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This submission was prepared by Clive Attwater, a Director of SGS Economics & Planning. SGS have been working on a project to assess the impacts of climate change on coastal areas in Clarence City Council area in Tasmania. The work was co-funded by the Department of Climate Change and the Tasmanian State Emergency Services (Tasmanian Risk Mitigation Program).

Technical analysis on that project, including the cost estimates in this submission and potential actions to adapt in coastal areas, was provided by the Water Research Laboratory of the University of New South Wales.

The following is adapted from Chapter 7 of the report on that project recently submitted to Clarence Council, to be released for public discussion and debate on 23 January 2009.

The submission has two sections, the first dealing with a policy framework proposed for the Clarence project, the second looking at some of the practical issues associated with adaptation to climate change impacts, including a 'work plan' for areas where some risks have been identified.

The first section deals with (from the terms of reference):

- mechanisms to promote sustainable development
- mechanisms to promote sustainable communities
- governance and institutional arrangements for the coastal zone

It addresses the management of both new development and existing assets. It proposes that developing risks from rising sea levels should be actively managed to keep risks to acceptable levels, and that in the long run, the cost of this should be borne by land owners and users of coastal areas. Because of the substantial change to obligations for landowners, there is a proposal for a transition period of 25 years. There is a discussion about acceptable levels of risk and criteria for acceptable risk management.

The second section deals with:

- strategies to deal with climate change adaptation, particularly in response to projected sea level rise

This section addresses some of the possible responses to different risks identified: erosion, inundation, storm surge and rising water tables. The emphasis is on strategies for managing risks as they develop for existing assets. It notes some of the complexities of undertaking good cost benefit analysis with changing and uncertain conditions. The section concludes with a summary 'work plan' for assessing and dealing with developing coastal risks.

1. A framework for responding to climate change impacts on coastal areas

1.1 Overall objective

Very long term predictions (hundreds to tens of thousands of years) suggest sea level may rise several metres with a worst case suggesting rises of up to 70 m[1]. Clearly it is inappropriate to exclude all use of land below this level 'just in case'. The actual level of rise will depend on the effectiveness of measures to reduce green house gas emissions. The rate of rise is subject to significant uncertainties, even over the relatively short term of 25-50 years.

Given these uncertainties, but the high probability that the sea level will continue to rise over the long term, the issue to be addressed is: **How do we beneficially use coastal areas while recognising the long term need to protect, accommodate or retreat as sea levels rise**? While use and occupancy of any given area may be practical and desirable for many years, there will come a time when a response will be required to manage the increasing risks.

1.2 Managing climate change risk

The technical assessments of wave and tidal action can identify future risk areas for different climate change scenarios that will be affected by, say 1% annual exceedence probability (AEP) events (100 year average return interval ((ARI)) as sea level rises over time **if nothing is done**.

The most effective action would be effective mitigation of global greenhouse gas emissions, bringing the outcome from the high scenario that we are currently tracking to the medium or lower scenario. Community surveys in the Clarence project strongly supported mitigation as a major priority.

Any such technical assessments to identify areas at risk maps identify locations where active risk management will likely be required. Furthermore, substantial areas will be identified as being at risk now. In most cases further detailed work will be required before a specific response is made.

1.2.1 New development

Planning Schemes need to recognise identified risk areas. The question is: What level of caution should be applied for future developments?

There is a developing practice around Australia to use the hazard associated with the estimated high range for sea level rise in 2100 to determine acceptable development when revising planning schemes to take climate change into account[2]. For erosion, set backs would be established that allow for expected erosion over this time frame while ensuring continued foundation stability.

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1 The Future Oceans – Warming Up, Rising High, Turning Sour, German Advisory Council on Global Change (WBGU), (GACGC 2006)

2 The actual numbers adopted for sea level rise has varied according to jurisdiction as thinking unfolds, ranging from 0.4m to 1.0m for 2100.

Such a level substantially exceeds usual safety margins for most of the service life of the buildings, intending to ensure low levels of risk normally associated with development will still apply by 2100 after allowing for the 'maximum' expected sea level rise and other climate change effects.

The arguments for adopting this relatively cautious approach can be summed up as applying the "precautionary principle". Practical arguments for adopting this level of caution include:

- **Uncertainty** – while using the high scenario may seem conservative, recent evidence shows sea level rise and greenhouse gas (GHG) emissions are following the high scenario. They could go higher, sooner.
- **Service life** – while the initial service life of the development (typically 50 years for a dwelling) may be less than the period to 2100, reinvestment and renewal typically extends the life of structures well beyond that. The infrastructure to serve the building may also have a longer service life.
- **Low marginal cost** – The extra cost of allowing for additional safety factors, for example by lifting buildings further above flood levels, is relatively low at the time of construction but much higher if the building has to be lifted once built.

While setting floor levels to suit 2100 high scenario flood effects or set backs for erosion may be appropriate as a general 'deemed to comply' basis for development, it is suggested that the emphasis should be on encouraging performance based responses that maintain acceptable levels of risk over the life of the structure. Thus a dwelling designed to be moved back from a moving erosion face, piled to be stable in spite of erosion and capable of withstanding waves or a structure designed to be elevated readily as sea levels rise could also be acceptable.

Some structures with a shorter service life may need to meet lesser standards: garden sheds, pergolas, boat sheds, etc. provided they are relocated or demolished before risks increase to the point where they represent a hazard to others.

In general it is not proposed that land use zoning be changed specifically in response to climate change risk. The appropriate zoning of land should respond to the broad range of planning considerations and key coastal management considerations are generally already identified. New development should be subject to conditions to ensure levels of risk are acceptable, but this can be achieved in most locations with appropriate responses, not just by excluding development. In this way, areas subject to potential hazards may be occupied for many years before further adaptation responses are required, including, potentially, retreat.

For areas where risks cannot be managed realistically, eg where erosion threatens future development and protection is either impractical or undesirable, a freeze on development may be most appropriate.

In particular, it is recommended that opportunities to permit coastal ecosystems to evolve inland with rising sea levels be identified and changes made to Planning Schemes to accommodate this where necessary and practical. The significance of this is discussed further below.

Even property development approved with the expectation that it will face acceptable levels of risk up to 2100 may face increasing and unacceptable risk if it exists beyond that time. If sea levels rise faster than expected, this could even occur sooner than 2100. An approach to managing risk in the longer term is also required. In particular, developments in areas identified as subject to longer term risk should clearly be notified that they will be subject to requirements to actively manage risk when unacceptable risk levels are approached, as described in the following sections.

1.2.2 Existing property

Setting standards for new development does not address the developing risk for existing property. At present there is limited requirement to manage increasing risk to existing property. When damage does arise from a storm or other extreme event, emergency relief may be provided, but this after-the-fact assistance is usually far more costly than risk management before the event. It also has higher risk of injury or death.

Given the current and foreseeable, systematic, long term development of increased risks in coastal areas, it is appropriate and less costly to actively manage risks to existing assets in these areas, including natural assets, through protection, accommodation or retreat. For example, individual property owners should be encouraged to consider whether to reinvest in existing, low lying structures or to demolish and rebuild in a way that reduces risk.

The philosophy of managed/adaptive approach with multiple interventions responds to risks in a number of smaller steps as they develop. With this approach, it is unnecessary to construct protective works now for high sea level rise in 2100, particularly if the provision to upgrade is incorporated in the design. It is prudent, to consider a range of sea level rise scenarios for future planning, as most of the present day risk is due to inadequate past planning and risk assessment.

For erosion, hard protection (in the form of seawalls) and soft protection (through sand nourishment, supplemented with groynes) are generally technically feasible (subject to additional studies) and are expected to have benefit to cost ratios well over one for most locations, for sea level rise scenarios to 2100. For inundation for existing buildings there are fewer options, but some reduction in flooding may be achieved by flood barriers and a substantial reduction in risk through hazard reduction and emergency planning. These are also expected to have benefit cost ratios greater than one. Retreat from existing, serviceable structures generally has a benefit to cost ratio of less than one.

The economic factors of adaptive management need to be balanced against environmental and social factors to achieve the optimum outcome. An example of a social factor is the continued availability of a recreational beach for use by non-beachfront residents, although this too has an economic value, albeit harder to quantify. Successful coastal management will usually combine elements of *retreat, accommodate and protect.*

1.3 Equity and responsibility

Foreshores have a mix of public and private land, and are used by both local residents and those from outside the area.

People choose to occupy or use coastal areas because of the substantial benefits these areas provide. They are attractive locations to live, work and play. **In the long term** it is appropriate that people who choose these areas and gain the benefits - even while knowing the long term risks - accept and pay the costs of managing the risks that they incur. It would be poor public policy to subsidise people to locate in areas of known developing risk.

Many locations will be subject to hazards from climate change that otherwise would be at low risk from coastal hazards. The current owners and occupants of these properties - who chose these properties without being aware of these long term risks - will be disadvantaged by climate change effects largely beyond their control.

There is a need to allow existing owners to re-evaluate their choices and to suffer minimal losses from the changing conditions, while ensuring in the future that coastal property owners factor in the costs associated with managing developing risk.

As existing owners were not aware of the developing risk and are not in control of the causes of this developing risk, we have proposed that **for a period of 25 years, the cost of risk reduction and management measures be borne by the wider community. After that time, the cost of further risk management measures would be the responsibility of those that benefit from coastal use or occupation.** This condition should eventually be applied to all coastal property titles. Risk management works that continue to be undertaken by the Council could be paid for by a special coastal risk reduction rate in affected areas.

It is likely to be well beyond the means of local governments to meet the costs of risk management and reduction measures on their own, and equally inequitable for coastal councils to bear the costs of changes brought on by global changes. Councils may even require assistance to meet the costs of adapting their own infrastructure. Assistance from the State and Australian Governments will be required.

At this time there are no formal programs designed to directly address this issue. Further, it is a situation that will be repeated around the state and around the country, making substantial demands on the wider community and will have to compete with other government spending priorities. These costs may, however, have some claim on revenue raised from the Carbon Pollution Reduction Scheme - although the many other claims on these funds are also known - with the effect that those emitting these gases compensate those who are losing out. Whatever the source of funds, arguably some dedicated climate change adaptation funding will be required.

Thus it may take some time before a formal or structured response becomes available, and even then it may not fully meet the costs involved. However, it is desirable that the situation is clarified as early as possible both to keep risks manageable and to allow coastal communities to plan with some certainty for their futures. The approach to managing and reducing risk is described in detail below.

1.4 Risk management triggers and responses

For existing property subject to increasing risk, it is proposed that triggers be identified that would require an adaptation response to keep risks at acceptable levels. Triggers would be invoked where risks exceed agreed levels. This could be where a 100 yr ARI (1% AEP event) is likely to lead to significant damage to some property or where more extreme events would make emergency responses difficult.

Acceptable levels of risk

The issue of acceptable levels of risk may need to be the subject of community debate before being set. While there are guidelines associated with some areas of risk, (typically those embodied in design and engineering standards, and those associated with traffic management to cite two examples) and have been developed in some jurisdictions (Victoria WorkCover Authority, NSW Department of Planning, WA Environmental Protection Authority) developing risks arising in coastal areas from climate change for existing structures may need to be considered as having a distinct set of issues.

In general it is accepted that levels of acceptable risk are higher where risks are taken on voluntarily (skydiving) than when imposed (nuclear reactor built next door). Living in coastal areas is a voluntary risk. Living in bush fire prone areas is similarly if not more risky than living in coastal areas. Many have chosen to live in areas of demonstrably high risk. The most important thing – from the point of view of those taking on these risks – is that those making the choice are aware of the risks and how to minimise them.

From the community point of view, the most significant consideration is that those making these choices not impose unacceptable risks and costs on the rest of the community. This means that the wider community has an interest in seeing these risks managed and kept to an acceptable level.

The level of risk accepted may be higher where potential damages to property represent a modest part of total property values and the chance of total loss is low. Higher risk is also acceptable where the chance of injury or loss of life is low, even if property is lost. Arguably reducing risk of injury and to life can be achieved by good storm warning systems and emergency management, even where property risks are high.

It is entirely possible that different communities may choose different levels of risk. While the overall framework for managing coastal risks should be consistent, there is no reason why the chosen risk level may not be different.

"In the south west of the Netherlands, the delta plan has been implemented with the aim of guaranteeing protection against the North Sea storm event which has an estimated 1 in 10,000 chance of occurring each year. For most of the river dykes along rivers such as the Rhine and the Ijssel, the accepted design event is the 1 in 1250 event. Along the Meuse, where flooding has been a lesser problem, measures are being taken to reduce the average chance of water damage to towns to 1 in 250 per year."

Different triggers will be required for different risks: high water tables, inundation, and erosion. Hazard maps will be required for each of these risks.

We propose that the hazard maps be reviewed with each update of Council Planning Schemes, or a maximum of every ten years to determine what areas are 'triggered'. In addition, if a major storm event has a significant impact on the coastline, a response may also be triggered between these reviews.

In this way the community will respond to actual changes in risk as the sea level rises or erosion progresses, not to events forecast for the distant future. Triggers should be soon enough to plan action and respond before risk become excessive, not sooner. The action taken should manage the risk as it develops – it need not all be done immediately.

Managing risk should ensure that risks to the wider community are avoided where possible and the risk to life is minimised. Managing the risk does not mean elimination of all risk. More extreme events can and will occur from time to time that exceed the capacity of the actions taken. However, if suitable actions are taken these more extreme events will be relatively rare and the damage and safety impacts remain manageable.

Managing risk also does not mean avoidance of all costs of damage. Rather it would seek to ensure that, where adaptation in the short term is likely to cost less than likely damages arising from risks, property owners are aware and able to act, where necessary with support from the wider community.

