Tasmanian Coastal Adaptation Pathways Project

Lauderdale Recommended Actions

July 2012

SGS Economics & Planning

Independent insight.

SGS Economics and Planning Pty Ltd
ACN 007 437 729
www.sgsep.com.au
Offices in Brisbane, Canberra, Hobart, Melbourne, Sydney

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Living safely and responsibly in coastal hazard areas may be more costly than we expect.

EXECUTIVE SUMMARY

This report aims to review the Lauderdale community's preferred pathway for adapting to coastal climate change in light of recently completed 'reality check' reports and to recommend specific actions Council can take to adapt to present and expected coastal hazards. The forty recommended actions are in a consolidated list at the end of the Executive Summary, ordered by timing: short term, 1-5 years, 5-20 years and ongoing.

Recommendations in this report will need to be considered by all levels of government.

Community workshops showed a preference for giving nature precedence in relatively undeveloped areas while protecting property in more developed areas even if modifying the natural setting. Four reports were commissioned to 'reality check' the options the community identified as preferred.

1. Natural values Derwent Estuary Program
2. Investigation of sand nourishment and use of offshore reefs for erosion protection Water Research Laboratories, University of NSW
3. Investigation of drainage and road elevation works to protect against inundation pitt& sherry
4. Investigation of funding and governance options SGS Economics & Planning

Natural values of the Lauderdale area contribute to the lifestyle and to the property values and community members at the workshops generally wanted to retain much of the natural character as long as possible, specifically the beach but also trees, wetlands, offshore flats, etc.. The report prepared by the Derwent Estuary Program provides documentation of the main natural values of the area and the services and values they provide. These include threatened species and vegetation communities on Roches Beach and in the saltmarshes on Racecourse Flats, important bird habitat in Ralphs Bay mudflats and adjacent shore areas, and sea grass and saltmarsh areas that potentially contribute to water quality and fish breeding for the benefit of the local and wider community. Recommendations are made that would contribute to protecting these values and allowing them the best chance to respond to changing coastal conditions arising from seal level rise and climate change.

There was considerable concern among residents for the immediate risks of erosion arising from recent storms and the lack of protection remaining for some properties from future storms. Thus, while the workshops were focussing on long term adaptation pathways, there was a sense of urgency about action over the short term.

Beach nourishment was proposed as the lowest risk form of protection in the short term to address residents concerns as it has the least impact on coastal processes, provides protection more quickly, with fewer approvals requirements. However the reassessment of beach nourishment by WRL showed that the sand available in sufficient quantity was finer and the volume required and cost was two to four times higher than previously estimated. The large quantity of finer sand would put the threatened sea stars on Bambra Reef and Mays Point and remnant sea grass beds at risk.

A number or participants favoured a submerged reef as a means of protecting the beach but the WRL report strongly advised against this. In the short term some protection would be provided by continued beach scraping supplemented by some terrestrial sand. The combination of a groyne at Bambra Reef and an emergent offshore reef would reduce the amount of sand nourishment required and if properly designed, protect the sea stars on the reef while providing longer term protection. The priority would be to provide protection to the north end of the main beach where most houses at present day risk are located. The total cost of this would be about $5-$10 million.

Lauderdale has had floods in the past and storm surges that allow water to cross the road have been more frequent in recent years. Floods from rainfall coupled with high tides have reached levels up to about 1.5m AHD in the lower basin area. A 1% AEP storm surge could take sea levels along the shore of Ralphs Bay up to as high as 2.0m AHD in the lower basin and could cause flooding to over 100 properties, many above floor level.

Recent flood modelling by pitt&sherry (2012) shows expected flood levels of about 1.64m AHD in the lower basin area north of the canal from a 1% AEP (100 yr ARI) **rainfall event** if tides are high enough to entirely prevent drainage to Ralphs Bay or the canal. **Storm surges** along the Ralphs Bay coast above about 1.75m AHD can overtop

the South Arm Highway and North and South Terrace. The WRL (2008) report showed that storm surges for today's conditions could reach 2.0m in a 1% AEP event causing significant flooding.

While raising new buildings will place them above expected flood levels, existing low lying buildings will remain vulnerable. Improved drainage can reduce levels of rainfall driven floods to a limited extent. Raising South Arm Road and the roads around the canal can reduce the risk for flooding from a storm surge in Ralphs Bay. While a gate on the canal would mean that North and South Terrace would not need to be raised as high, it may not be cost effective to include this.

Maintaining effective drainage will require control over development and filling in low lying land. Analysis done for the Structure Plan shows some of the requirements. Further development would require similar analysis to ensure drainage is not impeded. The cost of improved drainage and protection from storm surge is of the order of $12 - $15 million with most work being done in conjunction with future renewal work on the roads.

Raising the land can protect property against flooding but will increase flood levels on remaining low lying land. Eventually raising dwellings will become widespread and there are grounds for expecting that many will raise their land levels when redeveloping. The pitt&sherry report provides estimates of the areas that need to be left unfilled to avoid excessive increases in flooding but recommends that all filling be assessed for its impact flooding in the vicinity.

Participants at the community workshops generally agreed that contributing to the cost was acceptable as long as the contributions reflected the benefit gained and recognised that many benefits were gained by residents well beyond Lauderdale. Any contributions scheme needs to be equitable and those contributing should have some say in the management actions chosen. The need for a transition from past expectations to the future was recognised, but some said this should not prevent prompt action if early contributions from the community were necessary. There was widespread agreement that there should be some concession for those with limited means.

SGS Economics & Planning considered a number of contribution arrangements assessing them for equity, consistency with adaptive action and practicality. The recommended approach would be to charge contributions on the basis of the property value (for properties in an identified hazard zone or affected area) for property protection works and ensuring access, which provides a reasonable albeit imperfect link between contribution and benefit, is easy to implement and provides an incentive for efficient adaptation. Broader community benefits would be funded from the wider community through general rates and contributions from other levels of government.

Specific costs to residents would require more detailed analysis, but indicative early estimates on a plausible scenario suggest dwelling at present day risk of erosion may face contributions of $4,000-$10,000 per year while those at present day risk of inundation may contribute $2,000- $5,000 per year. This is with substantial parts of the total cost met by others at lower risk or gaining benefits such as access to the area even though their property is not at risk.

Action by Clarence Council is best undertaken within a State sanctioned framework that supports an overall coastal adaptation plan and approves specific works of actions required. Such a framework would be developed in a process that has parallels with local planning schemes. It would be developed by the Council with review from all stakeholders. It would be a plan that involves taking action, not just the regulation of activity by others. State legislation would be required to authorise and approve the development of a CAP, to formalise the roles and responsibilities and to authorise Councils to act, thereby reducing their exposure to legal challenge.

In the workshops the community advocated strongly to protect property from coastal hazards, even if it means modifying the environment. Areas that may in the future be encroached by the sea from erosion or inundation that are developed to any significant extent will likely be modified unless specific provisions are made in advance to prevent this. Even with such conditions, lobbying may well make lead to pressure to allow works to protect property.

If natural beaches are valued, do not allow development to occur in the areas behind them that may come into the erosion zone over the life of the development without strict requirements that they may not be protected clearly written in advance, and strong authority such as Federal or State government legislation to back this requirement.

Areas other than Lauderdale will be affected by coastal hazards from climate change. Coastal adaptation planning for these areas would also be required to permit levies to be applied on properties in the erosion and flood hazard zones that reflect the expected cost of adaptation. To address this wider scope, the results of the Lauderdale process should be canvassed widely in coastal areas with current or potential hazard areas for comment and response.

Summary List of Actions by Timing

The actions are grouped below by timing. For each action the category is listed along with the number as each action is labelled in the body of the report. Where some actions are very closely related or would be undertaken jointly, they have been combined.

Within each time period, the ordering is roughly the expected priority or sequence expected, although for many the exact sequence would not be critical. A few of the later actions may be contingent on the earlier decisions or outcomes.

Short term		**While the adaptation pathway focuses on the long term direction, these actions are recommended to be undertaken soon to ensure that the selected pathway remains available, and continuation of short term works to reduce immediate risk.**
Funding	32	Determine the capacity of the Council to continue to support coastal protection works over a transition of three years until long term funding arrangements can be put in place
Beach protection Natural areas	18, 12	Continue to use beach scraping each year to reinforce the low lying and low volume sections of the dunes in the short term, minimising impacts on beach biota by following past recommendations
Decision making	37	Determine the Council's position on the proposed approach to developing a State backed Coastal Adaptation Plan or variation on this approach and negotiate a basis to permit the Council to proceed in a timely manner
Beach protection	21	Investigate offshore sand in Frederick Henry Bay at distances up to 1.5 km to determine suitability as a sand source for further nourishment
Decision making	38	Develop the detailed formulae for contributions using funding methods described based on an approved Coastal Adaptation Plan under a framework supported by State Government for the development of such plans. The formulae would be developed using detailed assessment of the properties affected from the hazard maps and council rate base information
Natural areas	17	Prevent landfilling of remaining saltmarsh especially at Racecourse Flats and council land north of the Lauderdale canal
Drainage and filling	28	Adopt the detailed drainage recommendations from the JMG (2012) and p&s (2012) reports in conjunction with implementing the Structure Plan and permitting any further development in the lower basin area
Drainage and filling	29	Prohibit development or filling of land at elevations lower than 0.75m within the lower detention basin to retain flood storage and drainage capacity
Drainage and filling	30	Investigate suitable fill options for land that may be filled and adopt guidelines to ensure that only suitable fill is used in future filling
Drainage and filling	31	Require any development that requires filling to make appropriate provision for low level overland flow paths to be maintained and to consider possible consequences on other properties in the vicinity of the development due to reduced retention capacity of the area
One to five years		**These actions mostly provide the funding and decision making framework to support the more substantial works required to provide longer term protection from erosion while protecting important natural values.**
Decision making	39	If discussions with State government indicate a lack of support or unsatisfactory timing for developing the framework for a Coastal Action Plan, proceed to develop a funding framework within existing statutory powers to fund such works as are called for in the action plan in this report
Funding	33	Use general rates and where possible State and Federal grants, donations and sponsorships to cover the wider community benefits of coastal adaptation and to make contributions on behalf of the wider community to adaptation works that protect community assets, natural areas and amenity for the wider Clarence community on an ongoing basis
Funding	34	Use special rates to raise required contributions from properties in identified hazard areas based on the total property value
Funding	35	Use development contributions for new development to support coastal adaptation works, by setting conditions for development approval. These conditions would be incorporated in the planning scheme

Funding	36	Extend relief to low income households through a concession scheme, adjusting the rate set to non-concession properties to ensure that the total contribution required is still raised
Beach protection Natural areas	19, 6	Extend Bambra Reef both to the shore and as necessary seaward with a rock groyne to protect Bambra Reef from being buried in sediment from beach nourishment works. Assess risk level to threatened seastars from sand nourishment or groyne construction as part of works design
Natural areas	7, 9	Identify a trigger for management action, and determine appropriate management action steps if the colonies are at risk of localised extinction. Identify appropriate sites for potential translocation of the threatened seastar as insurance colonies
Beach protection	20	Place a trial geotextile offshore emergent reef extending in 'panels' south from Bambra Reef about 1 km to protect the most exposed portion of the beach from wave action and capture additional sand
Beach protection	22	Augment the coastal works with sand nourishment as required
Decision making	40	Undertake discussions with the State government and other coastal LGAs, possibly through the auspices of LGAT, to develop a pool or other 'insurance' option to be drawn upon to meet responses to extreme events when local capacity to pay is exceeded
Five to twenty years		**These actions mostly address flood risks which are expected to be undertaken in conjunction with road renewal works sometime in the next twenty years.**
Natural areas	16	Ensure saltmarsh will be able to transgress inland, south of Lauderdale
Storm surge protection	24	Raise South Arm Highway to about 2.6 m AHD when next due for major repair and maintenance works
Natural areas	14	Work to restore tidal flushing beneath the South Arm Road to the tidal flats of East Marsh Lagoon in conjunction with road works
Storm surge protection	25	Raise the roads around the canal to at least 2.0m AHD, in conjunction with cyclical road maintenance programs for these roads
Drainage and filling	26	Improve drainage under South Arm Road and North Terrace to help drain the lower detention basin in conjunction with raising the roads. Culverts to the canal and Ralphs Bay should be fitted with non return flaps
Ongoing		**The majority of these ongoing issues represent good management practice in support of natural areas, as well as monitoring and ensuring drainage capacity is not impaired. Some are already current practice but are included to reinforce their importance for good adaptive outcomes.**
Natural areas	1	Management would seek to improve the condition and function of natural areas
Natural areas	2	Use beach protection measures to prolong the viability of the current foreshore dune vegetation.
Natural areas	3	Use water sensitive urban design to enable maximum freshwater infiltration to the sand dune aquifer
Natural areas	4	Alternative sites for establishment of eucalypt dune vegetation should be sought if it is considered important to maintain this vegetation type in the area
Natural areas	5	Retain rocky seastar habitats in good condition and monitor the populations at both sites
Natural areas	8	Retain good water quality near sea star sites.
Natural areas	10	Manage stormwater discharges near seagrass beds to maintain water quality
Natural areas	11	Reduce physical disturbance associated with anchor or boat chain mooring drag in sea grass beds
Natural areas	13	Manage stormwater entering Ralphs Bay to reduce sediment and nutrient loads
Natural areas	15	Introduce protective management practices to the saltmarsh areas
Beach protection	23	Monitor the changes to the beach and acceptability of structures over a period of 10 to 20 years
Drainage and filling	27	Keep the easements recommended for drainage of the northern and southern catchment areas into the lower detention basin free from development

1 INTRODUCTION AND AIM

1.1 This Report

The aim of this report is:

- to review the Lauderdale community's preferred pathway for adapting to the potential hazards and risks associated with future climate change and sea level rise in light of recently completed 'reality check' reports; and
- to recommend specific actions Council can take immediately and in the short term to adapt to present and expected coastal hazards.

The report follows from the report submitted to Clarence City Council in March 2012 on community workshops where participants explored various pathways for the long term adaptation to climate change.

The report starts with a summary of the preferred pathway that emerged from the community workshops, describes the results of the investigations of feasibility that followed and concludes with a recommended series of actions.

1.2 Background to this Report

This is the final report to Clarence City Council from the Tasmanian Coastal Adaptation Pathways study.

Recommendations in this report will need to be considered by all levels of government.

SGS was 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.

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.

Clarence Council is at step 10 of the 15 step pathway and in responding to this report will reach step 11. The 15 steps are as follows:

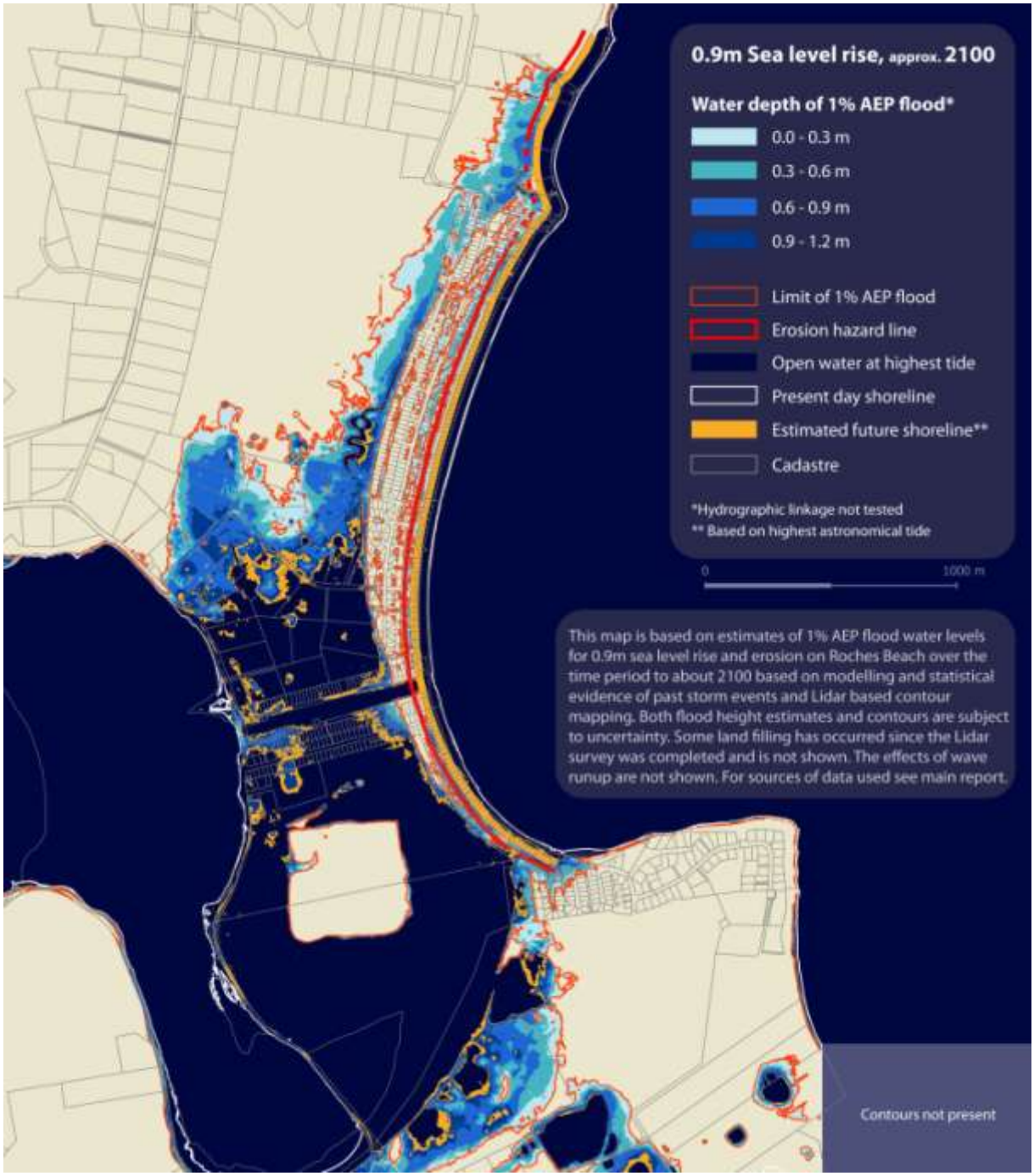
1. Establish hazards and future sea level rise effects and map at the local/relevant scale
2. Interim planning scheme amendment in hazard areas
3. Assess assets at risk
4. Establish the expected cost of risk
5. Assess the value of occupation or use
6. First cut assessment of adaptation options and costs
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

1.4 Expected coastal hazards

Figure 1 shows the Lauderdale area mapping the inundation hazard associated with a 0.9 m sea level rise that might occur by about 2100, including identifying the future shoreline, depth of flooding from an extreme event (1% annual exceedance probability (AEP) flood from Ralphs Bay) and the change in shoreline along Roches Beach from anticipated progressive erosion plus the erosion hazard from a 1% AEP storm event after about 90 years combined with 0.9m sea level rise.

