# RISK ASSESSMENT METHODS FOR ASSESSING EROSION PROTECTION STRUCTURES – BYRON BAY CASE STUDY

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## Abstract

Various erosion protection structures have been constructed along the Byron Bay foreshore, by public authorities and individual residents. Several of these have been identified by previous studies as being degraded and not compliant with contemporary coastal engineering standards.

A Risk Assessment was carried out on each of the identified erosion protection structures in the Byron Bay Embayment. The risk assessment examined the design and capability of the structures to withstand a large coastal storm event, assessed the physical impact of the natural coastal processes interacting with the structures, the environmental impact of the natural coastal processes interacting with the structures and the risk associated with the public use and amenity of each structure.

The Risk Assessment considered the resilience of the structure against coastal processes, impact on foreshore alignment, downdrift, updrift and in front of the structure, ecological impact, public use and beach amenity as well as consequence of structure failure.

This paper describes the methodology used for the risk assessment. The Risk Assessment was carried out based on both qualitative and quantitative criteria. For structure resilience, it considers the “likelihood” of an event causing damage to the structure, in conjunction with the consequences of that event. For the effect of the structures on the coastal ecology, coastal processes, public use and amenity, the risk assessment is more qualitative and a risk rating has been derived for each structure, which considers both “likelihood” and “consequence”.

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## Introduction

The erosion protection works along the Byron Bay foreshore include the Jonson Street Protection Works and interim beach access stabilisation works in front of the Byron Surf Life Saving Club (SLSC). At Belongil Beach, a number of interim beach access stabilisation works have been constructed, including at Manfred Street, Don Street and Border Street. On either side of these interim works, erosion protection works are located adjacent to and on private landholdings.

The risk assessment of the erosion protection structures was commissioned as a result of the recommended Management Action 2.2.2 of the Draft Coastal Zone Management Plan for the Byron Bay embayment, which was to “Make a risk analysis of erosion protection structures and works, both private and public in relation to public safety, the integrity of the structures and impacts to surrounding environment”.

The Risk Assessment classified each structure in terms of the following criteria:

- The design and capability of the structures to withstand a large coastal storm event and consequence of failure of the structure on the landward side infrastructure.
- Impact of the structure on public and private landholder safety under a range of conditions, beach access and amenity;
- Impact of each structure on foreshore alignment and beach width; and
- Impact of each structure on the ecology of the beach, including effects on beach habitat.

In a classical risk assessment, overall risk is assessed as the product of *likelihood* and *consequence*. For structure resilience, the risk assessment considers the "likelihood" of an event causing damage to the structure, in conjunction with the consequences of that event. However, for the effect of the structures on the coastal ecology, coastal processes, public use and amenity, the risk assessment is more qualitative and a risk rating has been derived for each structure, which considers both "likelihood" and "consequence". Consequence of failure of the structures was assessed as part of the assessment of the resilience of the structures. For structural integrity, likelihood can be linked back to a storm event with a known probability of occurrence. For the observed impacts, likelihood is "certain" as the impacts have already occurred.

### *Study Area*

The Byron Bay embayment faces north-east, with the shoreline oriented in a southeast-northwest direction. The embayment is exposed to waves from the north-east sector, with the predominant offshore waves from the south-east sector refracting and diffracting around Cape Byron and into the embayment. Long-term recession of the shoreline at Byron Bay has been identified in previous studies (PWD, 1978, WBM 2000). The strong wave refraction and diffraction processes drive a predominant south-east to north-west sediment transport along the foreshore at Byron Bay, with sand being supplied to the embayment from a nearshore sand lobe, and from sand bypassing Cape Byron and being driven by wave-generated surf-zone currents into Wategos beach (PWD 1978). The study area is shown in Figure 1.

## Methodology

The methodology applied for the risk assessment of the structures included:

1. A detailed on-site inspection of each of the erosion protection structures;
2. A desktop investigation into the stability of each of the structures as a result of their interaction with the local coastal processes;
3. An assessment of the impact of the structures on the coastal processes and shoreline alignment;
4. An assessment of the impact of the structures on shoreline ecology;
5. An assessment of the impact of each of the structures on public use and amenity of the beach; and
6. An overall risk assessment for each structure based on a combination of qualitative and quantitative criteria.


**Figure 1 – Study Area**

## On-site inspection of structures

The visual assessment provided a qualitative measure of the condition of the structure and inferred information about the structure resilience, as well as observed failure mechanisms in the field. The qualitative assessment was based on the site observations and on review of the background historical and design information available for each structure.

Individual structures were documented by capturing a detailed photographic record, and taking detailed notes on each structure, identifying the main structural features and general features of note.

Structures were defined based on visible changes in structure material, slope, height and condition. Structure crest levels were estimated with reference to survey information and by estimating the height of the structure from the beach berm. Although some sections of shoreline have continuous erosion protection along the shore, these were separated into different sections based on visible differences in the structural features. Sixteen individual shoreline erosion protection structures were identified in this way.

