Decision Making in the Face of the Rising Tide.

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Abstract:
The inexorable rise of sea levels as a result of runaway global greenhouse emissions is beginning to gain traction as an issue for both the Australian federal government and coastal planning authorities. Whilst various policy mechanisms to regulate future developments are becoming mainstream, existing developments which face an increased flooding or erosion threat remain problematic. Three strategies exist, namely defend, accommodate or retreat, but the appropriate policy choice is dependent on a broad range of factors. Local geomorphology, the value of existing property and infrastructure, community opinion and the legislative background, especially in respect of public liability, all weigh on such policy decisions. We report on research designed to develop a tool to assist local councils make informed policy choices in respect of such vulnerable development. A decision map is developed and explained and tested on case study sites in South Australia. The research demonstrates that the "common sense" strategy of managed retreat may in fact prove the least productive over the next few decades.

Keywords: Sea level rise, defend, development, policy, liability, retreat.

Introduction

A recent national assessment of the risks to Australia's coasts from climate change identified approximately $63 billion of residential assets as at risk of inundation from a 1.1 metre sea level rise (SLR). Other coastal assets at risk include commercial and recreational land and associated infrastructure such as roads, footpaths, stormwater networks, jetties and marinas, most of which are owned or are under the planning jurisdiction of local government (Department of Climate Change, 2009). Coastal local governments are therefore faced with the challenge of adapting to the likely impacts of climate change in a timely and cost-effective way. Councils often find themselves the target of residents' complaints and concerns in respect of coastal storm damage (see the discussion of Byron Bay below) so it is appropriate to focus on their potential for response through policy. This paper explores the range of available responses and outlines a Decision Mapping approach, which has been developed to inform policy choice. Internationally, coastal vulnerability from climate change was noted by the IPCC in 1991 when it proposed a Common Methodology (CM) for assessment (Wigley & Raper, 1992). Subsequently a number of studies have attempted to investigate extreme storm surge events (Cayan et al, 2008) and map flooding and erosion (Dodds et al, 2010) with a view to improving predictions of future events. Risk analysis as an approach to dealing with climate change has proved a common theme in the coastal literature (Mai & Zimmerman, 2003 McGranahan et al, 2007, Nicholls and Klein, 2005). In many instances the ultimate aim of risk analysis is to inform policy, although it is recognised by a number of commentators (O'Riordan & Ward, 1997, Tompkins et al, 2008, Schmidt et al, 2013) as needing to be matched by a consultative approach that involves potentially affected coastal communities. The Australian states developed a range of approaches for assessment of coastal vulnerability throughout the 1990s, including coastal engineering studies, inundation mapping and storm surge analysis. In addition, the Australian federal government published a policy document *Living on the Coast* (DEST, 1995) and funded a number of coastal management and vulnerability studies (Graham & Pitts, 1997, Harvey et al, 1999). Such contributions along with Harvey et al's (1999) studies of South Australian coastal locations extended the scope of coastal policy concerns to include other human induced problems such as increased coastal development, waste disposal and groundwater withdrawal. As a result of the increasing levels of internal migration to coastal areas that in turn provoked concern from the insurance industry, by the mid 2000s the need for a co-ordinated national assessment had become apparent. As a result, the federal government published a *First pass national assessment of Australia's coasts* (Department of Climate Change, 2009) and instituted further position papers and mechanisms such as the Coast and Climate Change Council. The details of policy developments since the early 1990s are set out in detail by Harvey & Woodroffe, 2008 and Harvey et al, 2012). It is clear that while there has been an attempt to develop a national overview, a national policy approach to coastal planning and management has not yet been established and as the politics of climate change become more polarised some Australian states appear to be reluctant to commit to clear directions. Much of the work to date has focussed on quantifying and assessing the problem and less on developing workable solutions. This paper builds on the background set out above but has a specific focus on how local councils might address the issue of existing development that is threatened by SLR.

Policy Options

In most parts of the world options for climate change adaptation in coastal areas are categorised by the following three approaches:

- *Protect*: construction of sea walls, beach sand replenishment or improved drainage to protect existing developments from loss or damage by tidal encroachment.
- *Accommodate*: raise buildings on stilts, or redesign lower floors to allow flooding to take place without significant damage.
- *Retreat*: plan for future development inland of the current coastal zone and progressively abandon existing settlements in the face of rising sea levels (Hennessey et al, 2007).

Doing nothing, of course, provides a fourth option that may be espoused by authorities that are sceptical of the evidence in support of climate change induced SLR, but apart from situations where no property, infrastructure or human safety is threatened, this appears to be an unlikely policy choice. It is also important to note that time is a critical variable in the policy equation. Whilst the scientific evidence for progressive SLR is expressed by the IPCC as "unequivocal", the projected increase in sea level of typically 3-4mm per year allows scope for manoeuvre in policy making. So governments have options both in the type of policy they choose and when they propose to implement it. Consequently, a temporal dimension to risk assessment is important. Identifying the nature of risk and at what point it increases beyond tolerable limits is critical.

Protect: Various types of engineered structures can be placed so as to protect coastal development. Soft protection options, such as sand nourishment and revegetation are often preferred over hard protection options such as sea walls. Hard protection options including groynes, sea walls and offshore reefs can cause problems such as enhanced erosion at other points along the coastline, and their initial implementation cost is usually high. In addition, a range of legal liability issues emerges when a council installs a hard protection option. Despite these drawbacks, there is often public pressure for existing coastal settlements, even smaller ones, to be defended against rising sea levels. Furthermore beach access often provides local economic benefits and is viewed as a reason for protection. For governments compulsory acquisition of water-front properties can be costly and politically risky, so despite its cost, protection may be regarded as a less costly and more politically expedient solution than retreat.

Retreat: Most advances in policy development have been in planned retreat. In Australia all the State Governments have instituted policy to deal with the planning of future development and this policy has been adopted by local councils. There are two versions of planned retreat. The first responds to sea level rise through planning mechanisms included in development plans and covenants on titles, and allows for appropriate protective measures as well. So development in certain defined costal zones may be prohibited or if is allowed, may be subject to time limits. Buildings may have to be of a type that can be readily moved back from the encroaching coastline. The second version provides for similar planning mechanisms and legal title constraints, but prohibits the land owner from protecting their assets. Retreat is usually planned for 30-50 years but may be better regulated by reference to sea levels rather than time (Abel et al, 2011). Rolling easements are a further mechanism which allow the transfer of ownership or access rights to the state as sea levels rise and the strip of beach or foreshore reduces in width. This approach enables public beach access to remain viable and allows time for coastal landholders to adjust to potential losses (O'Donnell & Gates, 2013).

Accommodate: Except for those that exist in defined planning schemes, policies to accommodate SLR are less well developed in Australia. Raising floor levels within infill development is one simple strategy. A coastal zone designation such as that used in South Australia may trigger such conditions on development approvals. Constructing dwellings on stumps or stilts so that flood water can flow underneath without damage impacts represents a simple design approach. Other accommodation options could include the retro-fitting of houses and infrastructure to allow flood waters to pass while limiting damage. Providing owners with temporary flood skirts to protect their property is an example of such measures.

The acceptance on the part of most Australian states that sea levels are likely to rise by at least 0.8 of a metre by 2100 has prompted concern about future policy in the coastal zone. These vary in nature. SA for example, via its Coast Protection Board (CPB), places restrictions on siting and finished floor levels in the coastal zone. SA local development plans require developers to confirm that they have taken appropriate measure to accommodate anticipated changes in sea level due to natural subsidence and probable climate change during the first 100 years of development. New development should not require public expenditure, now or in the future to protect it from rising sea levels. Development should not occur where essential services cannot be economically provided and maintained having regard to flood risk and SLR and where emergency vehicle access would be prevented by a 1 in 100 year Average Return Interval (ARI) flood adjusted for 100 years of SLR (Govnt of SA, 2011, p33). In essence this suite of policies and their counterparts in other Australian states set limits on coastal development which in some instances amount to a policy of managed retreat. But a common experience in a number of coastal areas where this approach has been implemented has been community opposition or backlash. For example the refusal of development approval for a holiday park at Marion Bay in SA (Northcape Properties Pty Ltd v District Council of York Peninsula, 2008) and a residential development at Gippsland Lakes in Victoria (Myers v Gippsland Shire Council, 2009) both generated appeals. Community and developer opposition has stimulated concern in respect of council liabilities for property damage or loss (Abel et al, 2011). As a result several Australian States have sought to amend their legislation to protect Councils from liabilities resulting from coastal inundation and erosion as sea levels rise. A detailed discussion of these amendments is included in a report on *Local Council Risk and Liability in the Face of Climate Change* (ALGA, 2011). NSW was the first state to attempt to clarify its liabilities in respect of SLR via amendments to its *Coastal Protection Act*, 1979 via the *Coastal Protection and Other Legislation Amendment Act* 2010. Subsequently other states have followed suit. The question of who has the right or duty to protect coastal assets has proved to be a contested area that has produced a number of legal challenges. Most notable amongst these is the case of Byron Bay in NSW. Here the council granted itself consent to construct a geobag erosion control wall to protect private beachfront property. The private owners brought an action alleging breach of the development consent following a storm that caused beach erosion including about 10 m of private property. The court held that the terms of the consent obliged the Council to monitor, maintain, and repair the beach protection works that it had erected and ordered the council to restore the interim protection wall to its height and shape before the storm event. In addition the court found that the private owners had the option to bring an action for negligence or nuisance seeking damages for the loss of their property (ALGA, 2011, p. 60). So in this instance the action of the council in attempting to protect private beach front property had placed a legal liability on itself. An outcome of this case was the extension of rights to private property owners to install protective works under the *Coastal Protection and Other Legislation Amendment Act* 2010. This shift in rights and responsibilities may be interpreted as government bowing to landowner pressure to remove managed retreat policies or as a subtle attempt to shift the liabilities resulting to SLR into the laps of owners thereby forcing them to determine at what point retreat becomes the best option. In addition to specific cases a spectrum of growing community concern, ranging from economic impacts to health and emergency response provisions deriving from coastal SLR has been identified by Gurran et al. (2011). In many cases the value of private beachfront property may represent many millions of dollars, but the value of publically owned infrastructure can be similarly high. Roads, drains and sewers, council owned properties such as sporting facilities and sea defences themselves may all be threatened. In many cases councils are likely to arrive at a similar position to private property owners in viewing the cost of retreat as prohibitively high.

Decision Mapping

It is clear that the formulation of workable policy in respect of SLR is complex. Not only do the precise physical threats need to be evaluated but the nature and value of prospective targets need to be carefully considered. Detailed data on coastal elevations and geomorphology that can reliably inform projections of flooding and erosion are not always readily available but are a vital precursor to risk assessment. Similarly detailed analysis of the location, type, structure and value of coastal development which may be affected is necessary. As the preceding discussion has shown, ownership and legal liability for damage are key concerns. Together, such information can provide a perspective on the scale and cost of potential impact. By itself this is not enough to determine the best policy approach, but it is vital information that can be used to inform policy development. If this information is provided to all potentially affected stakeholders a workable strategy may be capable of being developed. We set out to determine what data was necessary, how it might be sourced and in what order it is required in order to better inform coastal policy decision making, specifically in the case of threats to existing coastal developments. Our approach constituted the development of a decision map and a spreadsheet based financial model to analyse resultant scenarios. Decision mapping, through flowcharting, is a response to the challenges of decision analysis outlined above. It has been developed from a combination of flowcharting and business mapping. Flowcharting emerged in military and business environments in the 1940's and 1950's as data flow charting, which was brought to a sophisticated level of theory and practice in the 1970's (Gane and Sarson, 1979). It provided a foundation for the discipline of process mapping, which is central to the continuous improvement and quality strategies in modern management practice (Damelio, 2011).

The principal purposes of decision mapping are:

- To develop a graphical presentation of states, actions, and outcomes relevant to the decision problem;
- To resolve the complexity of the decision environment into its parts;
- To identify all the individual elements relevant to the decision outcome, and formally define the scope and limits of the decision environment;
- To identify structure and functional relationships between the identified elements, and to sequence elements, actions and emergent outcomes;
- To identify subsidiary decision points in the sequence, and subsidiary parallel action structures that emerge from these decision points;
- To identify external inputs into the decision framework required to inform internal decision points;
- To develop the alternatives set, with its relevant input factors and relationships;
- To construct an action framework as a business process map that identifies a logical sequence of actions and outcomes that lead to a final decision;
- To identify elements or variables in the decision framework that are most subject to uncertainty;
- To identify points in the decision analysis sequence where subjective judgement and subjective factors are material; and
- To identify the set of stakeholders - including community, political, governmental, business or community - most influenced by or most contributing to the decision.

Standard risk assessment and risk management frameworks applied in the Local Government context have so far been largely qualitative, with some general ratings and rankings on likelihood and frequency estimates (Bara et al., 2010; DEFRA, 2009, 2011; Environment Agency 2008, 2011a, b). In contrast, the decision mapping technique used here allows for a rigorous, detailed analysis of the challenges presented to local councils by rising sea levels; of the risk and uncertainty associated with the variables that characterise it, and of the options open to local government in the management of such risks. The decision map also generates quantitative input into the financial model. With this data, analysis and modelling in hand, the final policy can be developed by local councils using risk management rules, Multi-Criteria Analysis or another multi-dimensional decision framework in concert with a public consultation exercise.
The Decision Map developed here consists of six steps:

