options and participants were asked to give their feedback.

See Appendix A for examples of feedback sheets utilised.

7.2 Community feedback

<u>Feedback sheet 1:</u>

Q1. Do you think it necessary to be flood ready?

The general feedback from participants that to be 'flood ready' was a 'good idea'. Specific feedback included:

> *'First thoughts are, it's a new concept. Answer is Yes! Definitely an exit strategy is needed'.*
>
> *'Yes, Yes!'*

Q2. What type of warning systems could be implemented?

> *'Utilise the mobile app – Alert SA'*
> *'Zone emergency management committee (SES)' (consult?)*
> *'Put king tide information on community calendar'*
> *'Use the community as a first response'*
> *'Use SMS warning system'*

Q3. What emergency procedures could be implemented?

'Progress Association to do Community Flood Plan (dual plan to cater for sea and stormwater flooding for example, areas to sand bag)'
'Properties at risk could do a flood management plan'
'buy a sand bag machine'

Feedback sheet 2:

Generally the feedback was positive about the adaptation proposals. One question was raised in the formal presentation as to why sea-flood protection options were not being considered for the southern 'shack' area. The meeting was informed that the four properties in this area are under land management agreements that state that all protection works are the responsibility of the owners. Some negative response was received to Option 3 &4 (see below).

1. Install 130m of rock revetment with top at minimum 2.30m AHD.

'Ensure revegetation is done'.
'Needs to absorb energy – 'gabion' style is better' and 'engineered solution to prevent back flow'
'A great idea'.

2. Raise height of existing levee to 2.80m (where deficient) and extend 65 m to the north

'A very good idea as the water laps to the top of the levee now, and the levee is not all the same height along there now'.

3. Relocate the southern end of the existing levee, extend into the road reserve of Main Street, at height 2.80m AHD.

'Instead could be temporary installed planks as part of response plan. Don't like '1-way' road idea'.

4. Raise portion of Main Street to 3.0m AHD.

Transportable homes are brought into the community on this road (general feedback)
See also (3).

5. Identify low points in dunes and raise to 2.70 m AHD.

'Revegetate with deeper rooted [plants]'.
'This is a great idea and very necessary'.

6. Install mechanism to cater for storm water flows and limit sea water from entering.

General feedback indicated that stormwater was adequately draining away in the current system (despite there being no opening to the sea).
One written response said, 'more investigation of stormwater'.
Note: this option has now been removed from the final list.

7. Monitor rate of erosion over ten years and then implement protection strategy to cater for 2050 sea-flood scenario (where already not implemented).

No specific feedback

Appendix A: Community consultation feedback sheets

(Samples – originals in A3)

Community Feedback – Adaptation Options for Pine Point

	Adaptation option	Reason	Feedback
1	Install 130m of rock revetment with minimum top at 2.30m AHD.	Pine Point is subject to erosion that will soon threaten Main Street and is already threatening the southern portion of the earthen levee. Installation of rock revetment should prevent further erosion.	
2	Raise height of existing levee to 2.80m AHD and add extension to the north.	Current flood risk levels are set at 2.70m AHD. Raising the levee in this location and adding an extension is likely to prevent water flowing through the dunes on the northern end of the levee.	
3	Relocate southern end of existing levee, extend half way across Main Street, raise to 2.80m AHD.	Current flood risk levels are set at 2.70m AHD. Extending the levee across Main Street is to work in with Option 4 so as to ensure that water is unlikely to traverse north past the levee.	
4	Raise half width of Main Street to 3.00m AHD that creates a slow traffic lane with appropriate signage.	Current flood risk levels are set at 2.70m AHD. Raising half of Main Street in conjunction with Option 3 will ensure that water is unlikely to traverse north past the levee.	
5	Locate low points in dunes and raise to 2.70m (where possible)	Should the current flood risk of 2.70m AHD eventuate, it is likely that sea water would flow through the dunes into the settlement.	
6	Install mechanism to cater for storm water flows and limit sea water from entering	Should the current flood risk of 2.70m AHD eventuate, it is likely that sea water would flow through the dunes into the settlement.	
7	Subsequent to monitoring of rate of erosion, implement protection strategy adjacent the Esplanade	The sea flood risk level for 2050 is 3.1m AHD. It is unknown how long the existing dune system might remain in place. Ongoing monitoring over the next 5-10 years will assist in making appropriate protection decisions.	

Adaptation Options (south)

Adaptation Options (north)

How can our community be flood ready?

Do you think it is necessary to be flood ready?

What type of warning systems could be implemented?

What emergency procedures could be implemented?

WRITE YOUR COMMENTS HERE: