Tasmanian Coastal Adaptation Pathways Project

Kingston Beach – Public Interim Report

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SGS
Economics & Planning

This report has been prepared for:

Tasmanian Coastal Adaptation Pathways Project

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1 Introduction and Aim

1.1 This Report

The aim of this report is to inform the Kingston Beach and wider community about coastal risks in light of sea level rise resulting from climate change. It also considers ways to respond to risks while also considering the values of living in Kingston Beach and other benefits such as beach recreation and swimming.

A better understanding of the issues and possible responses will help the community to make informed decisions to respond to sea level rise and its potential impacts.

The report starts with an overview of the potential coastal hazards (inundation, erosion) at the present day and expected changes in the future as a result of expected sea level rise.

The report then describes the potential damages that may occur as a result of sea level rise and extreme storm events. It also describes how likely it is that damages would occur, now and in the future.

While coastal risks may increase over time, the area will continue to exhibit a range of specific values, such as access to the beach and the river, which make it attractive to live and recreate there. In deciding how to respond to sea level rise it is important to not only consider the risks but also the values or benefits of using the land.

The report therefore considers the benefits of the Kingston Beach area, and any values that may be foregone if new development is prohibited or lost if existing development is required to retreat.

The final part of the report provides an overview of potential responses or options to respond to sea level rise. This last section considers those options that are potentially relevant in the Kingston Beach area.

1.2 Background to this Report

This report has been prepared as part of the Tasmanian Coastal Adaptation Pathways study. SGS has been engaged to assist the Local Government Association of Tasmania (LGAT), working with the Tasmanian Climate Change Office (TCCO) and the Tasmanian Planning Commission (TPC), and relevant Councils to develop future pathways for climate change adaptation in four coastal areas in Tasmania:

- Lauderdale (Clarence City Council),
- St Helens/Georges Bay (Break O'Day Council),
- Port Sorell (Latrobe Council) and
- Kingston Beach (Kingborough Council).

Funding for the Tasmanian Coastal Adaptation Decision Pathways (TCAP) project has been provided via the Australian Government's Coastal Adaptation Decision Pathways program, with matching contributions from project partners. Project partners include LGAT, TCCO, TPC, the four councils, Antarctic Climate and Ecosystems Cooperative Research Centre and the University of Tasmania.

The TCAP project aims to significantly improve the ability of Tasmanian decision makers and communities to plan and respond to likely futures for coastal communities. The results and lessons learnt from the four project sites can then be applied in other coastal areas.

This report summarises the coastal climate adaptation pathway work and findings so far for the Kingston Beach (Kingborough Council) project site.

1.3 Coastal Climate Adaption Pathways

Based on previous and ongoing work, SGS developed guidelines for communities and states for coastal climate adaptation pathways. The adaptation pathways cover approximately 15 steps in total and present a consultative approach involving the community, local and other government, land managers and other key stakeholders. The pathway approach does not prescribe a one-size-fits-all solution, but as the word 'pathway' suggests, is a process to achieve adaptation responses.

It is anticipated that this study will progress Kingborough Council to approximately step 9 of the 15 step pathway. The 15 steps are as follows:

1. Establish hazards and future sea level rise effects and map at the local/relevant scale
2. Interim planning scheme amendment in hazard areas
3. Assess assets at risk
4. Establish the expected cost of risk
5. Assess the value of occupation or use
6. First cut assessment of adaptation options and costs
7. Plan and implement necessary short term protection works in hazard areas
8. Establish preliminary policy and decision making framework
9. Strategic options assessment (Scenario Planning)
10. Detailed assessment of short listed options
11. Select preferred scenario
12. Establish financial framework
13. Revised 'final' planning scheme
14. Implementation
15. Review

Each section of this report relates to one of these 15 steps and this is identified at the start of each section. This report as a whole can be seen as a component of Step 6.

1.4 Kingston Beach – project site introduction

The project site in Kingborough Council consists of the area known as Kingston Beach. This seaside suburb is along an extended beach area (Kingston Beach) and largely enclosed by the Browns River which flows into the sea at the northern end of the beach (see map below). The area includes houses, retail and some hospitality as well as part of the Kingston Beach golf club. There is an esplanade which runs along the beach. The beach is backed by a sea wall protecting the esplanade. To the north, south and south-west there is significant elevation, reducing any risks of sea level rise to properties in this area.

Figure 1 Kingston Beach project site

1.5 This Report

The remainder of this report describes the findings so far for the Kingston Beach project site. It covers:

- Current day and future coastal risks
- Current relevant planning scheme mechanisms
- Costs of risks in the study area
- Current property values, public benefit and other values in the project site
- Adaptation options with an introduction that explains what is likely to happen if nothing is done to manage current and future risks.

2 Coastal Hazards

Kingston Beach is relatively low lying land at the mouth of Browns River. It is potentially subject to coastal erosion (periodic or progressive), movement of the river mouth, flooding from the sea, flooding from peak river flows and erosion along the river banks. All of these can occur under present day conditions, but are expected to change with rising sea levels and other climate change effects.

This section relates to step 1 of the coastal adaption pathway process.

2.1 Kingston Beach coastal erosion

The foreshore along the beach is protected by a curved seawall built in the 1950s. This shows that there were concerns about coastal erosion at that time.

The top of the sea wall is about 2.4 m AHD[1] at the northern part of the beach and about 1.9 m AHD along the southern part of the beach with a step down occurring at the boat ramp at the end of Beach Road.

At the north end, the beach reaches nearly the full height of the wall face as shown below. The sand is well vegetated in places but there are no large trees or shrubs.

At the southern end of the beach, the sand has been largely scoured away to expose most of the full height of the wall, with little beach remaining at high tide. This may partly reflect the erosion from the stormwater outlet. The southern end of the beach largely lacks any vegetation.

Figure 2 Photos of Kingston Beach

[1] Is an abbreviation of Australian Height Datum and is a commonly agreed measure of the current average sea level.

The pattern suggests that the beach may be subject to a degree of sand movement and episodic erosion, but limited if any long term progressive erosion. This may change with sea level rise but there is no immediate evidence of this.

2.2 Movement of the river mouth

The beach extends north from the wall to the rocky cliffs north of the river outlet. The river outlet breaches the beach. The location of the outlet is mobile between the wall at the south and the cliffs to the north. It is currently relatively to the northern end of its range of movement. The river is blocked by sand during periods of low or no river flow.

With sea level rise the mouth of the river is expected to move landward and become elevated somewhat, by an amount that is equal to the average rise of the sea level. In short, the river level will rise with sea level rise.

Figure 3 Photos of Browns River mouth

2.3 Coastal inundation

Sea height varies with tides, storms and regional wave effects. The combined effects can lead to extreme storm surges. The most extreme heights occur with a lower probability. Present day storm sea level heights of different probability/frequency are shown in the summary table below.

Table 1 Storm sea level by probability, present day

Average Return Interval (ARI)[2] (years)	1	5	10	50	100	200
Annual exceedance probability (AEP[3])	63%	18%	9.5%	2.0%	1.0%	0.5%
Storm sea level (m AHD)	0.97	1.12	1.18	1.28	1.32	1.35

Source: John Hunter, ACE CRC

In addition to these effects there are local influences such as local wind setup, local wave setup and local wave runup. For Kingston Beach it is anticipated that local wave setup is an important additional effect that would add about 50 cm to coastal inundation levels.

Likely coastal inundation levels for Kingston Beach are summarised in the table below. A more detailed discussion of the local effects on inundation levels is provided in Appendix 1.

Table 2 Likely coastal inundation levels for extreme storm events (1% AEP), 2010 and 2100

1% AEP	*Present day (2010)*	*SLR 1.0m*
Storm sea level (m AHD)	1.32	2.32
Wave setup (m)	0.50	0.50
Total (m AHD)	1.82	2.82

Note that all values are 'best estimates' and subject to inaccuracies:

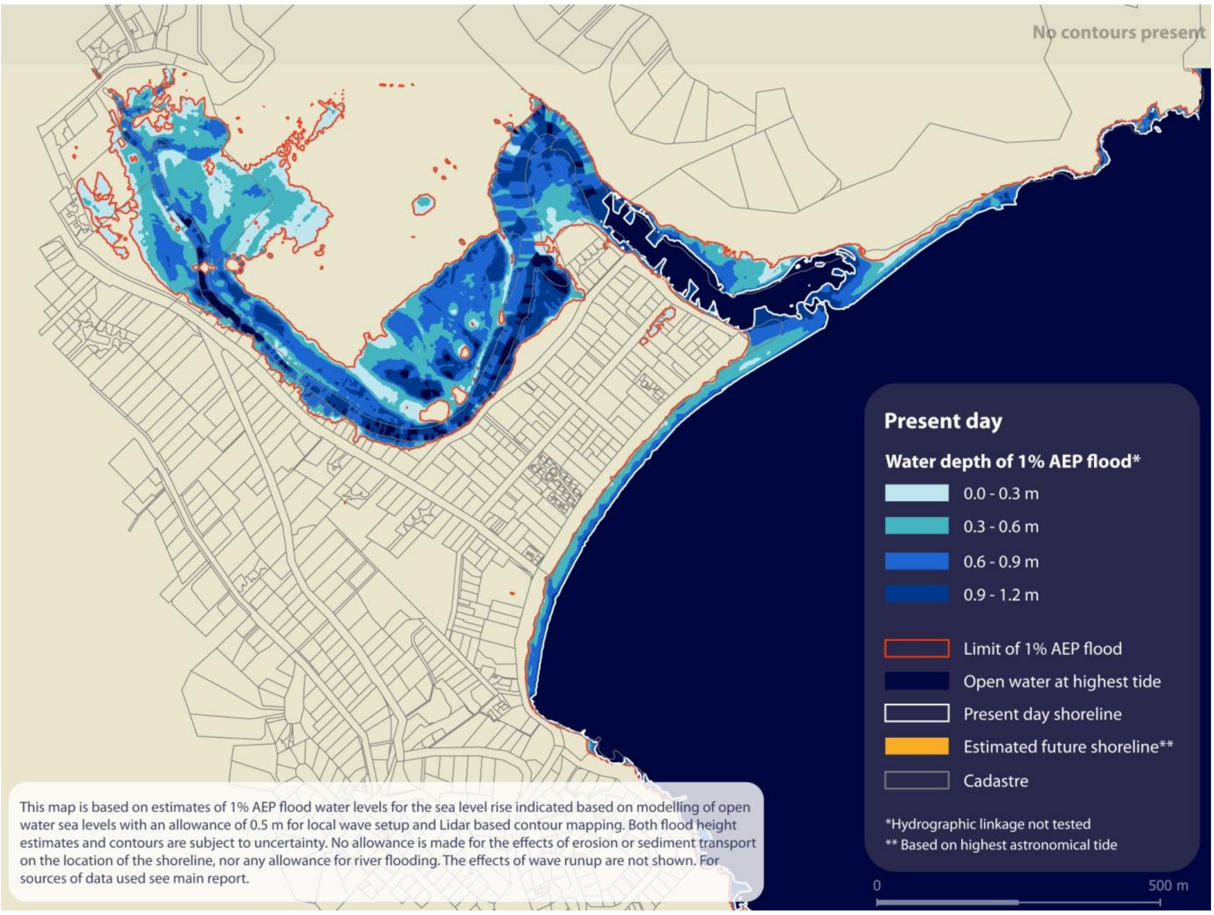
- Inundation depths may vary from estimates by ±0.2m
- Land levels based on Lidar (best available mapping surface) may vary by ±0.2m
- Actual floor heights may vary from the estimate ±0.15m
- These errors may act to offset each other **or** may add together

The map below shows current inundation levels for 1% probable extreme storm event.