This map was used in support of discussions with the community.

FIGURE 1 LAUDERDALE IMPACTS OF 0.9M SEA LEVEL RISE AND EROSION TO ABOUT 2100



2 THE WORKSHOPS

Four adaptation pathways were investigated by the Lauderdale community at workshops that were described in more detail in the March 2012 report. The four pathways were:

- Pathway 1 – Let nature take its course (early retreat)
- Pathway 2 – Protect existing development as long as practical while protecting natural values and giving natural processes as much freedom as possible
- Pathway 3 – Protect existing development as long as practical while protecting property values in preference to natural processes
- Pathway 4 – Protecting existing and permitting future development to the maximum possible extent for as long as possible

2.1 Preferred pathway

The workshops made it evident that the community pictures a patchwork approach for Lauderdale with areas where pathway 2 would prevail while pathway 3 would apply to more developed areas. Pathway 3 was seen as the most desirable outcome for developed areas particularly as it:

- Enables continuation of lifestyle and protection of property values in the foreseeable future
- Maintains many natural values (most importantly the beach) for longer
- Is seen as a 'do-able' solution
- Provides the opportunity to 'scale up' to pathway 4 if this is seen as desirable and feasible.

Pathway 4 is seen as a possible longer term direction. It was recognised such a decision would have to be made based on future understanding of actual sea level rise and its impacts and, importantly, by the future community.

Importantly, the discussions were based on information provided about alternative adaptation and protection measures associated with each pathway, and estimates of cost available from earlier investigations. These cost estimates were preliminary, with the expectation that more detailed cost assessments would be part of the actions taken to confirm the viability of the pathway provisionally selected.

2.2 Actions to confirm pathway

The following actions were identified as necessary to 'reality check' the preferred pathway:

1. Identify areas of high natural value and the values provided (ecosystem services such as water filtration and fish breeding, habitat for threatened species,) to be given priority for protection.
2. Determine the conditions required to ensure that these services continue into the future to see if they can realistically be met.
3. Determine the extent of legal obligations on existing areas and how these may apply to new areas with climate change and rising sea levels.
4. Assess the volume of sand required and the cost to place sand that could realistically give about 10 years of protection from the average rate of erosion, recognising that erosion processes do not progress evenly and that actual lifetime may be more or less than ten years.
5. Develop a clear and effective drainage plan that can develop over time accounting for both future filling and sea level rise. The plan should meet the requirements of natural areas for tidal flushing where applicable.

6. Develop a staged filling plan that minimises hazards and adverse consequences to unfilled land.
7. Determine the potential risks, costs and benefits of less intrusive below surface reefs as well as for groynes (already investigated) as a backup to beach nourishment.
8. Determine the length of local roads (Manatta Road, North and South Terrace, Bayview Road) that need to be raised, the degree of elevation and timing to fit in with expected future flood levels, normal road renewal cycles and the associated cost.
9. Determine the treatment of South Arm Road that would contribute to protection of the community and at the same time provide adequate flushing of the wetland south of the former landfill site as well as an estimate of the cost and suitable timing to implement.
10. Determine the cost and feasibility of putting gates on the canal to exclude storm tides from Ralphs Bay, including the merits of fitting them to the existing bridge or waiting until the highway is upgraded/elevated to provide further protection.
11. Determine the available mechanisms for charging for contributions to coastal hazard adaptation and risk management. Propose possible formulae for the allocation of costs between beneficiaries and test them with the public.
12. Explore decision making and governance models to implement coastal strategies with a wide range of stakeholders. In the short term there is a need to consult relevant stakeholders about the importance of a governed approach and of ways to address that.
13. To report back to Council by June 2012 with a list of recommended actions and timelines for Council's consideration.

2.3 Reality Check investigations

The actions listed above were used as the basis for four briefs to consultants. These resulted in the following reports:

1. *Lauderdale Environmental Assets: assessment of climate change impact on coastal and marine areas*, Derwent Estuary Program
2. *Investigation of Beach Protection Works*, Water Research Laboratory, University of New South Wales
3. *Inundation Control Works for the Lauderdale Area,* pitt&sherry
4. *Funding and Decision Making,* SGS Economics & Planning

Summaries of these reports are included in Section 6.

3 INVESTIGATION FINDINGS AND IMPLICATIONS

3.1 Protecting natural values - a place for nature

It is widely acknowledged that the natural values of the Lauderdale area contribute to the lifestyle and to the property values in the community and community members at the workshops generally wanted to retain much of the natural character as long as possible, specifically the beach but also trees, wetlands, offshore flats, etc.. While early retreat was not considered an acceptable strategy, protection of natural values was seen as a suitable priority for parts of Lauderdale with great natural values and limited property development, most notably the wetlands and potential wetlands. Protection of the beach was seen as a priority more for aesthetic and recreational values but some environmental values (coastal trees and bird habitat) were also noted.

While some in the community have appreciation for natural areas and the values and environmental services they provide, it was clear from the community discussions that many had a limited knowledge of the specific environmental values of the area or services provided by wetlands, mudflats and beaches. It is also true that many of these services benefit the wider community beyond Lauderdale and the interests of the wider community also need to be recognised although they were not represented in the discussions. In part, these are protected by legislation (such as the Tasmanian Threatened Species Protection Act 1995 (TSPA), Nature Conservation Act 2002 and the Environmental Protection and Biodiversity Conservation (EPBC) Act 1999).

The report prepared by the Derwent Estuary Program provides documentation of the main natural values of the area and the services and values they provide. The key findings of the investigation into natural values are summarised for the two main areas, Roches Beach and Ralphs Bay.

Roches Beach

1. Threatened coastal eucalyptus vegetation communities on the dunes[1] would be lost with continued erosion and, in the longer term, could be affected by rising salt levels from sea level rise and reduced freshwater recharge (conversion from septic tanks to sewers). These trees provide shelter from wind and habitat for birds and are generally appreciated by residents.
2. Threatened sea stars (listed as Endangered under the TSPA and Vulnerable under the EPBC Act) that uniquely bear live young and occur in only eleven known colonies in the world have two colonies along Roches Beach, at Bambra Reef and Mays Point. They may be affected by sand deposition on the colonies. As the colonies cannot easily disperse to other habitat, translocation assistance may be needed if these colonies become subject to sand burial. Actions that may impinge on the sea stars could be subject to referral to the Australian Government under the EPBC Act.
3. The sub-tidal sea grass beds off the southern end of Roches Beach provides spawning grounds and habitat for a number of marine species and assist in denitrification and carbon capture. Seagrass extent has dramatically declined throughout south-eastern Tasmania since the 1970's and effort to prevent further decline and promote recovery would benefit the region. The southern Roches Beach seagrass bed is likely to experience episodic sediment burial the impact of which depends upon the condition of the seagrass.
4. Beach scraping has potential impacts on beach fauna but these are likely to recover.

Ralphs Bay and shore area

1. **Ralphs Bay tidal flats** provide an important, high quality habitat for birds:
    - The Derwent Estuary Pittwater Area (DEPA), provides habitat for at least eight migratory shorebird species (four listed for protection under the *EPBC Act* 1999) and six resident shorebird species. The migratory species are listed under international agreements aimed at ensuring habitat protection for their survival. The Ralphs Bay tidal flats, relative to other parts of the DEPA tidal flats, appear to be of high importance to migratory Double-banded plover, Whimbrel and Grey-tailed tattler.
    - The DEPA is internationally significant for resident Pied Oystercatchers, supporting some of the largest numbers of this species in Australia and the second-largest in mainland Tasmania. At times up to 10% of the global population of Pied Oystercatchers can be observed foraging on the Ralphs Bay tidal flats.
    - The Red-capped plover is a commonly observed resident shorebird at Ralphs Bay.
    - The northern tidal flats of Ralphs Bay appear to be the favoured foraging area for many shorebirds, notably Pied Oystercatchers who also have a preference for nesting on the adjacent foreshore where there is good connectivity for their flightless chicks between the nesting and tidal flat foraging areas. Sea-level rise will reduce the extent of the northern tidal flats and loss of the adjacent preferred nesting areas due to coastal squeeze and increased exposure of nests to waves. Some birds will then nest in the less satisfactory Racecourse Flats, but this is expected to result in poorer breeding success unless this area provides improved feeding opportunities that may occur if the area is flushed by the tides.
2. The Ralphs Bay tidal flats also contribute to improved water quality throughout the greater Ralphs Bay region. A net decline in the overall extent of the tidal flats by 2100 may cause a decline in nutrient removal within the region. However, re-establishment of seagrass (which assists nutrient removal) on sub-tidal areas that were formerly tidal flats may see this ecosystem service retained. There is currently a lack of sub-tidal seagrass in Ralphs Bay, although it was extensive here in the 1970s. Increased sea grass

[1] *Eucalyptus viminalis and E. globulus* coastal forest and woodland and *Eucalyptus globulus* dry forest and woodland

coverage could improve sediment capture and extend the time the tidal flats remain as feeding areas as sea levels rise.

3. The Lauderdale saltmarsh has the highest vegetation diversity across its profile from seaward to landward edge in the DEPA. Saltmarsh is in decline across the DEPA due to human disturbance (including clearance, changed drainage and landfilling), sea level rise (coastal squeeze), and coastal erosion reducing habitat for shorebirds and other saltmarsh flora and fauna. The area around Lauderdale offers one of the few areas where saltmarsh can move inland. This area currently hosts a number of species of special significance
    - The saltmarsh looper moth (Dasybela achroa) listed as threatened (vulnerable) under the TSPA, may have its only remaining population at Lauderdale. It is likely that this species requires saltmarsh connected with adjoining woody vegetation such as Acacia species for development of its larvae.
    - Two threatened (rare) plants species (listed under the TSPA) appear to be confined to saltmarsh areas, these are: narrowleaf blowngrass (Lachnagrostis punicea ssp. filifolia) and slender buttons (Cotula vulgaris var. australasia).
    - Shorebirds roosting, nesting (when optimal sites elsewhere are unavailable) and foraging (typically when tidal flats are inundated or chicks hatched in saltmarsh areas).
4. With sea level rise, saltmarsh can develop in areas south of Lauderdale and into the Roscommon wetlands, replacing 'drowned' saltmarshes that become tidal flats or open water. If opportunities for this landward movement are prevented, the habitat (and associated species) will be lost.

Recommended actions for natural areas

1. While some natural assets will change or move in response to climate induced changes in conditions, their expected loss from an area should not be used to justify development of sites that would hasten their loss. **Management would seek to improve the condition and function of natural areas**, as they provide important ecosystem services in the short term, and an improved condition will increase their capacity to move in response to changes as conditions require.

Roches Beach area

Eucalyptus vegetation communities

2. **Use beach protection measures to prolong the viability of the current foreshore dune vegetation**, retaining both the amenity and habitat values.

3. **Use water sensitive urban design to enable maximum freshwater infiltration to the sand dune aquifer** to reduce the risk of rising saline groundwater. This would include fully grassed swales and detention basins, no new kerb and guttering and possibly the removal of some existing kerb and guttering, and the promotion of onsite reuse of grey water. Rising sea levels and water tables will make this strategy unworkable by increasing flooding in the lower lying areas.

4. The survival of the eucalypt dune vegetation is doubtful due to rising salinity in the root zone. **Alternative sites for establishment of eucalypt dune vegetation should be sought to maintain this vegetation type in the area if it is considered desirable to maintain this community in the area**, although these sites may not be present in Lauderdale and vicinity.

Seastar (Patiriella vivipara)

5. **Retain rocky seastar habitats in good condition and monitor the populations at both sites**. Consider potential to extend habitat in conjunction with protection works discussed below.

6. **Assess risk level to threatened seastars from sand nourishment or groyne construction as part of works design** that may result in altered sand deposition or other impacts.

7. **Identify a trigger for management action, and determine appropriate management action steps if the colonies are at risk of localised extinction** due to sediment burial or other impacts.

8. **Retain good water quality** by avoiding placement of stormwater outfalls **near these sites**, and prevent human disturbance (e.g. collection of threatened seastars).

9. **Identify appropriate sites for potential translocation of the threatened seastar as insurance colonies**. Determine the legal requirements of site assessment and permitting for translocation.

Seagrass

10. **Manage stormwater discharges near seagrass beds** via WSUD **to maintain water quality**.

11. **Reduce physical disturbance associated with anchor or boat chain mooring drag** by discouraging anchoring or mooring at the southern end of Lauderdale Beach or providing 'seagrass friendly moorings' for community use.

Beach biota

12. **Minimise impacts on beach biota from beach scraping** by using a mosaic pattern or staging works to allow recovery from disturbance as previously recommended.

Ralphs Bay area

Tidal flats

13. **Manage stormwater entering Ralphs Bay** consistent with WSUD principles **to reduce sediment and nutrient loads** that may harm seagrass, natural tidal flat sediment dynamics or biological processes

Existing saltmarsh

14. **Work to restore tidal flushing beneath the South Arm Road causeway to the tidal flats of East Marsh Lagoon**. Stages would include:

- Identify an appropriate initial partial tidal flushing volume that poses little risk of activating landfill leachate or causing erosion at the Lauderdale landfill site in its current, but will improve tidal flat and saltmarsh habitats east of the South Arm Road causeway.

- Working in conjunction with DIER, install measures to permit partial tidal flushing, expected to be undertaken in conjunction with future road maintenance or upgrades.
- Monitor habitat changes arising from partial flushing and risks to the Lauderdale landfill.
- Prepare site for full tidal flushing by installing mitigation measures (if required) to reduce risk associated with the Lauderdale landfill site potentially including
  - Measures to reduce risk from leachate mobilisation by controlling rainwater recharge and ground water into the landfill or if required leachate treatment
  - Preventing wind-wave erosion of the Lauderdale landfill capping when the flats are flooded at high tide
  - Ensuring appropriate drainage exists on the north-eastern side of Racecourse Flats, where the landfill site causes retention of surface water runoff.
- Increase full tidal flushing to Racecourse Flats at a rate that enables the transition of plants to the new conditions and monitoring of impacts.

15. **Introduce protective management practices to the area** that:

- improve condition and increase extent of fringing woody native vegetation (e.g. Acacia species) on the landward side of the saltmarsh, which is likely to be of critical important for larval development of threatened moth species that feed on the saltmarsh.
- Reduce human disturbance of the saltmarsh. Review current user activities (e.g. motor bike and pushbike use, dog walking, horse riding, walking area). Prevent off- road vehicle use (through fencing, signage, changed user behaviour and use of the area, increase policing if some user activities are prohibited).

Future Saltmarsh

16. **Ensure saltmarsh will be able to transgress inland, south of Lauderdale** to avoid coastal squeeze and loss of the saltmarsh as much of the Racecourse Flats saltmarsh will become tidal flat habitat in the future. This is the most achievable direction for future tidal flat development as sea-level rises. This is likely to require amendments to the Planning Scheme in accordance with the *Southern Tasmanian Regional Land Use Strategy* (STCA 2011) regional policy:
    C 2 Ensure use and development in coastal areas is responsive to effects of climate change including sea level rise, coastal inundation and shoreline recession
        C 2.3 Identify and protect areas that are likely to provide for the landward retreat of coastal habitats at risk from predicted sea-level rise.
    The amendment may need to recognise three different land categories of importance to saltmarsh:
        1. Current sensitive coastal habitat (current tidal wetlands complex and saltmarsh).
        2. Near future (2100) sensitive coastal habitat. (2100 saltmarsh extent, but areas excluded where infrastructure currently exists).
        3. Long term refugia corridors for saltmarsh.
17. **Prevent landfilling of remaining saltmarsh,** especially at Racecourse Flats and council land north of the Lauderdale canal.

3.2 Controlling beach erosion

The public workshop participants clearly wanted a Lauderdale where some development continued, at least within established areas, consistent with pathway 3. This is in line with the current planning scheme which allows further development within areas zoned for this. There was also considerable concern for the immediate risks arising from recent storms and the lack of protection remaining for some properties from future storms. Thus, while the workshops were focussing on long term adaptation pathways, there was an understandable sense of urgency about action over the short term.

Whilst pathway 3 has some more interventionist approaches such as groynes or offshore reefs in the long term, participants saw beach nourishment as a necessary short term undertaking regardless of what may be required under this scenario in the longer term.

Beach nourishment was proposed as the lowest risk form of protection in the short term as it has the least impact on coastal processes. It provides protection more quickly, with fewer approvals requirements, and can address residents' concerns about protection in the short term. While it will not last for a long time, it was expected to be cost effective compared to alternatives in the short run.

Reassessment of Beach Nourishment

Beach nourishment needs to be done at a much larger scale than the works done to date to provide sufficient protection for a 1% annual exceedance probability (AEP) erosion event. The subsequent assessment by WRL has cast some doubt on both the effectiveness and moderate cost that was estimated for large scale beach nourishment.

In the 2008 report on coastal hazard, Water Research Laboratories (WRL) established an initial estimate of the sand volume buffer required to provide protection to property from a 1% AEP storm. Participants in the workshops considered that to be a desirable trigger for topping up beach nourishment rather than letting it get as eroded as at present. Under present day conditions, about 15-20 dwellings would be at risk in a 1% AEP event, showing the desirability of acting soon to improve the available safety margin.

As a follow up to the workshops WRL was commissioned to review the volumes in light of more recent investigations and the effects of recent storms and to assess the cost of providing sufficient additional sand to reach this level of protection for the present day, and for longer periods of ten or twenty years, given the expected rates of erosion over that time.

While some sand for nourishment can be obtained from scraping in the intertidal zone, the quantity available is insufficient to meet the stated objectives. Two likely larger scale sand supplies are available for nourishment of Roches Beach:

- Offshore sand deposits
- Terrestrial sand quarries

WRL estimate that 75,300 m^3 of sand *with the same characteristics as the native sand* would be required currently to provide protection from a 100 year ARI event at Roches Beach. An additional 119,800 m^3 would be required for protection until 2022 and 100,200 m^3 more would be required to provide protection until 2032, at total of 295,300 m^3. However, the amount of sand needed depends on the sand grain size, with finer sand forming a lower slope from the shore, and requiring a much larger volume than coarser sand to provide the same beach width and protection. Because the grain size of sand found so far in large quantities is smaller than the native sand at the beach, significantly greater volumes of nourishment sand would be required from these likely sources.

Offshore sand

Aquenal (2010) identified approximately 425,000 m^3 of sand offshore of Roches Beach as potentially suitable for sand harvesting. This volume was determined based on limiting the sand pumping distance to 600 m from shore. With distances significantly further than 600 m the volume of sand available is likely to be much greater. Based on the finer grain size identified from the initial investigation, **approximately three to four times as much sand would be required from this offshore source to provide the same protection compared to using native sand**, depending on the period of protection expected.

Terrestrial sand

WRL consulted a possible supplier of terrestrial sand from a quarry at the back of Seven Mile Beach. This terrestrial source of sand is coarser than the offshore sand but still slightly finer than the native sands. **Between one and a half to three times as much sand would be required from this terrestrial source to provide the same protection compared to using native sand**, depending on the period of protection expected.

The required volumes and estimated costs for nourishment using offshore and terrestrial sand sources are summarised in Table below for 1% AEP (100 year ARI) protection in present day, 2022, and 2032 scenarios.

	Native sand	**Offshore sand**	**Terrestrial sand**
		Volume (m^3)	
Present day	75,300	320,300	214,700
To 2022	195,100	726,500	355,300
To 2032	295,300	857,600	450,600
		Cost ($m)	
Present day	Insufficient	5.5	7.7
To 2022	sand	11.7	12.5
To 2032	available	13.8	15.8

The original cost estimate for Roches Beach from the 2008 report was based on the assumption of volumes required using sand with the same characteristics as native sand. This was $2.6 million for present day risk and $5.2 million to protect to 2050. This estimate formed the basis for costs used in community discussions. **The current estimates are two to four times times higher than this**.

Impacts of beach nourishment

Beach nourishment was favoured in the community workshops in part because it poses fewer risks to adjacent areas arising from modification of coastal process. Shoreline armouring, groynes and offshore reefs may affect sediment transport and starve adjacent areas of sand, causing or enhancing erosion elsewhere. However beach nourishment with non-native sand can also have some environmental impacts.

If sand comparable to native sand were available, nourishment to the extent required to provide say ten years margin of safety would be roughly equivalent to restoring beach profiles to where they were 10-20 years ago. Arguably, after a transition period for the initial disturbance, environmental conditions could recover if the work was undertaken appropriately. However, the availability only of finer sand requires much more sand to be placed that for native sand. This additional sand will fill the surf zone to a greater depth, and being finer will also be more mobile to adjacent sea grass beds and reefs.

A report by Aquenal (2010b) assessing the impacts of beach nourishment focused on the concept of removing sand from the intertidal zone for dune building and recommended measures to reduce impacts on beach fauna. Mass scale beach nourishment and burial of existing creatures was not specifically considered. Introducing different species to the beach through supply of non-native sand was also not assessed.

While the majority of active profile offshore of Roches Beach is sand with very sparse seagrass, the region of seagrass of varying but generally greater density at the southern section of the beach (Aquenal, 2010) may be affected by placement of the large volume of finer nourishment sand.

As noted in Section 3.1.1, Bambra Reef contains threatened sea stars as well as other reef biota. Whilst direct nourishment of Bambra Reef would be avoided, with large scale nourishment using finer non-native sand, it is likely some sediment will be transferred through littoral drift processes to the reef. If this sediment volume is greater and/or very different to the sand naturally passing through the area there may be impacts on the ecological habitat, including complete habitat destruction if the reef is buried. The effects of burial and increased turbidity in the nourishment zone were not considered in earlier studies.

The primary biological effect of dredging to obtain beach nourishment material is removing benthic vegetation and creatures present on the sediments. Dredging can also increase turbidity in the borrow area. While dredging operations have also been known to damage reef habitats in areas adjacent to a borrow area, with adequate buffer zones as recommended by Aquenal (2010) and the use of accurate positioning systems this should be avoided.

If nourishment sand is sourced by dredging offshore of the beach, the dredging pattern should be designed to minimise wave refraction effects. Ideally this would be informed by numerical SWAN wave modelling, but at the least, post dredging contours should align with the dominant wave crest alignment at the site.

Small changes in the compatibility of the material result in large changes to the required nourishment volumes. The Aquenal (2010) analysis showed that sand compatibility improved with increasing distance offshore so additional sampling at greater distances offshore may reveal even more compatible sand. More detailed sediment sampling of both the borrow material and the native sand on the beach is likely to improve effectiveness and potentially substantially reduce the cost of works. Undertaking nourishment in smaller stages with monitoring in between would allow for refined predictions of performance, but would incur more mobilisation/demobilisation costs.

In light of the 'reality check' investigations undertaken on the control of beach erosion on Roches Beach, it appears that the scenarios presented in the community workshops were unduly optimistic about the costs and assessment of impacts from beach nourishment:

- The cost of beach nourishment as protection against erosion is likely to be two to four times higher than originally suggested although some modest reduction from this may be achieved;
- Use of available finer sand alone for nourishment without other measures may put the threatened sea stars and remnant sea grass beds at risk.

The WRL Report (2011) on the revised hazard lines, Figure 3.9 includes a note at the end of Bambra Street that there is a risk that "Erosion may exceed estimates in this area due to loss of control from Bambra Reef". Further discussion with James Carley of WRL has indicated that recent storms and the erosion to the point may well put this near the point of separation. Should this occur, erosion rates could increase dramatically along the northern end of Roches Beach south of Bambra Road. As the consequences of this would be grave, it would be appropriate to take preventive action to prevent separation of the shore from the reef.

Works to enhance nourishment effectiveness

Given the higher than expected cost of beach nourishment and the potential environmental effects, it is prudent to consider supportive works that can both enhance the effectiveness of beach nourishment and reduce the impacts

on threatened and important environmental assets, and to do so much earlier than proposed in discussion with the community. Such action is still consistent with pathway 3.

Participants in the community consultation recognised that groynes and offshore reefs will change the beach, either immediately or over time and ideally they would be deferred. While there was a preference for submerged reefs, the WRL 'reality check' report makes very clear that they are less reliable and predictable in their effects than either groynes or emergent reefs (breakwaters), and strongly recommends against them. The same report also advised that properly designed works are unlikely to adversely affect Seven Mile Beach and property owners there.

The use of a groyne at or near Bamba Reef can capture a substantial portion of the longshore sediment drift until if fills, significantly improving protection of the currently most vulnerable properties to the northern end of the beach. Almost all properties at present day risk are north of Epping Road. Such a groyne, if property designed, could:

- Protect the reef including the sea star and other fauna present from burial by sand from nourishment
- Extend and enhance the available habitat for the threatened sea star colony
- Reduce or eliminate the risk of loss of control of the Bambra Street point by Bambra Reef

Until the area to the south of the groyne fills, there may be some additional erosion north of the reef. While there are few properties there, most set well back from the shore, and the beach there has shown progradation over the past five decades, provision of a contingency plan to address developing erosion should it occur would be desirable.

Emergent offshore reefs (breakwaters) both reduce the erosive impact of breaking waves on the beach and promote the retention of some sediment moving along the shore to build sand deposits between the reef and the beach. This can occur even without nourishing the beach, reducing costs, and reducing impacts on the reef and seagrass beds. However, the initial level of protection would increase if some nourishment is provided.

The offshore emergent reef would both reduce wave energy (therefore the storm cut from a 100 yr ARI event) and via sand trapping and changing the shore parameters, potentially diminish to some extent the 'Bruun rule erosion' associated with sea level rise. Combining these effects may greatly reduce the amount of beach nourishment that would be required. In contrast, while the groynes would trap sand from longshore drift or hold sand placed on the beach, it would not reduce the extreme storm cut or influence sea level rise effects. Groynes would reduce the rate of loss by longshore drift (ie the main contributor to long term *progressive* erosion in the absence of sea level rise).

The WRL(2012) 'reality check' report makes clear that major permanent works need appropriate modelling and design before being implemented. Even with this, the use of geotextile bags for some works will allow their removal if impacts prove to be unacceptable. One strategy that has been used is to place geotextile bags initially and to later cover them with rock, should they prove satisfactory to make them more permanent. As the bags tend to settle after placement, the final dimensions would still be near the design dimensions. This additional rocky reef area could provide additional sea star habitat if suitably designed. Such an approach should be checked by detailed design work for suitability at this site.

While these works are technically appropriate, the cost is high, of the order of $5-$10 million, and an appropriate funding mechanism must be established before works on this scale can proceed. The following recommendations need to be taken in conjunction with the proposed funding and decision making arrangements discussed in section 4.6 and 4.7.

Recommended actions for beach protection works

18. **Continue to use beach scraping each year to reinforce the low lying and low volume sections of the dunes in the short term.** Beach scraping uses native sand which reduces the volume required to achieve a given effect. If scraping cannot provide enough sand to maintain minimum requirements, supplement with terrestrial sand. Based on recent experience, this costs about $250,000 per year.

19. **Extend Bambra Reef both to the shore and as necessary seaward with a rock groyne to protect Bambra Reef from being buried in sediment from beach nourishment works** and capture sand moving northward, assisting protection of properties just south of the reef. (indicative all up cost built in rock $500,000, subject to detailed design)

20. **Place a trial geotextile offshore emergent reef extending in 'panels' south from Bambra Reef about 1 km to protect the most exposed portion of the beach from wave action and capture additional sand.** An indicative cost would be about $3-$3.5 million, subject to detailed design.

21. **Investigate offshore sand in Frederick Henry Bay at distances up to 1.5 km to determine suitability as a sand source.** Review quantities required for beach nourishment in light of findings and compare cost effectiveness of larger scale beach nourishment using offshore sand with annual scraping and select accordingly. (investigations approximately $25,000)

22. **Augment the coastal works with sand nourishment as required** including spot nourishment of lower areas, repairs after storms and nourishment near dwellings north of Bambra Reef if required. (cost of nourishment $2million to $10 million plus annual top up)

23. **Monitor the changes to the beach and acceptability of structures over a period of 10 to 20 years.** Subject to monitoring:
    - Extend the reef to protect the central area of the beach
    - Make the reef permanent by covering in rock
    - Continue some beach nourishment either by scraping or from external sources as proves most effective and cost effective
    - Maintain or upgrade the revetment at the southern end of the beach as required.

3.3 Coastal inundation

In the discussions with the community there has been a strong emphasis on coastal erosion and relatively less focus on inundation. This probably reflects the recent, clearly evident impacts of erosion on Roches Beach, the fact that erosion repairs itself relatively slowly, if at all, and that a house that is undermined by erosion may be more heavily damaged and costly (or pointless) to repair than one that suffers a flood. Erosion can permanently eliminate land while flooding is more likely to be transient, at least for the near future.

Nonetheless, Lauderdale has had floods in the past and storm surges that allow water to cross the road have been seen more frequently in recent years. Floods from rainfall coupled with high tides have reached levels up to about 1.5m AHD in the lower basin area, so far causing little property damage. A 1% AEP storm surge could take sea levels along the shore of Ralphs Bay up to as high as 2.0m AHD in the lower basin and could cause flooding to over 100 properties, many above floor level.

Recent flood modelling by pitt&sherry (2012) shows expected flood levels of about 1.64m AHD in the lower basin area north of the canal from a 1% AEP (100 yr ARI) **rainfall** event if tides are high enough to entirely prevent drainage to Ralphs Bay or the canal. This is the level to which rainfall would fill the low lying areas if there is no capacity to drain to the sea until after higher tides subside. More realistically floods are likely to reach about 1.5 m given some drainage during low tide. Levels would be higher, about 2.5m AHD in the Roscommon wetland area for rainfall driven floods.

Storm surges along the Ralphs Bay coast above about 1.75m AHD can overtop the South Arm Highway and North and South Terrace (as well as flowing in through stormwater outlets) and could contribute to flooding of low lying land even without heavy rainfall contributing. It would take a surge well in excess of 1.75m to result in a significant volume of water flowing over the roads to lead to flooding from a storm surge alone. However the WRL (2008) report showed that storm surges for today's conditions could reach 2.0m in a 1% AEP event.

Various combinations of rainfall and storm surges could result in floods high enough to damage existing low lying dwellings. In the unlikely event of a 1%AEP rainfall and storm tide combined, flood levels might reach about 2.0m AHD across the entir lower basin area. Storm surge driven floods are less likely to affect areas further from the coast such as the Roscommon wetland unless there is also heavy rain.

Addressing inundation hazards is made more challenging by the relatively flat character of the area, reducing the rate of drainage even during low tides.

Under the current planning scheme, new structures in Lauderdale are required to be built with floor levels at or above the expected coastal storm tide level with a 0.9m sea level rise, plus freeboard; that is 3.2m AHD. This is likely to protect these new structures from inundation hazards for the life of those structures. This does not address the risk to existing structures and low lying infrastructure, nor does it assure safe access to new or existing structures during coastal inundation events.

Damage to existing dwellings can be minimised by ensuring good drainage for rainfall, avoiding filling that reduces the storage capacity of the low lying areas that act as detention basins and preventing entry of sea water from storm surges into low lying areas.

Storm surge protection

To prevent entry of storm surges from the sea, a continuous barrier around the low lying areas would be required. To be effective against a 1% AEP (100 yr ARI) storm surge, it would need to be kept about 2.0m above the mean sea level, and raised as sea levels increase. South Arm Highway is currently about 1.75m AHD at its lowest point. Drainage outlets would also need non-return valves to prevent sea water entering through the barrier. Given that South Arm Highway runs along the coast of Ralphs Bay, raising the highway would have the dual benefit of protecting land behind and ensuring access during storm events to Lauderdale and the entire South Arm Peninsula.

Raising the road to 2.6m AHD would provide protection against expected storm surge even with sea level rise of about 0.3m, and should provide good protection from storm surge from Ralph Bay until the road needs further major maintenance and upgrading in about forty or fifty years.

It would be raised further in the future, probably to about 3.2m, but this would be reassessed in light of actual sea level rise, assessments of expected sea level rise, extent of vulnerable developed land and flood experience in the interim.

Raising the road to these levels exceeds the level needed for road access alone. It is normally considered acceptable for a road to be inundated for short periods by a 1% AEP (100 yr ARI) event as long as it remains serviceable after the waters recede. In this case, it is considered appropriate to raise the road level higher to prevent over-topping and reduce the flood risk to property behind. This imposes additional cost on road construction for the benefit of private property behind. As discussed in section 4.6, the beneficiaries should contribute to part of this cost.

The p&s report recommends that raising the road should not encroach on Ralphs Bay. The increase in elevation of the road is likely to require some encroachment on private property on the land side for a broader right of way. The contribution of this land could be a potential contribution to the cost of protection being provided to these properties.

At present the canal is open to Ralphs Bay. The canal is a receiving body for some drainage lines. If the raised roads are to be effective in protecting low lying areas from flooding by storm surges from Ralphs Bay, either the roads around the canal will also have to be raised as barriers, or the canal will need a gate to exclude higher tides and storm surges.

The cost of a gate ($750,000) is likely to be somewhat less than the cost of raising the North and South Terraces, and defending the eastern end of the canal ($1.5-$2.0 million). However, it is worth paying at least a modest premium to raise the roads rather than gate the canal:

- Raising the terraces will be required eventually anyway, being kept about 1.7m above mean sea level as it rises to ensure access during floods even with the gates;
- Maintaining the east end of the canal above storm surge levels from Frederick Henry Bay is necessary should there be a breach in the dunes near that point;
- New or redeveloped houses along the canal will be required to be built at 3.2 m. Elevating the roads reduces the difference in levels, particularly should the property owner also choose to raise some of the land around the house and the driveway;
- The gate will have ongoing maintenance and management costs and raised roads may have reduced costs compared to if they are flooded more often;
- Raising the roads is relatively fail safe whereas the gate may fail and leave areas exposed to flooding in a storm;
- Leaving the canal open permits flushing and will probably contribute to higher water quality than having it closed from time to time, especially as sea levels rise and it needs to be closed more often.

The main benefit of gating the canal instead of raising the roads would be to provide additional retention volume. However, the capacity available is modest and the drainage to the canal would have to be greatly increased for this

to be effective. Modelling of the drainage (p&s 2012) showed little benefit from the storage capacity of the canal on flood levels.

Recommended actions for Storm Surge Protection

24. **Raise South Arm Highway to about 2.6 m AHD when next due for major repair and maintenance works.** This would likely be carried out in conjunction with recommendation 14 on tidal flushing of the salt marsh at racecourse flats. The p&s (2012) report provides a number of specific recommendations about the form of construction for the raised road. This will be the responsibility of DIER, not Clarence Council. An indicative cost to raise the road to 3.2 m AHD is $16 million, but raising it to 2.6 m should cost less than this.

25. **Raise the roads around the canal to at least 2.0m AHD, in conjunction with cyclical road maintenance programs for these roads.** Indicative cost $1.5 million

3.4 Improved drainage and drainage plan

Improved drainage can reduce flooding from rainwater by allowing more water to escape during the low tide part of each tidal cycle. Improved drainage broadly means more or larger outlets to Ralphs Bay or the canal, and ensuring drainage channels are adequately sized and kept clear and generally straight.

Drainage must also be maintained in the event that any development occurs in low lying areas that currently contribute to the drainage through the lower basin. A report by JMG (2012) addressed the issues arising from development proposed under the Structure Plan. The JMG report recommended swales at the front and back of all properties on the Structures Plan with these swales connecting into the existing drainage channels.

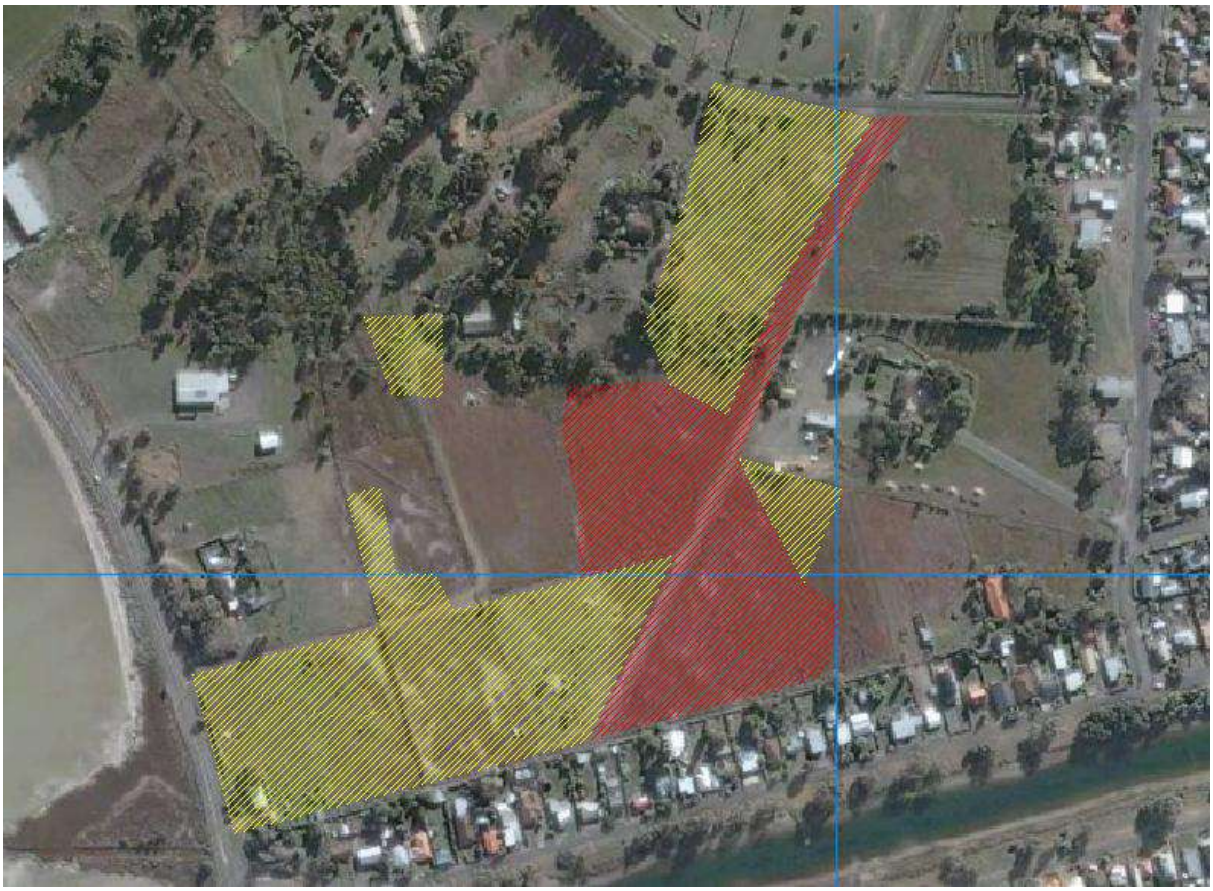
Mannata Road will need to be raised prior to development along the road, and provision of overland flow paths will be required when this occurs to minimise the risk of overland flows disturbing adjacent properties during construction and development. This will take detailed design work at that time.

P&s (2012) recommend that an easement of 25m wide should be maintained along the northern overflow route from the Roscommon Wetlands to the lower detention basin.

Recommended actions for improved drainage

26. **Improve drainage under South Arm Road and North Terrace to help drain the lower detention basin. Culverts to the canal and Ralphs Bay should be fitted with non return flaps.** These works would be undertaken in conjunction with raising roads (recommendation 23). Indicative cost $400,000.

27. **Prohibit development or filling of land at elevations lower than 0.75m within the lower detention basin,** to ensure adequate drainage connectivity and capacity of the basin is maintained.



28. **Require any development that requires filling to raise floor levels to make appropriate provision for low level overland flow paths to be maintained.**

29. **Investigate suitable fill options for land that may be filled and adopt guidelines to ensure that only suitable fill is used in future filling.**

30. **Keep the easements recommended for drainage of the northern and southern catchment areas into the lower detention basin free from development.**

31. **Adopt the detailed drainage recommendations from the JMG (2012) and p&s (2012) reports in conjunction with implementing the Structure Plan and permitting any further development in the lower basin area.**

3.5 Raising the land

Raising the road and improving drainage would not completely protect lower lying areas from inundation as mean sea levels rise, only from the extremes of storm surges. These areas would still be subject to flooding by rainfall that cannot drain out to higher sea levels, and as mean sea levels rise, water tables are also likely to rise. High water tables can reduce soil load bearing capacity and make foundations less stable. It will also change vegetation, and potentially reduce the health and quality of life for residents on waterlogged sites with damp houses.

Structures on land below about 0.8m are potentially affected by the effects of high water tables. There are few if any dwellings on land below about 1.4 m AHD at present. With a sea level rise of 0.9 m, structures with floor levels below about 1.7 would be affected by high water tables. There are about 75 parcels south of the canal and about 30 on North Terrace that have land below this level. There are others along Manatta Street and in a few isolated locations. These structures will need to be raised or rebuilt at a higher level over the next 100 years or so if they are to be continued to be occupied safely.

Eventually low lying houses will need to be redeveloped at a higher floor level, and when doing so, there would be benefits in raising at least some of the ground level around the dwelling. (Houses with floor levels at 3.2m would be 1.8m above ground level in areas that are at 1.4m AHD, the lower lying occupied sites in the suburb). To avoid adverse effects from high water tables, land levels would need to be kept about 1 m above sea level. To avoid risk of flooding from extreme rainfall, levels need to be about 1.6m above the current sea level to be above the 1% AEP rainfall flood level, assuming storage capacity is not reduced.

However, if low lying land that currently provides flood storage is filled, the flood level from rainfall will increase. Modelling by pitt & sherry (2012) shows reducing the detention volume by half would increase flood levels from rainfall by about 0.3m. This calculation assumes that the main channel is entirely unfilled and land initially above 1.5m is not contributing to the detention volume and can be filled without effect. Thus if significant filling of existing low lying land (below 1.5m AHD) is permitted, the target fill level would need to be higher, and unfilled land above 1.6 m currently relatively flood free would become potentially flood affected.

The calculations performed by pitt & sherry are based on the current detention volume available. Some previously low lying areas have already been filled, about 15% of the area below 1.5m. If rainfall and high tides of the severity that previously caused flood depths of about 1.5m AHD occur again, this filling and loss of storage volume is likely to increase the flooding to a higher level. While sea levels remain low, this can be offset by improved drainage to Ralphs Bay and the canal.

Recommended actions for raising land

32. **Future developments not outlined in the Structure Plan be required to consider the impact of filling on the natural drainage paths, and possible consequences on other properties in the vicinity of the development.**

3.6 A plan for payment

Participants at the community workshops generally agreed that contributing to the cost was acceptable as long as the contributions reflected the benefit gained and recognised that many benefits were gained by residents well beyond Lauderdale. Benefits gained beyond the local community particularly apply to preservation of natural areas and ecosystem services, but also to South Arm Road and users of the beach from out of the area.

Any contributions scheme needs to be equitable. A decision making approach that both ensures adequate funding is raised and management actions are appropriately coordinated is also required.

There was also recognition of the need to make provision for a transition from past expectations to the future, but some sentiment that even a transition should not prevent prompt action if early contributions from the community were necessary. At the same time there was widespread agreement that there should be some concession for those with limited means (such as a pensioner discount or waiver).

SGS Economics & Planning prepared a report on Funding and Decision Making (2012) to review possible approaches to funding adaptation works. Four ways were explored to apportion costs of coastal adaptation to users or beneficiaries. These were on the basis of:

- **The costs to provide the works**, where property owners contribute proportionate on the basis of coastal length of property (in case of erosion), on the basis of flood prone area (inundation) or on the basis of road access (raising roads). For 'collective works' there may be significant debate around the 'free rider' issues where those who also benefit (indirectly) are not required to contribute;
- **The value contribution of coastal benefits to the overall property value**. Coastal property values often carry in them premiums due to their 'beach frontage' or close proximity to the beach. Contributions would be raised according to the coastal benefit of 'being coastal'. Charging the contributions in hazard zones only would improve the equity of this arrangement;
- **The total property value**, where all properties in a suburb would be charged in proportion to the total property value. This option is in principle not equitable, because it is not directly related the level of risk that each property is exposed to. Charging the contributions in hazard zones only would improve the equity of the arrangement;
- **The expected cost of damage**. Where properties would be charged relative to the avoided risk for the property. It is an equitable approach but complex to administer (requires significant data collection).

The SGS report explored the implications of these different approaches. The principles used to assess them were that:

- The allocation by all contributors could be regarded by the community as equitable
- The contributions should reward or encourage efficient adaptation actions, that is, choices where the benefits of occupancy in general outweigh the costs, or where this is not possible, occupation is effectively discouraged.
- The method used should be practical, understandable and transparent to the community

Findings of the report showed that it would be the most equitable approach to charge contributions to coastal adaptation works on the basis of the expected cost of damage for adaptation works that protect property. However, it is not a practical approach due to the complexity of collecting information on damage avoided for each property.

Given the different distribution of benefits, different methods could apply to different adaptation works (eg raising roads for access would use a different mechanism than coastal erosion protection), but that some consistency in approach will make it easier for the community to understand and simpler to administer. The recommended approach would be to charge contributions on the basis of the property value (for properties in an identified hazard zone or affected area) for property protection works and ensuring access, which provides a reasonable albeit imperfect link between contribution and benefit, is easy to implement and provides an incentive for efficient adaptation.

Where active intervention is proposed to protect property rather than environmental values, but environmental values will potentially be affected by the property protection works, the cost of reducing environmental impact of the works should be borne by those benefiting from the property protection works.

Broader community benefits would be funded from the wider community through general rates and contributions from other levels of government.

More detailed work is required than possible within the scope of the current project to determine the final costs and an acceptable allocation among contributors. However the following examples highlight some indicative numbers to put things in perspective. The estimates focus on the cost to those in present day hazard areas but substantial parts of the total cost are being met by others at lower risk or gaining benefits such as access to the area even though their property is not at risk.

Taking costs for **coastal erosion protection** over the next 25 years as $10-$15 million and making some assumptions about the sort of allocations among properties at risk today, those at risk in future time periods and the willingness of the wider community to contribute gives indicative contributions of $4,000-$10,000 **per year** for those at immediate risk[2], depending on the final cost and allocation method used. Imposing this cost would equate to reducing the property value by about $80,000 to $200,000 but would reduce the risk of loss or damage to the property to low levels. Without this protection, the value of these properties would likely be devalued in the market and may already be affected to some extent. By making the property more secure, these works are expected to lift the value by an amount similar to the cost of the payment making the investment cost neutral. The alternative may be loss of most of the value of a $400,000-$800,000 property should an extreme storm hit the beach near these properties.

For inundation protection, the costs are comparable for protection against storm surge, but can be deferred a few years until the roads are upgraded, reducing financing costs. Also, the cost is spread over a different set of households in the inundation zone, will likely extend for a longer time period and would receive contributions from South Arm Peninsula residents as well as those in Lauderdale. Costs per household even for those in the present day inundation hazard zone would be considerably less than for erosion protection, of the order of $2,000-$5,000 per year. Contributions from South Arm residents to raising the road to ensure access might be of the order of $100-$200 per household per year. As a state government road also serving visitors and tourists and with part of the cost being associated with a normal rebuild cycle, a larger portion of the costs may be borne by the State and the cost to residents may be lower than this estimate.

Cost to resident for both types of risk may be reduced if some transition funding can be obtained in the form of grants or other assistance. However it is not expected that this will form the basis of long term funding.

One issue that will need to be addressed is the need for relatively prompt action to address erosion, requiring a large capital contribution up front. While resident contributions may repay this over time, there may be limits on Council borrowing capacity or willingness to incur debt that may constrain this. Wherever possible, works should be staged and contributions collected partly in advance to avoid the need to borrow and the added interest cost that is incurred.

Recommended actions for funding contributions

33. **Determine the capacity of the Council to continue to support coastal protection works over a transition of three years until long term funding arrangements can be put in place.** This would primarily be allocated to controlling erosion risk.

34. **Use general rates and land taxes and where possible grants, donations and sponsorships to cover the wider community benefits of coastal adaptation and to make contributions on behalf of the wider community to adaptation works that protect community assets, natural areas and amenity for the wider Clarence community on an ongoing basis.**

[2] This assumes contributions are also made by the larger number of dwellings at risk up to 2050 at a lower rate, and those at risk up to 2100 at a lower rate still. Contributions would also be made from the wider Lauderdale community at a rate of about $100 per household and there is some contribution from the wider Clarence community too. The balance of these contributions would need to be subject to wider debate.

35. **Use special charges and where possible separate charges to raise contributions for properties in identified hazard areas on the basis of the total property value**

36. **Use development contributions for new development to support coastal adaptation works, by setting conditions for development approval. These conditions would be incorporated in the planning scheme.**

37. **Extend relief to low income households through a concession scheme**

3.7 A plan for decisions and responsibilities

Participants believed that Council needs to take the lead in making the decisions, however, they also believed that those that pay (the community) will need to continue to have a say. Once decisions are made there needs to be a process and necessary controls to ensure that a single strategic direction is followed by all relevant stakeholders, land managers and infrastructure providers. This is a point about which many participants expressed uneasiness. A key example in this regards is the very different approach Council and State Government (Crown Land Service) take in regards to beach protection works in Lauderdale. Council protects the beach and dunes mainly through beach nourishment, while the State has an approach of let nature take its course.

This issue of agreeing on a decision process and coordinated implementation is not pathway or even location specific. It would apply across all coastal areas of Clarence, and ideally be consistent across the State.

Council cannot unilaterally determine the framework for decision making and implementation as it will require agreement about the management of some state land, approvals at the State and potentially Federal Government levels and ultimately funding. This will require dialogue and agreement with the State government before it can be finalised.

The SGS paper on Funding and Decision Making (2012) noted that coastal adaptation works by one property owner may have significant adverse impacts on other land users. Also, collective works are mostly more cost effective. Therefore, there is a need for a common strategy across the range of land owners and stakeholders for delivering effective coastal adaptation works in an area.

Key stakeholders, both landowners and those expected to contribute to the costs of coastal adaptation need to have a say in the formulation of a coastal adaptation strategy.