The 16 structures identified and inspected during the site visit were grouped into three main areas, namely:

- Jonson Street Protection Works (Group 1, Figure 2)
- Border Street group (Group 2, Figure 3)
- Manfred Street group (Group 3, Figure 4)


**Figure 2** – Jonson Street Protection Works – left – looking south; right – looking north from carpark.


**Figure 3 –** Left – Border Street interim protection works; Right – ad-hoc rock protection in Border Street area


**Figure 4 –** Left – Manfred Street interim protection works in July 2012 (prior to their collapse in January 2013); Right – rock protection near Manfred Street, looking south

The condition of each structure as gleaned from the site inspection was assigned a simple classification as follows:

- **Good condition** – structure armour intact, with little or no displacement of armour units and no visible slumping of the structure crest. No visible deformation of structure profile. No gaps observed between structure and retained material. No settlement or cracking of the area immediately behind the structure and no visible loss of retained material through the structure's armour.
- **Fair condition** – Structure has suffered some minor damage but is still providing some degree of erosion protection. Some deformation of the structure profile or minor weathering of individual armour units but no displacement of individual units from the structure. No loss of retained material through the structure and no large gaps in the structure's armour. No excessive slumping of the structure crest or toe.
- **Poor condition –** Structure has suffered extensive damage or is not effectively providing erosion protection. Structure may have suffered slumping, displacement of some armour units from the face, erosion behind the structure or some loss of retained material through the structure. Structural properties are not appropriate for the coastal engineering conditions experienced at the structure based on visual assessment.
- **Failed condition** – Structure is not providing any erosion protection. Structure has largely collapsed with armour units displaced and retained material having washed through the structure. Erosion of the coastline behind the structure is continuing or has resumed.

### *Structure Failure Mechanisms*

The term "failure" may imply a total or partial collapse of a structure. However, the term "failure" in the context of coastal engineering structures and their design performance, is defined by USACE (2011) as "*Damage that results in structure performance and functionality below the minimum anticipated by design*". Design failure occurs when either the structure as a whole, including its foundation, or individual structure components cannot withstand load conditions within the design criteria. Design failure also occurs when the structure does not perform as anticipated.

Several modes of "failure" were documented for coastal structures in general, with some of these mechanisms observed in the Byron Bay embayment.

The following failure mechanisms are most relevant:

- Damage to armour layer and exposure of underlying material to wave action
- Overtopping and loss of material on the landward side of the crest
- Failure of the toe protection
- Piping failure through the armour layer due to the buildup of groundwater pressure
- Slipping failure
- Flanking erosion around the ends.

The potential for catastrophic collapse of the foreshore structures could arise also as a result of toe scour or geotechnical failure of the slope.

## Quantitative Assessment of Structure Stability

Desktop analysis was undertaken to determine the resilience of the existing erosion protection works within the Byron Bay embayment, with respect to the following parameters:

- Hydraulic stability of the structure armour at each structure against direct wave attack, under 1 year, 10 year and 100 year ARI wave and water level conditions
- The degree of wave overtopping hazard for each structure
- The future effects of climate change on the resilience of each structure
- The potential for geotechnical slip hazard at the various structures.

An additional factor in describing the resilience of each structure is the observed condition of each structure, rated as “good”, “fair” or “poor”.

Items with a rating of “good” against the above criteria were assigned a score of 1. Items with a rating of “fair” were assigned a score of 2. Items with a rating of “poor” were assigned a score of 3. The scores for each structure were averaged across each of the criteria to obtain a “likelihood” score describing the resilience of the erosion protection works.

### *Derivation of Design Parameters*

The design wave for the structures was defined as the largest wave that breaks on the structure.

Wave modelling was undertaken using a SWAN (Delft University of Technology, 2011) offshore-nearshore wave transformation model to assess the effects of wave refraction into the Byron Bay embayment and diffraction around Cape Byron.

As the SWAN model does not account for wave setup, directly extracting the results from the SWAN model would result in an underestimation of the design conditions.

To establish the design conditions for the various seawall structures, the SBEACH model (Rosati *et al.*, 1993) was used. Along with beach profile changes SBEACH is able to simulate depth induced wave breaking, shoaling, wave generation due to wind and wave induced setup. SBEACH modelling was carried out assuming an eroded beach profile, which represents the most critical condition for assessing the resilience of the structures. The eroded profile was constructed based on photogrammetry from 2010 for the portion of the profile above the water line, (which was the most eroded profile in the historical record), and LADS bathymetry data. As the bathymetry data did not accord with the photogrammetry, a wave equilibrium profile (Dean, 1977) was used to interpolate between the toe of the photogrammetric profiles and the depth of closure, to represent the most eroded conditions that could occur. In reality, the nearshore profile would be shallower than a wave equilibrium profile, so assuming an equilibrium profile provides for a conservative analysis. An example profile is shown below in Figure 5 showing the various datasets used to derive the SBEACH profiles.

Future data collection of bathymetry using LADS data would provide a bathymetric dataset over a range of conditions which could be used to construct a more realistic nearshore profile for modelling.

