GEOTECHNICAL AND COASTAL ENGINEERING ASPECTS OF RISK ASSESSMENT FOR COASTAL PROTECTIVE WORKS AND ASSETS

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ABSTRACT

There are numerous coastal assets in NSW that are located in areas subject to beach erosion and hence are at potential risk of damage in coastal storms. Two risk assessment procedures are presented herein, namely:

- a geotechnical risk assessment of foreshore stability and protective works that was applied by Jeffery and Katauskas on the north coast of NSW and
- a coastal engineering risk assessment of damage to assets along beaches in Warringah as applied by WorleyParsons for Warringah Council.

The geotechnical assessments of risk to property and risk to life were based on the AGS (2007) procedures. These risk assessments are seen to be useful in informing emergency services of the potential need for evacuation of some properties in coastal storms, and allowing a framework for monitoring of the foreshore to be developed and implemented.

The coastal engineering risk assessment comprised the development of:

- an inventory of individual property details relevant to consideration of risk,
- resistance ratings for existing protective works located along the beachfront (e.g. based on toe levels and rock size),
- procedures for assigning likelihood ratings for occurrence of damaging events (based on the position of the Immediate Coastline Hazard Line relative to the seaward face of an asset, assuming no protective works),
- procedures for assigning consequence ratings to expected property damage (including consideration of whether the asset was supported on piles and the likely effectiveness of protective works seaward of the asset) and
- an overall risk analysis matrix used to derive a risk rating from different combinations of likelihood and consequence ratings.

These coastal risk assessment procedures are noted as being useful in preparing in advance for coastal storm events.

1 INTRODUCTION

There are numerous public and private coastal assets in NSW that are located in areas subject to beach erosion and hence are at potential risk of damage in coastal storms. Protective works such as seawalls and revetments may be located seaward of these assets, which reduces this risk of damage. Two risk assessment procedures are presented herein, namely:

- a geotechnical risk assessment of beach stability and protective works that was applied by Jeffery and Katauskas on the north coast of NSW (see Section 2) and
- a coastal engineering risk assessment of damage to assets along beaches in Warringah (a Local Government Area on Sydney's northern beaches) as applied by WorleyParsons for Warringah Council, which included consideration of the effectiveness of protective works (see Section 3).

These procedures are noted as being useful in preparing in advance for coastal storm events.

2 GEOTECHNICAL RISK ASSESSMENT OF BEACH STABILITY AND PROTECTIVE WORKS ON NSW NORTH COAST

2.1 PREAMBLE

Coastal storms in May 2009 eroded sections of foreshore on the north coast of NSW, due to combined wave action and elevated ocean water levels. Jeffery and Katauskas and WorleyParsons were engaged to:

- undertake a geotechnical and coastal engineering assessment of the stability of recently eroded sections of the foreshore (including protective works) and

- provide a preliminary assessment of current levels of risk to both life and property.

2.2 DESCRIPTION OF FORESHORE EROSION

The coastal storm that occurred in May 2009 resulted in:

- eroded over-steep sandy foreshore slopes (approximately 2 m to 5 m high) with former sand-filled geotextile bag protective works at the lower portions of the slope located 2 m to 8 m seaward (prior to the storms, these bags lined the toe of the foreshore slope), see Figure 1,
- erosion adjacent to the ends of existing rock seawalls and
- localised displacement of portions of rock wall protective works due to undermining, which generally resulted in downslope movement of the entire mass of the rock wall and steep erosion scarp features within the sand located landward. At some sites where rock displacement had occurred, tension cracks located about 6 m to 9 m landward of the foreshore crest were observed (Figure 2), which appeared to indicate more deep seated rotational failure planes affecting the foreshore slope (i.e. global failure).

Figure 1: Sand-filled geotextile bags located seaward of eroded sand slope.

Figure 2: Tension cracks in foreshore slope indicating more deep seated rotational failures.

2.3 POTENTIAL LANDSLIDE HAZARDS

Based on foreshore inspections, the following potential landslide hazards were identified:

- global (deep seated) rotational failure of the sandy foreshore slopes,
- localised near surface slumping of the over-steep crest areas of the sandy foreshore slopes (with the base of the slump controlled by the top surface of underlying 'coffee rock', where present),
- collapse of rock seawalls and
- collapse of sand-filled geotextile bag walls.

2.4 RISK ASSESSMENT

2.4.1 Preamble

For the risk assessment, it was assumed that a similar storm event to May 2009 would occur within the next 12 months to 10 years (i.e. an 'almost certain' likelihood). Further, the impact of 'typical' weather and tidal patterns (i.e. no severe storm events) as an additional trigger mechanism to ongoing foreshore instability was considered (again with an 'almost certain' likelihood). The design life and age of protective works is also pertinent with regard to their ongoing performance.

The elements most at risk were considered to be:

- residents,
- existing buildings and structures,
- utility infrastructure and
- foreshore slopes.

The geotechnical assessment of the risk of instability was based on the methodology proposed by AGS (2007).

2.4.2 Risk to Property

A qualitative assessment of the potential landslide hazards listed in Section 2.3 under existing conditions, defining the consequences to property should further collapse/instability occur, is provided in Table 1.

Table 1: Qualitative assessment of risk to property for dwelling setback at least 10 m from crest of foreshore slope

Elements of Risk	Potential Landslide Hazard			
	Global Instability of Foreshore Slope	Localised Instability of Crest of Foreshore Slope	Seawall	Geotextile bag wall
Assessed Likelihood	Almost Certain	Almost Certain	a. Almost Certain, or b. Possible (if no previous signs of movement and/or masonry wall)	Almost Certain
Assessed Consequences (damage to seaward yards and seawall as % of property value)	Insignificant, or Medium (if tension cracks identified within seaward yard)	Insignificant	Minor (damage less than 10% property value and entire length of wall affected due to undercutting of toe of wall)	Minor (damage less than 10% of property value)
Assessed Consequences (dwelling)	Insignificant	Insignificant	Insignificant	Insignificant
Risk: loss of land, damage to rock seawalls, geotextile bag walls	Low, or Very High (if tension cracks)	Low	a. High b. Moderate	High
Risk: damage to dwelling	Low	Low	a. Low b. Very Low	Low

Strict application of the assessment of consequences to property as outlined in AGS (2007) requires that "the approximate cost of damage be expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures." This was adopted, except that no attempt was made to quantify any loss of property value due to loss of land as a result of coastal erosion.

In determining consequences (based on approximate cost of damage), the following information was used:

- land valuations and plan areas of lots,
- an assumed typical property value (land plus dwelling) of $5 million, although occasionally higher values were adopted based on the land valuations,
- a cost of localised 'top-up' repair of rock seawalls of $3,000/metre and
- a cost of repair of geotextile bag walls of $1,000/metre.

Note that based on AGS (2007), "very high" and "high" risks are considered to be "unacceptable" (without treatment), "moderate" risks are considered to be "tolerable", and "low" and "very low" risks are considered to be "acceptable".

The results in Table 1 indicated that (under existing conditions, for locations where existing dwellings are over 10m landward of the foreshore crest, and assuming a storm similar to May 2009 affects the foreshore within the next 12 months to 10 years):

- the assessed risk to property (loss of land, damage to rock seawalls and geotextile bag walls) varied between "acceptable', "tolerable" and "unacceptable" levels,
- for localised instability or global failure of the foreshore, risk levels were "low" unless tension cracks had been recorded within the seaward yard areas (in which case the risk was assessed to be "very high"),
- for instability of existing rock seawalls and geotextile bag walls risk levels were "unacceptable", unless the existing rock seawall was in good condition (in which case risk levels were "tolerable") and
- the assessed risk to property (damage to the existing dwellings) was at "acceptable" levels.

A similar risk assessment was completed for dwellings located within 10m landward of the foreshore crest where foreshore protection measures comprised rock seawalls. A similar range of risk levels as recorded in Table 1 was obtained.

For 'typical' weather and tidal patterns, the assessed risk for loss of land and wall damage in almost all circumstances was at "acceptable" levels, as was the risk to property for damage to existing dwellings.

2.4.3 Risk to Life

With regard to risk to life, it is noted that foreshore instability and any rock seawall or geotextile bag wall collapse or damage generally occurs during or soon after a storm event. In such instances, members of the public or residents would generally not be expected to be in close proximity to the foreshore (i.e. on the beach or in the seaward yards) and so temporal, vulnerability evacuation and spatial factors would be at low levels. On this basis, it is considered that levels of risk to life for members of the public or residents in such areas would be at "acceptable" levels, in relation to the criteria given in AGS (2007), namely an annual probability less than 10^{-5}.

For residents within their dwelling under existing conditions (assuming a similar storm event occurred within the next 12 months and caused a similar degree of coastal erosion), it was found that the occupants within one dwelling may be regarded as being exposed to elevated levels of risk to life. This was because it was conceivable that the erosion scarp might form close to the edge of the dwelling, or possibly undermine the dwelling causing localised collapse of a portion of the structure. On the basis that foreshore instability affected the dwelling, and with a temporal probability of 50% for the seaward side of the dwelling, the estimated risk to life was 10^{-3}/annum (and hence considered to be "unacceptable").

For other dwellings where deep seated failure of an existing foreshore dune sand slope may occur, assuming similar erosion as for the recent storm events, the dwellings were generally considered to be far enough landward to be outside the zone of influence of the erosion event. Therefore, under existing conditions the levels of risk for occupants of these dwellings was regarded as being "acceptable". However, for two locations, if a similar erosion event to May 2009 occurred, the erosion scarp would be within about 3 m of the existing dwellings (assuming the erosion scarp was located at the tension cracks identified within the seaward yards). At this point, any further storm erosion would be expected to expose the occupants to an increased "unacceptable" level of risk to life.

2.5 DISCUSSION

It is recognised that, due to the many complex factors that can affect a site, the subjective nature of a risk analysis, and the imprecise nature of the science of geotechnical engineering, the risk of instability for a site cannot be completely removed. However, it is essential that risk be reduced to at least that which could be reasonably anticipated by the community in everyday life and that landowners be made aware of reasonable and practical measures available to reduce risk as far as possible. Hence, risk can only be reduced, as complete removal of risk is not practically achievable.

For dwellings close to the zone of influence of any global failure of the foreshore slopes, the client was advised that the State Emergency Service and NSW Police should be made aware of the findings of the risk assessment, in relation to the need for evacuation of these properties prior to a storm peak occurring.

It was also recommended that ongoing monitoring of the foreshore land be undertaken on a periodic basis and immediately after heavy or prolonged rainfall events and storms, particularly if these storms occurred in conjunction with elevated ocean water levels. This monitoring would enable identification of any deterioration such as tension cracks within the surfaces landward of the crest of the foreshore slopes, recession of erosion scarps, or new soil slumps/erosion scarps etc.

AGS (2007) provides a systematic method for assessing risk levels associated with significant coastal erosion events. The risk assessment enabled an understanding of the risk levels associated with coastal erosion events over the study area to be identified, and allowed a framework for monitoring of the foreshore to be developed and implemented.

3 COASTAL ENGINEERING RISK ASSESSMENT FOR ASSETS ALONG BEACHES IN WARRINGAH

3.1 PREAMBLE

WorleyParsons (2011) has completed a study entitled “Management of Coastal Erosion Emergencies at Beaches in Warringah” for Warringah Council, located on Sydney’s northern beaches. This included a risk assessment for Warringah’s coastal structures, including both private development (such as residential houses) and public assets such as Surf Life Saving Clubs.

Warringah’s beaches extend from Collaroy-Narrabeen Beach in the north to Freshwater Beach in the south. Collaroy-Narrabeen Beach is one of the most capitalised sections of the NSW coast, much of which has protective works located seaward of the development, mostly rock revetments constructed in the 1960s and 1970s (but also other works such as reinforced concrete seawalls, sandstone blockwork seawalls and steel sheet piling).

These protective works provide substantial protection at some locations, but are variable in quality, do not generally satisfy current design standards, and cannot necessarily be certified by a qualified coastal engineer as providing full protection.

Although these works are usually buried under sand, coastal storms in June 2007 exposed sections of the rock revetment in the vicinity of Stuart Street at Collaroy, to Clarke Street at Narrabeen, see Figure 3 and Figure 4.

Figure 3: Historical protective works exposed at Collaroy-Narrabeen Beach in June 2007 (ground view)

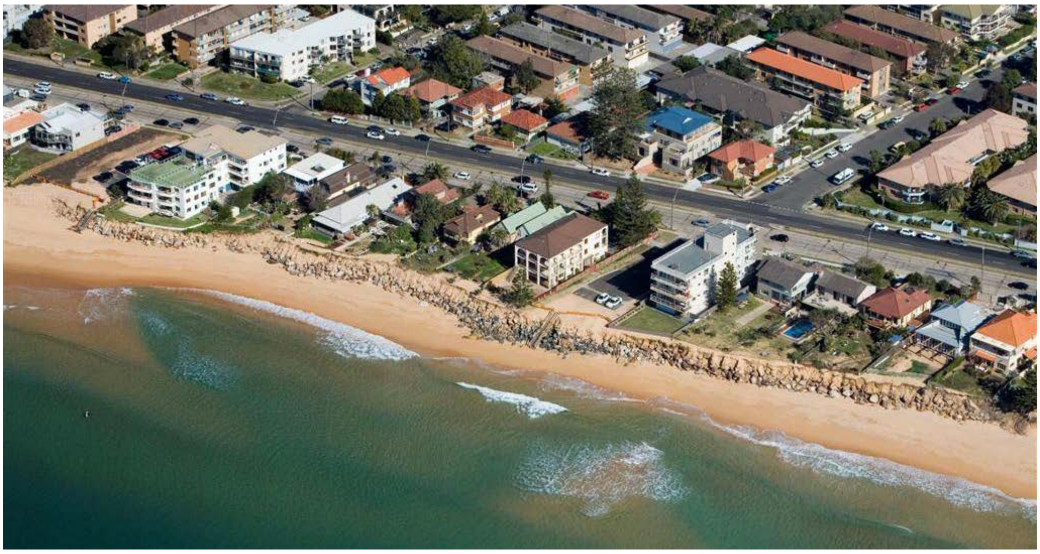

Figure 4: Historical protective works exposed at Collaroy-Narrabeen Beach in July 2007 (aerial view)

As described in subsequent Sections, the risk assessment for Warringah's coastal structures comprised the development of:

- an inventory of individual property details relevant to consideration of risk (see Section 3.2),
- resistance ratings for existing protective works located along the beachfront (see Section 3.3),
- procedures for assigning likelihood ratings for occurrence of damaging events (see Section 3.4),
- procedures for assigning consequence ratings to expected property damage (see Section 3.5) and
- an overall risk analysis matrix used to derive a risk rating from different combinations of likelihood and consequence ratings (see Section 3.6)

3.2 PROPERTY INVENTORY

An inventory of properties along Warringah's beaches was compiled from Council GIS information, knowledge of historical protective works and site inspections. This included details on the presence of protective works, whether development at the property was supported on piles and significant assets within each property boundary.

3.3 PROTECTIVE WORKS STORM RESISTANCE RATING

The protective works along Warringah's beaches were rated based on an assessment of their ability to resist storm erosion. This was considered to be dependent on a number of factors including:

- the depth of the founding level or toe level relative to typical beach scour levels of -1 m AHD,
- reliance of the structure on toe support for stability,
- type of protective structure (for example rock, sheet piling, concrete seawall) and
- adequacy of the size of protective elements (such as rock mass).

A "low", "medium" or "high" storm resistance rating was given to different sections of protective works along Warringah's beaches based on the following criteria:

- "low" storm resistance: structures that rely on adequate toe support for stability, but are founded metres above beach scour levels of -1m AHD and could therefore fail in a catastrophic manner or structures that do not provide coverage over the entire lot or have significantly undersized rock,
- "medium" storm resistance: boulders that would be expected to have some movement in storms or that are present in only limited volumes or heights, or that are founded metres above beach scour levels of -1 m AHD,
- "high" storm resistance: boulders of high mass that generally resist movement or structures (such as sheet pile walls and concrete seawalls) covering most of the height of any erosion escarpment that would form, founded to near or below typical beach scour levels.

Based on this methodology, structures recently designed by professional coastal engineers (such as concrete seawalls at South Curl Curl Beach and Dee Why Beach) were given a "high" storm resistance rating.

3.4 LIKELIHOOD RATING

Likelihood was defined as "the likelihood of the erosion scarp caused by the 100 year average recurrence interval (ARI) storm reaching the seaward face of an asset in the next 10 years, ignoring protective works". The likelihood rating was related to the position of the Immediate Coastline Hazard Line relative to the seaward face of an asset in accordance with the criteria outlined in Table 2 as represented schematically in Figure 5. The description of the six likelihood ratings is consistent with that adopted by AGS (2007).

For those not familiar with coastal engineering practice (and as defined in WorleyParsons, 2011), the Immediate Coastline Hazard Line typically represents the expected landward limit of storm erosion in a severe coastal storm (e.g. 100 year ARI) on a sandy beach (ie ignoring any protective works or inerodible subsurfaces). This position takes into account both the Zone of Wave Impact (that part of the beach which is seaward of the beach erosion escarpment, ie that suffers direct wave attack during a severe coastal storm) and the Zone of Slope Adjustment (that portion of the seaward face of the beach that would slump to the natural angle of repose of the beach sand following storm erosion) as per Nielsen *et al.* (1992)[1].

Table 2: Criteria for assigning likelihood ratings

Position of Immediate Hazard Line Relative to Seaward Face of Asset	Description	Descriptor	Level
> 20 m landward	The event is expected to occur	Almost Certain	A
Between 10m and 20 m landward	The event will probably occur under adverse conditions	Likely	B
<10 m landward or intersecting asset	The event could occur under adverse conditions	Possible	C
< 10 m seaward	The event might occur under very adverse conditions	Unlikely	D
Between 10 m and 20 m seaward	The event is conceivable but only under exceptional circumstances	Rare	E
> 20 m seaward	The event is unconceivable or fanciful	Barely Credible	F

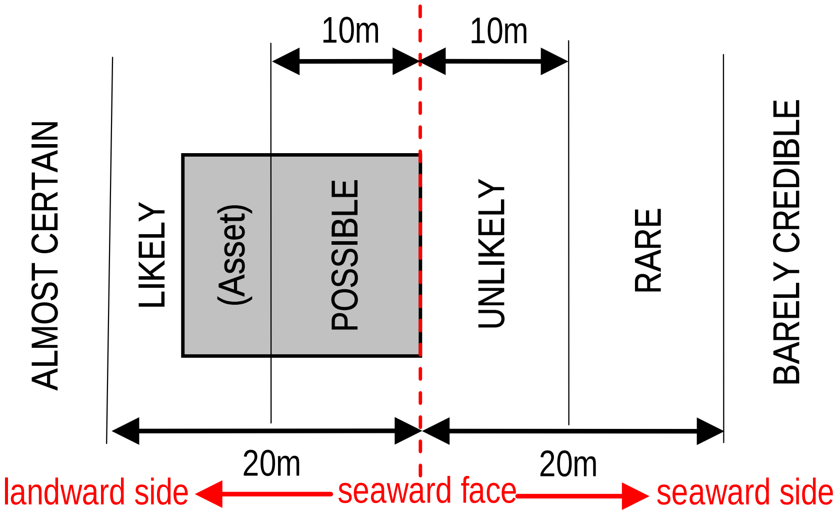

Figure 5: Schematic representation of likelihood rating criteria in relation to position of Immediate Hazard Line

For example, if the seaward face of an asset such as a house was located 15 m seaward of the Immediate Coastline Hazard Line (assuming no protective works), the likelihood rating would be "likely". Conversely, if the seaward face was located 15 m landward of the Immediate Coastline Hazard Line (assuming no protective works), the likelihood rating would be "rare". Note that these distances are particular to Collaroy-Narrabeen Beach and, although they would generally be expected to be reasonable for most other Sydney open coast

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[1] Recent changes to NSW legislation have also incorporated the Zone of Reduced Foundation Capacity as per Nielsen *et al.* (1992) into the definition of "beach erosion hazard" (DECCW, 2010), and thus into the Immediate Coastline Hazard Line.

beaches, it should be recognised that they could vary depending on exposure to wave energy, offshore bathymetry and dune morphology.

3.5 CONSEQUENCE RATING

Consequence was defined as "the degree of damage to assets and surrounding property resulting from coastal erosion associated with the occurrence of a 100 year ARI storm event". The severity of the consequence (or damage) was defined by five consequence ratings that were consistent with those adopted by AGS (2007).

The level of damage that could be experienced at beachfront properties in a coastal storm is dependent on several factors including:

- the position of the Immediate Hazard Line (assuming no protective works) relative to assets (as per the likelihood rating described in Section 3.3),
- whether the asset is supported on piles,
- whether there are existing protective works seaward of the asset and
- the effectiveness of any protective works (related to the storm resistance rating, refer to Section 3.3).

To address all of the above factors, an iterative procedure was developed to derive a final consequence rating. This involved assigning an initial Immediate Hazard consequence rating to an asset based on the position of the Immediate Hazard Line (assuming no protective works) relative to assets in accordance with Table 3.

Table 3: Positional criteria for assigning Immediate Hazard consequence ratings

Position of Immediate Hazard Line Relative to Asset	Description	Descriptor	Level
Landward of the landward face of the asset	Structure completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	Catastrophic	1
Intersecting at more than 50% of asset cross-shore width landward of seaward face	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	Major	2
Intersecting at less than 50% of asset cross-shore width landward of seaward face	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	Medium	3
< 10 m seaward of seaward face	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	Minor	4
> 10 m seaward of seaward face	Little damage.	Insignificant	5

If the asset was not supported on piles and did not have existing seaward protective works, then the initial Immediate Hazard consequence rating above was adopted as the final consequence rating for the asset. If the asset was supported on piles then the initial Immediate Hazard consequence rating was adjusted in accordance with Table 4. If the asset had existing seaward protective works then the initial Immediate Hazard consequence rating was adjusted in accordance with Table 5 based on the associated storm resistance rating of the protective works seaward of the asset under consideration (as per Section 3.3). If the asset was supported on piles and had existing seaward protective works, then the highest of the adjusted consequence ratings was adopted.

Table 4: Adjusted Consequence Ratings for Assets Supported on Piles

Immediate Hazard Consequence Rating	Adjusted Consequence Rating
1	3
2	3
3	4
4	4
5	5

Table 5: Adjusted Consequence Ratings for Assets with Protective Works

Immediate Hazard Consequence Rating	Adjusted Consequence Rating		
	Low Resistance	Medium Resistance	High Resistance
1	3	3	4
2	3	4	4
3	3	4	4
4	5	5	5
5	5	5	5

For example, if the Immediate Hazard Line (assuming no protective works) was located landward of the entire structure, the Immediate Hazard consequence rating would be “1 (Catastrophic)”. If the structure was piled but had no protective works seaward, this rating would increase to “3 (Medium)”. If the structure was not piled but had “high resistance” protective works seaward, the rating would increase to “4 (Minor)”. If the structure was piled and had “high resistance” protective works seaward, the rating would again be “4 (Minor)”.

3.6 RISK ANALYSIS MATRIX

The likelihood and consequence ratings were combined into a risk analysis matrix, in which the effect of both of these components of risk were considered, and an overall risk level was assigned to a given asset. The adopted risk matrix is summarised in Table 6, with risk levels defined as:

- VH – very high risk,
- H – high risk,
- M – moderate risk
- L – low risk and
- VL – very low risk.

Table 6: Risk analysis matrix

Likelihood	Consequence				
	1 - Catastrophic	2 - Major	3 - Medium	4 – Minor	5 - Insignificant
A – Almost Certain	VH	VH	VH	H	M
B – Likely	VH	VH	H	M	L
C – Possible	VH	H	M	M	VL
D – Unlikely	H	M	L	L	VL
E – Rare	M	L	L	VL	VL
F – Barely Credible	L	VL	VL	VL	VL

For example:

- if the likelihood of the erosion scarp caused by the 100 year ARI storm reaching the seaward face of an asset in the next 10 years (ignoring protective works) was “possible” (e.g. if the Immediate Hazard Line was at the seaward face of the asset, or up to 10 m landward of the seaward face), and
- the consequence (degree of damage to assets and surrounding property resulting from coastal erosion associated with the occurrence of a 100 year ARI storm event) was “medium” (the Immediate Hazard Line intersected at less than 50% of the asset cross-shore width landward of the seaward face and there were no protective works and the asset was not piled), then the risk of damage to the asset would be defined as “medium”.

3.7 RISK ASSESSMENT RESULTS

A risk assessment was completed for all structures along Warringah’s beaches based on the above procedures. Most of the private development along the southern portion of Collaroy-Narrabeen Beach was found to be at medium risk, with the risk mainly lowered due to the presence of substantial protective works seaward. Assets in this area that were not piled and did not have protective works seaward were generally found to be at “very high” risk.