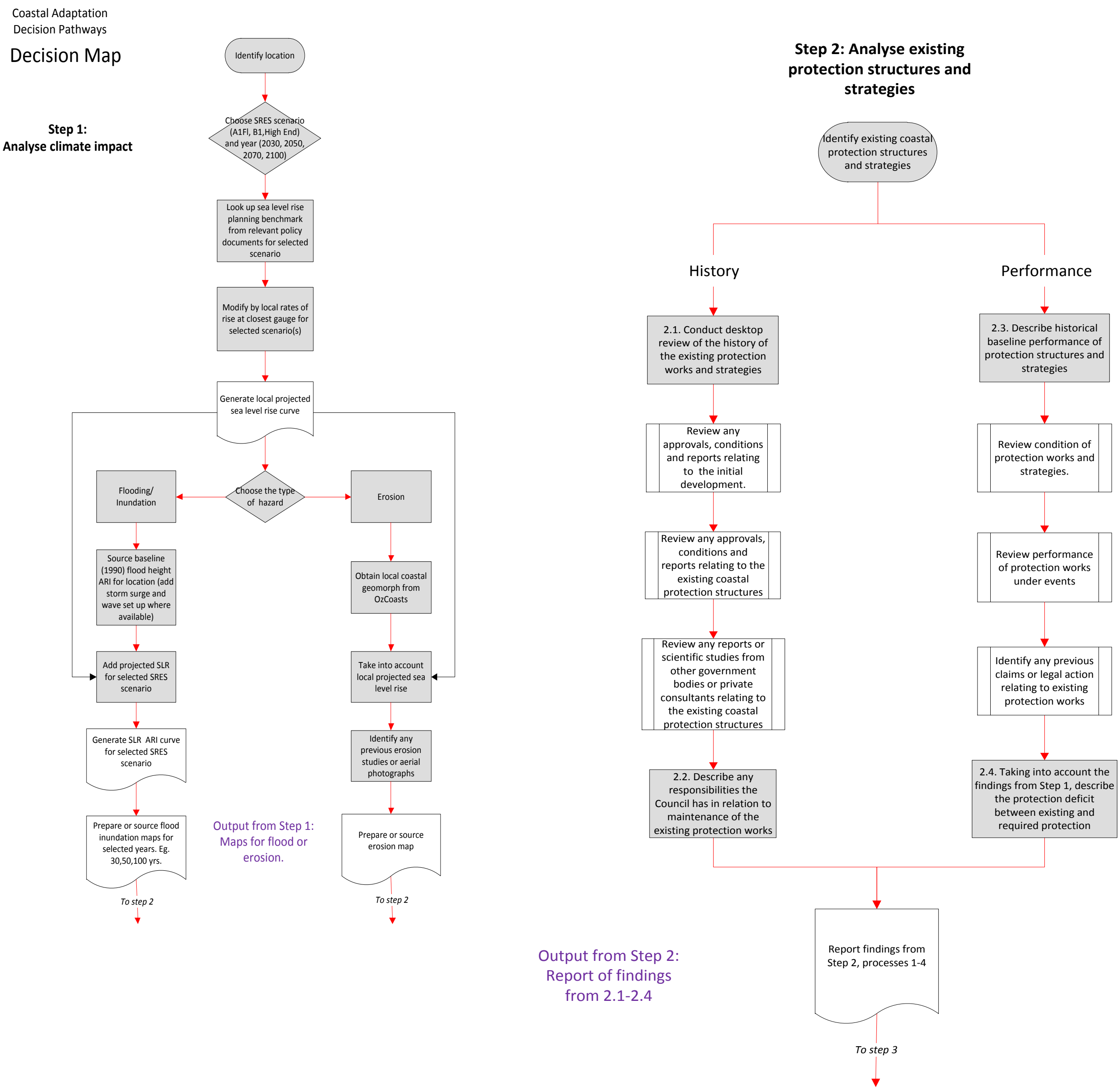
1. Analyse the climate impact;
2. Analyse existing protection structures and strategies;
3. Establish the profile of assets at risk;
4. Determine Council liability;
5. Determine monetary value of assets at risk; and
6. Analyse actions.

Step 1 – Analyse Climate Impacts

Coastal inundation occurs as a result of slow topographic changes in coastal land resulting either from uplift or subsidence, changes in water height as a result of tides and storms measured as the probability of a particular water height occurring (or the average recurrence interval (ARI) of a particular water height), wave run-up and wave set-up as a result of wind and topographic effects and SLR as a result of anthropogenic climate changes. To be accurate enough to determine if a particular site on the coast is inundated (and hence determine potential damage costs), each of the contributors to total water level needs to be measured relative to the land (or elevation zero) for the location that is to be assessed. These data are not always available at a vertical resolution fine enough to accurately quantify these measures so specialist survey to gather data using Lidar may be required. An accuracy of 10-15cm is needed to ensure accurate projections of flood impact. Once the site and detailed time and elevation baselines have been defined, the necessary measurements for each contributor to total high water level need to be estimated for the site as many of the factors are locally specific. Added to the baseline measurements is a SLR between the baseline year and a defined future year. For example, SLR can be determined by either consulting a SLR projection (A1FI for the year 2100 = 0.79 m) or by selecting a SLR height based on policy or other parameters (eg. South Australia = 1.0 m by 2100). Next inundation maps need to be generated to show those areas that will be flooded. In most cases the inundation maps generated will be 'bathtub' or 'bucket fill' maps that project a total water height across the landscape. Using software modelling to interpret the Lidar data it is possible to create a Digital Elevation model that clearly shows which areas will be flooded and how deep the flood will be at any given point.

Erosion is more difficult to quantify than flood and is dependent on numerous local influences including bathymetry and topography, geomorphology of the coastline, longshore drift, and the availability of sediment for beach recharge. In addition, although coastal erosion often results in response to an extreme storm surge event, models for predicting erosion are based on changes in mean sea level and so only provide long-term projections of coastline recession rather than 'real time' estimates. In addition, some sections of the coast are already eroding as a result of the observed SLR over the past century and from geological processes in play for thousands of years. Models for predicting coastal erosion (e.g. the Bruun rule) are as yet simplistic equations for estimating the interaction of the complex coastal processes described above. The Smartline database as part of the OzCoasts project has assessed the geomorphology of the Australian coast with the aim of providing guidance on likely stability of the shore but local estimates for erosion in particular places needs to be made for more detailed studies.

Figure 1: Decision Map steps one and two



Step 2 – Analyse Existing Protection Structures and Strategies

There are two main reasons for analysing existing protection works and strategies. Firstly, the original development application and conditions of approval can provide information on the science that was utilised, the options considered, the rationale for the adopted approach and the engineering specifications used in the construction of the works. Additionally, any conditions of approval relating to the ongoing maintenance of the protection works will be more easily identified. Secondly, potential liability may be a concern for Councils where protection works have been implemented. The UK government has recognised this factor and has ordered a review of all protection structures with the express purpose of divesting itself of as much liability as possible. Review of the circumstances of the implementation and historical performance of existing protection works and whether any maintenance obligations have been fulfilled, informs on council liability, which, as in the Byron Bay case, may be a critical factor. It is important to investigate how the protection works have performed over time. A visual inspection and photo record is recommended to identify suspected deficiencies. Review of Council records will reveal whether there have been any reports commissioned that relate to the section of coast under review, or whether there have been any incidents where breaches of the protection works have occurred. Taking into account the data from Step 1, the analysis should also describe the protection deficit between the existing and required protection.

Step 3 – Establish Profile of Assets at Risk

The purpose of this stage of the Decision Map is to identify all the assets whether in public or private ownership, that may be at risk from SLR and to characterise these. Two factors are important at this stage; first to identify the level of risk or damage to specific assets or asset groups (an example of an asset would be a group of houses), and second to identify the ownership of these assets. When assessing a flood scenario, the flood map(s) from Step 1 are used to identify all assets affected by the greatest depth of flood in the chosen flood scenario. Cadastral maps or aerial photographs can be used to identify specific locations. Public assets such as roads and footpaths are recorded separately. The most critical factor is the finished floor level of buildings relative to projected flood heights. Once flooding is higher than floor levels significant damage costs to property accrue. Below this level property damage is likely to be much less severe. Once the data is collected it is possible to assign a flood depth for each asset (house, road, infrastructure item). With small area studies (say less than 200 dwellings) it should be possible to record each property's details. With larger areas, it may be necessary to aggregate data on properties (e.g. most dwellings in a particular flood depth zone are lightweight construction and raised on piles).

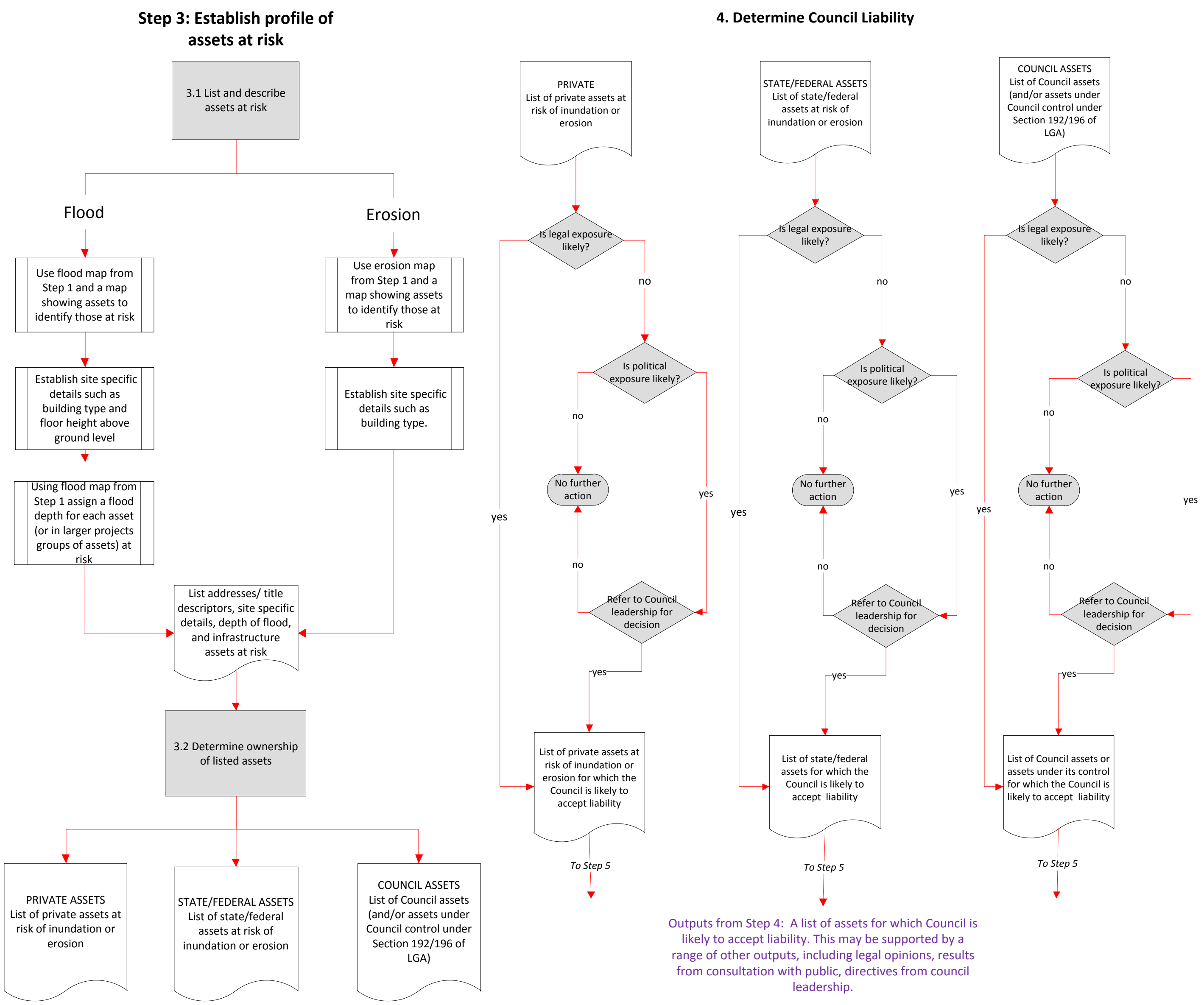
Table 1: Example spread sheet output from Step 3 for a flooding scenario.

Property Address			Construction Type	Notes (if any)	Sea Flood Depth	Site specific Factors	Total Sea Flood Depth
Str. no.	Lot no.	Street Name	V; LWC; TR; PH; BR*.		Depth from flood map using ARI 100 year flood (mm)	above/below natural ground (mm)	Modified by site specific factors (mm)
1		The Esplanade	BR	Elevated bench	1000	600	400
3		The Esplanade	LWC	On 400mm stumps	800	400	400
5		The Esplanade	PH	Pole house.	1200	2500	-1300

In potential cases of erosion, the erosion map(s) generated in Step 1 should identify all assets that will be affected by erosion for each increase in mean sea level.

The final stage in Step 3 is to assign ownership of the assets identified. Ownership may be grouped according to the purpose of the study but a useful approach is to separate private, state/ federal and Council owned assets. A spread sheet as shown in Table 1 that includes property details (either singly or grouped), construction type, details of finished floor levels and flood details taken from the Step 1 maps is an appropriate output from this step.

Figure 2: Decision Map steps three and four



Output from Step 3: List of assets that includes location descriptors, ownership, and where appropriate, site specific details such as building type.

Step 4 – Determine Council Liability

While the issue of liability has been touched on in Step 2 in relation to existing protection works, Step 4 deals specifically with responsibility for the assets at risk. Liability to Councils is worth examining from two perspectives. The first is legal liability. A Council that accepts legal liability for an asset may face claims for future damage from its owners. If liability has not been clearly established such claims may result in legal action where the Council may have to spend time and money to defend itself in court, possibly paying damages and costs if it loses the case.

The second aspect is political liability. Governments can come under significant pressure to install protection works and other measures, regardless of whether they are legally obligated to protect assets belonging to others or not. The Byron Bay case demonstrated how a Council could find itself in the national media spotlight. Nevertheless, policy review notes a trend for Governments at a National and State level to shift liability on to individual asset owners. ALGA (2011) provides both an insight into the range of actions where a Council may be exposed and the limitations of exposure. For example, the responsibility of Council may be limited to simply warning its constituents of a potential risk. Additionally, the Council needs to evaluate the legal consequences of actions such as new protection works which may incur a new range of liabilities.

Council have a responsibility to protect their financial investment in assets which they own or manage. Information on infrastructure and insurance should be corroborated by council asset managers. At the conclusion of this step, the Council should have ascertained if it is liable for assets owned by others should flooding or erosion eventuate or whether it is only responsible for its own assets.

Once liability is clear the Council has a responsibility to warn its constituents and by doing so is likely to limit its liability (ALGA, 2011). In situations where new development is allowed in areas at risk from inundation, conditions of approval may ensure that emergency action plans are prepared by residents. While concern for the safety of residents is paramount, such plans serve as the ultimate 'warning' to residents that they are putting themselves at risk and can eliminate Council liability. This strategy is similar to those implemented for developments in bush fire zones where planning regulations may require vegetation clearance around vulnerable properties but do not confer liability for safety on the issuing authority.

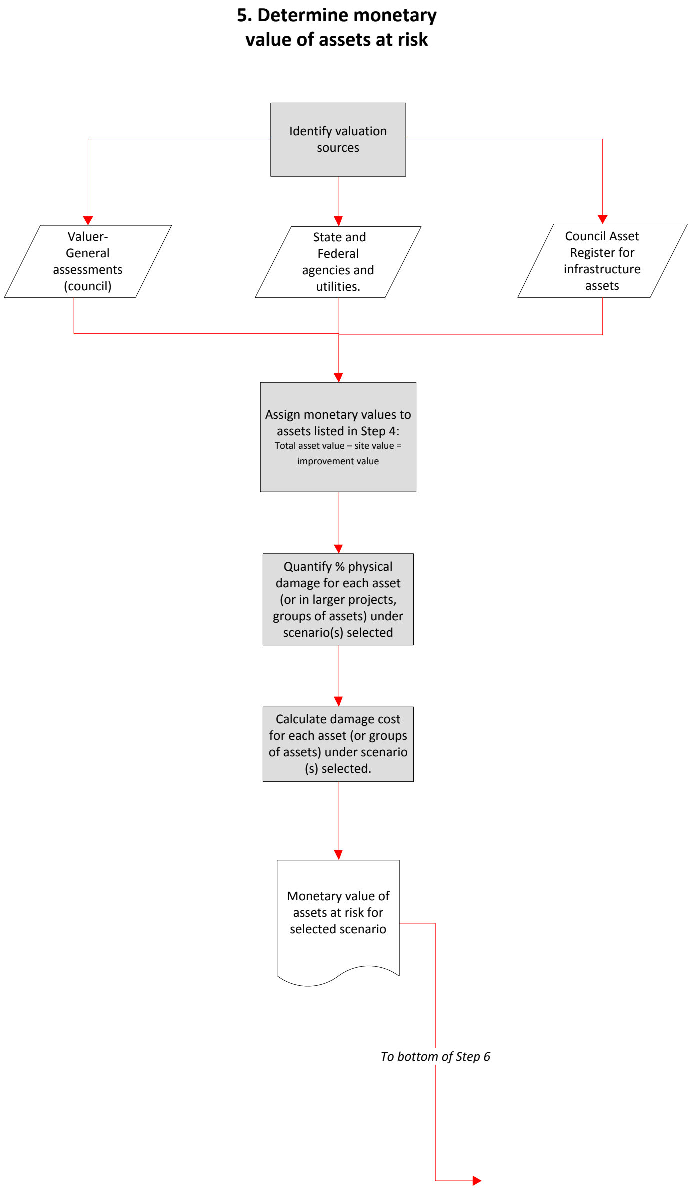
Step 5 – Determine Monetary Value of Assets at Risk