[2] The Average Return Interval, expresses the likelihood for an event to occur as the average number of times an extreme event would occur in a given timeframe.

[3] The Annual Exceedance Probability is a way to express the likelihood for an extreme event to occur.

Figure 4 Likely Inundation at Kingston Beach for extreme storm event (1% AEP), present day



Source: SGS (2011)

2.4 River flooding

The river mouth is generally restricted by a sand bar that seasonally tends to build to the high tide level or above, when there are limited or no river flows.

Most past flood events from the river have been from fresh water runoff combined with a 'blocked' bar. The land manager, Parks and Wildlife Service, does not allow the bar to be breached mechanically unless the river level exceeds a mark on the footbridge (shown below). The height of the mark is about 1.2m AHD. The water in the river in the photo below was about 330 mm below the mark.

If the flood height is above the mark shown in the picture, Kingborough Council is permitted to breach the bar, leading to a rapid widening of the channel by the out-flowing water and the river level subsiding. Thus flood heights do not exceed this height very often. Anecdotally:

- the highest floods in the last 50 years were caused by debris accumulating on a former wooden foot bridge causing water levels upstream to build up.
- 81 Beach Road has been occupied by the current owner for the last 50 years and has seen about 6 floods that overtopped the banks at that address or nearby in that period. The dwelling floor level is about 600mm higher than the banks and has not been flooded in its 150+ year history.
- Adjacent properties have been flooded above floor height on at least one or two occasions.

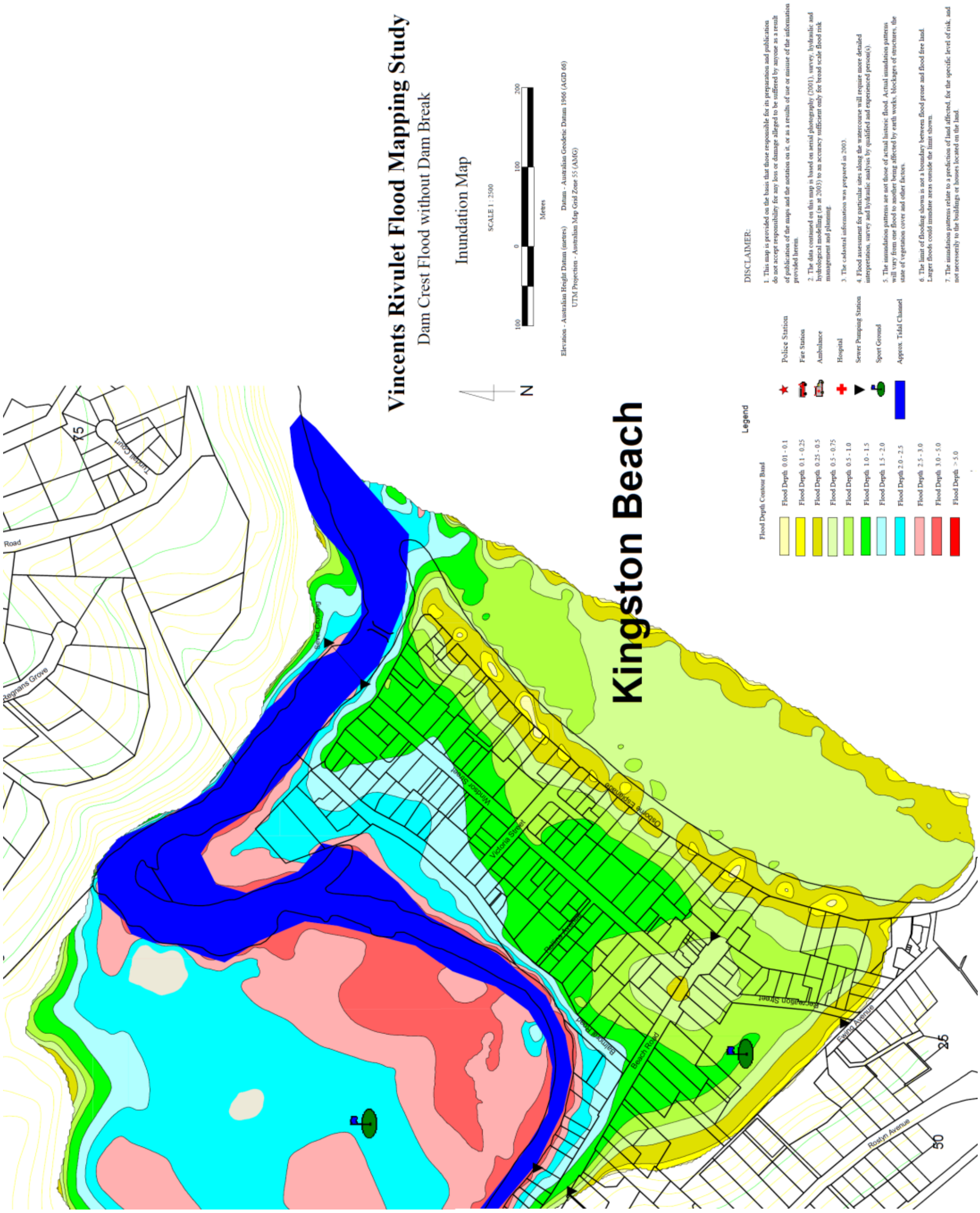
Figure 5 River Level Mark at Browns River

A map of river flooding for the probable maximum flood is shown below[4]. Such a flood is likely to occur only once every 10 million years based on historic rainfall patterns.

As the map shows, flood depths are far greater than for coastal inundation (Figure 4) albeit for a much more extreme event.

A likely effect of sea level rise is that the bar will move landward and will become elevated, thereby pushing the average river level up.

[4] From a study undertaken by Coffey Consultants, 2003



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2.5 Riverbank erosion

Along the river banks, much of the shoreline has been hardened against erosion, using variously rocks, concrete, tyres and timber. The hardening suggests that erosion had taken place prior to the works being undertaken. According to Council staff, there have been no permits issued for any shore protection works on private land.

Figure 6 Photos of the banks of Browns River

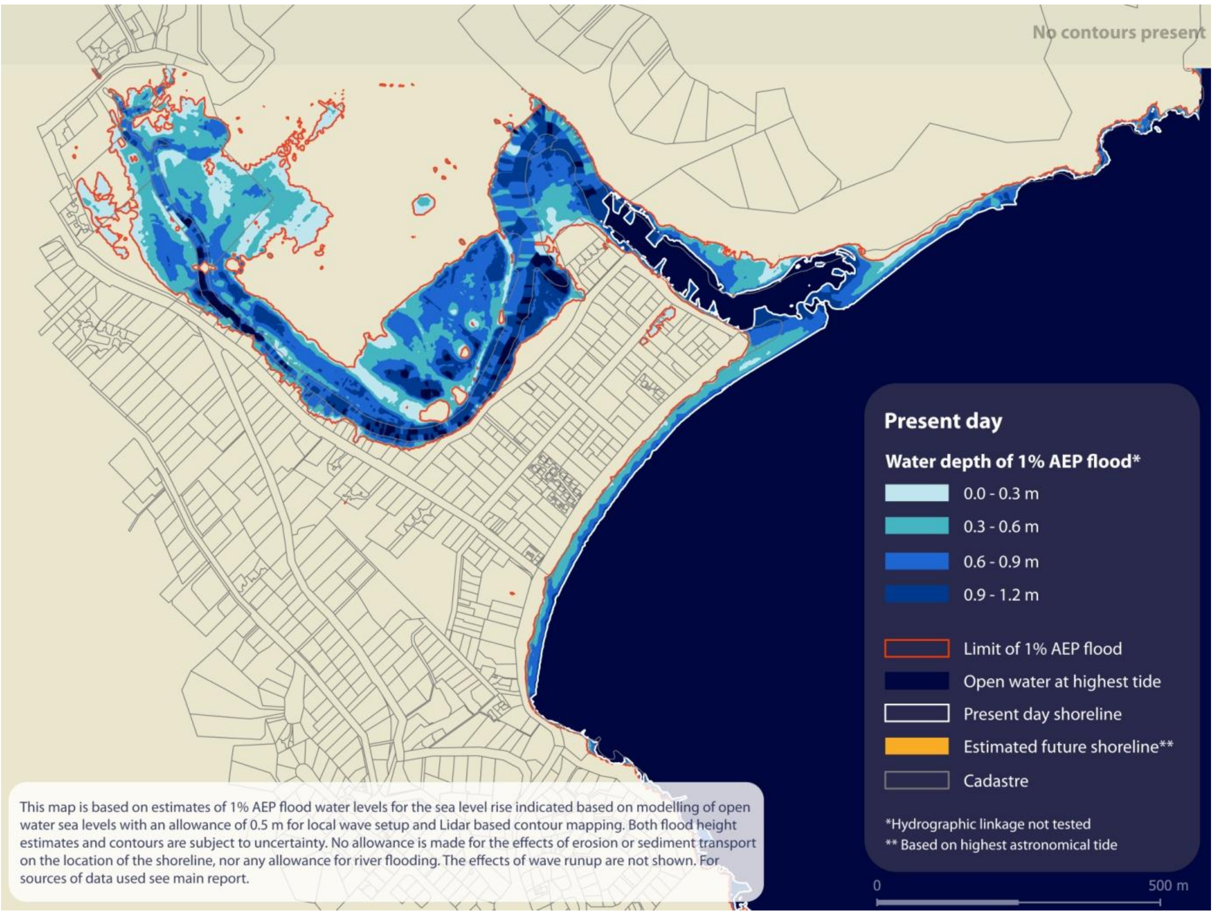
2.6 Coastal inundation with Climate Change

Future coastal inundation will increase as climate change causes sea level to rise. The following series of maps shows two features for a given sea level rise:

- The approximate shoreline given current topography assuming little or no significant erosion
- The area flooded in a 1% (100 yr ARI) event with an indication of the depth of flood.

These maps have been produced for present day and a sea level rise of 0.3, 0.9 and 1.8 m. These might be considered to be roughly 40 years, 80-100 years and 150-200 years into the future. This corresponds roughly to the highest sea level rise rate estimated by the IPCC, Fourth Assessment Report. The current rate of sea level rise is just over 3 mm per year, double the average rate during the twentieth century and at the highest rate estimated by the IPCC.