In short, there is a need for:

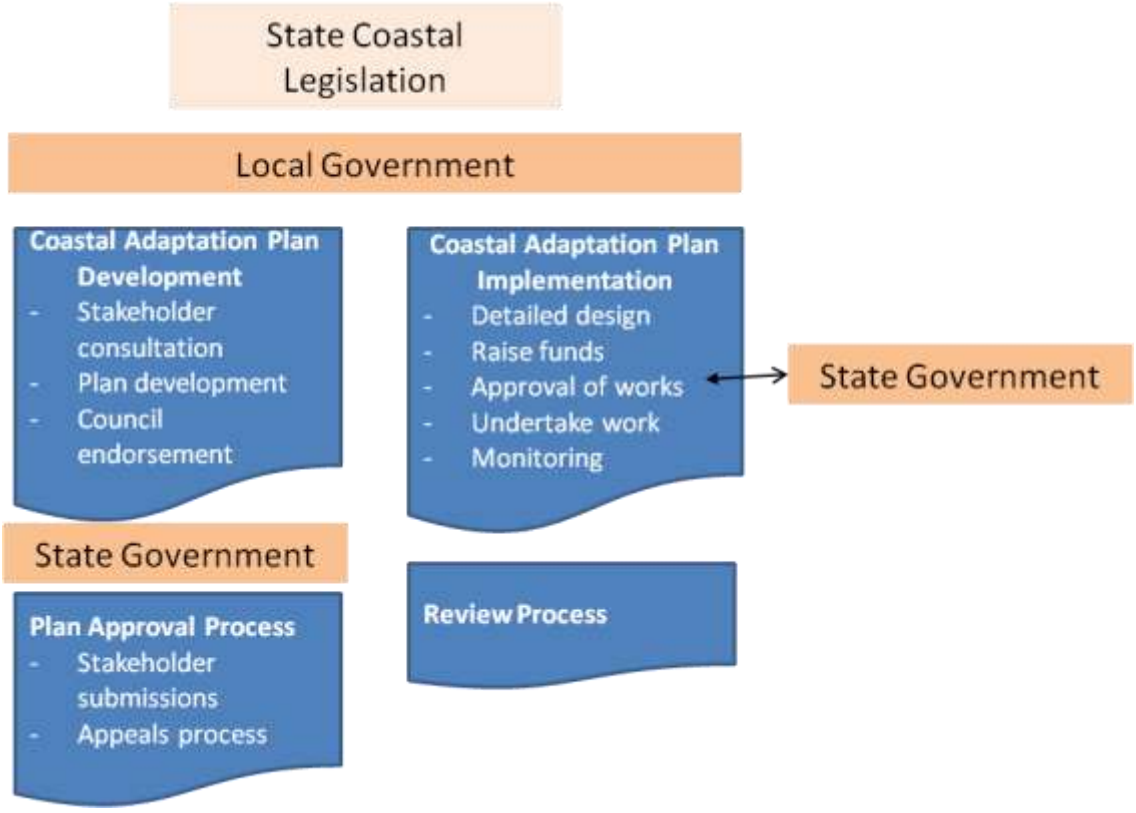
- a common adaptation strategy, which requires stakeholders to have a say
- an agreed and authorised body to implement the strategy
- robust financial management of unpredictable events and costs

It is proposed that the coastal adaptation plan (CAP) would be developed in a process that has parallels with local planning schemes. It would be developed by the Council with review from the stakeholders identified above. While it would have some things in common in process, it would differ significantly in that it involves taking action, not just the regulation of activity by others. It would need an identified funding base and specified performance criteria to ensure that it is carried out in accordance with the agreement among stakeholders.

The CAP would specify the area to which it applies, the objectives, the responsibilities and the actions to be taken, the expected budget, the funding arrangements and approvals processes for specific works. It is expected that a plan would articulate a long term pathway, but that the actions would be specified for a period of up to 20 years.

The recommended model is illustrated in the chart below.

FIGURE 2 RECOMMENDED DECISION MAKING AND IMPLEMENTATION MODEL



State legislation would be required to authorise and approve the development of a CAP, to formalise the roles and responsibilities and to authorise Councils as the Administering Body, thereby reducing their exposure to legal challenges. The administering body would have the responsibility to raise funds for coastal adaptation, to implement coastal adaptation options and to undertake monitoring of the impacts of climate change and the effectiveness and sustainability of the works undertaken. Specific works would still require state government approvals if required under normal approvals processes.

The review process would also be led by the Council. The strategy would in principle apply for 20 years. Within 10 years or on the occurrence of a significant change of events/circumstances, the strategy would be reviewed. Monitoring data would be used to guide the future direction of the strategy.

Recommended actions on decision making and responsibilities

38. **Determine the Council's position on the proposed approach to developing a State backed Coastal Adaptation Plan or variation on this approach and negotiate a basis to permit the Council to proceed in a timely manner.**

39. **Develop the detailed formulae for contributions under funding methods above based on an approved Coastal Adaptation Plan under a framework supported by State Government for the development of such plans. The formulae would be developed using detailed assessment of the properties affected from the hazard maps and council rate base information, a level of analysis beyond the scope of the current project.**

40. **If discussions with State government indicate a lack of support or unsatisfactory timing for developing the framework for a Coastal Action Plan, proceed to develop a funding framework within existing statutory powers to fund such works as are called for in the action plan in this report.**

41. **Undertake discussions with the State government and other coastal LGAs, possibly through the auspices of LGAT, to develop a pool or other 'insurance' option to be drawn upon to meet responses to extreme events when local capacity to pay is exceeded.**

4 BROADER CONSIDERATIONS FOR COASTAL ADAPTATION

The community consultation process revealed the strength of advocacy on the part of the community to protect property from coastal hazards, even if it means modifying the environment. This clearly shows that, with rising sea levels areas that may in the future be encroached by the sea from erosion or inundation that are developed to any significant extent will be modified unless specific provisions are made that this is not permitted before development begins. Realistically, even with such conditions, lobbying and the capacity of local communities to defend their perceived interests may well make enforcing such a provision difficult in practice.

The conclusion seems to be: If you want to have any natural beaches, do not allow development to occur in the areas behind them that may come into the erosion zone over the life of the development without strict requirements that they may not be protected clearly written in advance, and strong authority such as Federal or State government legislation to back this requirement.

The discussions in this document have been developed in response to considerations of managing coastal risks in Lauderdale. However, the WRL (2008) report examined 17 locations for future climate change risk and the resulting amendments to the Clarence Planning Scheme shows erosion and inundation hazard zones in a number of areas around the LGS. Other areas will have access affected if coastal roads are not protected or raised.

In anticipation of adaptation works, coastal adaptation planning for these areas would also be required to permit levies to be applied on properties in the erosion and flood hazard zones that reflect the expected cost of risk mitigation and infrastructure upgrades required to provide continued access and to adapt to climate change.

To address this wider scope, the results of the Lauderdale process should be canvassed widely in coastal areas with current or potential hazard areas for comment and response.

5 LIST OF ACTIONS

The recommended actions are listed below in the order they appear in the report, grouped by:

- Natural areas
- Beach Protection
- Storm surge protection
- Drainage
- Raising land
- Funding
- Decision making

Actions for Natural areas

1. Management would seek to improve the condition and function of natural areas.

Roches Beach area

Eucalyptus vegetation communities

2. Use beach protection measures to prolong the viability of the current foreshore dune vegetation.
3. Use water sensitive urban design to enable maximum freshwater infiltration to the sand dune aquifer.
4. Alternative sites for establishment of eucalypt dune vegetation should be sought if it is considered important to maintain this vegetation type in the area.

Seastar (Patiriella vivipara)

5. Retain rocky seastar habitats in good condition and monitor the populations at both sites.
6. Assess risk level to threatened seastars from sand nourishment or groyne construction in works design.
7. Identify a trigger for management action, and determine appropriate management action steps if the colonies are at risk of localised extinction.
8. Retain good water quality near these sites.
9. Identify appropriate sites for potential translocation of the threatened seastar as insurance colonies.

Seagrass

10. Manage stormwater discharges near seagrass beds to maintain water quality.
11. Reduce physical disturbance associated with anchor or boat chain mooring drag.

Beach biota

12. Minimise impacts on beach biota from beach scraping by following past recommendations.

Ralphs Bay area

Tidal flats

13. Manage stormwater entering Ralphs Bay to reduce sediment and nutrient loads.

Existing saltmarsh

14. Work to restore tidal flushing beneath the South Arm Road to the tidal flats of East Marsh Lagoon.
15. Introduce protective management practices to the area

Future Saltmarsh

16. Ensure saltmarsh will be able to transgress inland, south of Lauderdale
17. Prevent landfilling of remaining saltmarsh, especially at Racecourse Flats and council land north of the Lauderdale canal.

Actions for beach protection works

18. Continue to use beach scraping each year to reinforce the low lying and low volume sections of the dunes in the short term.
19. Extend Bambra Reef both to the shore and as necessary seaward with a rock groyne to protect Bambra Reef from being buried in sediment from beach nourishment works
20. Place a trial geotextile offshore emergent reef extending in ‘panels’ south from Bambra Reef about 1 km to protect the most exposed portion of the beach from wave action and capture additional sand.

21. Investigate offshore sand in Frederick Henry Bay at distances up to 1.5 km to determine suitability as a sand source for further nourishment.
22. Augment the coastal works with sand nourishment as required.
23. Monitor the changes to the beach and acceptability of structures over a period of 10 to 20 years.

Actions for storm surge protection

24. Raise South Arm Highway to about 2.6 m AHD when next due for major repair and maintenance works.
25. Raise the roads around the canal to at least 2.0m AHD, in conjunction with cyclical road maintenance programs for these roads.

Actions for improved drainage

26. Improve drainage under South Arm Road and North Terrace to help drain the lower detention basin in conjunction with raising roads. Culverts to the canal and Ralphs Bay should be fitted with non return flaps.
27. Keep the easements recommended for drainage of the northern and southern catchment areas into the lower detention basin free from development.
28. Adopt the detailed drainage recommendations from the JMG (2012) and p&s (2012) reports in conjunction with implementing the Structure Plan and permitting any further development in the lower basin area.

Actions for raising land

29. Prohibit development or filling of land at elevations lower than 0.75m within the lower detention basin to retain flood storage and drainage capacity.
30. Investigate suitable fill options for land that may be filled and adopt guidelines to ensure that only suitable fill is used in future filling.
31. Require and development that requires filling to make appropriate provision for low level overland flow paths to be maintained and to consider possible consequences on other properties in the vicinity of the development due to reduced retention capacity of the area.

Actions for funding contributions

32. Determine the capacity of the Council to continue to support coastal protection works over a transition of three years until long term funding arrangements can be put in place.
33. Use general rates and land taxes and where possible grants, donations and sponsorships to cover the wider community benefits of coastal adaptation and to make contributions on behalf of the wider community to adaptation works that protect community assets, natural areas and amenity for the wider Clarence community on an ongoing basis.
34. Use special rates to raise required contributions for properties in identified hazard areas based on the total property value.
35. Use development contributions for new development to support coastal adaptation works, by setting conditions for development approval. These conditions would be incorporated in the planning scheme.
36. Extend relief to low income households through a concession scheme, adjusting the rate set to non-concession properties to ensure that the total contribution required is still raised.

Actions for decision making and responsibilities

37. Determine the Council's position on the proposed approach to developing a State backed Coastal Adaptation Plan or variation on this approach and negotiate a basis to permit the Council to proceed in a timely manner.

38. Develop the detailed formulae for contributions under funding methods described based on an approved Coastal Adaptation Plan under a framework supported by State Government for the development of such plans. The formulae would be developed using detailed assessment of the properties affected from the hazard maps and council rate base information.
39. If discussions with State government indicate a lack of support or unsatisfactory timing for developing the framework for a Coastal Action Plan, proceed to develop a funding framework within existing statutory powers to fund such works as are called for in the action plan in this report.
40. Undertake discussions with the State government and other coastal LGAs, possibly through the auspices of LGAT, to develop a pool or other 'insurance' option to be drawn upon to meet responses to extreme events when local capacity to pay is exceeded.

6 SUMMARIES OF REALITY CHECK INVESTIGATIONS

Summaries of the four reality check reports prepared during March to June are included in this chapter, as extracted from the executive summary, conclusions or recommendation of these reports. The four reports are:

- *Lauderdale Environmental Assets: assessment of climate change impact on coastal and marine areas*, Derwent Estuary Program
- *Investigation of Beach Protection Works*, Water Research Laboratory, University of New South Wales
- *Inundation Control Works for the Lauderdale Area,* pitt&sherry
- *Funding and Decision Making,* SGS Economics & Planning

All of these reports have been made available to Council and are recommended to be made available to the wider community.

6.1 Lauderdale Environmental Assets: assessment of climate change impact on coastal and marine areas, Derwent Estuary Program

The Local Government Authority of Tasmania (LGAT) engaged the Derwent Estuary Program (DEP) to contribute to the Tasmanian Coastal Adaptation Pathways (TCAP) project in the Lauderdale area through the following report which:

- Identified six major environmental asset types, which loosely conform to specific geographic coastal and marine areas.
    - Lauderdale & Roches sand dunes, threatened flora & fauna
    - Bambra Reef and Mays Point rocky shore: threatened seastars
    - Southern Lauderdale sub-tidal seagrass beds
    - Lauderdale and Roches Beaches and sub-tidal sand
    - Ralphs Bay tidal flats and foreshore
    - Lauderdale saltmarshes
- Described the ecosystem services the environmental assets provide.
- Discussed how the environmental assets will respond to climate change, most notably to sea-level rise, in the context of TCAP pathway scenario 3. Land areas of high importance for environmental asset transgression as sea-level rises, have been identified south of Lauderdale.
- Prioritised the environmental assets and action options required for their perpetuity.
- Identified legal obligations relating to the management of the environmental assets.

It is acknowledged that specific environmental assets, such as threatened shorebirds are dependant upon the presence and condition of larger environmental assets, such as tidal flats and saltmarsh.

The changes within environmental assets projected in this document should not be used to justify development of these sites in a manner that would otherwise expedite their loss and prevent their transformation into new asset types. Instead, management effort should be made to improve their condition and function, as they have important ecosystem services to continue providing.

Conclusions and major assets prioritised for action

This document identifies marine and coastal environmental assets that occur in the Lauderdale area. The assets have been grouped into six major types, which loosely conform to specific geographic areas (Table 3). It is acknowledged that specific assets (such as threatened species) occur nested within the major asset types. In the future some assets are projected to move (transgress inland), and as this occurs the major asset types will change at certain locations. The changes within specific asset types identified in this document should not be used to justify development of these sites that would otherwise expedite their loss and prevent their transformation into new natural asset types. Instead, management effort should be made to improve their condition and function, as they

have important ecosystem services to continue providing. The following conclusion includes a prioritisation of the major actions required for each of the major asset types and that are required to increase the assets resilience to climate change, enable transgression inland, or be relocated to new sites where they can continue to survive and provide ecosystem services. The prioritisation in this document is a first pass assessment, and is based upon urgency for action and likely loss of environmental assets if action not undertaken.

Lauderdale & Roches sand dunes, threatened flora & fauna

RISK

The Lauderdale dunes are eroding (~8m over the last 50 years) due to storm damage exacerbated by sea-level rise (Sharples, pers. comm., March 2012). Erosion of the Lauderdale dunes is causing the loss of threatened vegetation communities growing here, which consists of:

- *Eucalyptus viminalis* and *E. globulus* coastal forest and woodland (TASVEG: DVC vegetation community) and
- *Eucalyptus globulus* dry forest and woodland (TASVEG: DGL vegetation community).

Emergent *Eucalyptus* trees within the threatened vegetation growing on the dunes add greatly to the landscape character of Lauderdale and provide habitat for threatened species (e.g. Swift parrots). Emergent *Eucalyptus* trees on the dunes are at risk from coastal erosion, salt water ingress into their root zone, and removal for abatement of personal injury or property damage. The DVC vegetation community is only found in Tasmania, and is generally confined to sandy coastal areas that formed in the Holocene and Pleistocene, such as back-dunes, sand spits and tombolos (Harris and Kitchener 2005) and as such is at high risk from sea-level rise and coastal erosion throughout most of its range.

Sea-level rise will cause the saline groundwater table beneath the Lauderdale sand dunes to become shallower and closer to the root zone of threatened vegetation communities growing here and will cause loss of less salt tolerant vegetation and larger trees with deeper roots. This risk may be exacerbated once the sand dune aquifer experiences a decline in freshwater recharge due to Lauderdale domestic water being piped to a waste water treatment plant and no longer discharged via filtration trenches on individual properties.

ACTION - MODERATE PRIORITY

The management of the Lauderdale dunes and their supporting vegetation remnants are very much linked to the Lauderdale and Roches Beach foreshore protection options raised in TCAP Pathway Scenario 3. These measures will prolong the current position of the foreshore dune and supporting vegetation, thus this asset type has been given a moderate priority rating for immediate action.

The risk of a rising saline groundwater table beneath the Lauderdale sand dunes damaging threatened vegetation can be reduced through reuse of onsite grey water (which should be an option explored and residence encouraged to use) and the use of water sensitive urban design (WSUD) principles for stormwater management. WSUD is highly recommended, so as to enable freshwater infiltration to the sand dune aquifer, through the use of fully grassed swales and detention basins. Areas that lack curb and gutter should be retained in this fashion, and those areas already developed in this manner should have WSUD features retrofitted. The use of concrete inverts within the swales, to expedite stormwater conveyance, should also be avoided if possible.