The purpose of this stage of the Decision Map is to determine a dollar value for all of the assets that have been identified as at risk to flood or erosion and for which the Council considers it has some responsibility or liability (Step 4). All assets previously considered, for which Council does not accept liability, can be excluded from consideration in this step. Various sources of data are potentially useful. These include the Councils' own asset register of Council owned property and infrastructure and the State Valuer General's list of rateable property values. Other state and or federally owned assets, such as major roads, airfields and waste water treatment plants may require approaches to these agencies. Values are handled differently in the case of floods and erosion. Building value needs to be calculated in cases of flooding since inundation has no permanent effect on site value. Damage curves are normally applied by insurance companies to assess flood damage to buildings. The extent of damage is normally expressed as percentage of total building value and depends on flooding depth (Middelmann-Fernandes, 2009). By contrast erosion is likely to affect total capital value as it can potentially destroy both land and buildings. Various infrastructure assets such as roads, pipelines, fences and outdoor structures will need to be assessed separately and damage estimates made before costs can be quantified. Roads and other infrastructure items may suffer minimal damage from flooding, but could be seriously affected by erosion. Sealed and unsealed roads will suffer different damage from flooding. Localised and asset specific aspects need to be determined before values are determined. Councils may hold data on damage estimates or may need to refer to professional advice from engineers or insurers in particular cases. The final stage in Step 5 is to total all the monetary values and input these to a financial assessment tool such as a spreadsheet or cost model. An example output from Step 5 is shown in Table 2.

Table 2: Presentation of data to estimate flood damage to a building.

l Sea Flood Depth	Flood depth above FFL (in five scenarios)					Value of assets (land and improvements - land = value of improvements)			Value of assets under threat (in five scenarios)				
fied by site ific factors (mm)	Depth at 1.00m SLR flood scenario	Depth at 0.80m SLR flood scenario	Depth at 0.60m SLR flood scenario	Depth at 0.40m SLR flood scenario	Depth at 0.20m SLR flood scenario	Land and improvements	Land value only	Value of improvements	Damage $ at 1.00m SLR flood scenario	Damage $ at 0.80m SLR flood scenario	Damage $ at 0.60m SLR flood scenario	Damage $ at 0.40m SLR flood scenario	Damage $ at 0.20m SLR flood scenario
400	400	200	0	0	0	$350,000	$190,000	$160,000	$72,000	$64,000	0	0	0
400	400	200	0	0	0	$280,000	$175,000	$105,000	$47,250	$42,000	0	0	0
-1300	0	0	0	0	0			$0	0	0	0	0	0