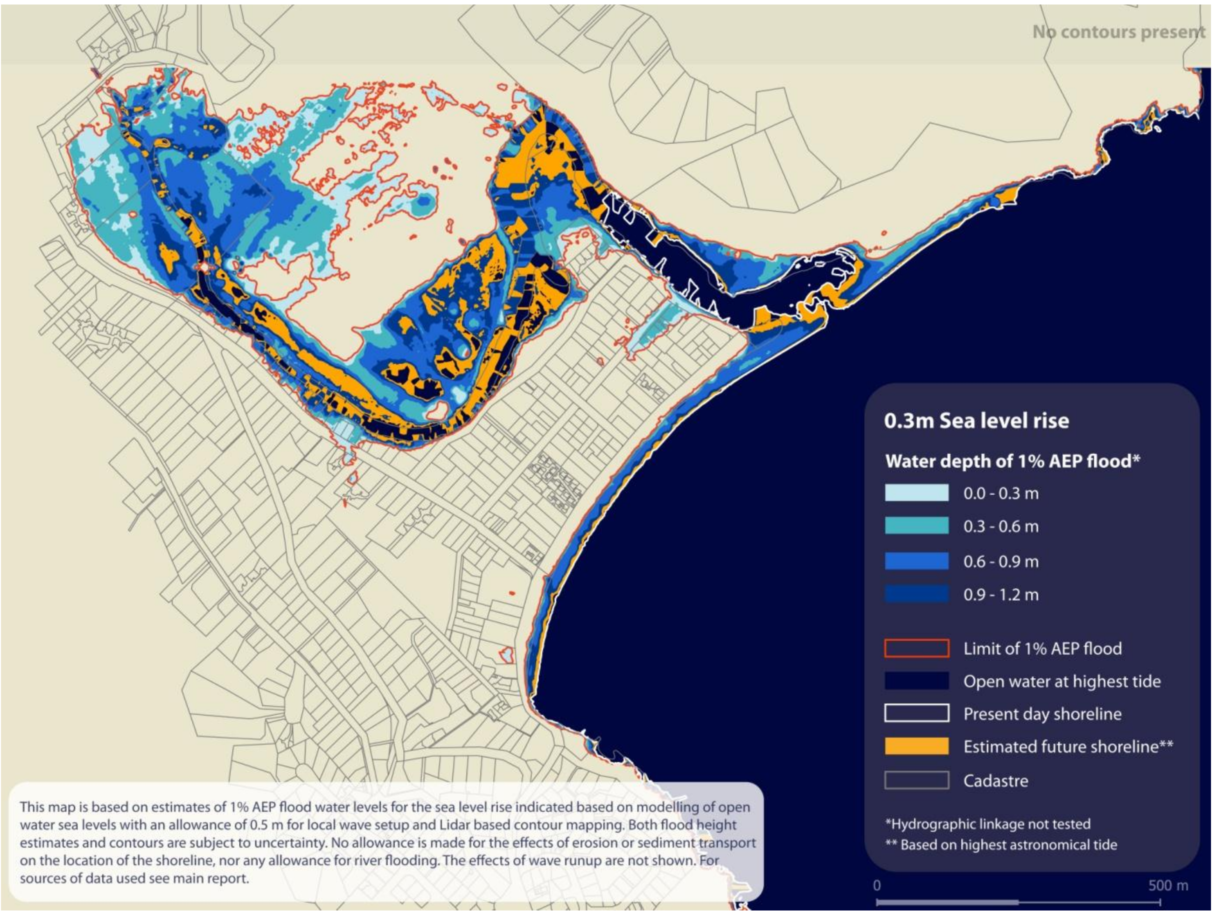
Figure 7 Likely Inundation at Kingston Beach for extreme storm event (1% AEP), present day



Source: SGS (2011)

The maps assume that the topography does not change with erosion of the movement of sand from wave action, which is clearly unrealistic. More likely, the bar will move inland and remain above high tide, and the river will tend to fill the area behind with fresh or brackish water. Only with the highest sea level rise shown is this likely to change, if there is insufficient sediment to maintain the bar and it breaks open to form a tidal lagoon. Rising sea levels will eventually 'drown' the beach, with the sand below sea level even at low tide.

Figure 8 Likely Inundation at Kingston Beach for extreme storm event (1% AEP), 0.3 m sea level rise



Source: SGS, 2011

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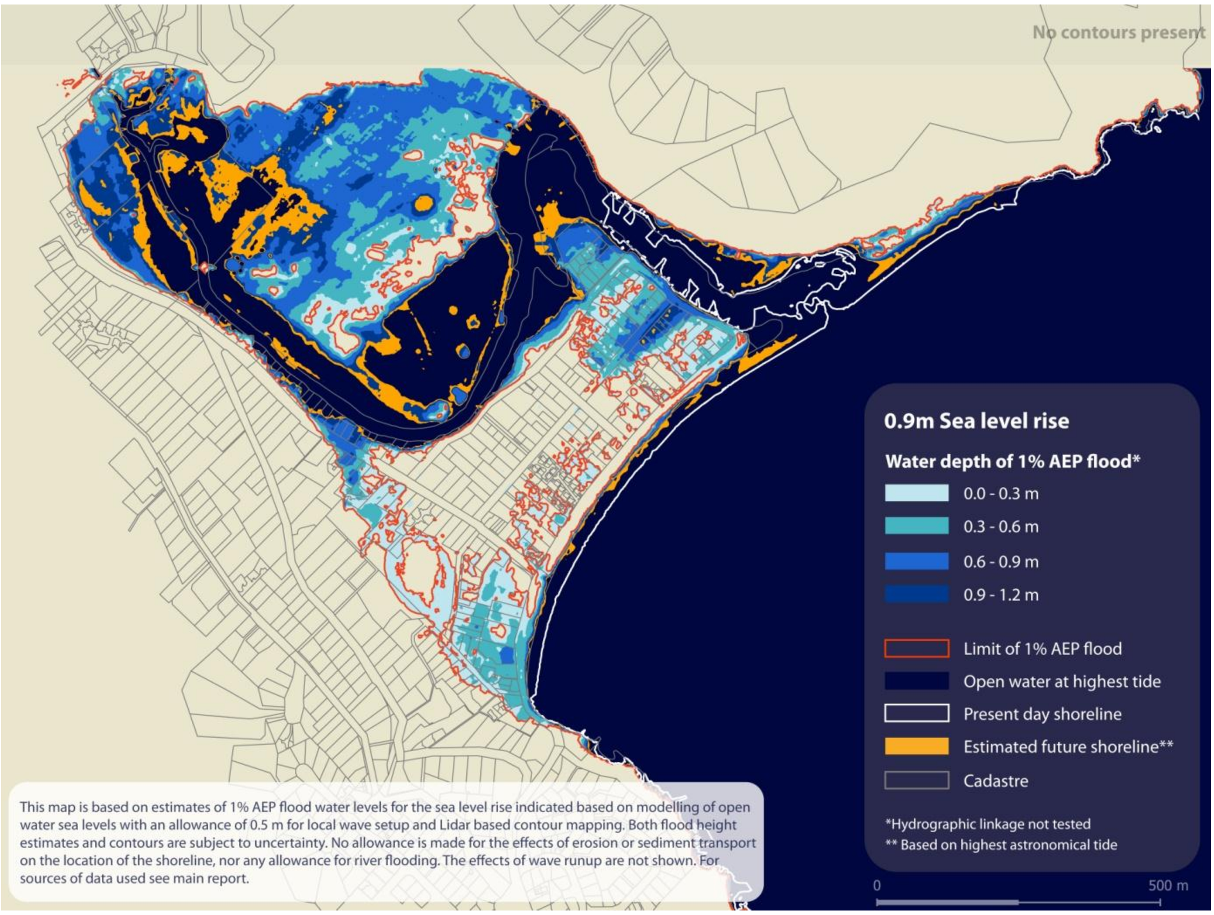
Figure 9 Likely Inundation at Kingston Beach for extreme storm event (1% AEP), 0.9 m sea level rise



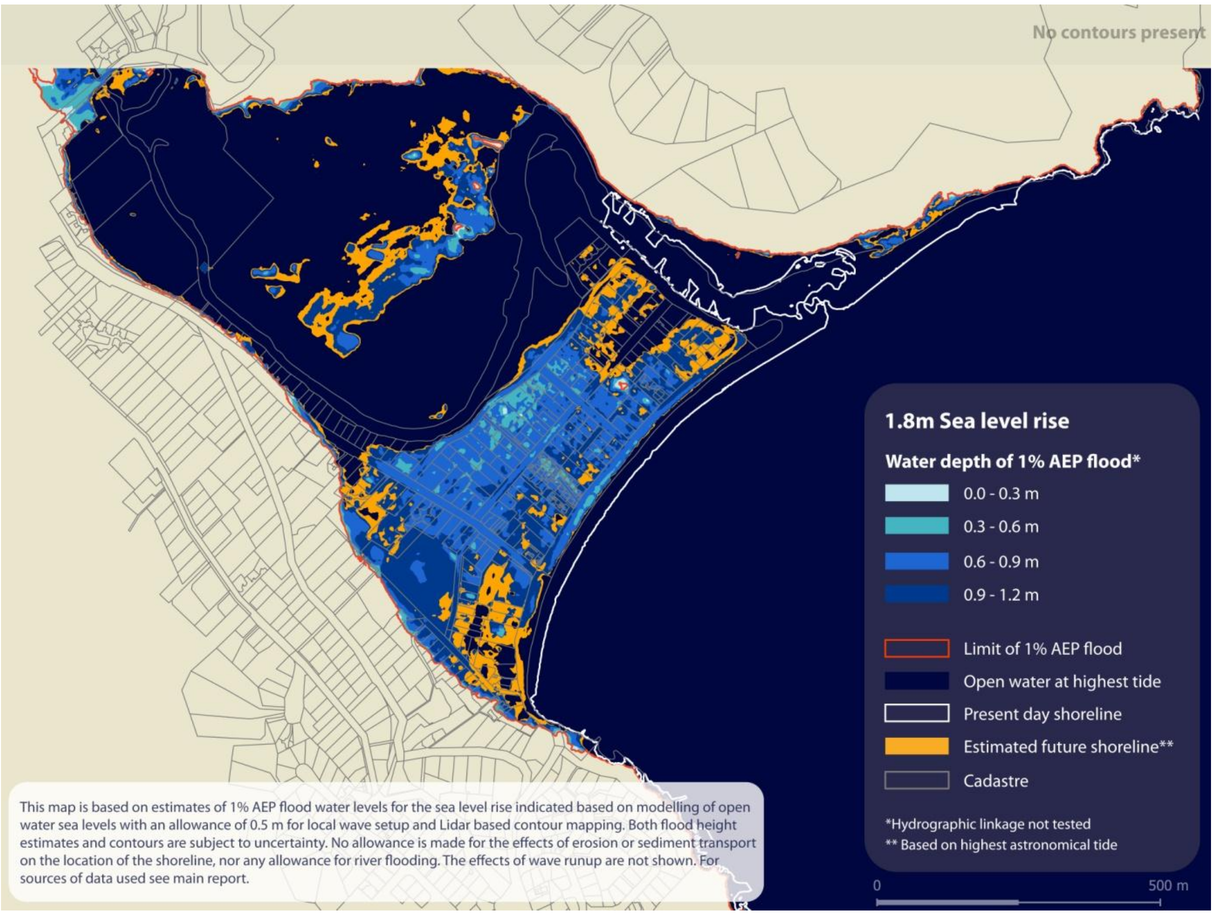
Source: SGS, 2011

Overall the maps suggest that there will be little coastal flooding of residential areas in Kingston Beach for sea level rises up to 0.9m, even for an extreme event such as a 1% AEP/100 yr ARI storm. Most of the impact is on the golf course, which becomes progressively more flooded and could be affected in parts even by present day extreme floods.

However, if sea levels keep rising (to 1.8 m), and if nothing is done, the entire suburb will eventually be at risk from flooding from the sea in an extreme storm. It would be possible to raise the suburb over the intervening years – probably well over one hundred years – if desired.

In general the shore hardening is expected to reduce risks from erosion although the existing sea walls and other hardening may be subject to increasing levels of maintenance as sea levels rise.

Figure 10 Likely Inundation at Kingston Beach for extreme storm event (1% AEP), 1.8 m sea level rise



Source: SGS, 2011

With climate change the probability of more intense rainfall is likely to increase (ACECRC[5], 2010). The peak flow rates associated with more frequent extreme events such as 1% AEP river flood events are likely to increase throughout the catchment, even without sea level rise. Rainfall driven floods are likely to remain the most serious issue for Kingston Beach into the future. metre. Rising sea levels, by raising the sand bar with serve to aggravate river flooding near the mouth whether there is more intense rainfall or not. The worst case would be a combined high sea level from a storm coupled with heavy runoff from an extreme rainfall event. The scale of this joint impact has not been estimated.

[5] ACE CR C 2010, Climate Futures for Tasmania extreme events: the summary, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

3 Planning Scheme Mechanisms

This section describes how the current planning scheme deals with coastal risks in Kingborough.

As part of Step 2 (interim planning scheme amendment in hazard areas) of the adaptation pathway process, the current planning scheme of Kingborough Council and relevant regional directions were reviewed.

3.1 Regional Context

As part of the regional planning initiative and the *Planning Directive 1 – The Format and Structure of Planning Schemes (May 2011)*, municipalities are working towards new planning schemes based on the new Planning Scheme Template for Tasmania. This will align future planning schemes including consistent zonings, layout and terminology. It is intended the new planning schemes take effect in 2012.

At the regional level it is important to note that in October 2011 the Minister for Planning declared the Southern Tasmania Regional Land Use Strategy. It sets common planning and development goals for the region. The strategy makes some reference to climate change, mitigation and adaptation. Policy 2 on the Coast intends to '*ensure use and development in coastal areas is responsive to effects of climate change including sea level rise, coastal inundation and shoreline recession'*. Policy 2 of Managing Risks and Hazards aims to '*minimise the risk of loss of life and property from flooding'*.

Since more data and knowledge is required prior to implementing measures the Tasmanian Planning Commission initiated the Tasmanian Coastal Vulnerability Project. The project aims to deliver GIS map layers identifying inundation and erosion risks in coastal areas under various climate change scenarios.

The Tasmanian Planning Commission has established a Coastal Planning Advisory Committee to scope the advancement of the Tasmanian coastal planning framework.

DPIPWE has developed tools to assist with risk-based management and planning for infrastructure, assets and values in coastal zones[6].

[6] DPIPWE (2010), Tasmanian Coastal Works Manual: A best practice management guide for changing coastlines.

3.2 Kingborough Planning Scheme 2000

The impacts of climate change on coastal areas are addressed in the Scheme through Schedule 1.0 Environmental Management Schedule. The issues addressed in the Schedule include:

- Issue 2 – Natural Hazards: areas of natural hazard will be avoided or suitable strategies to minimise risk applied.
- Issue 3 – Coastal Processes: to protect, maintain and/or enhance existing coastal processes and landforms.
- Issue 4 – Sea Level Rise and Storm Surge: to avoid or mitigate the impacts of any potential rise in the level of the sea or ocean along the coast and inshore, particularly with respect to existing and future physical and social infrastructure.

The Schedule includes an Acceptable Solution and an Alternative Solution for each issue. The Acceptable Solution often includes prescriptive provisions about acceptable floor level height and building location in relation to water ways, cliff edges and dunes. The Alternative Solution is used if the development does not meet the requirements of the Acceptable Solution. Applications using the Alternative Solution must provide justification for why the Acceptable Solution could not be met and require the applicant to demonstrate that mitigation measures have been undertaken and that risks to life, property, environmental features and coastal processes are minimised as is the need for future engineering or remediation.

In regards to Issue 2 (Natural Hazards) the Scheme uses standard definitions for coastal areas considered at risk. The definitions do not reflect the particular and varying risk levels along the coast, meaning risk levels may be overestimated or underestimated. There is no explicit recognition of time frames. For example, is the 1 in 100 year flood limit assessed at the time of application or over the expected life of the building? With climate change, erodible or mobile coastal areas currently not showing recession may begin to erode, moving the position of the 30 m allowance inland. There is no provision for dealing with this dynamic situation.

In regards to Issue 3 (Coastal Processes) the Scheme does not specify who should assess whether proposed development would significantly increase the requirement to protect from coastal processes in the future, or how this assessmtent would be made.

In regards to Issue 4 (Sea Level Rise and Storm Surge) the Scheme makes a distinction between ‘high risk’ and ‘moderate risk’. These terms are not defined in the Scheme. Again, no timeframe or measure to respond to changes in risk over time (as sea level rise is expected to progress) is provided.

It is recommended that the future Kingborough Planning refers to regional planning directions and initiatives to provide it a solid strategic basis. Hazard areas, definitions of acceptable levels of risk and changes of risk over time would require more specification and consideration.

4 Cost of Risk

This section assesses properties at risk of being affected by inundation or sea level rise to 2100. The total risk is expressed in net present value, which is the present day value (in $) of future costs and revenues (cash flows).

This section relates to step 3 of the adaptation pathway process.

In reading this section it is important to define the term **risk**. Risk is the result of the **total damage** times the **probability** of an event happening. While the total damages of an event actually happening can be very substantial, the probability of it happening is often quite low. Therefore, the total risk (in $) may be substantially below the total damages of an extreme event.

The analysis on the costs of risks is presented here only for private properties. Infrastructure, public amenities the golf course and open space also may be damaged by coastal inundation. The same level of information about the cost of damage as a result of flooding is not readily available for infrastructure as it is for dwellings. However, further consultation with some of the infrastructure agencies is expected to provide some indication of expected costs. This will be complete by mid 2012.

A description of the method to determine risks is provided in Appendix 2.

4.1 Inundation Risks

The key findings about inundation risks in Kingston Beach are summarised below:

- About ten properties between Beach Road and Browns River are at present-day risk from coastal inundation. However, because some of these houses are well elevated above the ground (0.4 m in some cases), the chance of above floor flood from a coastal extreme event is very low. The risk of below floor inundation (-0.3 to 0 m) at these addresses ranges from 5% to 30%. There is also significant, but unquantified risk from river flooding (from rainfall).
- With a sea level rise of 0.25 m, potentially occurring by about 2050, the number of properties at risk from inundation at or above floor level increases to 15-20. Most of these have river frontage.
- With a sea level rise of 1 m, the roughly ten properties at present-day risk are expected to be flooded quite regularly. The chance of flooding would be around 80% in any year, and with a significant chance of floods up to 1.5 m above floor level for at least one property. This sea level rise and consequent flood frequency is expected to occur by about 2100.
- With 1 m sea level rise, there will be about an additional 100 properties at potential inundation risk, most of which are close to Browns River. Of those at potential risk by about 2100, over 80 properties would be inundated by a 1% AEP flood and about 60 properties will be inundated by a 5% AEP flood (20 year ARI) with an average above-floor depth of 0.3 m.

The table below shows the estimated number of properties in Kingston Beach that would be flooded above floor level by an event with a 1% annual exceedance probability (100 year ARI) at present day sea levels, with 0.25 m sea level rise and with 1.0 m sea level rise.

Table 3 Number of inundated properties and average over-floor depth caused by 1% AEP flood

		Estimated No. of inundated properties	Average over-floor depth (m)
0.0	**(2010)**	4	0.15
0.25	**(2050)**	11	0.20
1.0	**(2100)**	84	0.32

Source: SGS estimates (2011)

4.2 Property Risks

The charts below depict the expected risks (structure damages x probability) in dollar values over time. As there is some uncertainty in flood frequency estimates and the land elevation levels, the risks to residential properties at Kingston Beach over time were calculated according to three cases to test the sensitivity of the outcome to this uncertainty:

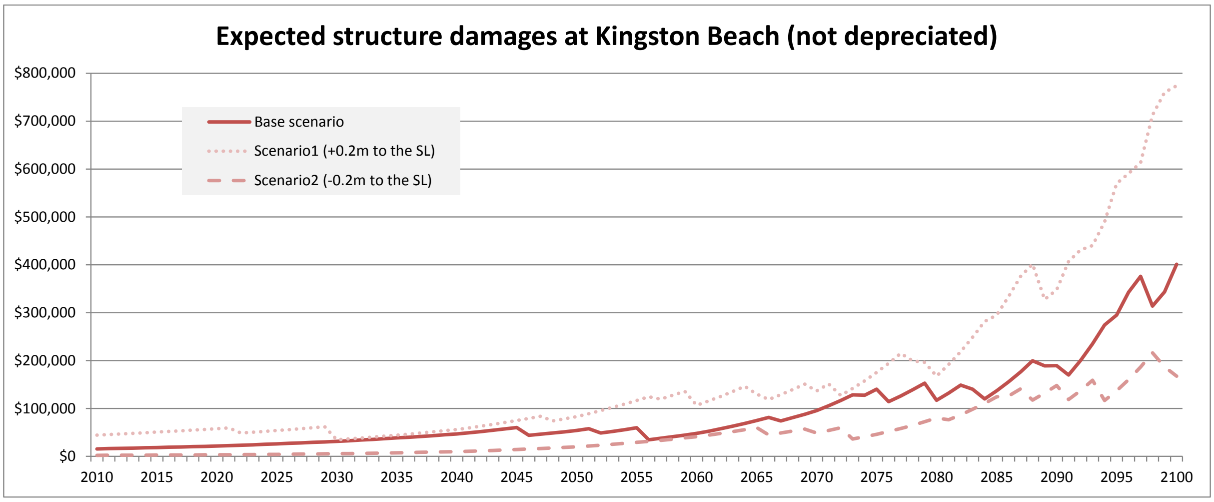
- Base case – based on the flood frequency estimates from Table 2 and assuming land levels are correct
- Variation 1 – increasing the 1% AEP flood level estimates by 0.2 m relative to the land levels above the base case
- Variation 2 – decreasing the 1% AEP flood level estimates by 0.2 m relative to the land levels below the base case

Expected risk is calculated for each property within the study area for each year by considering likelihood/probability of different flood depths occurring and associated structure damages (derived from the damage curve) as sea levels rise. The total risk at Kingston Beach is a sum of the risk to all properties.