Future revegetation - Roscommon or other sites

ACTION - MODERATE PRIORITY

In the future, beyond 2100, the survival of the vegetation on the Lauderdale dunes is doubtful. Revegetation efforts should be made soon at an appropriate alternate site to ensure the threatened vegetation communities and mature trees (for swift parrot use) are present in the future to offset habitat loss from the Lauderdale dunes. It has been acknowledged that nearby Roscommon may be unsuitable for DVC and DGL vegetation type re-establishment, due to differences in soil type; therefore, an alternate revegetation site may be required. Revegetation efforts at an alternate site; however, will not address a change in the character of Lauderdale, which would arise from the loss of the larger remnant Eucalyptus trees from the dunes.

Bambra Reef and Mays Point rocky shore: threatened seastars

RISK

The Bambra Reef and Mays Point rocky intertidal zone are habitat for two separate colonies of live-bearing seastars (Parvulastra vivipara), which are threatened Tasmanian endemic species, of which there are only eleven known colonies in existence. The seastars have little ability to disperse between reefs, as they do not travel across sand and do not disperse gametes or offspring by water. Poor dispersal and an inability to move away from rocky habitats, means that Bambra Reef and Mays Point are essentially isolated 'island-like' habitats for the live-bearing seastar colonies that may have resulted in genetic variation between colonies.

The Bambra Reef and Mays Point intertidal zone are low in profile and prone to temporary sediment burial, arising from the deposition of sand eroded from coastal dune and beaches during storm events, which could cause local extinction of the live-bearing seastar colonies at these sites. The loss of any given colony may result in loss of the genetic diversity within the species.

ACTION - HIGH PRIORITY

It has been deemed of high priority to retain these rocky habitats in good condition for the threatened seastars and to monitor the populations at both sites. It is of high importance to identify a trigger for management action, and determine appropriate management action steps if the colonies are at risk of localised extinction due to sediment burial. The effect of sand nourishment or groyne construction coastal works (proposed in TCAP Pathway Scenario 3) needs to assess altered risk level to threatened live-bearing seastars caused by altered sand deposition over these rocky habitats. The Bambra Reef and Mays Point areas also need to be managed so as to retain good water quality (avoid placement of stormwater outfalls near these sites), and prevent human disturbance (possible collection of threatened seastars).

Future seastar habitat location

ACTION - HIGH PRIORITY

It is a high priority that appropriate sites be identified for potential translocation of the threatened seastar (Parvulastra vivipara), through the movement of some individuals from Bambra Reef and Mays Point, for the establishment of insurance colonies. Translocation risks to the current colonies and also to the native fauna and flora at the potential translocations sites needs to be assessed. If the risk of sediment burial and loss of the colonies at Bambra Reef and Mays Points are high, such that a trigger for management action (translocation) now exists, this action should be deemed a very high priority. The regulatory aspects of site assessment and permitting for potential translocation of a threatened species have not been covered in this document.

Southern Lauderdale sub-tidal seagrass bed

RISK

A dense seagrass bed ~84, 000 m2 in area off the southern end of Lauderdale Beach provides spawning substrate and habitat for a number of marine species and assists in denitrification, nutrient processing and carbon capture. Seagrass extent has dramatically declined throughout south-eastern Tasmania since the 1970's (Rees 1994) and effort should be made to prevent further decline and promote seagrass recovery. The southern Lauderdale seagrass bed is likely to experience episodic sediment burial arising from the deposition of sand eroded from coastal dunes and beaches during storm events, or movement in a sediment lobe that forms off Mays Point due to long shore sediment transport. The resilience of the seagrass to episodic sediment burial will depend upon the condition of this habitat type.

ACTION - MODERATE PRIORITY

Management of the dense seagrass bed off the southern end of Lauderdale Beach should be aimed at increasing resilience against climate change related impacts (most likely episodic sediment burial events). The resilience of seagrass is increased by ensuring water quality is good (low nutrient loads to avoid excessive epiphytic algal growth that reduce seagrass photosynthesis). Good water quality can be retained through the use of water sensitive urban design principles for managing stormwater runoff from the adjacent urban areas. The resilience of seagrass is also improved by reducing physical disturbance that is associated with anchor or boat chain mooring drag. It may be appropriate to discourage anchoring or mooring at the southern end of Lauderdale Beach. If this area is popular for boat anchorage and fishing, it may be appropriate that 'seagrass friendly moorings' (or similar structures) be installed for community use, but it would be necessary to identify who would purchase and maintain such infrastructure. Increasing the resilience of the seagrass beds has been given a moderate priority in comparison to actions needed for the maintenance of other major environmental asset types in the Lauderdale area.

Lauderdale and Roches Beaches and sub-tidal sand

RISK

Management of Lauderdale Beach, so as to retain this feature into the near future, through coastal works has been raised as part of TCAP Pathway Scenario 3. The potential coastal works may have benefits for retaining the dune system and protecting associated foreshore vegetation (discussed in Section 6.1). However, some measures to maintain the beach (e.g. beach sand scraping from the intertidal zone to rebuild the fore-dune) may be deleterious to some sand fauna.

ACTION - LOW PRIORITY

Managing the Lauderdale or Roches Beaches for the benefit of the sand biota has been given a low priority, compared to action required for the perpetuity of the other major environmental asset types in the Lauderdale area.

The sand biota are not unique to Lauderdale or Roches Beaches and will still be well represented on beaches elsewhere that are left in a natural state and allowed to transgress inland with sea-level rise.

Ralphs Bay tidal flats and foreshore

RISK

The Lauderdale tidal flats are important habitat for wading shorebirds. The Derwent Estuary Pittwater Area (DEPA), which includes the Ralphs Bay tidal flats, provides habitat for at least eight migratory shorebird species (four are listed for protection under the *Environmental Protection and Biodiversity Conservation Act* 1999) and six resident shorebird species (Birds Tasmania records). The migratory species are listed under international agreements aimed at ensuring habitat protection for their survival, such as the *Japan–Australia Migratory Birds Agreement* (JAMBA) and *China–Australia Migratory Birds Agreement* (CAMBA). The Ralphs Bay tidal flats, relative to other DEPA tidal flats, appear to be of high importance to migratory Double-banded plover, Whimbrel and Grey-tailed tattler (Cardno 2009). The DEPA is internationally significant for resident Pied Oystercatchers, supporting some of the largest numbers of this species in Australia and the second-largest in mainland Tasmania (Lane 1987). At times up to 10% of the global population of Pied Oystercatchers can be observed foraging on the Ralphs Bay tidal flats (E. Woehler, pers. comm., March 2012). Another commonly observed resident shorebird at Ralphs Bay is the Red-capped plover (B.O.A.T. 1982). The northern extent of the Ralphs Bay tidal flat appears to be the favoured foraging area for many shorebirds, notably Pied Oystercatchers who also appear to have a preference for nesting on the adjacent foreshore where there is good connectivity for their flightless chicks between the nesting and tidal flat foraging areas (Harrison 2008; Aquenal 2008b).

Sea-level rise will cause a relative decline in the extent of the northern tidal flats and loss of the adjacent preferred nesting areas due to coastal squeeze and increased exposure to wind driven waves. Pied Osytercatchers breeding at the site will likely move to the less optimal Racecourse Flats saltmarsh, east of the South Arm Road causeway. This move is likely to result in a decline in breeding success of Pied Oystercatchers at Lauderdale because the chicks will be:

- raised in less preferred saltmarsh foraging areas,
- at increased risk of being hit by vehicles if they attempt to walk from nesting areas in the saltmarsh to foraging areas on the tidal flats west of the causeway, and are
- exposed to predators when left unattended by parent birds that fly away to forage on the tidal flats west of the causeway.

The Ralphs Bay tidal flats also contribute to denitrification and nutrient removal processes that improve nitrogen levels throughout the greater Ralphs Bay region. A net decline in the overall extent of the tidal flats by 2100 may cause a decline in denitrification within the region; however, establishment of seagrass (which assists denitrification) on sub-tidal areas that were formerly tidal flats may see this ecosystem service retained. There is currently a lack of sub-tidal seagrass in Ralphs Bay, although it was extensive here in the 1970s' (Rees 1994).

ACTION – VERY HIGH PRIORITY

Future development at Lauderdale should not reduce the existing tidal flat extent as this habitat is important for shorebirds and provides a range of important ecosystem services (e.g. nutrient removal). A very high priority action is the restoration of tidal flushing beneath the South Arm Road causeway to the tidal flats of East Marsh Lagoon. This will reduce eutrophication of the lagoon and improve the condition of this tidal habitat for foraging shorebirds that may increasingly nest in the Racecourse Flats saltmarsh. A management plan needs to be created for the Lauderdale Racecourse Flats and East Marsh Lagoon and funding sourced to improve the tidal flushing beneath the South Arm Road causeway. Restored tidal connectivity is required to enable the establishment of healthy tidal flat habitat east of the road, which can be more readily accessed by flightless shorebirds chicks for foraging. Breeding success is likely to increase amongst the shorebirds if they can nest in areas of saltmarsh that have direct connectivity to preferred tidal flat foraging areas.

It has been acknowledged that restoring tidal flushing to the Racecourse Flats area could potentially increase risks associated with the Lauderdale land fill (e.g., erosion at the base of the landfill slope and potential leachate release and mobilisation) and it is essential that these potential risks be investigated and managed. It is proposed here that partial tidal flushing be restored until the risk to the Lauderdale landfill can be assessed and mitigated (if required) prior to full tidal connectivity being restored (discussed in Section 6.6).

Attention is also needed to improve the condition of the existing Ralphs Bay tidal flats so as to encourage the return of seagrass here and on the adjacent shallow sub-tidal sediments. The value of encouraging seagrass re-establishment here would include:

- increase nutrient removal
- increase carbon storage,

- increase sediment capture, which may extend the longevity of current tidal flat position.
- In the past seagrass beds in Ralphs Bay provided breeding habitat for commercially important school shark (Aquenal 2008a). Return of seagrass to the bay may encourage school shark breeding here again.

Management of stormwater entering Ralphs Bay should be consistent with WSUD principles to reduce sediment and nutrient loads that may be harmful to seagrass, natural tidal flat sediment and biological processes.

Future tidal flat- Racecourse Flats & areas south of Lauderdale
ACTION – VERY HIGH PRIORITY
Restoring tidal flushing to Racecourse Flats beneath South Arm Road will assist the creation of healthy tidal flats adjoining the saltmarsh, and will provide foraging and nesting habitat connectivity beneficial to resident shorebirds that may increasingly nest here as sea-level rises and displaces them from current nesting areas adjacent to the northern Ralphs Bay tidal flats. Restoring tidal flushing beneath South Arm Road will enable tidal flat transgression over the Racecourse Flats saltmarsh, and areas south of Lauderdale, as sea-level rises. This is the most achievable direction for future tidal flat development consistent with TCAP Pathway Scenario 3; however, a long-term planning solution is required to enable tidal flat transgression to occur south of Lauderdale beyond 2100 (see Section 6.6).

Lauderdale saltmarshes
RISK
The Lauderdale saltmarsh is of regional significance within the DEPA, having the highest vegetation diversity across its profile from seaward to landward edge (Prahalad 2009). The regional significance of the Lauderdale saltmarsh will increase in the future, as there will be major saltmarsh loss from nearby areas such as Pittwater and Orielton by 2100 due to sea-level rise and coastal squeeze (Prahalad 2009). This will have a regional impact on shorebirds within the DEPA and other species that live in and use saltmarsh habitat. The future loss of saltmarsh from Pittwater emphasises the importance of encouraging saltmarsh retention and transgression at Lauderdale. Specific values of global and regional significance within the Lauderdale saltmarsh include:

- The saltmarsh looper moth (*Dasybela achroa*) listed as threatened (vulnerable) under the *Tasmanian Threatened Species Act 1995* (TSPA), may have its only extant population at Lauderdale. It is likely that this species is dependant upon the survival of the Lauderdale saltmarsh and that this saltmarsh needs to have connectivity with adjoining woody vegetation (e.g. Acacia) for development of its larvae.
- Two threatened (rare) plants species (listed under the TSPA) appear to be confined to saltmarsh areas, these are: narrowleaf blowngrass (*Lachnagrostis punicea ssp. filifolia*) and slender buttons (*Cotula vulgaris var. australasica*).
- Shorebirds roosting, nesting (when optimal sites elsewhere are unavailable) and foraging (typically when tidal flats are inundated or chick hatched in saltmarsh areas).

ACTION – VERY HIGH PRIORITY
Urgent action is required to prevent the current Lauderdale saltmarsh and associated natural values from declining in condition or being lost, due to inadequate tidal flushing. A management plan to improve the condition of these assets is required, and should support very high priority actions that:

- Improve current saltmarsh condition at Racecourse Flats by restoring tidal flushing.
- Improve condition and increase extent of fringing woody native vegetation (e.g. Acacia species) on the landward side of the saltmarsh, which is likely to be of critical important for larval development of threatened moth species that feed on the saltmarsh.
- Prevent landfilling of remaining saltmarsh, especially at Racecourse Flats and council land north of the Lauderdale canal.
- Reduce human disturbance of the saltmarsh. Review current user activities (e.g. motor bike and pushbike use, dog walking, horse riding, walking area). Prevent off- road vehicle use (through fencing, signage, changed user behaviour and use of the area, increase policing if some user activities are prohibited).
- Undertake weed management and reduce grazing (e.g. exclude rabbits).

A very high priority action is to restore tidal flushing beneath the South Arm Road causeway, which will improve the condition of the Racecourse Flats saltmarsh and tidal flats. Before full tidal reconnection is installed, only partial tidal-flushing should be allowed until the leachate risk from the former Lauderdale landfill is reassessed and mitigation measures in place (if required). Restoring tidal flushing to Racecourse Flats will require funding and the following action steps:

- Reassess the topography of the saltmarsh and surrounding land so inundation levels can be assessed in greater detail and used to decide upon an appropriate tidal flushing regime.

- Identify an appropriate initial partial tidal flushing regime, which poses little risk to the Lauderdale landfill (former tip) associated with leachate mobilisation and landfill erosion, and will improve tidal flat and saltmarsh habitats east of the South Arm Road causeway.
- Install partial tidal flushing measures
    - On ground work requires consent and cooperation from the Tasmanian Department of Infrastructure, Energy and Resources (DIER) (who manage and maintain the South Arm Road causeway) and Clarence Council (owners of Racecourse Flats).
    - A communication strategy is required prior to and during any on-ground work associated with installation of new pipe work beneath the South Arm Road causeway. East Marsh Lagoon currently becomes eutrophic and public complaints are regularly made about the smell of rotting organic mater here. Increased tidal flushing should reduce the risk of eutrophication; however, previous efforts to open existing pipes beneath the causeway have failed due to deliberate blocking of these pipes.
- Monitor habitat changes arising from partial flushing and risks to the Lauderdale landfill.
- Prepare site for full tidal flushing by installing mitigation measures (if required) to reduce risk associated with the Lauderdale landfill site.
    - Install measures to reduce risk from leachate mobilisation
        - prevent rainwater recharge and ground water into the landfill
        - create leachate treatment options if required
    - prevent wind-wave erosion of the Lauderdale landfill
    - Ensure appropriate drainage exists on the north-eastern side of Racecourse Flats, where the landfill site causes retention of surface water runoff.
- Gradually increase full tidal flushing to Racecourse Flats at a rate that enables natural asset adjustment.
    - A transition to full tidal flushing should also be accompanied by certainty that future saltmarsh will be able to transgress inland, south of Lauderdale. This will ensure that restoring full tidal flushing does not result in coastal squeeze and loss of the saltmarsh as an increasing area of the Racecourse Flats saltmarsh will become tidal flat habitat in the future.

Future saltmarsh - areas south of Lauderdale & north to Roscommon

RISK

It is of critical importance that areas be retained for saltmarsh transgression inland in the future. It is of very high importance for the saltmarsh vegetation to retain connectivity to tidal flats at their seaward edge (for shorebird use, nutrient cycling, and tidal flushing) and woody vegetation at their landward edge (for survival of threatened moth species). In the near future, to 2100, those areas south of the current Lauderdale saltmarsh will provide the only location where the habitat continuum (tidal flat - saltmarsh – woody vegetation) can be locally achieved. A long term habitat refugia, linking up with existing wetlands between Lauderdale and Pipeclay Lagoon, can provide a long term future transgression pathway option for saltmarsh and associated environmental assets. Land use planning or other land management strategies (e.g. such as acquisition or covernancy), will need to enable saltmarsh transgression south of Lauderdale, otherwise the saltmarsh, tidal flats and their associated environmental assets will be lost as sea-level rises and these habitats become squeezed against areas:

- where infrastructure or property is protected against inundation,
- inappropriate land use (e.g. stock grazing and vehicle use), and areas of
- naturally steep topography.

The area of Roscommon, to the north, can also support saltmarsh development in the future. However, the habitat here will not have connectivity to tidal flats, due to suitable areas being occupied by infrastructure that is likely to be protected from inundation (consistent with TCAP Pathway Scenario 3). Some existing areas of saltmarsh north of the Lauderdale canal, could provide a pathway for tidal flushing and connection to Roscommon, but are currently being landfilled. Drainage needs to be designed between areas of this landfill so as to enable tidal connectivity to Roscommon in the future and the landfilling activities occurring here also need to be consistent with the Tasmanian Acid Sulphate Soil Guidelines. Beyond 2100, saltmarsh may develop at Roscommon, but this would then be at risk of being lost if inundation levels exceed the Lauderdale and Roches beaches sand dune height, and then expose the saltmarsh to wave activity and erosion. Roscommon may not provide as a secure long term saltmarsh habitat refugia compared to the areas south of Lauderdale.