1.4.1 Criteria for acceptable response

Risk management responses should be flexible and allow creative solutions to local circumstances. However, while being flexible, they need to conform to certain minimum conditions to be acceptable. Acceptable responses should:

1. Demonstrably reduce risk to defined acceptable levels for an estimated time period
2. Be designed to be durable and effective for the estimated time period and/or have reasonably well known maintenance and operating costs for the design period
3. Indicate the anticipated response at the end of the estimated extended period when risks again approach unacceptable levels
4. In normal operation or in the event of failure, not adversely affect other properties, including integrity of property, continued beneficial use and cause no adverse health or safety risks to residents or users of other properties
5. Allow practical emergency response to events that exceed design risk
6. Identify the financial and operational capacity to meet any ongoing maintenance or operating costs
7. Allow for the continued viability of valued coastal ecosystems where these have been identified and continued viability is achievable at a cost acceptable to the wider community.
8. Define the agreed trigger for follow up responses in the event of continued change

2 Practical Adaptive Responses

IPCC (2001) lists three classes of adaptive management options, namely:

- Retreat
- Accommodate
- Protect

Practical management options include:

- Planning controls for new development, which deal with:
  - Building setbacks
  - Minimum floor levels
  - Appropriate engineering assessments
  - Appropriate construction techniques (eg piled buildings, flood resistant materials)
  - **Or**: a development freeze in some locations
- Physical works such as seawalls, groynes, dune management or sand nourishment, offshore breakwaters and/or surfing reefs, temporary or permanent flood barriers, reconstruction of public infrastructure (eg roads, other services above flood levels)
- Detailed emergency management and evacuation planning, with hazard reduction requirements for affected properties
- Providing community education and information to improve awareness and ability to cope
- Ongoing monitoring, analysis and review of findings
- Additional data collection or studies
- A timeframe for review – currently five years for Council planning schemes

Planning controls deal with new construction and major renovations. Other responses are required to address developing risks for existing structures and services. These are discussed in more detail for different risks in the following sections.

The following sections discuss potential responses to different risks and some of the implications including indicative costs, as order of magnitude estimates only based on the study for the Clarence local government area. They may or may not be directly applicable in other situations. It is recommended that a full, detailed cost benefit study is done for any given situation to determine that a particular response is warranted.

Cost benefit calculations

The cost is the cost of any works required to protect property or other assets, including natural assets (eg beaches). This includes capital costs plus any maintenance costs over the life of the investment, including consideration of the effective life of the protection before upgrading or renewal is required. Other costs may include a loss of amenity if a beach or access to a beach is lost to residents, or loss of ecosystem services and bio-diversity values if a wetland is lost.

The benefit is the avoided loss or damage to property, and potentially injury or death avoided. A full calculation would consider:

- Each property separately as they all face different degrees of hazard (being at different degrees of exposure ie elevations and distance back from the shore) and different susceptibilities (form of construction, foundation, etc.). This can be simplified by grouping properties with similar exposures and susceptibilities together after they have been assessed.
- In any given year, a given property (or group of similar properties) faces a range of potential flood or erosion risk levels, each with a different probability and with a different level of expected damage. This full scope of damage and probabilities needs to be integrated to calculate a net expected damage for that year.
- However, unlike static risks, with climate change the risk rises slightly each year, with the result that the damage for any given property will rise and additional properties are brought into the calculation as time goes by. As changes are slow enough, the calculation can be simplified by looking at the rising risk profile, say each decade, at least for the first 50 or so years. As the rate of change is expected to increase in later years, the interval for these changes may have to be reduced.
- An allowance for additional uncertainty for future years as the rate of change of sea level rise and storm intensity becomes harder to estimate the further into the future one projects
- The timing of costs and expenditures to allow for interest/discounting future costs and benefits.

Other benefits may be retention of a beach or foreshore access that otherwise may have been lost, or continued provision of environmental services if these are retained with some options.

Calculating this with any degree of accuracy is complex and requires substantial detailed information. Even without calculating this in detail some broad observations are possible:

- In many situations very high cost but very low frequency events may dominate total costs. Thus it may be that the highest costs are associated with damaging one in 200 or 500 year events rather than 'minor' effects from 100 yr ARI events. Evidence from insurance claims from riverine floods shows this pattern.
- Houses unlikely to be affected much before 2100 are likely to have very low risk for most of this century, with almost all damage occurring near the end of the period. There is little justification for spending on protection works for these properties until very much closer to the time when these properties are at risk.
- Properties at risk at present will face escalating risks to the level of certain, serious damage in some cases for sea levels expected for the high scenario in 2050 and in almost all cases when sea levels associated with the 2100 high climate change scenario occurs[3], albeit the likelihood of these costs and expected annual costs will rise steeply in the later years.

[3] These sea levels may or may not be reached on this particular date.

2.1.1 Inundation

Inundation triggers

It is proposed that properties in areas expected to be flooded by events with a 1% AEP would be required to manage risks effectively. Affected areas would be determined and mapping revised at least every 10 years.

The extreme water level due to inundation is likely to persist for approximately two hours at the peak of the tide, though ponds of water may persist much longer in some locations.