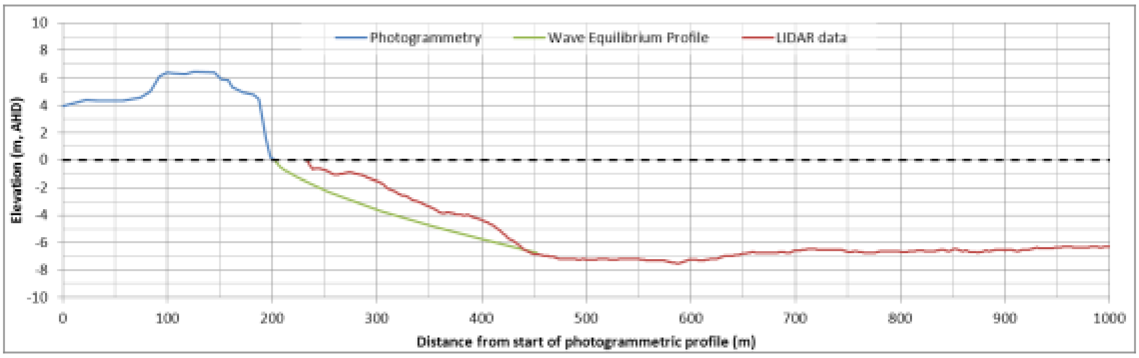


**Figure 5 –** Example SBEACH profile

Significant wave heights were modelled under the 1, 10 and 100 year ARI wave conditions from the east. Waves from all sectors from south-east to north-east were modelled, and it was found that waves from the east result in the highest wave energy arriving at the structures. Wave heights tend to increase along the beach from the southeast (which is partially sheltered by Cape Byron) to the northwest (Figure 6).

Wave conditions close to the shore are depth limited, which can be seen by the sharp drop in wave heights close to the shore. In effect, this means that the 1 year ARI wave heights are almost as high as the 100 year ARI wave heights. This is because the largest waves in the wave train break offshore in deeper water, so the height of the waves that are able to reach the shore and break onto the erosion protection structures is limited by the bathymetry and the nearshore water depth.

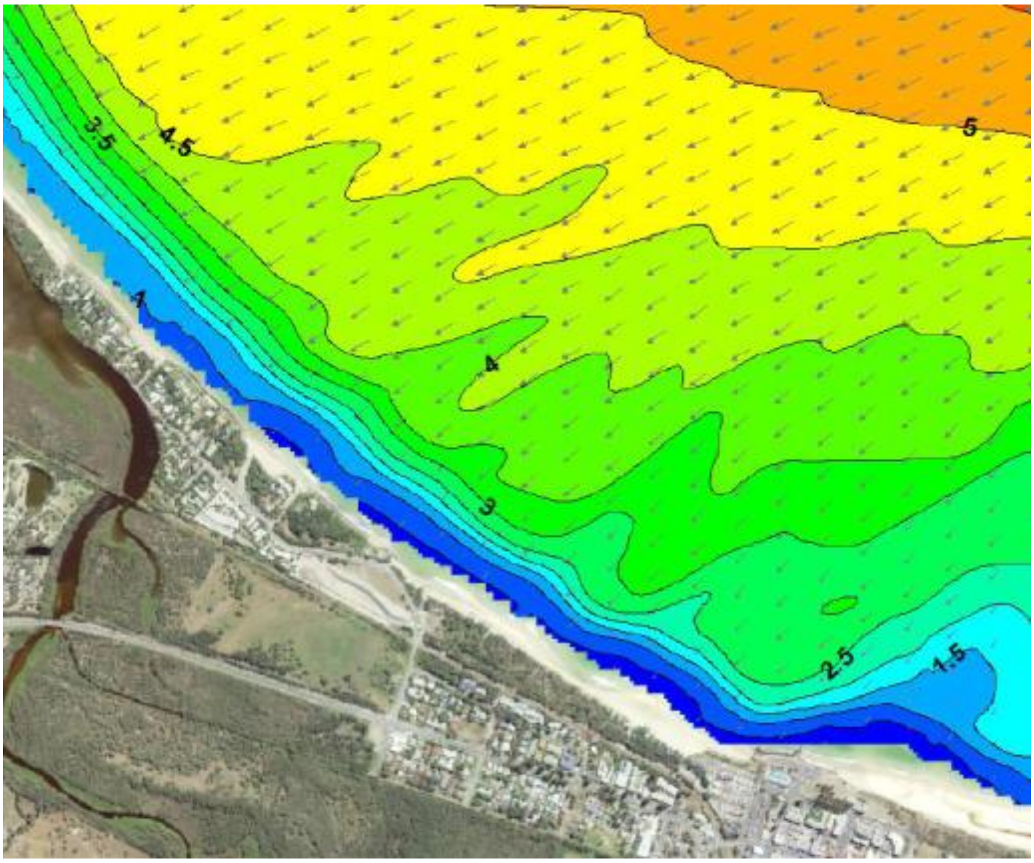


**Figure 6 -** Transformed 100 year ARI significant wave height (Hm0, m) from the east

***Hydraulic Stability of Rock Revetments***

The most important parameters for assessment of the stability of the existing rock armour and the probability that the structures would be overtopped are the breaking wave height in front of the structure, the scour level at the structure toe and the water level at the structure.

For the rock revetments, the stability of the primary armour against wave attack was assessed using the Hudson equation.

The median primary armour diameter needed for hydraulic stability against wave attack for the 1 year ARI storm event was calculated for each structure, based on the structure specific nearshore breaking wave height as determined from wave transformation modelling. These diameters were compared with the actual median armourstone diameters determined from the results of the site inspection. It was found that, for all the rock revetment structures, the rock armour would be hydraulically unstable for wave heights at the structure resulting from an eroded beach profile, for storm events greater than or equal to a 1 year ARI. The existing structures, therefore, currently do not meet a 1 year ARI standard, if the beach is in an eroded or scoured state.

If greater levels of damage were considered, CERC (1984) outlines the equivalent wave height at the structure for use in the Hudson analysis that would result in a particular level of damage to the cover layer. It was found that, in a 10 year ARI event with an eroded beach profile, the section of rock protection in front of the surf club and reserve, as well as the western section fronting the carpark and First Sun caravan park, would suffer around 30% - 40% damage to the cover layer.

The level of observed damage to the structures is in accord with this assessment, with approximately 30 – 40% of the primary armour of the structure having been dislodged from the structure face.

Wave overtopping was considered as part of the assessment of hydraulic stability. Wave overtopping calculations were undertaken and validated against a recorded wave overtopping event on Christmas Day, 2011 caused by the passage of Tropical Cyclone Fina off the southern Queensland coast (WorleyParsons, 2013).

The influence of whether the beach is eroded or accreted was considered also. The limiting factor for design occurs when the beach is in a scoured condition. Using the SBEACH model (Figure 7), it was found that, should the beach profile be accreted, the structures would temporarily withstand the wave conditions occurring under a 100 year ARI storm event. However, it would be expected that the beach would rapidly scour down to levels that would allow the much higher maximum breaking wave heights to reach the structure.

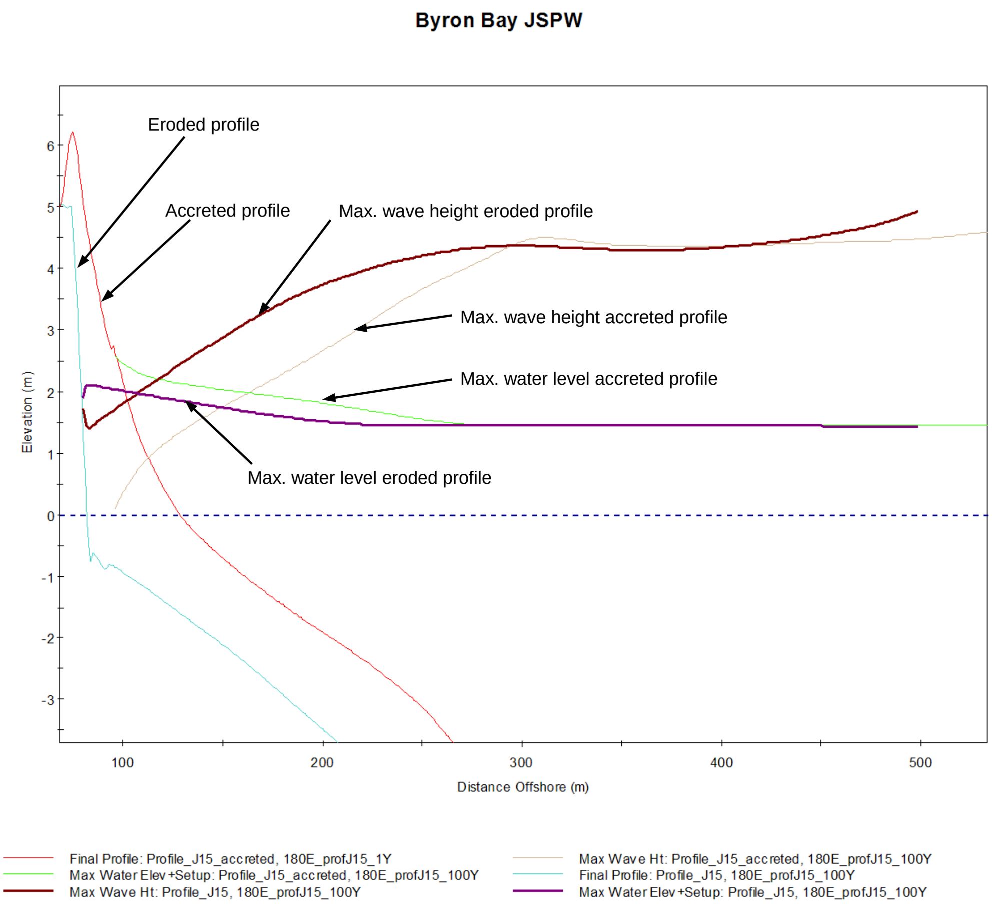


**Figure 7 –** SBEACH simulation of eroded and accreted conditions at Jonson Street.

### *Hydraulic Stability of Geotextile Container Revetments*

The geotextile container revetments within the Byron Bay embayment comprise 0.75 $m^3$ geotextile units. Hydraulic stability of geotextile container revetments was examined by Coghlan *et al.* (2009) through a series of physical model tests.