If the properties are fully maintained over time with a minimum level of depreciation in structure value, the structure damages at Kingston Beach by 2100 are expected to reach about $0.8 million per year in the base case, but potentially ranging from a low of just under $0.2 million to a high of$0.8 million under variation 1 (Figure 11). Relatively little damage is expected to occur up to the middle of the century, with damage rising quickly in the later years. The relatively wide range of estimate suggests that there will be value in making more exact estimates of damage as risks rise.

In practical terms, there is not much risk to most homes early in the century, with most of the damage occurring to those few houses already at some level of risk. Later in the century, if a major flood occurs with significant damage, or even a series of minor floods at frequent intervals, the most affected dwellings will likely either be demolished and abandoned, or rebuilt in a less vulnerable manner. Thus it is unlikely that very high annual cost of floods that would be calculated by leaving all of these frequently exposed dwellings subject to flood and repeated repair would actually occur. Thus the model removes houses from the calculation that are exposed to frequent high levels of damage, resulting in downward jogs in the line as dwellings are removed.

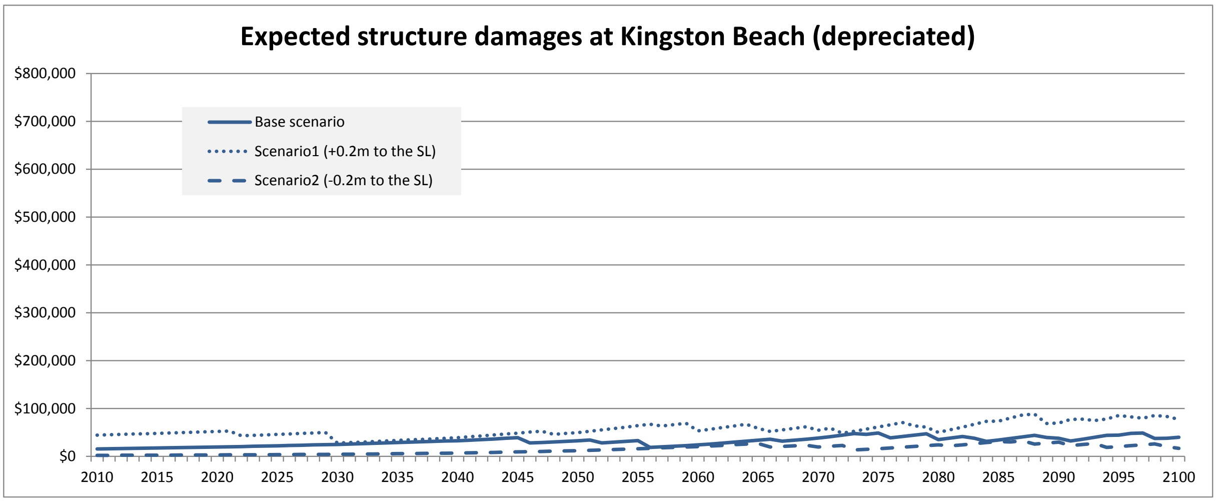
Figure 11 Expected annual coastal inundation damages at Kingston Beach, without depreciation



Source: SGS (2011)

On the other hand, if the structure value is assumed to be fully written off in 100 years (with 1% depreciation rate per annum), the expected annual damage by 2100 is significantly lower and likely to range from $8,000 to $80,000 under three scenarios (Figure 12). Rather than rising sharply in the later years, the curve is relatively flat as declining property value offsets increased flood probability.

Figure 12 Expected annual coastal inundation damages at Kingston Beach, with depreciation



Source: SGS (2011)

The net present values (NPV) of these expected future coastal inundation structure risks are calculated using a real discount rate of 5 percent per annum and are provided in Table 4 below. For this table we have classified the dwellings in the study area into three categories, including:

1. The eight dwellings at present-day inundation risk
2. The 129 dwellings not at present-day inundation risks but at risk with 1 m SLR
3. Those not at risk even with 1 m SLR

The eight dwellings in Category 1 account for the vast majority of damage that occurs for each variation, with or without depreciation. For dwellings in category 1, the NPV of future expected damages under the base case is around $570,000 (assuming no depreciation) and represents more than 40 percent of the existing structure value in NPV terms. The total of expected damage occurring, not discounted, would be far in excess of the value of the structure. Two variations show that the NPV is likely to range from $190,000 to $900,000, which represents 14% or 65% of the current capital value. With the structure depreciation, the NPV falls back to around $440,000 under the base case, and $750,000 under variation 1.

Table 4 NPVs of total structure damages, and their shares of the existing structure values

		Category 1		Category 2		All
	Current value and count	$1.4 million	8 dwellings	$27 million	129 dwellings	242 dwellings
	Variations	NPV of expected damages	% of existing capital value	NPV of expected damages	% of existing capital value	NPV of expected damages
Without structure depreciation	*Base case*	$570,000	41%	$150,000	0.57%	$730,000
	Variation 1 (+0.2m to the SL)	$900,000	65%	$490,000	1.82%	$1,400,000
	Variation 2 (-0.2m to the SL)	$190,000	14%	$48,000	0.18%	$240,000
With structure depreciation	*Base case*	$440,000	31%	$51,000	0.19%	$490,000
	Variation 1 (+0.2m to the SL)	$750,000	54%	$220,000	0.82%	$980,000
	Variation 2 (-0.2m to the SL)	$120,000	8.3%	$11,000	0.04%	$130,000

Source: SGS estimates (2011)

Without structure depreciation (i.e. assuming ongoing investment on maintenance and capital upgrade), the NPV of the expected future risks amounts to $0.73 million under the base case[7] for all dwellings, with a very wide range from about $0.24 million up to $1.4 million if the low and high variations are considered.

[7] It is the net present value of all the annual costs shown in Figure 6 up to 2100

If the properties at Kingston Beach are assumed to be fully depreciated in 100 years (i.e. not fully maintained and upgraded), the NPV of the structure risks is almost halved to $0.5 million under the base case, and a range of between $0.1 million and $1.0 million.

The table shows most of the flood risk expressed as NPV is incurred by the properties at present-day risk and that the total risk to structures at present day risk is high compared to their value.

Although the expected risk seems relatively low in today's value, the actual damage of an extreme storm event when it actually does occur can be quite significant. The table below (Table 5) shows the potential damage caused by an extreme storm with a 1% probability of happening. It shows that a flood of 1% chance could result in a total damage of around $7 million in 2100 under the base case if the dwellings are well maintained.

Table 5 Total damages caused by 1% probability flood

	Variation	Total damages caused by 1% AEP (100 yr ARI) flood		
		2010	**2050**	**2100**
Without structure depreciation	*Base case*	$220,000	$670,000	$6,820,000
	Variation1 (+0.2m)	$550,000	$1,370,000	$12,490,000
	Variation2 (-0.2m)	$30,000	$230,000	$3,750,000
With structure depreciation	*Base case*	$220,000	$400,000	$680,000
	Variation1 (+0.2m)	$550,000	$820,000	$1,250,000
	Variation2 (-0.2m)	$30,000	$140,000	$370,000

Source: SGS estimates (2011)

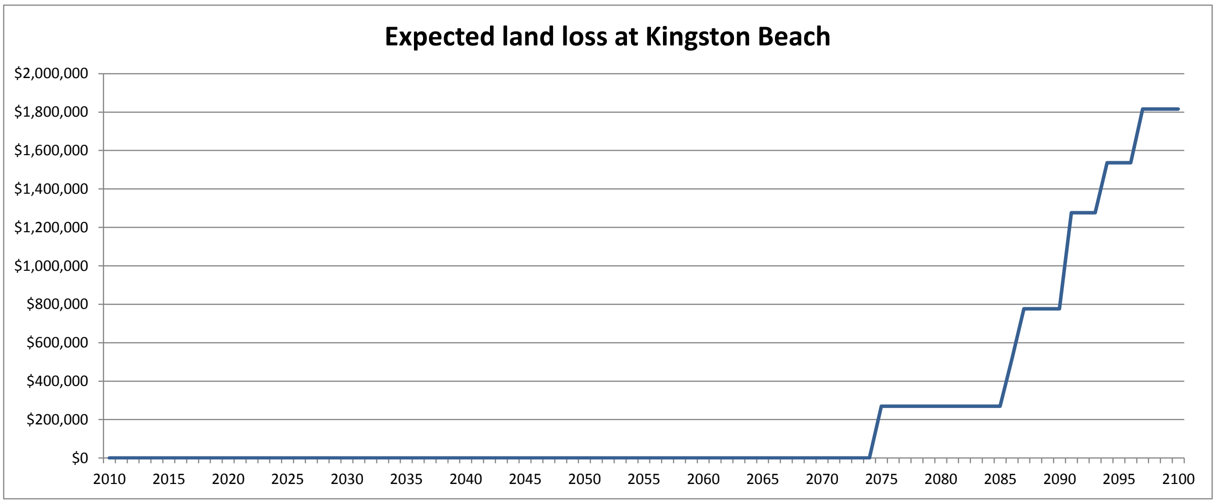
For the base case without depreciation, about 90% of the estimated $220,000 damage is contributed by a handful of dwellings for a present day 1% AEP flood. By 2050, 90% of estimated $670,000 damage is still contributed by the damage to about ten dwellings. In 2100, the picture changes with roughly $7 million costs more widely distributed with about 120 dwellings affected, but about 20 houses still contribute over 30% of the damage of a 1% AEP event. For Variation 1 the numbers of dwellings involved increases earlier, while for Variation 2 the involvement of more than a handful of dwellings comes later. Thus while risk is eventually more widely spread, for most of this century is it concentrated on the relatively few dwellings that are at some risk today.

As noted above, this relatively few most affected dwellings would likely see some form of response to reduce costs before the end of the century.

These flood estimates are based on the effects of sea level rise on coastal inundation (from the sea) and ignore rainfall runoff floods from the river, which may be more frequent and more severe than coastal flooding. The extent of the river flooding has not been quantified.

In addition to the structure damages as a result of the over-floor flood, we have estimated the value (Valuer General valuation) of land losses over time as the land loses its value once it sits under the average high tide level. The figure below (Figure 13) shows the land value loss over time in Kingston Beach, along with the assumed future sea level rise.

