Submerged and emergent revetment concept design of Golden Beach

Stantec

Agenda

1. Background
2. Condition assessment
3. Marginally overtopped revetment Design
4. Low-Crest revetment Design
5. Splash area and Scour protection Design
6. Conclusion

Background

Golden Beach is a coastal suburb of Caloundra in the Sunshine Coast Region, Queensland

Cyclone Seth caused the split of Bribie Island in January 2022 and a high-water levels in Pumicestone Passage.

The new channel has changed the wave, current, and sediment regimes, that can cause damage to the existing coastal protection, increase coastline erosion, increase siltation and inland flooding.

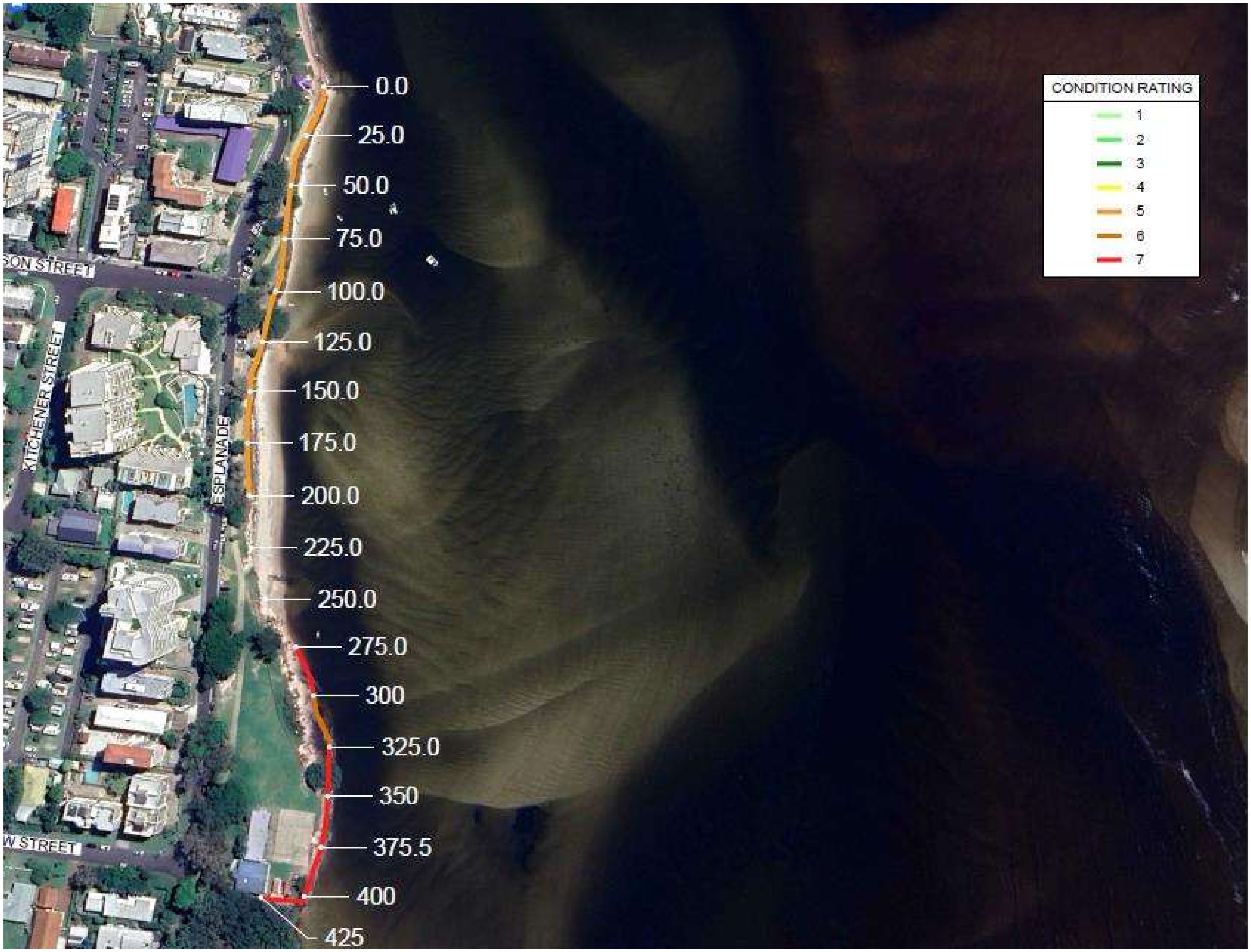
Stantec was engaged to conduct a condition assessment and a concept design for a 225m long revetment along the Golden Beach.

Condition Assessment

A visual inspection was conducted by two Stantec engineers

The map was prepared based on the condition rating provided in WSCAM (Wharf Structures Condition Assessment Manual 2022)

The condition assessment confirmed that the existing revetment is in poor condition, and the design of a new revetment was required.