The wave height threshold for initial damage would be exceeded for all storm events greater than or equal to the 1 year ARI event, for conditions where the beach is eroded and the revetments are exposed to direct wave attack. However, while the initial damage is described by Coghlan *et al.* (2009) as being 2% damage, geobag walls (in contrast to the rock revetments which can sustain a higher degree of damage and still remain functional), are prone to displacement of multiple individual units once a single unit is dislodged, due to the progressive loss of interlocking (WorleyParsons 2009).

The exposure to direct wave attack varies for the different geotextile revetments. The revetment at the Byron Bay Surf Lifesaving Club is currently protected by a wide vegetated dune, and the wave heights expected to cause initial damage at the structure would not be realised unless the frontal dune erodes away. Conversely, the geotextile structure at Manfred Street is located further seaward into the active beach zone, and so is exposed to direct wave attack more frequently than the other geotextile structures.

The performance of each of the structures against the hydraulic stability criteria developed by Coghlan *et al.* (2009) is illustrated in Figure 8.

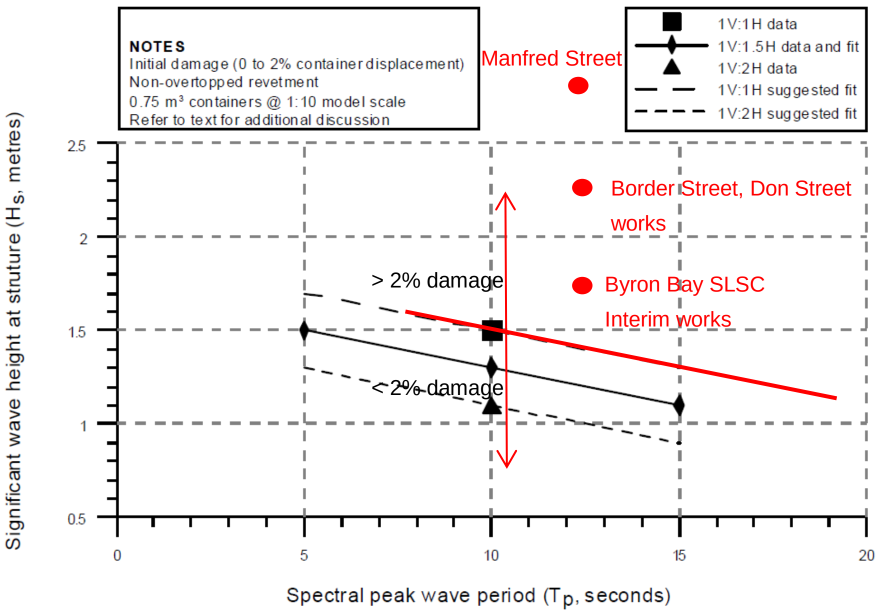


**Figure 8** – Hydraulic stability of geotextile container revetments (after Coghlan *et al.*, 2009)

### *Climate Change*

The main design parameters for the erosion protection structures within the Byron Bay embayment that would be affected by climate change are as follows:

- **Incident wave height** – this would be expected to increase at the structure face, due to a deepening of the nearshore profile and increase in sea level. The incident wave height at the structure could also be influenced by future long-term changes in offshore wave height and direction.
- **Scour Level –** Increased scour would be expected immediately in front of the erosion protection structures. As the unprotected beach profile on either side of the structures would be expected to recede with sea level rise, the structures would extend further seaward onto the future active beach profile. The impact of the structures on longshore sediment transport would increase in the future as they would extend further into the active zone of littoral sand transport.
- **Crest Level –** As the sea level rises, the crest level with respect to mean sea level will decrease over time. This would result in increasing frequency, depth and discharge of wave overtopping.

The effect of both a lowering in the beach profile and a rise in sea level at the structure is illustrated in Figure 9, based on the changes in the nearshore wave equilibrium profile as predicted by the Bruun Rule (Bruun 1954, 1962, 1983).

It was found that an increase in water level as well as incident wave height at the structure would increase the level of wave runup by a higher value than the quantum of the sea level rise alone. Thus, raising the crest of the structure by the quantum of expected future sea level rise would not be sufficient to prevent an increase in future wave overtopping. For example, for the Jonson Street protection works, if 0.4 m sea level rise by 2050 combined with additional scour is realised, the impact of a 1 year ARI event in the future on the structure stability would be similar to the impact of a 100 year ARI in the present day.