A number of different options are available for responding to risks of inundation. They have substantially different costs and benefits, as well as other implications for effective risk management, community amenity and sustainability.

Dikes and levees

Dikes, levees and other flood barriers are sometimes proposed and used to keep floods from encroaching on low lying land. Large areas of the Netherlands are protected in this way as are coastal areas in USA (eg. Louisiana). London has a flood barrier on the Thames and one is under construction for Venice on its lagoon.

The development of walls to hold back the sea can provide protection for a given peak sea level from high tides and storms. Structures of modest height may be quite affordable. But the cost of these structures increases with the square of the height. Thus a structure twice as high costs roughly four times as much. Therefore if sea levels rise and continue to rise, costs will continue to escalate in the long term, potentially becoming increasingly hard to justify. The catastrophe in New Orleans from hurricane Katrina had been predicted and proposals to upgrade the levees prepared, but were rejected by government as being too costly. The eventual cost of damage was much higher.

Dikes may also not be effective on their own. If sea water levels are frequently close to or above land levels behind the dike, as they will be in the longer term, pumping will be required to keep the water from coming to the surface from under the dike where the underlying land is sandy or porous. If dikes are chosen for protection in the long run in sandy areas, pumps will need to operate there **forever**. In the event of an extended power failure, such as may happen in a severe storm event, water can penetrate these areas from below.

Dikes and levees should be designed to withstand more severe conditions than a 1% AEP (100 year ARI) event. For example, the Netherlands use a 0.01% AEP design event for North Sea protection. This is because the consequences of failure would be catastrophic, with large sudden flooding arising from a breach or overtopping of the protection. Maintaining levels of protection at the desired levels of safety has proven challenging in many jurisdiction where dikes and levees have been used.

Dikes or levees are typically located close to the natural shoreline to protect the maximum area of land behind them. As the sea level rises, the face of the dike will become the low water line, with no tidal beach or shallows on the outer side. The height of the dike will increase the separation of those on the coast from the sea, changing the character of the coastline in areas where these are used. This will make the area very different from the current beachside environment in many locations at risk of inundation.

Low sea walls or levees may be appropriate for reducing flood risk in the short term for infrequent peak events while the sea level remains below land level most of the time, but are unlikely to be viable as long term protection for land in Clarence coastal areas as sea levels rise. If dikes or levees are to be considered for protection from inundation in the long term, the following conditions should be met:

- there is likely to be long term commitment to a high level of development in the area to justify the rising long term costs
- other options are not viable or cost effective
- the area will remain ultimately defendable and
- there are compelling reasons why this area rather than a less vulnerable, higher elevation areas nearby should attract continued development and occupation.

Short term reducing or impeding hydraulic linkage (flood barriers)

There are a number of locations where low lying land is separated from the foreshore by dunes, roads or other higher land. This land is generally linked to the sea by storm water outfalls, stream outlets or other channels. In extreme flood events, low areas in the dune front, roads or elsewhere may also allow water to flow from the sea onto the land.

During storms, sea level peaks lasting a few hours may not be sufficient to flood the inland areas to the same levels as the maximum open water height through these sometimes limited hydraulic connections. Further, by restricting the inland flow of water, maximum flood heights from sea water flooding may be further reduced. This can be achieved by ensuring storm water pipes have one way flow caps on the ends, restricting water entry during storms and floods through some channels and maintaining dune heights, roads or other land levels well above maximum flood heights. In some instances, raising road heights is desirable to maintain access during storms, and can act as an effective barrier for flood events. The seaward face of the road would need to be protected against erosion.

An indicative cost would be $400 per m of suburban roads raised 0.5 m and $600 per m of road for suburban roads raised 1 m. Major highways would be more expensive, $1500 per m or more including hardening the seaward face depending on the height and level of exposure to waves. The cost of preventing water entry to storm water pipes and through streams and canals would require site specific assessment.

While impeding hydraulic linkage may reduce flooding from the sea, it may **increase** flooding from heavy rain events. Past floods have usually found both rain and high sea levels occurring together. Fresh water is less damaging than sea water, but flooding would not be prevented entirely. As sea levels rise, the capacity for rain water to drain away is reduced, raising the likely height of rain driven flooding events, even when the sea is kept at bay. For this reason, reducing the hydraulic linkage is seen as a short term measure only. The safest long term response is to raise the level of developed land and/or any structures in low lying areas.

Raising land levels and structures

The most secure and sustainable response to rising sea levels for developed low lying land is to raise the land level. For any new development or major redevelopment in affected areas, this would be controlled by the Planning Scheme. While building new structures with floor levels above expected flood heights would reduce damage, raising the land level in general would further reduce risks and maintain access and use of the property even during events with high sea levels.