Figure 3: Decision Map step 5

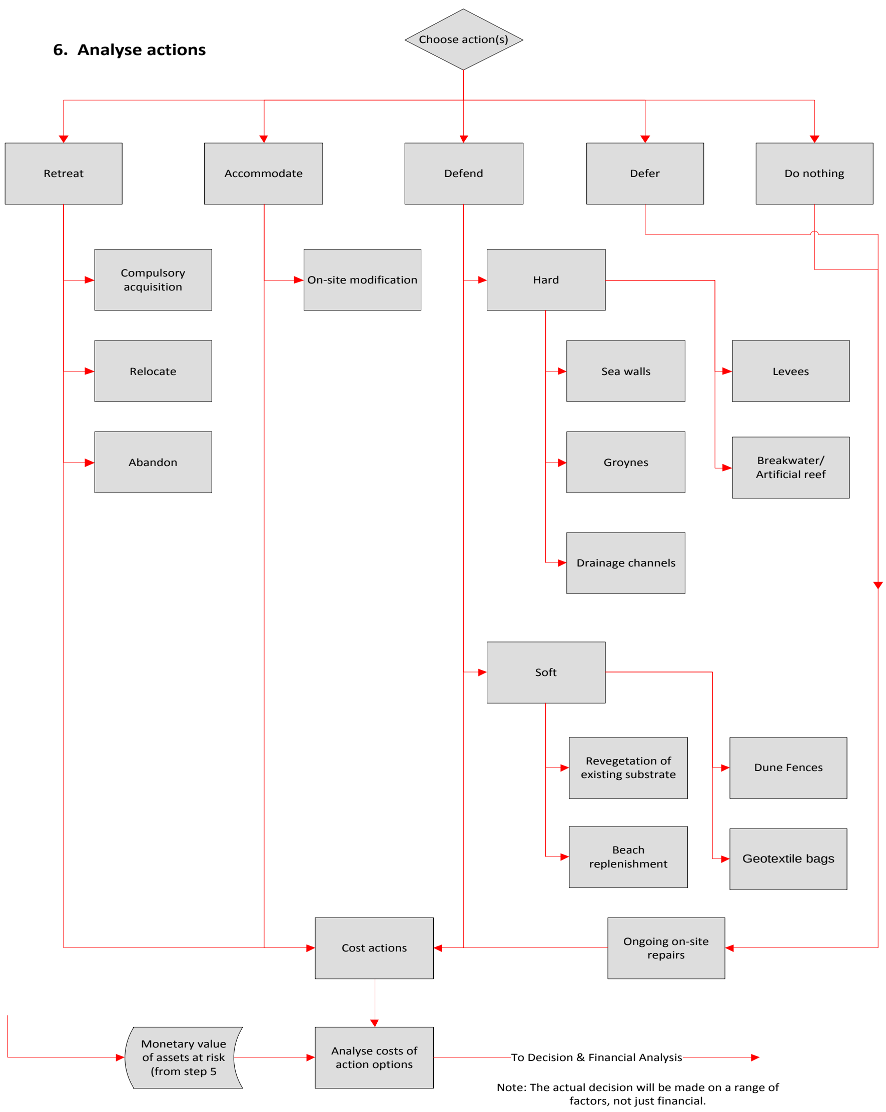


Step 6 – Analyse Actions

Step 6, the final step in the Decision Map, is designed to present and analyse the range of alternative actions. It is designed to be a clear and useful set of choices which can inform policy outcomes. By tabulating and making explicit the requirements of different actions, dollar values may be attached and a comparison of these may be used to arrive at an appropriate policy pathway. It should be noted at this point that because of the inclusion of uncertainty and complexity, compounded by the need to consider the standpoints of multiple stakeholders and objectives, the financial cost of these alternative actions is unlikely to be the only or the most important variable in reaching an agreed policy direction. For example, the preservation of a sandy beach because of its social value may eliminate other options that in pure monetary terms are more cost effective.

The Decision Map sets out five parallel pathways or ‘swimlanes’ that may be taken to respond to the rising sea level threat to existing coastal developments. These options were derived from literature review and represent an exhaustive set of alternatives grouped as retreat, accommodate, defend, defer or do nothing. As such they cover the full spectrum of possible actions. Each option is then broken down into subsidiary actions or decisions. For example, the choice of a defend strategy requires subsidiary choices regarding the nature of hard or soft defence mechanisms and within these, further technical choices such as using beach nourishment or revegetation within a soft option pathway. The analysis should follow each action choice in turn and ascribe relevant cost and value data from steps 1-5 to each alternative. So for example, using a retreat option, the relative costs of compulsory acquisition, relocation or abandonment should be recorded. These costs should include the capital value of private properties, the cost to Council of abandoning infrastructure, replacement costs where relevant, and income forgone by such action (e.g. loss of rateable income to Council). When complete, Step 6 allows Council to view a tabulated breakdown and comparison of the relative cost of all five potential actions pathways.

Figure 4: Decision Map step six



Conclusions

The Decision Map outlined above was developed in association with two councils in South Australia. On completion it appeared to represent a logical and robust approach to informing policy development in respect of the threat posed to existing developments by rising sea levels. One council has chosen to further test its implementation. A key consideration that emerged has been the involvement of residents in using the output of the Decision Map to arrive at policy solutions. Whilst this work is not yet complete, bringing residents into the process has confirmed the need for accurate evidence and verifiable data. So, for example, the provision of highly accurate land form and elevation data is a vital step. Allowing room for doubt or controversy clouds the debate and allows sometimes irrational or unsubstantiated arguments to gain traction. Demonstrating that a future threat exists is not simple. Accessing locally held information such as photographs and videos of past flooding events has proved a valuable approach that was not explicitly foreseen in the design of the Decision Map. The consultation process has also confirmed our view that liability is likely to lie at the heart of any policy outcomes. Clearly the Decision Map is capable of identifying the potential financial cost to council of any policy decision. This is likely to rule specific strategies in or out depending on their cost to the public purse. But equally, the recognition that they may be financially responsible for the gradual impacts of rising sea levels may provoke a range of responses on the part of private landowners. The most likely of these are denial and conflict with council as was evident in the Byron Bay case. Managed retreat, which represents the inevitable and common sense strategy, may prove difficult to implement in cases where landowners themselves have to shoulder the financial costs. Whilst in the long term (100 years or more) retreat may be inevitable, in the medium term we are likely to see a prolonged period of defence and adaptation policies which seek to spread liabilities and costs across landowners and government. Issues such as access to emergency services and the reliability of various types of infrastructure may become the critical factors which dictate policy as threatened properties become more vulnerable. Retreat may be the inevitable long term outcome of rising sea levels, but the interim period which may extend between now and the later decades of this century are likely to be characterised by a shifting landscape of legal and financial liability and localised case by case disputes about policy. The Decision Map approach outlined above can assist in clarifying some of the key issues for councils and communities, but how these will play out in policy terms, remains to be decided.

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