Currently the Clarence Planning Scheme 2007 mapping overlays and planning codes enable development to proceed within the sensitive coastal habitat areas needed for saltmarsh transgression south of Lauderdale in the near (2100) and long term future. There is a high risk of the loss of the Lauderdale saltmarsh beyond 2100 unless the is appropriate inclusion of the need for transgression areas withinland use planning

ACTION – VERY HIGH PRIORITY

It is of critical importance that the Clarence Planning Scheme accommodates planning map overlays and planning codes that enable the transgression of natural coastal habitats and processes into the long term future at sites such as southern Lauderdale. It is a very high priority that local planning measures be put in place for important areas needed for the transgression of saltmarsh in the near (2100) and long term future at Lauderdale.

Future Clarence planning schemes amendments are required to accord with the following Southern Tasmanian Regional Land Use Strategy (STCA 2011) regional policy:

> *C 2 Ensure use and development in coastal areas is responsive to effects of climate change including sea level rise, coastal inundation and shoreline recession*
>
> > *C 2.3 Identify and protect areas that are likely to provide for the landward retreat of coastal habitats at risk from predicted sea-level rise.*

Areas available for saltmarsh transgression to 2100 have been identified throughout much of southern Tasmania and the Lauderdale area (Prahalad 2009; Prahalad et al. 2009; Whitehead 2011; Prahalad and Pearson, in prep), and a long term (post 2100) saltmarsh refugia corridor has been identified south of Lauderdale (Whitehead 2011); however, relevant planning map overlays and planning codes do not currently address this issue in the Clarence Planning Scheme. To assist development of appropriate planning measures, in 2011 the Derwent Estuary Program created a discussion paper presented to the Tasmanian Planning Commission, Southern Tasmanian Council Authority and local councils bordering the Derwent (Whitehead 2011). The paper recommended uptake of a mapping overlay for planning, called the 'natural coastal processes overlay', and the development of appropriate planning codes that would apply to areas identified as important for current saltmarsh and future saltmarsh transgression as sea-level rises. The overlay was created with principals similar to TCAP Pathway Scenario 3, allowing for protection of existing infrastructure from inundation, and included recognition and discussion of planning codes that could apply to three different land categories of importance to saltmarsh, which are:

1) Current sensitive coastal habitat (notably current tidal wetlands complex and saltmarsh extent).
2) Near future (2100) sensitive coastal habitat (notably 2100 saltmarsh extent, but excluded areas where infrastructure currently exists).
3) Long term refugia corridors for saltmarsh.

The overlay areas could be flexible, so as to enable the land categories to be moved landward as sea-level rises, or adjusted as future sea-level and storm surge projections improve. Different planning codes could apply to the different land categories, but to enable development of such codes there needs to be discussion about land use in the near future (2100) and long term refugia corridors, which should identify:

- The achievable balance between natural and built assets.
- What development is allowed in future sensitive areas required for coastal habitat transgression. If development is allowed:
    - what triggers or timeframes could be a condition of development approval within the planning codes that decide when planned retreat of infrastructure and site restoration occurs?
    - how will future planned infrastructure retreat and site restoration be funded?

The DEP, with the help of others, are exploring some of the following options to improve protection and management of our sensitive coastal habitats into the future:

- Improved public knowledge as to the value of saltmarshes
- An application for inclusion of the Succulent saline herbland (ASS), vegetation type as a threatened community type covered under the Nature Conservation Act 2002.
- Options for private land conservation covenants, through the DPIPWE Protected Areas on Private Land Program (PAPL) and the Tasmanian Land Conservancy.
- Explore options for purchasing critically important areas that are currently in private ownership.

It is a very high priority that a clear state policy is needed that leads to the creation of land use planning measures that will enable landward transgression of natural coastal habitats and processes.

6.2 Investigation of Beach Protection Works, Water Research Laboratory, University of New South Wales

Summary of study requirements

WRL were commissioned by LGAT to investigate the option of beach nourishment, potentially supplemented by artificial reefs or groynes, at Roches Beach. This task forms part of the Tasmanian Coastal Adaptation Pathways project, to develop future pathways for climate change adaptation in four coastal areas in Tasmania. The study has been undertaken in two parts. Part 1 involved the assessment of beach nourishment as a quick and safe strategy to alleviate present coastal hazards as well as mitigate ongoing beach recession due to sea level rise. In particular, the focus of Part 1 of the investigation was to assess the required beach nourishment volumes for protection against:

- A 100 year ARI erosion event at present;
- A 100 year ARI erosion event over the next 10 years; and
- A 100 year ARI erosion event over the next 20 years.

As well as estimating the required nourishment volumes, Part 1 of the study also involved consideration of nourishment sand sources, costs, implementation, environmental issues and social issues. Part 2 of the study involved a less detailed assessment of risks, costs and benefits of reef and groyne structures as a backup or to supplement beach nourishment.

Conclusions for Part 1: Beach Nourishment

Using empirical assessment techniques, it has been determined that 75,3000 m3 of sand with the same characteristics as the native sand would be required currently to provide protection from a 100 year ARI event at Roches Beach. A additional 119,800 m3 would be required for protection until 2022 and 100,200 m3 would be required on top of that to provide protection until 2032. However, the exact compatibility of available nourishment sand with native sand at the beach has a significant impact on the nourishment volumes required for specific sand sources. Two likely sand supplies are available for nourishment of Roches Beach:

- Offshore sand deposits
- Terrestrial sand quarries

Aquenal (2010) highlight an approximately 425,000 m3 reserve of sand offshore of Roches Beach as potentially suitable for sand harvesting. This volume was determined within a range of constraints including a limiting sand pumping distance of 600 m from shore. With alternative dredging equipment, line pumping of sand is possible up to distances significantly further than 600 m, and therefore the volume of sand available is likely to be much greater than this volume.

Based on the grain size distribution of sand located offshore of Roches Beach, significantly greater volumes of nourishment sand would be required due to the finer nature of the sand compared to the native sand at the beach. WRL consulted RNB Trading as a possible supplier of terrestrial sand for nourishment of Roches Beach. RNB Trading extract sand from a quarry at the back of Seven Mile Beach, and have supplied sand to individual household owners as well as Council for the purpose of beach nourishment at Roches Beach. While this terrestrial source of snad is more compatible with the native sand at Roches Beach, it is still slightly finer and therefore larger quantities are required to achieve an equivalent level of erosion protection.

The required volumes and estimated costs for nourishment using offshore and terrestrial sand sources are summarised in the table below for 100 year ARI protection in present day, 2022 and 2032 scenarios.

	Offshore Sand		Terrestrial Sand	
Scenario	Required Volume (m3)	Estimated Cost ($)	Required Volume (m3)	Estimated Cost ($)
Present day	320,300	5,483,000	214,700	7,703,000
2022	726,500	11,737,000	355,300	12,509,000
2032	857,600	13,778,000	450,600	15,765,000

Aquenal (2010b) profiled the macrofauna characteristics of the intertidal zone of Roches Beach and provided recommendations as to possible implementation and monitoring strategies for a beach scraping program. It was identified that Roches Beach had a high number of individual creatures but a low number of different species, which was typical of other south-eastern Australian beaches. In general the study focused on the concept of removing sand from the intertidal zone for dune building, and as a result the conclusions are only directly applicable to that

situation. The case of mass scale beach nourishment and subsequent effects of burial of existing creatures was not specifically considered. The risk of introducing different species to the beach trough supply of non-native sand was also not considered. As a result the expected effect of large scale beach nourishment on the subaerial beach macrofauna communities remains unknown.

Aquenal (2010) show the majority of active profile offshore of the main section of Roches Beach is sand with very sparse seagrass. However, a region of more dense seagrass (some sparse, some dense) can be found in the southern section of the beach. This area may be more affected than others by placement of the nourishment sand. The other place in the Roches Beach region that may be adversely affected is Bambra Reef. Whilst direct nourishment of Bambra Reef should be avoided, it is likely some sediment will be transferred through littoral drift processes to the reef. If this sediment volume is grater and/o very different to the sand naturally passing through the area there may be impacts on the ecological habitat, including complete habitat destruction if the reef is buried. Given the environmental significance of Bambra Reef (being one of only 11 known colonies of the threatened seastar *Patiriella vivipara*), this risk should be considered with caution in future planning for the implementation of beach nourishment.

The primary biological effect of dredging to obtain beach nourishment material is removing the benthic vegetation and creatures present on the sediments. Dredging can also increase turbidity in the borrow area. While dredging operations have also been known to damage reef habitats in areas adjacent to the borrow area, with adequate buffer zones as recommended by Aquenal (2010) and the use of accurate positioning systems this should be avoided. If nourishment sand is to be sourced by dredging offshore, of the beach, it is recommended that the dredging pattern be designed to minimise wave refraction effects. This would require numerical SWAN wave modelling, or at least alignment of post dredging contours with the dominant wave crest alignment at the site.

If borrow sand for nourishment is to be obtained by dredging offshore of Roches Beach, it is recommended that more detailed sediment sampling be undertaken of both the borrow material and the native sand on the beach. Small changes in the compatibility of the material result in large changes to the required nourishment volumes, and the analysis undertaken by Aquenal (2010) indicated that the sand improved in compatibility with increasing distance offshore. It may also be worthwhile to undertake nourishment in smaller stages with monitoring in between to allow for refined predictions of performance.

Conclusions for Part 2: Supplementary Structural Protection

In general there are three types of structure that are typically considered for supplementing beach nourishment:

- Emergent detached breakwater/s
- Submerged artificial reef/s (multi-purpose reef or submerged breakwater)
- Groynes

Due to the sheltered nature of Roches Beach, the additional expense associated with creating a reef with multi-purpose criteria, and the relatively small amount of increased amenity predicted to be gained, it is recommended that any submerged reef structure built at Roches Beach be a submerged breakwater designed specifically for coastal protection. On this basis, this study has focused on the use of groynes or submerged breakwaters to supplement beach nourishment.

Sand loss due to underlying recession (partially from littoral drift) are expected to be approximately one quarter of the overall sand recession rate, with the other three quarters of the total loss due to the projected sea level rise. From this is can be postulated that supplement nourishment with groynes or submerged reefs could at best reduce the recession rate of nourishment sand by about one quarter. The effectiveness of submerged reefs at retaining sand would also decrease as sea levels rise due to the increase in reef submergence. Previous experience has shown that small increases in reef submergence result in significant decrease in the amount of protection offered.

While the risk of groynes not providing an increase in the effectiveness of nourishment is low and the costs of groyne structures are predicted to be relatively small (~600,000) compared to the overall cost of beach nourishment, te benefits to be gained are also small. Submerged breakwater structures would result in less visual impact on the beach compared to groynes, however, the costs of these structures ($4 million to $6 million) are expected to be similar to the beach nourishment itself. This combined with the risk to public and complexities with design of submerged structures indicates that supplementing nourishment with submerged structures is unlikely to be cost effective and higher risk than with groyne structures. The use of structureal solutions to improve the longevity of beach nourishment may be best implemented through a combination of groyne/s and emergent detached breakwater structures. The use of emergent detached breakwaters may reduce the number of groyne structures required, thereby minimising the effects to the useability of the beach. This would also reduce the longshore extent of relatively expensive offshore reef/breakwater structures.

Risks to Seven Mile Beach as a result of building groyne or artificial reef structures at Roches Beach would be minimal, as the structures would take insignificant quantities of sand from the natural littoral drift (the beach nourishment would pre-fill the profile and littoral drift bypassing the structures would occur). There is also natural sand bypassing of the southern half of the Roches Beach embayment which would further reduce this risk.

6.3 Inundation Control Works for the Lauderdale Area pitt&sherry

The scope of work undertaken by **pitt&sherry** is to prepare a hydrological model of the two broader catchments draining to the north of the Lauderdale canal, and use this model to investigate the following:

- The impact of proposed developments under the Lauderdale Structure Plan
- The effects of sea level rise due to climate change
- Investigation of possible improvements to protect infrastructure from inundation
- Development of a concept drainage plan including stage filling requirements to minimise hazards and adverse effects for the future.

It should be noted that the land to the south of the canal has not been included in the model. Results from the modelling of the region to the north of the canal should give an indication of conditions in the southern region, however should developments be proposed in this region or further information required, additional investigation of this should be considered.

Detailed design of proposed works, the impact of erosion and sea water ingress from the western flank at Roches Beach and land tenure issues have all been excluded from this scope of works.

Recommendations - Flood Mitigation Strategy

It is recommended that the level of South Arm Road (including the bridge over the canal) be kept at least 2m above the current mean sea level to provide benefits of flood protection and reasonable security of access, and to help minimise the amount of water entering the lower detention basin from the canal and Ralphs Bay. In addition to this, it is recommended that flood gates be installed at the mouth of the canal, and North and South Terrace elevated above the expected water level in the canal. Upgrades of drainage and the installation of non return valves on pipe culverts will also be required in conjunction with these works.

The elevation of South Arm Road will act as a levee bank to prevent inundation of the land behind it, therefore the road shall be designed for preventing the overtopping of the 100 year ARI event. Roads deteriorate with age, therefore as the road is to be raised to provide protection from inundation, the time horizon selected for protection should be similar to the life span of the road. In addition to this, the longer term projections of sea level rise are likely to be less accurate than shorter term projections. When sea level rise puts the security of a road at risk again, further raising of the road would be required.

South Arm Road would need to be raised to achieve a road height suitable to protect the region from the sea levels. To raise the road to 3.2m AHD to offer protection from sea levels approximately 0.9m higher than the current sea levels (that may occur in about 2100), approximately 2.8km of South Arm Road would require elevation. This full length may not need to be raised for flood protection, but would be desirable for certainty of access to South Arm.

The initial concept proposes to raise the level of the roadway pavement to a level of 2.6 m AHD, with a 1:5 batter slope starting at the northern edge of the existing roadway and moving the alignment of the roadway slightly away from the Ralph's Bay foreshore. This level would be increased in the future to 3.2m AHD to offer protection from the predicted 0.9m increase in height that may occur in or around 2100. These levels, and the costings provided would require confirmation at the concept design stage of the works.

Raising the road should be located on the land side with no encroachment into Ralphs Bay. For the purpose of understanding the financial implications of the required works, a cost estimate has been prepared.

Assuming that the sea level will rise, the road embankment would need to be constructed of a material that will not deteriorate when saturated. There appears to be two options, rock or confined sand. Both of these materials would provide a strong sub grade. A relatively thin (350mm) pavement has to be allowed above the design water level. Although the WRL report does not consider wave run up for this location, during extreme high water level events and/or storm events waves are expected to impact the roadway embankment slope. It is likely that the embankment

would suffer erosion and damage if it is not properly armoured, therefore an allowance for embankment protection works is required.

It is considered that installation of a clay core to prevent underground drainage from Ralphs Bay into the detention basin would not be a cost effective solution as it would be unlikely to provide significant benefits in levels due to the short time frame of extremely high tides. It would likely have construction difficulties associated with its installation. The installation of a tide gate adjacent to the bridge is recommended to ensure water levels in the canal do not endanger adjacent houses. In conjunction with this, North and South Terrace should be elevated to 2.0m AHD. When this work is undertaken, it is recommended that improved drainage be installed under South Arm Road and North Terrace to help drain the lower detention basin. Culverts to the canal and Ralphs Bay should be fitted with non return flaps. Design of these improvements to the under road drainage system should be considered upon the full design of the road level increases.

It should be noted that the sea level rise projections, subsequent design options and cost estimates have been undertaken on preliminary information only and as such more detailed modelling will provide greater certainty. Importantly, a more detailed understanding of the levels of the existing South Arm Road would provide an indication of the specific sections of the 2.8 km road that are currently affected by sea level rise and inundation, or are to be threatened in the future.

Recommendations - Structure Plan

It is recommended that no development be allowed in elevations lower than 0.75m within the lower detention basin, to ensure adequate connectivity and capacity of the basin is maintained.

It is also recommended that proposed developments in those regions not covered in the Structure Plan be carefully considered on a case by case basis, that the protection of overland flow paths be ensured and impact on upstream and downstream properties assessed. Any development that requires filling to raise floor levels needs to make appropriate provision for low level overland flow paths to be maintained. It is recommended that Council require developers to make allowance for this in preparing the development proposals.

It is recommended that further investigation be undertaken to recommend a suitable fill material for use in the filling plan. The geotechnical report prepared by W C Cromer Pty Ltd on this region suggests that the underlying geology of the area is sand over clayey sand, silt and clay, thus is it believed that fill of a similar composition to the natural ground would be suitable for this application, although this is not expected to make any significant difference to peak storm events.

In the Tasmanian Acid Sulfate Soil Management Guidelines, it recommends an assessment if over 500 m3 of fill is proposed in an area with actual acid sulphate soils (ASS) or potential acid sulphate soils (PASS). The concern is that changes to the water table may affect exposure of ASS soils to flushing and acid release into the environment. This part of Lauderdale is identified as having a high risk of containing PASS conditions as outlined here: http://www.thelist.tas.gov.au/listmap/listmap.jsp?cookieteststate=check&llx=507800.0&lly=5238420.0&urx=544000.0&ury=5261900.0&layers=268

Consideration of this should be undertaken at the detailed design stage.