The cost of raising land levels will depend on the availability and cost of suitable fill. Sometimes fill material is even available for free. Costs of placing and grading may be quite modest, with higher costs for the load bearing area under the structure where consolidation and suitable material is required. An indicative cost to raise land level by up to 1 m may be $10 - $30/m2, perhaps 10% of the market value of land in many areas. Additional costs may be incurred under foundations or for edges that may face erosion from flood water. Public costs would also be incurred for raising roads and utilities/services to property in most locations.

In general the cost of raising land used for agricultural purposes will be too high to justify. Agricultural land that is flooded by sea water will require restoration to be useable. Frequent flooding would make even this expenditure unviable, leaving agricultural land to revert to tidal areas as sea levels rise.

For existing structures, it may be possible to raise the structure and rebuild the foundation underneath if the structure is of high value and lifting costs are acceptable. More often, it would be more cost effective not to reinvest in older structures for a period of time and rebuild when the building structure and fabric have reached the end of their normal service life.

An alternative for structures below flood level that have substantial remaining service life would be to waterproof lower levels and services where possible. A variety of technologies have been used to achieve this depending on the form of construction, flood depths anticipated etc.

Preparation for floods

For properties where the land remains vulnerable to inundation, the property should be kept free of floating/movable materials, polluting materials and chemicals. Services should be capable of inundation without damage. Where the level of 1% AEP floods exceed floor levels, different levels of response to flood warnings would be required ranging from short term protection (eg sandbags) to evacuation. Removal of the building may be warranted where it may be in danger of movement causing damage to other structures.

In locations where property is at risk of inundation and road access may be lost in the event of a flood, evacuation may be required upon notice of an extreme event.

Other options

While raising land and structures above flood levels is most appropriate for many situations, it should not be seen as the only response or best response for all cases. Other possible solutions include floating structures, tethered to prevent damage to surroundings or waterproof structures capable of being inundated with acceptable levels of clean up or damage.

In some cases retreat may be the chosen response as described for agricultural land above. If a structure is relatively isolated and would require either substantial filling of a large area or lifting of a long access road, the cost may not warrant the investment. If the land can serve other uses of value to the community, such as a tidal wetland as sea levels rise, then it may be preferable for this to become the future use. Areas of value to the community in this way should be identified in a systematic way so that if owners are interested a suitable price can be negotiated for the property.

2.1.2 Rising water tables

Rising water tables pose increased risks of flooding due to heavy rains and can lead to the failure of septic tank systems and attendant health risks. Constant damp will also affect foundations and lower areas of structures with inadequate damp-proofing.

In principle, it may be possible to reduce the effects of rising water tables by pumping groundwater to the sea to lower water tables. While this may have some short term merit, it would be a relatively expensive and unsustainable practice if used as the main solution forever.

Areas affected by rising water tables that are dependent on septic tanks will require alternate sanitary arrangements before health risks arise. This could include above ground digesters or installation of a sewerage system. Investment in a sewerage system would only be warranted if the community has a sufficiently long term future in spite of sea level rise. Given the potential to raise land levels in most locations, this is likely to be the case in most areas currently zoned for residential development and associated commercial areas. However, the merit of providing sewerage to isolated individual dwellings is less certain. These may require above ground treatment if sewerage cannot be justified.

2.1.3 Beach erosion and storm surge

Most beaches experience episodic erosion in response to storms followed by rebuilding in the periods that follow. Some beaches experience progressive erosion (or accretion) over the long term. With sea level rises, progressive erosion (recession) will become more prevalent as beaches respond to new conditions. The level and character of bedrock strongly influences the erosion risk.

New development would normally be restricted to landward of the erosion hazard lines. Buildings might be permitted seaward of the hazard lines shown if:

- Detailed assessment for an individual property by a coastal engineer varies the hazard line location;
- Rock is present beneath a veneer of sand, with the location and level of rock mapped and considered by a coastal engineer and/or geotechnical engineer;
- Buildings are constructed on piles, with design input from a coastal engineer, together with a structural and/or geotechnical engineer;
- A protection scheme is implemented (eg sand nourishment or seawall).

To reduce risk from wave runup, new development should be built with habitable floor levels at least 0.3 m above the estimated wave run-up levels. Habitable floor levels may be below this level if:

- The structure is protected by a dune barrier which has sufficient sand volume, crest height and continuity to prevent wave runup and inundation reaching it.
- The lower portions of the structure are constructed of flood resistant materials and are designed to withstand the water forces.
- For roads, alternative routes or other emergency contingency plans exist.

Erosion Triggers

While setbacks for new development should have regard to these long term trends and the expected erosion up to about 2100, existing property should also respond when more immediate threats are apparent. This includes any properties within the present day risk zone.