Figure 13 Expected land loss at Kingston Beach



Source: SGS (2011)

If nothing is done the area of residential land in Kingston Beach will start to diminish from 2075 onwards and by 2100, gradually losing 7 parcels the total land value loss amounts to $1.8 million based on present day valuation. All of this land is within the area subject to present-day risk. The NPV of these losses is estimated to be around $418,000.

Other costs

The calculations above include estimates of costs from flooding from the sea for private property (land and dwellings). These estimates do not include cost of damage:

- To public infrastructure (roads, street lighting, water supply, sewer, damage to the sea wall, sports fields or other public amenities)
- To other existing coastal protection works from erosion
- To other commercial infrastructure (telephone, electricity supply or
- From river flooding events for all assets, arguably as large or larger than from the sea

Comparison with acceptable levels of risk with no sea level rise

For risks that do not change over time, potential damage from events with an annual probability at or below 1% is often considered an **acceptable level of risk**[8]. A property that has a floor just at

[8] Different acceptable levels of risk would be applied to different uses. A much lower level of risk would be used for a school or hospital compared to a boat shed or car port.

the 1% AEP flood level has an expected damage in any given year of 0.35% of the value of the structure[9]. On a structure worth $100,000 this corresponds to an expected annual damage of about $350 if exposed to this level of risk from inundation from the sea in Kingston Beach.

Without sea level rise this value would remain the same each year. The lifetime NPV of risk would increase with the expected life of the structure to about 7% of the structure value in the Kingston Beach area. If it is assumed that the building depreciates over time, the value lost from a major flood would be less. The economic loss is only that of the depreciated value of the dwelling.

With sea level rise (about 1.0 m of sea level rise over the next 90 years) the risk of damaging floods increases every year. The risk rises particularly quickly in later years as the rate of sea level rise increases and many more flood events are expected to be damaging. In that case, the NPV rises continuously and can reach to about 50% of the structure value[10] in the Kingston Beach area.

The result is a level of risk several times higher than that normally considered acceptable. If this risk remains unmanaged in any way, either the householder or the government will eventually be faced with the consequences of a flood. Insurance is unlikely to be available, and usually where a large amount of property is damaged, government is faced with significant costs for clean up, recovery and assistance to ‘victims’.

For many properties, the risks can be reduced to acceptable level by increasing the floor level. For instance, structures with an expected lifetime of less than 60 years, the required increase in floor height above the present day 1% AEP level is very modest, less than 0.2m.

For dwellings with floor levels above the current 1% AEP flood level, risks for the first few decades are significantly lower than for those at the 1% AEP level. After that time, risks increase significantly and it may be wise to protect the structures or alternatively to not reinvest in the property, depending on the remaining life expectancies.

Conclusion

In short, the total cost of risk (in present day values) of coastal inundation to structures is between **$0.5 million and $0.7 million to 2100** depending on whether owners continue to maintain their dwellings. If 1% AEP flood levels are 0.2 m more than that estimated for the base scenario, then the total cost of risk would be between $1 million and $1.4 million.

In addition, by 2100 about 5 parcels expected to be mostly underwater at most high tides and may be lost to occupants with an estimated net present value of **$0.4 million**.

[9] It is normal to require a freeboard above the predicted flood level, usually of about 0.3 m. The expected damage for such a building could be even less, but the freeboard is often used to compensate for uncertainties in the estimate of actual flood levels.

[10] For properties with a life expectancy of maximum 100 years

The estimated damages of an extreme storm event actually happening can be significant. **By 2100, an extreme storm event (1% AEP) is estimated to cause $7 million worth of damage** (base scenario, without structure depreciation) if the existing buildings or comparable ones are still in their current locations and elevations.

The majority of the risk up to 2100 is borne by a relatively small numbers of properties, the relatively few dwellings that are at some risk today.

Also, the relatively few most affected dwellings would likely see some form of response to reduce costs before the end of the century.

Over time the risk and the number of dwellings affected is expected to increase, and this pace is expected to pick up as well. There are only four dwellings with floor levels estimated to be below the 1% AEP flood inundation height from a coastal inundation event. The lowest of these is about 0.25m below the 1% AEP level. By 2060 there will be about 14 dwellings with floor levels below the 1% AEP flood level. By 2100, about an additional 70 dwellings will have floor levels below 1% AEP level. After 2100, assuming a sea level rise of about 1.0m, the number of dwellings with floors below the 1% AEP line is expected to increase by about an additional 150 with a further sea level rise of 0.5 m.

The flood estimates are based on the effects of sea level rise on coastal inundation (from the sea) and ignore rainfall runoff floods from the river, which may be more frequent and more severe than coastal flooding. The extent of the river flooding has not been quantified.

In practical terms:

- Well maintained high quality buildings close to or below the 1% AEP flood level with a long expected lifetime would be well advised to invest[11] in flood protection measures such as flood skirts that can be deployed when required **and** to pay attention to extreme weather forecasts;
- The owners of buildings close to or below the 1% AEP flood level that are in poor to modest condition or buildings damaged by flood events should consider whether it is worth reinvesting in the existing building or demolishing and rebuilding at a level above the flood or in a form that is resistant to flood damage.
- All occupants in hazard areas with properties at some risk, even if only for extreme events with a probability below 1% AEP, should have and rehearse an emergency response plan.
- Governments have an interest in prohibiting redevelopment that will be affected by a higher than acceptable risk of damage during its lifetime, including discouragement of reinvestment in existing properties that are or will be at higher than acceptable risk over their lifetime. However, such risks can be addressed by raising dwellings by relatively modest amounts even for quite long lifetimes.

[11] Up to20% of the structure's depreciated value assuming a 50 yr lifetime.

5 Values

In contemplating appropriate responses to sea level rise, it is important to also consider the benefits occupying hazardous areas contribute.

People occupy and use areas near the coast, some of which are exposed to coastal hazards, because they derive value from doing so. In fact, coastal property values are typically higher than similar sized properties inland showing the premium value placed on these areas. Other public, natural and economic values are major contributors of value from the 'use' of the coasts.

If the planning response to sea level rise prevents all (re)development in areas potentially at risk, many of the values from using and occupying these areas would be foregone, while other natural values may be unaffected to gain from excluding development.

This section describes the private property values and other benefits of Kingston Beach's coastal location. Property values and the factors that drive differences between blocks (eg a premium placed on waterfront blocks compared to inland blocks) are relatively easy to evaluate. However, the attractions of the suburb as a whole may be increased by the setting shared by all property in the suburb – the presence of a beach and natural areas as well as man-made amenities and services (nearby Kingston town centre). Natural areas may enhance property value, but they also provide benefits to the wider community as discussed below. However, these benefits are harder to evaluate– there is no clear market to demonstrate their value – and may be quite variable for different people.

The reporting in this section relates to the work undertaken and the findings so far in relation to Step 5 of the adaptation pathway process: Value of Coastal Hazard Areas.

Private property values

Residents in hazardous areas derive a private property benefit from living in these areas. In order to assess the potential impacts of climate change and adaptation measures on coastal properties, one needs to understand how significant is the premium of living there. Once established, it is possible to assess how this value (private premium) may change as a result of climate change and adaptation. For instance, planning measures to prohibit development in hazardous locations may result in loss of value due to some of the examined characteristics (beach front access for instance).

Regression analysis was undertaken to determine the contributions to the value of land of various attributes, such as lot size, proximity to the beach and proximity to services.

Other values

Additional analysis was undertaken to better understand the 'other' values of the coastal area. These different values affect different people in different ways and interact with each other. These other values are often of more intrinsic and include:

- natural values, such as natural beauty and habitat for threatened species,
- public or social values, such as enjoying and recreating at the beach, amenity values, exercise opportunities that promote an active and healthy lifestyle, and,
- economic values, such as the number of jobs in coastal related economic activities such as commercial and recreational fishing and tourism.

5.1 Private Property Values

The following factors[12] determine and contribute to land value in Kingston Beach:

- Lot area (square metres);
- Distance from nearest local business (metres);
- Distance from ocean (metres);
- Beach front access;
- River front access; and
- Elevation of land above mean sea-level (metres).

Some of these variables such as beach and river front access may place the property in a potentially hazardous location.

The key findings of the analysis show that:

- The constant is the value of a lot when all other land attributes are zero. It can be interpreted as the average intrinsic value of land in the study area. In this case, the intrinsic value of $108,156 represents 45% of the average value of the land parcel.
- One additional square metre of lot area will on average, increase land value by $133. For a 100 sqm parcel of land, this suggests that the value derived purely from lot-size is $13,300.
- Each metre from local shops increases land value by $107. This result appears anomalous but is likely to be because resident owners place a premium being located away from the noise of business activity.
- Each metre from the ocean reduces land value by $161. This implies that lots closer to the ocean have greater value.
- Value derived from having beach front access is $210,460. Put another way, this value will be lost without direct access to the beach.
- Value derived from having river front access is $131,404. Put another way, this value will be lost without direct access to the river.
- Each metre of land elevation above average sea-level reduces land value by $1,415. This is likely to be because higher elevations in Kingston Beach are located further away from the beach and also often on steeper, hard to develop land.

[12] Full definitions of these variables and their derivations are provided in the Appendix.

For Kingston Beach, no properties were identified as becoming under the average high tide level permanently to 2050. By 2100 and an assumed sea level rise of 1 metre, about seven properties would lie below the average high tide level.

Nearly 50 percent of land value for these seven properties is due to river front access. In total approximately $920,000 (or about $130,000 per lot) is attributable to river front access. This is shown in the table below (Table 6).

Up to 2100, there will be about 84 properties at risk of an extreme storm event with a probability of experiencing a flood above floor height greater than 1% per year. The value that is derived from having river access adds to about $3 million in total or 14% of the total value. The impact of 'river access' on the value of these properties is limited because the flood risk applies to many dwellings close to the river, but many without direct river access.

Table 6 Value composition for lots at risk due to sea-level rise and extreme storm events (1% AEP) by 2100

	Due to Sea Level rise		Flood risk of ARI 100	
	Land value ($)	**Share of value(%)**	**Land Value ($)**	**Share of value(%)**
Total value due to river front access	$920,000	49%	$3,150,000	14%
Total value due to other attributes	$980,000	51%	$19,580,000	86%
Total estimated land value	**$1,900,000**	**100%**	**$22,730,000**	**100%**

Source: SGS (2011)

To entirely exclude future development on these properties, either if an owner wishes to extend or redevelop the existing structure, would largely destroy that land value for property where the structure is nearing the end of its service life. If such a policy was applied to land susceptible to a 1% AEP storm event by 2100, up to $23 million of land value would be lost over time.

Put another way, if the objective is to reduce risk, for the property owners it would be worth spending up to nearly $130,000 in methods that reduce risk by the same amount but do not compromise the amenity achieved from a water front location, as an alternative to restricting development.

It should be noted that the study only took the impacts of sea level rise into account and did not include modelling of future river flooding (due to rainfall).

5.2 Other Values

Kingston Beach commences at the river mouth of Browns Rivulet and curves to the south for 1 km to the first rocks of Boronia Point.