Recommendations - Drainage Plan

To ensure adequate drainage, it is critical that the easements recommended for drainage of the northern and southern catchment areas into the lower detention basin are kept free from development.

An easement of 25m wide should be maintained along the northern overflow route from the Roscommon Wetlands to the lower detention basin.

The JMG report recommended swales at the front and back of all properties on the Structures Plan with these swales connecting into the existing drainage channels. It is recommended that this plan be upheld. It is assumed that Mannata Road will be raised prior to development of this region, thus is it recommended that provision of overland flow paths be allowed for at this stage to minimise the risk of overland flows disturbing adjacent properties during construction and development.

The design of these channels and drainage systems should be undertaken at the detailed design stage.

It is also recommended that any future developments not outlined in the Structure Plan be required to consider the impact of filling on the natural drainage paths, and possible consequences on other properties in the vicinity of the development.

Council should consider the land tenure requirements for the provision of future drainage paths from the lower detention basin. This may require the purchase of land fronting either or both of North Terrace or South Arm Road.

To mitigate against the effects of rising sea levels preventing stormwater escaping from the lower detention basin, a large stormwater pump station would be required to supplement the gravity system at times of very high tides. A notional assessment has shown that a pump station in the order of 0.3m3/s capacity (subject to further detailed design) would be required to keep water levels in the lower detention basin consistent with pre sea level rise scenarios. This station would require generator backup and duty and standby pumps to ensure the system is operational when required. It would not be required if houses in the area were progressively raised to 3.2m floor level.

Conclusion

Analysis of the region to the north of the Lauderdale canal has determined that there are significant issues with the current drainage network which are expected to be made worse in the future by projected sea level rise.

Analysis of this catchment suggests that the tide level is the critical factor when assessing the flooding levels within the lower basin. As sea levels rise the frequency, duration and severity of flooding events are expected to increase.

It is recommended that the level of South Arm Road, be increased to 3.2m AHD, to improve access to the area under high tides and help to minimise the amount of water entering the lower detention basin from the canal and Ralphs Bay. In addition to this, North and South Terrace should be elevated to 2.0m AHD, and flood gates installed upstream of the bridge on South Arm Road.

In addition to these works, the installation of a stormwater pump station may be required to mitigate against the increase in levels in the detention basin due to the increasing high tide levels. This would reduce both frequency and severity of flood levels for existing residences.

It is recommended that any developments proposed in the low lying area between Mannata Street and the existing houses along North Terrace be carefully considered on a case by case basis to ensure filling does not have a detrimental impact on properties up or downstream of the proposed development.

6.4 Funding and Decision Making – SGS Economics & Planning

Workshops and consultation have been undertaken with the Lauderdale community to explore possible pathways for adapting to the potential hazards and risks associated with future climate change and sea level rise, as part of the Tasmanian Coastal Adaptation Pathways study. From this a preferred pathway was identified by the community based on broad consideration of the options and their implications for the Lauderdale community.

There are two guiding principles in relation to coastal adaptation:

- Developing risk will be actively managed
- People cannot be subsidised to occupy or use hazardous locations.

The community expressed a desire to better understand the options available for determining and raising contributions towards the costs of coastal adaptation works and what would be a preferred equitable model. Participants generally agreed that contributing to the cost was acceptable as long as the contributions reflected the benefit gained and recognised that many benefits were gained by residents well beyond Lauderdale. The community was also concerned that there needed to be a consistent approach to any adaptation action by all stakeholders.

The aim of this report is twofold:

- To determine the available mechanisms for charging for contributions to coastal hazard adaptation and risk management. Propose possible formulae for the allocation of costs between beneficiaries to allow them to be tested with the public.
- To explore decision making and governance models to implement coastal strategies with a wide range of stakeholders. In the short term there is a need to consult relevant stakeholders and reach a common approach to adaptation.

Funding of Coastal Adaptation

Local government authorities currently tend to respond to present day risks by undertaking protection works, funding these from general resources. With climate change, the risks of using and occupying certain coastal areas will increase over time. More areas in Australia will become subject to some level of increased risk due to climate change. The costs of managing these increasing risks will increase over time– all other things being equal.

If risk management costs continue to be borne by the wider community, and people continue to choose to live in these areas, the cost will eventually becoming financially unsustainable. If the people benefiting bear the costs of managing risks to acceptable levels, they are more likely to make choices that balance those costs against the level of benefits they receive from occupying an area.

In short, it would be poor public policy in the long term to (continue to) subsidise people to locate in areas of known developing risk. A transition process is required to allow existing owners to re-evaluate their choices and to suffer minimal losses from the changing conditions.

Coastal adaptation is meant to allow the continued enjoyment and use of coastal areas by various users including residents, property owners, visitors and tourists, while developing coastal risks are being managed.

Depending on the pathway adopted, in broad terms a coastal adaptation strategy may seek:

- to allow nature to take its course (retreat),
- to protect coastal communities as long as practical while protecting natural values and allowing natural processes to unfold
- to protect existing and to permit future development for as long as possible (while retaining some key amenity values), or
- to protect existing and to permit future development if necessary with significant modification to the environment.

In broad terms, there is a trade-off between the level of protection provided and the level to which amenity and natural values are retained. Residents and property owners in the hazard areas have a strong interest in protection. The wider community has an interest in the natural values for their intrinsic and environmental services value. To the extent that these have some element of tradeoff, this creates some tension in the two objectives.

Coastal adaptation can provide two 'services':

- actively manage the developing coastal risks
- continued use of coastal areas and its amenity and natural values

An equitable approach would require those who benefit the most to also contribute the most to coastal adaptation works. This will vary greatly with the pathway that is adopted and the type of works. Works on natural areas would benefit the wider community. Raising roads would benefit everyone who uses the infrastructure, mostly residents and visitors. Works to address risk of inundation benefit mostly those who live in the inundation hazard zone, particularly if the properties are vulnerable to flooding (low floor level, type of construction). The main beneficiaries of erosion works are those directly exposed to erosion (waterfront) and the level of wider benefits also depends on whether beaches are nourished or a sea wall is erected.

The first pathway explored would generate the greatest benefits to the wider community with beaches and natural areas being allowed to migrate landward. At the other end of the spectrum the pathway that aims to protect and intensify development 'at all cost' may sacrifice coastal amenities, such as beaches and saltmarshes to protect properties for instance with the use of sea walls.

Towards a fair way of apportioning of contributions

Four ways were explored to apportion costs of coastal adaptation to users or beneficiaries. These were on the basis of:

- **The costs to provide the works**, where property owners contribute proportionate on the basis of coastal length of property (in case of erosion), on the basis of flood prone area (inundation) or on the basis of road access (raising roads). For 'collective works' there may be significant debate around the 'free rider' issues where those who also benefit (indirectly) are not required to contribute;
- **The value contribution of coastal benefits to the overall property value**. Coastal property values often carry in them premiums due to their 'beach frontage' or close proximity to the beach. Contributions would be raised according to the coastal benefit of 'being coastal'. Charging the contributions in hazard zones only would improve the equity of this arrangement;
- **The total property value**, where all properties in a suburb would be charged in proportion to the total property value. This option is in principle not equitable, because it is not directly related the level of risk that each property is exposed to. Charging the contributions in hazard zones only would improve the equity of the arrangement;
- **The expected cost of damage**. Where properties would be charged relative to the avoided risk for the property. It is an equitable approach but complex to administer (requires significant data collection).

The recommended direction would be to charge contributions on the basis of the property value (for properties in an identified hazard zone) which provides a reasonable link between contribution and benefit, is easy to implement and provides an incentive for efficient adaptation.

Wider community benefits of coastal adaptation should be raised at the appropriate level (local, state or national level). For example, the causeway to South Arm is the only access road for residents of the South Arm peninsula to the remainder of Tasmania. Costs for adaptation works involving South Arm Rd would logically require significant contributions from South Arm residents as well as the wider community that may visit the area.

An important issue in relation to the funding of coastal adaptation is the ability of property owners and residents in Lauderdale to contribute. Households with limited ability to contribute, and who did not knowingly buy into an area subject to increasing coastal hazards, may receive a waiver or concession to the full contribution, as part of a transition process (future residents would know they are buying into a hazard area).

Also, when introducing coastal adaptation charges, property owners need to know upfront how high the contributions will be and how often they will be charged.

The most common funding mechanisms for public infrastructure, goods and services in Tasmania are:

- General rates and land taxes
- Varying general rates
- Service rates and charges
- Separate rates and charges
- Development contributions and
- Grants, donations and sponsorship

Rates are related to property values and provide no direct obligation to deliver services in return for payment. Charges are user pays fees for service and are related to the services provided. Separate rates and charges require community consultation and set conditions for duration and review of the contributions. The Local Government Act 1993 also requires that separate rates and charges are refunded if not used or the service is not provided. For

coastal adaptation management financial buffers may be required to be able to respond to unpredictable events. Separate rates and charges are suitable to cover specific projects and works for which the timing and costs are known upfront.

To fund coastal adaptation works it is recommended to:

- Use **general rates and land taxes and where possible grants, donations and sponsorships** to cover the wider community benefits of coastal adaptation
- Use **special charges and where possible separate charges** to raise contributions for properties in identified hazard areas on the basis of the total property value
- Use **development contributions** for new development to support coastal adaptation works, by setting conditions for development approval. These conditions should be incorporated in the planning scheme.

Decision Making in Coastal Adaptation

Neither council nor the Crown has a legal obligation to protect private property from coastal risks. As it stands, Council has no clear statutory obligation to protect established private property that becomes at risk from changed conditions, provided the original approval for development was consistent with the then prevailing Planning Scheme and that the Scheme was prepared with due regard to the known circumstances at that time.

Some of the key issues in Lauderdale and that will likely apply to other coastal areas as well, are:

- Need for coordination between diverse landowners and managers;
- The need to assess the consequences of any interventions to ensure that there are not adverse effects on wider community interests such as the environment or property assets in adjacent areas;
- Uncertainty of the pace of sea level rise, the occurrence of extreme events and therefore of works and funds required.
- Concern by Council about exposure to liability for adaptation and protection works, even where done in good faith and due care, under current legislative arrangements.

The coastal adaptation strategy of one property owner may have significant adverse impacts on other land users. Also, collective works are mostly more cost effective. Therefore, there is a need for a common strategy across the range of land owners and stakeholders for delivering effective coastal adaptation in an area.

Key stakeholders, both landowners and those expected to contribute to the costs of coastal adaptation need to have a say in the formulation of a coastal adaptation strategy.

In short, there is a need for:

- a common adaptation strategy, which requires stakeholders to have a say
- an agreed and authorised body to implement the strategy
- robust financial management to deal with the results of unpredictable events and costs

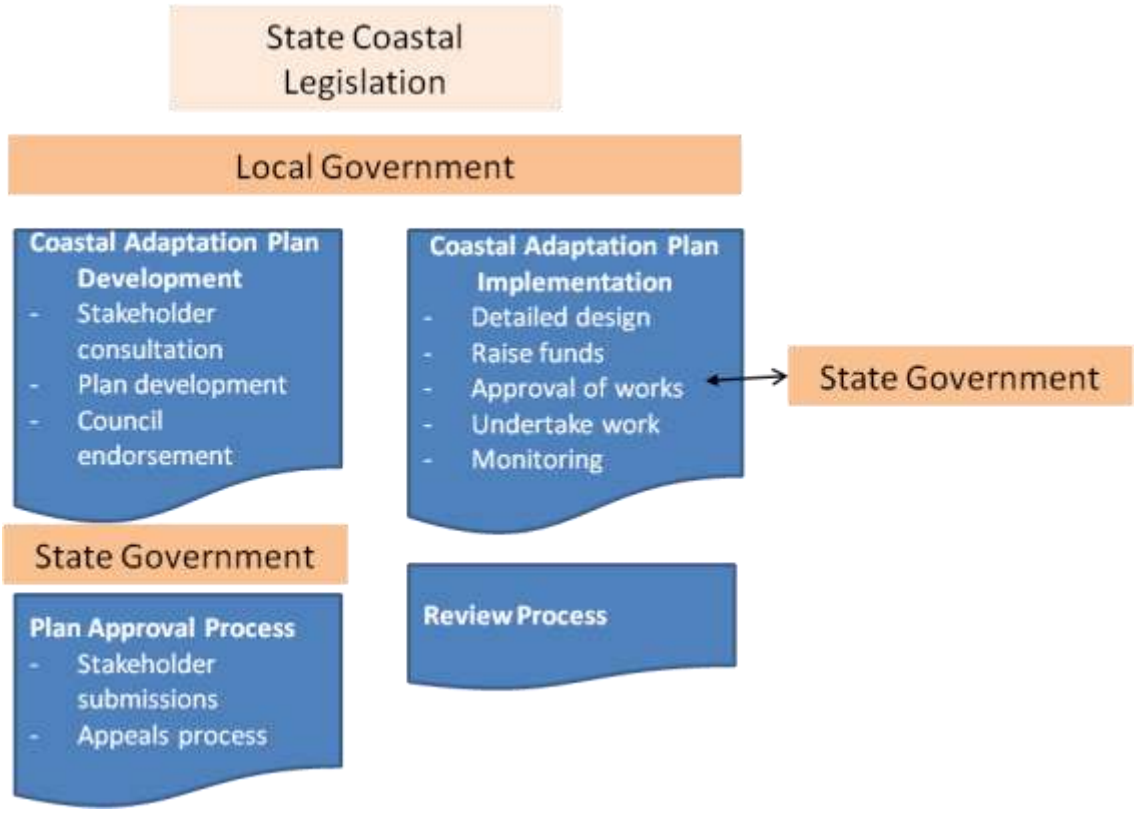
It is proposed that the coastal adaptation plan (CAP) would be developed in a process that has parallels with local planning schemes. It would be developed by the Council with review from the stakeholders identified above. While it would have some things in common in process, it would differ significantly in that it involves taking action, not just the regulation of activity by others. It would need an identified funding base and specified performance criteria to ensure that it is carried out in accordance with the agreement among stakeholders and contributors of funds.

The CAP would actively complement the planning scheme. Where aspects of the CAP are effectively addressed by planning provisions, amendments to the planning scheme would be made as part of the response to the CAP. In other instances, the CAP may propose specific works or development and this would need to be kept consistent with the scheme provisions.

The CAP would specify the area to which it applies, the objectives, the responsibilities and the actions to be taken, the expected budget, the funding arrangements and approvals processes for specific works. It is expected that a plan should articulate a long term pathway, but that the actions would be specified for a period of up to 20 years, with a ten year review.

The recommended model is illustrated in the chart below.

FIGURE 3 RECOMMENDED DECISION MAKING AND IMPLEMENTATION MODEL



References

Aquenal (2010) *Roches and Cremorne Beaches – Habitat Mapping Bathymetry and Sediment Analysis. Clarence City Council Dune Nourishment* Report for Clarence City Council

Aquenal (2010) *Biological Characterisation of Macrofauna at Roche Beach and Cremorne Beach, Tasmania,* Report for Clarence City Council

Blacka MJ, Davey EK, Carley JT (June 2012) *Investigation of Roches Beach Protection Works*, WRL Technical Report 2012/09

Carley JT, Blacka MJ, Timms WA, Andersen MS, Mariani A, Rayner DS, McArthur J, and Cox RJ (2008) *Coastal Processes, Coastal Hazards, Climate Change and Adaptive Responses for Preparation of a Coastal Management Strategy for Clarence City, Tasmania* WRL Technical Report 2009/04, 138 p

JMG (February 2012) *Lauderdale Stormwater Drainage Assessment*, for Clarence City Council

Shand TD, and Carley JT (2009) *Dune Building Using Beach Scraping at Cremorne Ocean Beach and Roches Beach, Clarence city, Tasmania I* Report for Clarence City Council, WRL Technical Report 2009/31, 88 p

Shand TD, Carley JT and Wasko CD (2011) *Roches Beach Hazard Line Reassessment, Clarence City, Tasmania* Report for Clarence City Council, WRL Technical Report 2011/05, 34 p

Shand TD, and Carley JT (2011) *Investigation of a Trial Groyne Structure for Roches Beach,* Report for Clarence City Council, WRL Technical Report 2011/06, 45 p

Sharples C (2007) *Shoreline Change at Roches Beach 1957-2006, South Eastern Tasmania* A report to the Antarctic, Climate and Ecosystems Cooperative Research Centre, Tasmania 2007

www.sgsep.com.au

Contact us

BRISBANE

PO Box 117
Level 1, 76 McLachlan Street
Fortitude Valley QLD 4006

+61 7 3124 9026
sgsqld@sgsep.com.au

CANBERRA

Level 1, 55 Woolley Street
Dickson ACT 2602

+61 2 6262 7603
sgsact@sgsep.com.au

HOBART

Unit 2, 5 King Street
Bellerive TAS 7018

+61 (0)439 941 934
sgstas@sgsep.com.au

MELBOURNE

Level 5, 171 La Trobe Street
Melbourne VIC 3000

+61 3 8616 0331
sgsvic@sgsep.com.au

SYDNEY

Suite 12, 50 Reservoir Street
Surry Hills NSW 2010

+61 2 8307 0121
sgsnsw@sgsep.com.au

SGS Economics & Planning