Development needs to be kept far enough from the erosion face at any given time to ensure that in the event of a series of severe storms, the property is not likely to be undermined and fail. A hazard line for the present day would show the potential erosion effects of a series of severe storms with a combined 1% AEP while still maintaining stable foundation conditions. Properties shown as at risk at present would require some adaptive response in the short term where detailed investigation confirms the locations at risk.

After a single severe storm event the erosion face may well move closer and a further response would be required.

Areas subject to erosion are generally also subject to wave run-up. In some cases, harder, non erosive areas will also be subject to wave run-up while not vulnerable to erosion. Run-up hazard can be estimated in terms of height reached, but it is generally difficult to map this as it depends on the distance and inland gradient, both of which may be subject to change.

On continuously upward sloping land it is preferable for development to be sited above the wave runup level. This may not be practicable on low land behind higher dunes fronting the coast and not necessary provided frontal dunes are preserved and maintained.

Vulnerability to wave run-up is affected by dune height and depth, and this can change significantly after a major storm or series of smaller storms. It is recommended that when erosion risks are assessed in detail for vulnerable beaches that wave run-up risk also be assessed. Further, after major storm events, potentially vulnerable areas should be reassessed to determine whether the height is now below run-up estimates. If dune heights or bulk have been substantially reduced, this could trigger an early response.

Beach and dune nourishment, revegetation

Beach and dune nourishment brings more sand into the system to offset losses and beach slope changes from erosion and sea level rise. It can be quite effective in protecting against damage in the short to medium term. It requires a cost effective (and environmentally acceptable) source of suitable sand. Subject to detailed studies and monitoring, ongoing replenishment may be required, however, for some schemes, particularly where groynes are used, replenishment may not be needed.

Building up and revegetating the dunes adds to dune stability and resists sand loss from wind and smaller storms. Maintaining dune height may be essential to defend against storm surge on beaches exposed to large storm waves. A large storm will not be significantly deterred from eroding the face of the dunes by vegetation and the dune may then collapse, but the presence of vegetation can increase the volume of sand available in a dune to resist erosion. This can be counteracted by maintaining sufficient dune depth. Dune vegetation can be protected at access to beaches via hardened entry points.

The indicative cost for beach nourishment is $15/m^3 but potentially ranging from $5 to $50 /m^3. The cost per linear metre of beach will depend on the particular beach and volume of sand required for different projected time frames and sea level projections. An additional cost of about $150 per m of beach would be incurred for vegetating the enlarged dunes. An indicative lifetime may be decades, but detailed assessment is required for each beach.

Groynes

Groynes are artificial barriers extended into the sea at right angles to the shore. These can reduce erosion and trap sand being carried along the shore (longshore drift). As such they can be effective in extending the life of beach nourishment. In some cases they may trap and build sand on the beach even without nourishment. They can have the undesired effect of increasing net erosion rates in the areas down stream. In some locations they may also have other adverse environmental impacts.

They need to be made to resist degradation from storms and have traditionally been made from rock or concrete. More recently groynes have also been formed from giant sandbags which are less abrasive and may be considered by many to be more attractive. They are also cost effective and easier to place and relocate.

An indicative cost for groynes is about $5000 per m with typical length about 100 m. Well designed and constructed structures should have a long lifetime, with minimal maintenance except where sea level rise necessitates raising the level of protection.

Shore protection, hardening

Shore protection can consist of vegetating existing dunes (as discussed above in conjunction with dune nourishment) or protecting soft sediment shorelines with erosion resistant facings (hardening). These may be rock, concrete structures, or could use geotextiles or sandbags of various types and sizes.

There is a significant risk with shore protection of protecting one section of coast but actually increasing erosion in others. This arises because the sand on a beach may move along the shore. The protected areas no longer supply sand further down the beach and the erosion in the unprotected areas then accelerates. Hardened surfaces may also reflect waves, increasing the damage caused by waves from some directions in storms, whether sand or erodible rock.

Hardened shorelines using rigid masonry or concrete based on soft sediments or even soft rock can be undermined if not well designed and deeply set into the surface. Poorly designed and undermined sea walls are quite common and rebuilding them is usually very difficult and expensive. For these reasons, dune protection needs to be carefully designed in each specific situation.

The analysis and design of any shore hardening should address a whole section of coast, not a single property or even a short section that may be threatened in the short term. Given the damage that poorly designed or constructed protection can do to adjacent coastal areas, and its danger to beach users and surrounding properties, it may even be argued that shore protection that is not professionally designed, built and monitored should be prohibited.

Rock structures require ongoing maintenance, typically after storms and/or at intervals of 10 to 20 years. Hard rock and concrete walls take up less space on beaches of limited width, but are more expensive to repair if they fail. Loose rock structures require a much wider base but are more easily repaired if disturbed by a major storm.

An indicative cost for rock structures is $100 per tonne, provided suitable rock is available. The rock structure must consider future sea level rise through increased wave height on the structure over time. This will lead to requiring larger rocks, and increased wave runup will lead to a higher crest and larger overall structure.