Natural Environmental Values

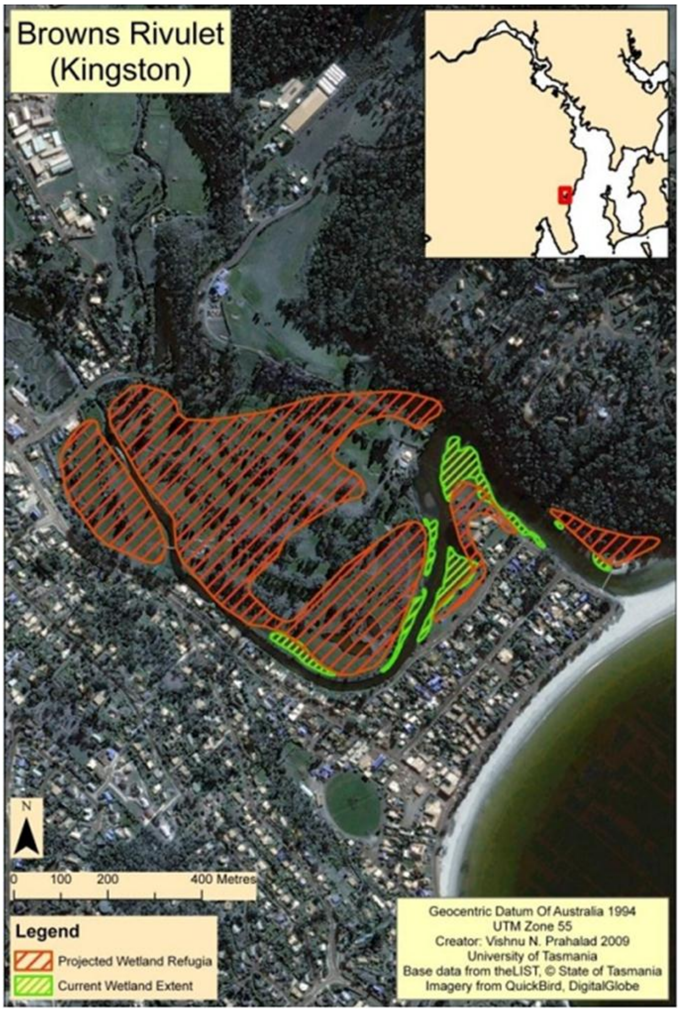
The Kingston Beach Golf Club area has been a bird sanctuary since 1942. Browns Rivulet in Kingston Beach contains a saltmarsh area and tidal wetlands area. The area covers approximately 2.2 hectares and key flora involving Saline Sedgeland/Rushland. A preliminary assessment of tidal wetlands shows that sea level rise pushes the wetlands landward (Figure 14) to the Golf Club land. Human development can potentially inhibit the transgression of wetlands. If allowed to transgress, the future wetland area may be larger than now, which would be a potential environmental benefit. Parts of the current wetlands could become permanently inundated and become a lake or lagoon area.

Browns River is a habitat recreational fishing spot for black bream (Acanthopagrus butcheri). Recent research by Tasmanian Aquaculture and Fisheries Institute (2009) involved acoustic tagging of black bream in the Derwent Estuary. It shows there is a small population of the fish in Browns River and it potentially also provides for a breeding ground. Retaining the Browns River as a breeding ground can serve as a means to support a sustainable population in the Derwent. However, the population in Browns River is relatively small and would not be large enough to sustain the entire Derwent system with black bream in case of some catastrophe in the (Upper) Derwent.

According to the Derwent Estuary Program retaining waterways in its natural form is important for enabling the transgression of wetlands as sea levels rise. Natural waterways are also beneficial for the water quality of the river, and indirectly contribute to the water quality and amenity in the beach and recreation areas of Kingston Beach. Channelising the river can have significant detrimental impacts on both water quality and the ability of wetlands to transgress. Already property owners and land managers have (reinforced) parts of the river bed to prevent erosion.

Kingston Beach itself is an area with natural values, especially to the north around the river mouth. The beach area has been significantly impacted by use and development (intense use of beach and the presence of the sea wall) and little vegetation remains in most parts along the beach.

Figure 14 Kingston Beach current and future refuge wetland areas



Source: UTAS (2009)

Public and Social Values

Kingston Beach is an important recreation destination for the local population. The beach and the foreshore are enjoyed for their amenity, opportunities to walk and exercise and to recreate on the beach and in the water. The population enjoying these values are primarily the 8,537 residents of Kingston (2006, ABS State Suburb). Kingston Beach attracts limited visitors from beyond the local area.

The golf course provides important recreational opportunities. The golf course is likely to be affected by sea level rise. There is potential to move parts of the course affected by flooding gradually to adjacent land owned by the Club. Also, it may be possible with careful landscape design to combine function with wetlands development.

Browns River provides recreational opportunities, among which recreational fishing (Black Bream).

A healthy and natural river system supports the social values in the area, most notably recreational fishing and the amenity of the beach and river outlet.

Economic Values

Retail outlets in the area are mostly oriented to local clientele. The area contains approximately 10 local shops, cafes, restaurants and accommodation providers.

Table 7 below is an overview of the key natural, social and economic values in the Kingston Beach area.

These businesses rely significantly on the natural and related recreational values of Kingston Beach. Poorer water quality and/or loss of the beach would likely have an adverse impact on these businesses.

Table 7 Summary overview of Other Values

Value	Description	Quantity / Order of Magnitude
Natural benefit	Browns Rivulet, saltmarshes/wetlands, fish habitat, beach and a bird sanctuary	• 2.2 hectares wetlands at Browns Rivulet, potentially expanded by sea level rise and expansion of lagoon type area
		• Kingston Beach Bird Sanctuary
		• Kingston Beach, approximately 1 km
		• Black Bream habitat and potential breeding ground
		• Natural river waterways improving water quality
Social and public benefit	Recreation, walking exercising and amenity	• 8,537 residents
	Golf course	• 772 members
	Recreation in the rivulet	• Recreational fishing
Economic benefit	The area contains a number of local shops, cafes, restaurants and accommodation providers	• Approx. 10 businesses • Primarily servicing the local population of 8,537 residents

Conclusion Coastal Values

In short, properties in Kingston Beach have significant value premiums due to their access and proximity to the beach and access to the river front. To 2100, seven to 84 properties would be affected by sea level rise and extreme storm events (1% AEP). Mostly, these properties have direct river front access or are located close to the river. Some of the properties with direct river frontage derive up to 50% of their value from having river frontage, suggesting it would be worth to invest significantly in protection (as far this has no adverse impacts on other values, and/or as far as the future planning regulations allow).

Refusing any (re)development in the area potentially affected by sea level rise and extreme storms by 2100 could result in $23 million worth of property values being lost over time.

The natural and environmental values of the Kingston Beach area are significant and include wetlands, bird habitat, fish habitat and nursery and natural river waterways that improve water quality.

Sea level rise may result in the expansion of wetlands and lagoon areas. This would cover parts of the existing golf course. The golf course may over time migrate to adjacent land that is higher, or implement smart landscape design that would combine the golf course function with wetlands, potentially enhancing the recreational value of the course.

Channelisation or large scale hardening of river beds may deteriorate the water quality and prevent wetlands from successfully transgressing land inward.

Social values in the study area involve beach related recreation and amenity, recreational fishing and river amenity and the golf course.

Economic activity in the area is related to the natural and recreational values of the beach and surroundings. Most activity is for local clientele. Loss of the beach and poor water quality could have negative impacts on theses economic activities.

6 Adaptation Options

6.1 What if Nothing is Done?

Before discussing any options to adapt to projected impacts of sea level rise it is important to consider what would happen if nothing is done. That is, what would the impacts be if nature takes its course and no measures are undertaken to manage the risks?

In the case of Kingston Beach, the sea level rise projections indicate that the impacts are fairly limited until sea levels rise about 1 m or more. The existing sea wall is expected to be able to protect most of the suburb from erosion until about 2100.

Most of the impacts up to 2100 would occur as a result of inundation during extreme storm events to some of the existing river front private properties. Rising sea levels and the bar will keep river levels higher than they are today. Flood events will mostly be caused by rainfall, but the extent of this has not been modelled. However, it is clear that the golf course will bear most of the flooding. As the water is expected to be increasingly brackish, this is likely to damage vegetation, gradually converting the low lying areas of the course to salt marsh. With one metre of sea level rise, parts of the existing fairways and some greens would be under water all the time.

The main initial impact from the sea is expected to be some loss in the width of the beach itself due to the rise of average sea level 'drowning' the beach. If nothing is done the beach would become narrower as sea level rises. While the sea wall protects the properties behind it, the beach cannot move landward and provide the sand required to allow the beach to build up with the rising water. By the time the sea has risen by about 1.0 m, much of the length of the beach would be underwater at high tide and at places, under water at mid or even low tide.

At the opening of the river, the beach likely will move shoreward, 'upriver' and maintain its height with respect to sea level. It is likely to continue to build the bar across the river mouth as it does today, but further inland. This may act to capture some of the sediment from other parts of the beach.

The risk to and loss of property of not responding to sea level rise is between $1 million and $1.6 million[13] to 2100. The estimated damage of an extreme 1% event actually occurring would be about $7 million with sea levels about 0.9 m higher by about 2100. The properties affected by sea level rise and extreme storm events up to 2100 are predominantly properties with direct river frontage or those within close proximity of the river. Properties closer to the beach are only expected to be affected by extreme storm events when sea level rises by 1.8 meter which would be 150 to 200 years from now.

[13] Risk according to base scenario, expressed in net present value plus the loss of land due to becoming under average high tide mark.

To 2100, about seven properties would become lost because they would lie below the average high tide level. Up to 84 properties would be susceptible to 1% AEP extreme storm events, and if nothing is done, the level of risk to these properties would likely be regarded as unacceptable.

Using and occupying 'hazardous' locations also provide benefits and add value to the land. For instance, some properties derive up to 50% of their value from having direct river frontage. For other factors such as direct beach frontage these premiums are even higher. From a private property perspective it would make sense to significantly invest in protecting a property if it has a significant remaining lifetime and if it is maintained well.

The natural and environmental values of the Kingston Beach area are significant and include wetlands, bird habitat, fish habitat and nursery and natural river waterways that improve water quality. Sea level rise may result in the expansion of wetlands and lagoon areas. This would cover parts of the existing golf course.

Beach recreation and economic activity in the area would be negatively affected by sea level rise. Most recreation and economic activity serves the local community of Kingston. Shops, cafes and accommodation providers would to some extent move away to areas with better recreational values.

These data are rough and ready indicators of the effects of sea level rise and are meant to provide some sense of perspective.

6.2 Options

This section reports on the work undertaken and preliminary findings in regards to Step 6. Of the pathway process: First cut assessment of adaptation options and costs.

There are many different options to adapt to the impacts of coastal impacts of climate change. The different options relate to different types of impacts resulting from erosion and inundation. The effectiveness of options varies considerably depending on characteristics of the coastal areas (such as sandy or rocky coast line) and the location-specific impacts of sea level rise.