It is therefore considered that the risk associated with climate change for the erosion protection structures is a function of:

- The crest level of the structure;
- The hydraulic stability of the structure against wave attack;
- The location of the structure within the beach profile; and
- The toe level of the structure.

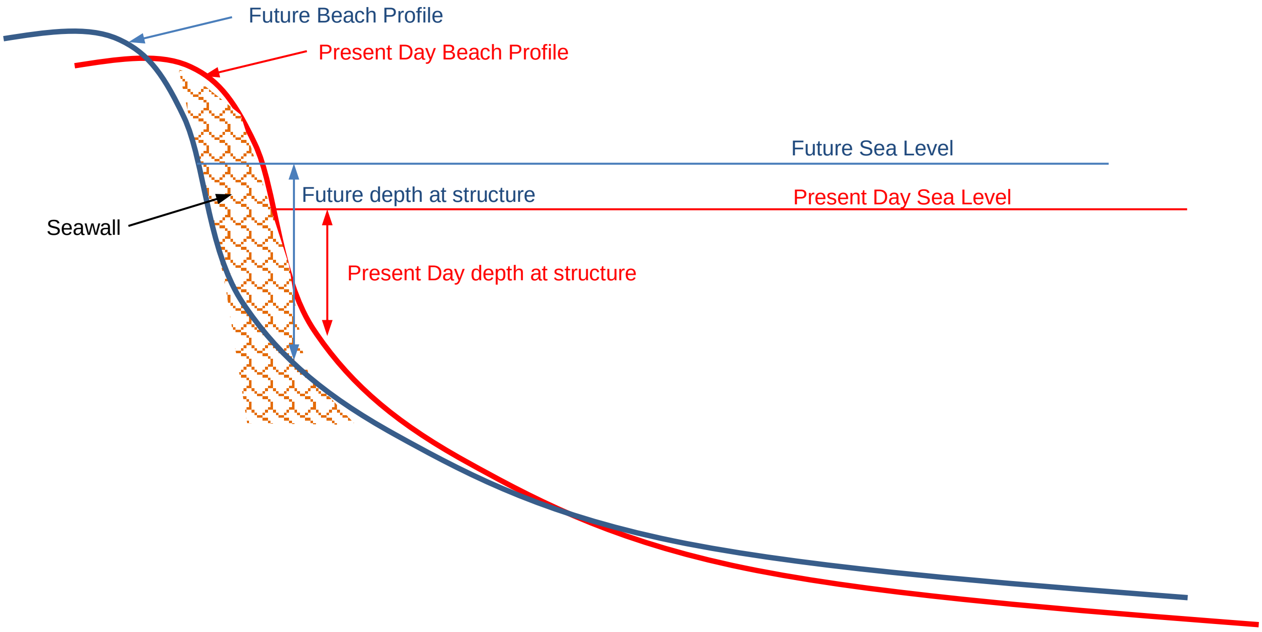


**Figure 9 –** Effect of sea level rise on water depth in front of the erosion protection structures within the Byron Bay embayment

***Geotechnical Stability***

The properties of the underlying soils are an important consideration when determining the stability of the structures against sliding failure. In particular, the internal friction angle of the underlying soil, the friction angle between the overlying filter material (rock or geotextile fabric) and the soil and the friction angle at the interface between the individual armour units (rock or geotextile).

Nielsen and Mostyn (2011) reviewed the angles of internal friction between non-woven needle-punched geotextiles and sand as well as the internal angle of friction between geotextile underlay and individual geotextile armour units and advised on the slopes and heights of geotextile and rock revetments required to achieve an acceptable Factor of Safety against slip failure. The performance of each of the erosion protection structures was assessed against the criteria described in Nielsen and Mostyn (2011) and assigned a risk rating based on the assessed geotechnical stability.

### Consequence of Structure Failure

As discussed, risk is generally defined as the product of *likelihood* and *consequence*. The *consequence* rating is a function of the location of the structure, the number of properties at risk, and the frequency of use of the area surrounding each structure. For coastal resilience, *consequence* was defined as **low**, **moderate** or **high** as follows:

> **Low consequence:** Only minor structures or assets (i.e. dune fencing, minor park furniture etc.) are impacted by failure of the structure. The impact on public safety would be low should the structure fail.
>
> **Moderate consequence:** Between 1 and 5 private lots are severely impacted by coastal erosion or inundation as a result of failure of the structure, or major public assets and infrastructure would be damaged with an estimated repair cost of less than $500,000. Potential for minor injuries to public and private landholders.
>
> **High consequence:** Greater than 5 private lots are severely impacted by coastal erosion or inundation as a result of failure of the structure, or major damage to public assets and infrastructure could occur with an estimated repair cost of greater than $500,000. Potential for major injuries or fatalities to public and private landholders.