If dune protection by hardening is continued over long periods of time while the sea level rises, there will be no further injection of sand into the shore system and eventually the hardened dune face will be the low water shoreline. At that point there is no longer a beach. This can greatly devalue the attractiveness of a 'beachside suburb' and consequently property values.

The runup levels for sandy beaches will also generally increase if seawalls are built.

Foundation underpinning and resistance to waves

It is possible to construct structures that are able to withstand erosion of the shoreline and the direct impacts of waves. Coastal structures may be built on piles and either set above the significant wave height or built sufficiently robustly to withstand wave impacts. The indicative cost to pile a new house is $50,000.

Planned retreat

Progressive retreat recognises that the most sustainable coastal form will reflect the form that will emerge under natural conditions. For sandy shores, dunes will move inland to add sand to the coastal system, rebuilding to continue to protect the area behind.

Progressive retreat means the loss of prime coastal property. In spite of this, it may prove to be the lowest cost long term alternative available, especially if the cumulative cost of maintaining a shoreline against increasingly severe erosive forces into the future is considered. This is particularly the case where there is a single row of houses and they are vulnerable to erosion or inundation from both the front and back sides as occurs on spits and isthmuses.

The cost of planned retreat is high, but can be diminished to the cost of land if a process of planned disinvestment occurs. For properties at risk where the cost of protection is very high, it would not be prudent to add improvements or even to renew features such as kitchens and bathrooms when they become substantially aged. The properties would be reduced to the status of 'shacks', which many began as, rather than full time occupied principal residences. In this way, when the property is finally abandoned, the main loss is in the land value. If the land has a public benefit as open space or public beach, this may be recognised in a re-purchase by the public.

2.1.4 Salt water intrusion

Salt water intrusion into fresh groundwater can make water supplies unusable. This may make the user dependent on other water sources. If the saline water comes into the root zone of the vegetation, the form of vegetation cover may change dramatically.

In general, salt water intrusion does not present immediate danger to health or property. Eventually high salt levels can have a corrosive effect on foundations and buried infrastructure. However, by this time risks from inundation will generally be of greater concern.

2.1.5 Outline of a work plan for readiness for climate change in coastal areas

The following provides a recommended approach to managing coastal risks.

Improve accuracy of risk assessment. This may involve:

- detailed modelling of inundation taking into account hydraulic linkage between low lying areas and the shoreline, combining these with flood studies of creeks and rivers;
- assessment of bedrock depth and character in identified eroding sandy areas;
- analysis of historic changes in sandy beaches based on past aerial photos and more recently on satellite imagery, supplemented with regular cross section beach measurements and surveys;
- undertake systematic visual observation or instrument measurement of wave heights on key beaches, relating this to offshore waves to improve the certainty of beach erosion and wave runup modelling
- Maintain detailed assessment of groundwater use and aquifer flows to allow identification of most vulnerable bores in unconfined sandy aquifers as conditions change.

Monitor developing risk:

- Monitor the sea level rise projections in revisions to the IPCC documents and consider the implications.
- Monitor lagoons and offshore areas through regular bathymetric surveys.
- Measure average and extremes of salinity in bores to track developing groundwater issues.
- Asses the implications of sea level rise for foreshore and estuarine ecology.
- Adequately monitor ground water around landfill sites subject to rising water tables.

Detailed assessment to select actions/responses and responding to known risk:

- With current sea level rise projections, development proposals for any land below 10 m Australian Height Datum[4] (AHD) and/or within 500 m of the coast needs at least a cursory consideration of whether more detailed assessment is required. The 10 m level is suggested as it is readily identifiable on most Council GIS systems and above any calculated wave runup level within the foreseeable 100 year planning period. Road access

[4] Australian Height Datum in Tasmania is based on mean sea level for 1972 at the tide gauges at Hobart and Burnie which was assigned the value of zero on the AHD

to sites also needs to be considered, for even if a site itself is above any inundation level, access to the site may be restricted during storm events.

- Prepare a forecasting and warning system for prediction of inundation of roads and buildings by high tides combined with large waves and strong winds. The basis for such systems already exist at the Bureau of Meteorology, but need to be better integrated into coastal emergency planning and made available to residents of areas at risk.
- Identify potential dune breach locations from a detailed analysis of available data.
- *Prepared and implement vegetation management plans need to be for all dune areas not* currently maintained.
- Inventory potential sand reserves for future beach nourishment needs. Initiate studies for access and in-principle approval.
- Identify suitable quarries for rock protection need to be identified and determine the suitability of their rock for coastal protection.
- Establish detailed sediment budget and littoral drift estimates on ocean beaches as input to the design of any sand nourishment / groyne scheme.
- Undertake detail site investigation and design where adaptation/protection works are required