In the case of Kingston Beach there are limited options that are potentially relevant to the impacts identified:

- Beach nourishment if a source of sand can be identified in combination with heightening of the sea wall;
- Long term raising of low lying residential areas;
- Retreat or protection of river front properties prone to inundation or redevelopment of structures in less vulnerable form (higher floor levels);
- Moving affected fairways and greens to higher ground or raising parts of the golf course (last option may not be available due to bird conservation status)

Detailed descriptions of the following options are provided in <doc Mark – Appendix B…>. Short descriptions are provided below.

Beach Nourishment

In the case of Kingston Beach, there is little evidence of long term erosion. It is more likely the beach will simply 'drown' as it is not high enough to remain above the water level. The beach may steepen initially, leading to a narrow steeper beach against the sea wall.

Beach nourishment can build up the bulk and height of the beach, keeping more of it above sea level and may increase beach amenity by retaining the width of the beach. It does this by bringing additional sand into the local sand budget for the beach. The availability of a suitable source for sand would need to be investigated and is critically important for this to be practical.

Beach nourishment may be used to retain some useable beach in front of the sea wall as a public amenity, while not being depended upon for protection against coastal erosion. However, raising the beach level can actually increase the tendency of waves to run up and over the sea wall and lead to its undermining from behind, as discussed further below, so this needs careful management.

Sea wall

A seawall is a structure that is designed primarily to resist wave action. A properly designed and constructed seawall can reduce the risks to properties and areas of the foreshore from the impacts of beach erosion and coastline recession hazards.

They may be located at the top of the shore out of reach of the water at low water. Sometimes they may be partly or even fully covered with beach sand if there has been a period of sand accumulation since the wall was built, as has been the case at Kingston Beach for many decades.

Very high water levels will cause waves to overtop the seawall resulting in erosion at the back of the structure. Trapping water behind the seawall may cause drainage problems resulting in erosion and structural instability. With sea level rise, coastal sea walls will need to be increased in height periodically. It will be possible to extend an existing sea wall if the foundations and sound and capable of withstanding additional loads. Otherwise, the existing wall will need to be demolished and a new larger structure built.

Raise land levels

Raising the land level of developed low lying land above the expected sea storm surge level is one of the most secure and sustainable responses to rising sea levels. For any new development or major re-development in inundation hazard affected areas, this could be a requirement controlled by the Planning Scheme.

Typically the edge of the raised land would need some protection from erosion. Given that most of the perimeter of Kingston Beach has already been hardened by the sea wall or other armouring it is likely that it will be necessary in the future to extend and raise this to protect the higher land level.

While raising land above the storm surge height can avoid inundation, it represents a complete obliteration of the existing flora and fauna in the filled area and may also have significant impacts at the source of the fill material. Given the heavily developed character of the suburban part of Kingston Beach, natural values are generally of limited concern. However, the fringes of the river, particularly on the side of the golf course, provide significant wetland areas and habitat, and filling these areas would have more significant consequences.

If the filling is done in stages, or property by property rather than on a widespread scale, some flora and fauna may recolonise the filled area from adjacent areas. Older trees may remain in unfilled areas while newly planted trees in filled areas mature. However, such a patchwork filling approach may create problems with drainage unless some considerable thought and planning is put in place to anticipate and manage this issue. A patchwork of fill may also lead to overland flow problems where higher ground obstructs drainage from lower ground.

Protection of Individual Properties

Protecting individual properties from erosion and inundation can be done in different ways:

- Elevated substructures (raised slab or floor, poles, non-inhabited ground floor,
- Flood barriers to protect existing dwellings from short term extreme events (not practical if water levels are permanently high)
- Moveable dwellings
- Water proof or resistant construction not affected by temporary flooding
- Floatable dwellings

Planned Retreat

Progressive retreat means the loss of private and other property. In spite of this, it may prove to be the lowest cost long term alternative available, especially if the cumulative cost of protection into the future is considered. This is especially true where there is a limited number of houses under threat. The cost of planned retreat can be diminished to the cost of land if a process of planned disinvestment occurs, such as not redeveloping and/or extending existing properties.

Appendix 1 Local effects to coastal inundation levels

Local wind setup is only significant in shallow bays, so Kingston Beach should not be affected by any significant wind setup.

Wave setup arising from the conversion of some of the waves' kinetic energy to an increase in potential energy (height of water) is about 15% of the significant wave height with breaking waves on a sandy beach. No calculation of the significant wave height from the swell has been estimated for Kingston Beach. However, based on comparison with the analysis of beaches in Clarence, Kingston Beach is in the same orientation as Hope Beach and Clifton, but being further up the estuary, relatively less exposed, particularly to the biggest SW swells. It is open to a potentially very long fetch from the SSE but quite sheltered from the south west. Based on this comparison, an allowance for a significant wave height for 100 yr ARI of the order of 3.25 – 4.0 m (in the range of those found for Seven Mile Beach and Cremorne) seems about the right order of magnitude. This would generate a wave set up of about 15% of this or about 0.5-0.6 m. For modelling inundation impacts, we have adopted 0.5m for wave setup (and tested sensitivity of ±0.2m).

Note that while this extreme wave setup is likely to occur during a storm, a 100 Yr ARI wave event may not correspond to the high tide and 100 year storm surge event. Thus the estimate based on adding these two factors is conservative (ie safe, likely a modest overestimate of inundation height).

Wave runup may carry water up the shore, over the road to nearby properties. Runup could add another 0.5-1.0 m to the height affected along the shoreline. However, as the beach has a curved reflective sea wall along its entire length it would prevent most wave runup unless the wall is covered to over half its height (curved face) in sand or if the waves are breaking over it anyway as they will eventually with sea level rise.

At the river mouth wave runup is likely to overtop the bar (usually present) and adjacent sand 'tongues' ensuring entry into the river at least somewhat in excess of that implied by a wave setup calculation.

Appendix 2 Cost of Risk – Method

The method used to determine the present value of expected damages associated with coastal inundation risks in Kingston beach (and the other project sites) is as follows:

1. Estimate the elevation level of each property within each project site, by overlaying the Geocoded National Address File (G-NAF) points to the earth surface image (LiDAR DEM[14])
2. Obtain the present-day water surface profile of each area that gives the depth of forecast coastal floods (and riverine floods in some areas) by their return interval or exceedance probability
3. Add the expected sea level rise over time to derive the future water surface profile
4. Derive the current and future inundation depth from floods of certain frequencies by differencing the water surface with the earth surface plus the floor height above the ground
5. Estimate the expected costs of inundation risks over time, in consideration of the likelihood of occurring different flood events and potential damage at different depths (damage curve)
6. Discount the expected damages over time back to today's value.

A detailed description of the method and the inputs in the modelling are provided in *TCCAP: Step 4 Assess assets at risk and quantify cost of risk*

[14] Digital elevation model representing the surface heights of the land, measured through the light direction and ranging (LiDAR), similar to "radar" but using infrared laser light pulses instead of radio pulses

Appendix 3 Acceptable risk over time while sea levels rise

Without sea level rise, this value would remain the same each year. The lifetime NPV of risk would increase with the expected life of the structure.

Column 2 of the table summarises the NPV (expressed as a % of the replacement value of improvements, using a discount rate of 5%) of the expected lifetime damage for different lifetimes. With a longer lifetime the amount of expected damage increases, but beyond about 40 years, the increase is greatly reduced by discounting and it levels out at just over 7%. This provides a benchmark against what is typically considered to be an acceptable risk for dwellings.

Figure 15 NPV expected cost of risk, with and without sea level rise, (with floor at 1% AEP flood level in 2010)

Length of time (yrs)	No sea level rise	With sea level rise	Increase in floor level for similar risk as no sea level rise (m)
10	3.1%	3.7%	0.02
20	4.8%	6.9%	0.04
30	5.8%	10.4%	0.06
40	6.4%	14.3%	0.08
50	6.8%	19.1%	0.11
60	7.1%	24.5%	0.13
70	7.2%	30.4%	0.15
80	7.3%	36.5%	0.17
90	7.4%	42.1%	0.19

If it is assumed that the building depreciates over time, the value lost from a major flood would be less. The economic loss is only that of the depreciated value of the dwelling[15].

If the same dwelling is exposed to about 1.0 m of sea level rise over the next 90 years, the amount of expected damage increases each year as the probability of damaging floods (or the depth of a flood of a given probability) increase. The expected damage in a given year rises particularly quickly in later years as the rate of rise increases and many more flood events are expected to be damaging. In that case, the NPV rises continuously as shown in the third column, the rising damage offsetting the effects of discounting.

The result is a level of risk several times higher than that normally considered acceptable, and increasing the longer the life of the structure. If this risk remains unmanaged in any way, the

[15] If the building is damaged and needs to be repaired, the cost of the repairs would be the replacement cost, but the occupant ends up with a partially renewed structure.

probability of a damaging flood event is quite high, and insurance is unlikely to be available. Either the householder or the government will eventually be faced with the consequences of a flood. Usually where a large amount of property is damaged, government is faced with significant costs for clean up, recovery and assistance to 'victims'.

The right hand column of the table shows how much higher a floor must be today to give an equivalent NPV risk of damage over a given period with sea level rise to one that is at 1% AEP level with no sea level rise, again without depreciation. The extra height required will be directly related to the intended or expected life of the dwelling: a short lived structure will only have to be a bit above the present day 1% AEP flood level as sea levels will not rise much in the short term; a long lived structure will need to be higher to deal with longer term higher rises. Because of discounting, damage far in the far future is not weighed as heavily as damage in the near future. This gives a much lower increase in floor height for a structure with a 90 year expected lifetime than might be suggested by an expected sea level rise of say, 1.0m by 2100.

Overall, it shows that for structures with an expected lifetime of less than 60 years, the increase in floor height above the present day 1% AEP level is very modest, less than 0.15m. For comparable levels of risk in terms of NPV of property damage up to 90 years, increased floor height of about 0.2 m would be required, still well less than the expected sea level rise of 1.0m.

For dwellings with floor levels above the current 1% AEP flood level, risks for the first few decades are significantly lower than for those at the 1% AEP level. This is then offset by much higher risks in the later years. While the present value of those future risks is low because of discounting, in practical terms the annual probability rises well above 1% and it would be wise to protect the structure at that time if it still had a significant service life or not to reinvest and allow it to depreciate in the later part of its life.

There are only four dwellings with floor levels estimated to be below the 1% AEP flood inundation height from a coastal inundation event. The lowest of these is about 0.25m below the 1% AEP level.

By 2060 there will be about 14 dwellings with floor levels below the 1% AEP flood level.

By 2100, about an additional 70 dwellings will have floor levels below 1% AEP level. After 2100, assuming a sea level rise of about 1.0m, the number of dwellings with floors below the 1% AEP line is expected to increase by about an additional 150 with a further sea level rise of 0.5 m.

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