The risk assessment matrix for structure resilience is presented in Figure 10.

| | Consequences Rating | 1 | 2 | 3 |
|---|---|---|---|---|
| Likelihood Rating | Consequences Description / Likelihood Description | minor structures assets impacted and/or low impact on public safety | 1 to 5 lots impacted and/or damage to public facilities < $500,000 and/or potential for minor injuries | >5 lots impacted and/or damage to public facilities >$500,000 and/or potential for major injuries or fatalities. |
| 1 | Good observed condition, good hydraulic stability, good geotechnical stability, good structure resilience against wave overtopping and climate change impact | 1 | 2 | 3 |
| 1.5 | | 1.5 | 3 | 4.5 |
| 2 | Moderate observed condition, moderate hydraulic stability, moderate geotechnical stability, moderate structure resilience against wave overtopping and climate change impact | 2 | 4 | 6 |
| 2.5 | | 2.5 | 5 | 7.5 |
| 3 | Poor observed condition, poor hydraulic stability, poor geotechnical stability, poor structure resilience against wave overtopping and climate change impact | 3 | 6 | 9 |

Low Risk | Moderate Risk | High Risk | Extreme Risk

**Figure 10 –** Risk Matrix for structure resilience

### Impacts on coastal processes

The impact of each of the erosion protection structures on the coastal processes within the embayment was inferred from observations made on site, complemented with the known understanding of the local coastal processes within the embayment, as described in previous studies (PWD 1978, WBM 2000, Patterson Britton & Partners 2006, Patterson 2010) and as modelled by WorleyParsons (2013).

From the historical escarpment locations, it was found that the profile of the Jonson Street Protection Works is seaward of the historical shoreline position and therefore acts as a headland, protruding onto the active beach. This has the effect of compartmentalising the beach into two distinct areas – Main Beach east of the Jonson Street Protection Works, and Belongil Beach west of the Jonson Street Protection Works. A similar effect can be inferred for some of the other structures within the Byron Bay embayment which are located relatively seaward along the beach profile (denoted by the protrusion of the structures seaward of the blue line in Figure 11).


**Figure 11 –** Position of erosion protection structures relative to the natural curvature of the beach

The timing and nature of the impact on the foreshore alignment was taken into account in rating the impact of the structures on coastal processes. While some of the erosion protection structures initially had a significant impact on the foreshore alignment (i.e. shortly following construction), some of these structures are no longer having an impact as they appear to be fully bypassed by longshore sediment transport. Other structures may still be having an effect on the surrounding foreshore which is ongoing and is yet to be fully realised.

In considering the risk posed by the structures on coastal processes, it was assumed that there is a high *likelihood* of the impact occurring, as the impacts have already been observed under a range of conditions for many years in the field.

Site observations and desktop analysis (including wave modelling and photogrammetry analysis) was used to determine the relative impact of the existing erosion protection works within the Byron Bay embayment, with respect to the following parameters:

- The structure impact on foreshore alignment (refer Figure 12)
- The impact of the structures on beach width

- Updrift impact of the structure on coastal processes.


**Figure 12 –** Erosion of natural dune downdrift of Belongil erosion protection structures

## Impacts on shoreline ecology

The seawalls result in the following impacts on shoreline ecology:

1. Direct impacts on ecological processes, habitats, communities and species (i.e. impacts on the intertidal zone such as modification and fragmentation of habitat).
2. Indirect impacts on ecological processes, habitats, communities and species (i.e. end wall effects and subsequent increased erosion of vegetation in hind dune).

To assess the impacts, a qualitative marine habitat field survey focusing on the intertidal zone was carried out, in accordance with the NSW Maritime Marine Habitat Survey Guidelines.

The impact of the structures on coastal ecology is felt in the following ways:

- Loss of sandy beach habitat caused by loss of beach width in front of the structure – this comes about through the location of the structure on the beach profile and how reflective the structure is to wave energy (which depends on the structure material and slope).
- Loss of natural dune habitat and vegetation as a result of the structure installation, structure footprint and degree of protection afforded to sandy dune habitat on the landward side
- The potential for the structure to create new foreshore habitat.
- Impact of the structure on marine pollution, e.g. whether foreign materials such as geotextile or twine are released from the structure into the marine environment (Figure 13).

**Figure 13** – Example of foreign materials that have potential to impact on marine environment

## Impacts on Public Use and Amenity

The public use and amenity associated with each structure was documented based on visual observations and review of previous studies. Features documented include:

- Visual amenity of the area
- Cultural and heritage significance
- Public and private access onto the beach
- Public access along the beach (Figure 14)
- The potential impact of climate change on the foreshore amenity associated with each of the structures.