Some public assets were found to be at “high” or “very high” risk, including three Surf Life Saving Clubs.

3.8 DISCUSSION

The risk assessment procedure that was applied at Warringah’s beaches as described was found to be a useful means of assessing the relative risk of damage to both public and private assets from coastal storms. Such knowledge is important in preparing in advance for storm events, e.g. in Council deciding if public assets are likely to require protection and the consequences of not undertaking protective works if required. The tool is also useful in informing landowners of the risk of damage to their own assets, such that they can assess measures to reduce risks well in advance of a storm occurring.

Under NSW legislation, emergency protective works cannot be placed along beaches without advance planning. For example, based on *State Environmental Planning Policy (Infrastructure) 2007*, Part 5 of the *Environmental Planning and Assessment Act 1979* applies to many of the type of works that Councils may undertake. This means Council must complete an environmental assessment of the works (a Review of Environmental Factors, or Environmental Impact Statement if significant impacts were expected) prior to the works being undertaken. This requirement, plus other issues (such as the need to obtain materials and organise plant/contractors for works) emphasises the need to act well in advance of a storm.

Landowners must also act in advance of a storm, and unless very restrictive sand or sandbags works were proposed at particular approved locations (based on Part 4c of the *Coastal Protection Act 1979*), protective works would require consent under *State Environmental Planning Policy (Infrastructure) 2007* and Part 4 of the *Environmental Planning and Assessment Act 1979* would apply to the works. This would require a Development Application to be submitted to a consent authority, as well as the preparation of an environmental assessment (Statement of Environmental Effects, or Environmental Impact Statement if significant impacts were expected).

For the risk assessment procedure to be effective, it is necessary to have defined the position of the Immediate Coastline Hazard Line (assuming no protective works), and to have a reasonable knowledge of the nature of protective works (e.g. toe levels, rock size) and whether the asset is piled. The procedure could readily be applied for future planning periods by defining future coastline hazard lines. With predicted long term recession due to sea level rise, future coastline hazard lines would move landward, thus increasing the risk of damage to coastal assets over time.

In the procedure described, the Coastline Hazard Line is used to define both the likelihood and consequence of damage (with other factors such as effectiveness of protective works and foundation conditions also affecting the consequence). It would also be possible to define Coastline Hazard Lines for other average recurrence intervals besides 100 year ARI, and to undertake the risk assessment in generally the same manner, except that the likelihood rating for a given hazard line position in Table 2 may change. For example, if a 1,000 year ARI Coastline Hazard Line was defined, if this Hazard Line was <10 m landward of the seaward face of the asset, the likelihood may become “rare” (as compared to “unlikely” for the 100 year ARI event).

Although coastal inundation (e.g. due to wave runup overtopping the foreshore) has not been included in the procedure described herein, it would be possible to include this hazard in a risk assessment. For example, for an inundation assessment, the likelihood could be defined as “the likelihood of inundation caused by the 100 year ARI storm reaching the floor level of an asset in the next 10 years, ignoring protective works”, and consequence could be defined as “the degree of damage to assets resulting from coastal inundation associated with the occurrence of a 100 year ARI storm event” (with the level of damage affected by factors such as the depth of inundation, nature of floor materials and crest level of any protective works).

4 CONCLUSIONS

Based on an application on the north coast of NSW, geotechnical assessments of risk to property and risk to life have been described using the AGS (2007) procedures. These risk assessments were seen to be useful in informing emergency services of the potential need for evacuation of some properties in coastal storms and allowing a framework for monitoring of the foreshore to be developed and implemented.

As applied for Warringah Council, a procedure has been described for defining the risk of damage to assets from coastal storms. This procedure is based on a knowledge of coastline hazards, the effectiveness of protective works and the nature of the asset’s foundations. This risk assessment is useful in preparing in advance for storm events, e.g. in Council’s deciding if public assets are likely to require protection and the consequences of not undertaking protective works if required. The tool is also useful in informing landowners of the risk of damage to their own assets, so that they can assess measures to reduce risks well in advance of a storm occurring.

5 ACKNOWLEDGEMENTS

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