**Figure 14 –** Difficulty of public access along beach at mid-high tide, near Manfred Street (photo Byron Shire Council)

## Overall Risk Assessment Results

Figure 15 illustrates the results of the risk assessment in terms of structure resilience, coastal processes, coastal ecology and public use and amenity. Each structure was given a risk rating of low, moderate, high or extreme against each of the criteria, with these ratings being based on the summation of the risk ratings determined for each of the sub-criteria.

| Structure No. | Structure Description | Structure Resilience Rating | Coastal Processes Rating | Coastal Ecology Rating | Public Use and Amenity Rating |
|---|---|---|---|---|---|
| 1.1 | Interim coastal protection works at Byron SLSC | HIGH | LOW | LOW | LOW |
| 1.2 | Rock protection at Byron SLSC | MODERATE | MODERATE | MODERATE | LOW |
| 1.3 | Rock protection in front of the main reserve area adjacent to the surf club, separated from adjacent protection by concrete ramp | MODERATE | MODERATE | MODERATE | MODERATE |
| 1.4 | Rock protection in front of main reserve | EXTREME | MODERATE | MODERATE | MODERATE |
| 1.5 | Rock protection in front of Jonson Street carpark and east of groyne marking location of original jetty | MODERATE | MODERATE | MODERATE | MODERATE |
| 1.6 | Rock protection in front of Jonson Street carpark and west of groyne marking location of original jetty | HIGH | MODERATE | MODERATE | MODERATE |
| 1.7 | Rock toe protection in front of First Sun Caravan Park | HIGH | MODERATE | LOW | MODERATE |
| 2.1 | Border Street geotextile container interim protection works | LOW | LOW | LOW | MODERATE |
| 2.2 | Rock protection adjacent to Border Street works | MODERATE | MODERATE | EXTREME | EXTREME |
| 2.3 | Don Street geotextile container interim protection works | LOW | MODERATE | MODERATE | MODERATE |
| 2.4 | Concrete cube and rubble protection works adjacent to Don Street works | MODERATE | MODERATE | EXTREME | EXTREME |
| 2.5 | Geotextile container revetment adjacent to ad-hoc rubble works | MODERATE | MODERATE | MODERATE | MODERATE |
| 3.1 | Rock revetment north of old jetty site | EXTREME | HIGH | EXTREME | EXTREME |
| 3.2 | Manfred Street geotextile container interim protection works | MODERATE | MODERATE | MODERATE | MODERATE |
| 3.3 | Geotextile container revetment fronting private land adjacent to the Manfred protection works | MODERATE | HIGH | MODERATE | MODERATE |
| 3.4 | Rock protection north of the geotextile container revetment | EXTREME | HIGH | EXTREME | EXTREME |
| 3.5 | Geotextile container revetment works at northern flank of the rock protection at Belongil Spit. | MODERATE | MODERATE | MODERATE | MODERATE |

**Figure 15 –** Results of the risk assessment for the Byron Bay Embayment Erosion Protection Structures

## Stakeholder Participation

A workshop was held in January 2013 with WorleyParsons, Byron Shire Council and OEH representatives to provide input to the risk assessment for coastal processes, ecology, public use and amenity. The results of this workshop were incorporated into the risk assessment.

The workshop was an effective method of assessing the qualitative aspects of the risk assessment, as a range of stakeholder perceptions and factors of importance were able to be considered in determining the relative risks at each structure. The process allowed the participants to provide input and therefore attain some ownership of the risk assessment outcome.

The participants in the workshop all agreed on:

- the definitions of the criteria to be used to rate each structure, for both the quantitative and qualitative aspects;
- the definitions of the ratings used for each structure; and
- the ratings assigned to each structure for the qualitative aspects such as public use and amenity.

Ratings were assigned to each of the criteria for each structure by discussion within the group, with a consensus achieved in defining the rating as Good, Fair or Poor.

## Conclusion

This paper has presented a methodology that can be applied in conducting risk assessments for coastal structures. The methodology can be tailored to and applied in any jurisdiction. Integral to the success of the risk assessment was the availability of data for quantitative analysis of structure performance, structure design and coastal processes, as well as stakeholder participation in the process.

In a classical risk assessment, overall risk is usually assessed as the product of *likelihood* and *consequence*. It was found that this approach is valid whenever both the consequence and likelihood can be quantitatively defined – *i.e.* the likelihood can be linked to a known probability of occurrence of an event which leads to a known consequence. For example, for structural integrity, likelihood can be linked back to a storm event with a known probability of occurrence. An analytical approach combining coastal processes modelling and derivation of design parameters for each structure provides a quantitative measure of the resilience of the structure when impacted by a storm with a known likelihood of occurrence. The consequence of the structure failing can be defined where the value of the assets that the structure is protecting is known. The likelihood and consequence can then be combined in a risk matrix to obtain a quantitative measure of the risk for each structure.

The approach needs to be modified when the effect on coastal ecology, coastal processes, public use and amenity is considered. For these aspects, the risk assessment is more qualitative and a combined risk rating can be developed which considers both “likelihood” and “consequence”. When considering the risk that each structure poses to the coastal processes, coastal ecology and public use and amenity of the beach, the probability of the structures interacting with these aspects is not linked to a discrete storm event with a known probability of occurrence, but rather, these impacts have been observed over a long period of time. The likelihood of the impact occurring is therefore always “certain”, so the risk assessment then becomes simplified to consider consequence of the impact.

While the criteria used for the risk assessment are subjective, the risk assessment presented here provides an effective tool for coastal managers to assess and prioritise management actions for coastal structures.

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