Marginally overtopped revetment concept design

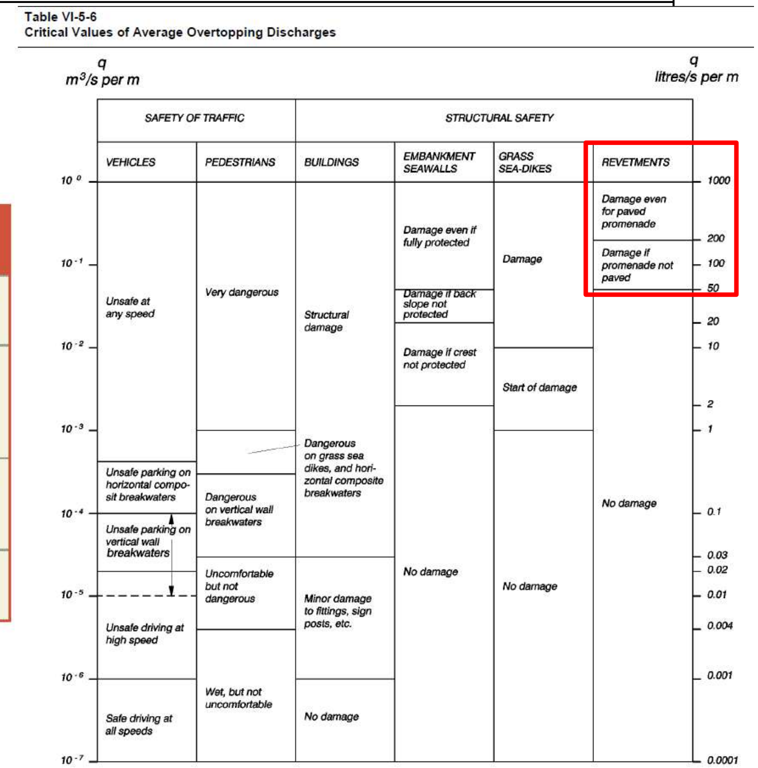
Design parameters were extracted from existing report provided by the client.

Parameter	Description	value
Hs (m)	Significant wave height	1
Tp (s)	Peak wave period	9.8
DWL(m)	Design water level	1.65

Climate change including future sea level rise was considered in the design water level (Goal 13 of United nations sustainability development)

The revetment was initially designed to limit the overtopping mean discharge and volume as recommended by EurOtop 2018 and CEM.

Return period	Tolerable discharge	Comment	Reference
1 in 1 year	q<1.0 l/s per m, V_{max} < 600 l/m.	For people and vehicles - People at seawall / dike crest. Clear view of the sea. H_{m0} = 2 m.	EurOtop (2018) Table 3.3
1 in 1 year	q<1.0 l/s per m V_{max} < 500 l/m.	For pedestrians – Trained staff, well shod and protected, expecting to get wet, overtopping flows at lower levels only, no falling jet, low danger of fall from walkway.	EurOtop (2007): Table 3.2
1 in 200 year	q<5.0 l/s per m, V_{max} < 2,000-3,000 l/m	For structural design - Grass covered crest and landward slope; maintained and closed grass cover; H_{m0} = 1 – 3 m	EurOtop (2018) Table 3.1
1 in 200 year	q<10 l/s per m	For damage to defence – No damage to crest and rear face of embankment of clay.	EurOtop (2007): Table 3.5



q (pedestrian) = 0.1 l/s/m

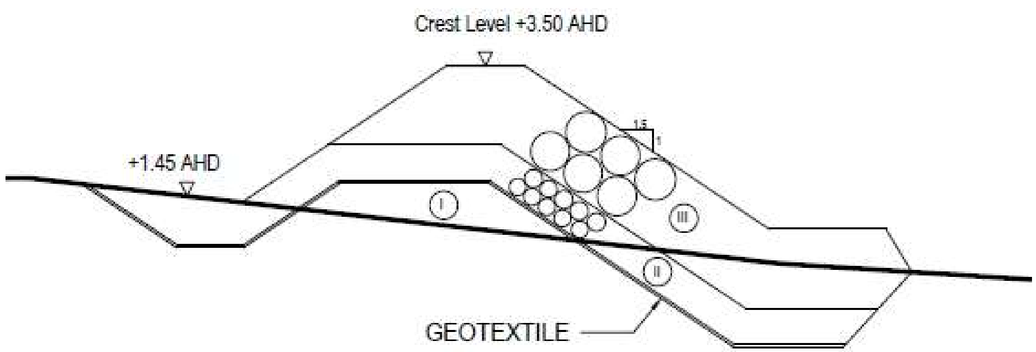
q (Structural design) = 5.0 l/s/m

Marginally overtopped revetment concept design

In order to meet the mean discharge and volume criteria, crest level of revetment was designed +3.5 AHD.

Van der Meer formulae – shallow water conditions was used to design the revetment.

Based on the discussion in the course of the project, a low crest revetment proposed for minimizing the adverse effect on visual amenity.



Low-crest revetment concept design

Natural surface level of the land in some sections was located almost at the same level or below the design water level.

Therefore, a submerged or emergent revetment design was proposed for those sections.

- Design water level +1.65AHD
- Revetment crest level +1.45 AHD (submerged)
- Revetment crest level +1.7 AHD (emergent)

Vidal et al (1995) developed a stability formula for rock-armoured statically stable low-crested structures (both emergent and submerged).

$$\frac{H_s}{\Delta D_{n50}} = A + B\frac{R_c}{D_{n50}} + C\left(\frac{R_c}{D_{n50}}\right)^2$$

Hs = significant wave height;
Rc = structure freeboard;
Dn50 = the median nominal stone diameter and
A,B,C = coefficients of the stability curves for initiation of damage.

Segment	A	B	C
Front slope	1.831	-0.2450	0.0119
Crest	1.652	0.0182	0.1590
Back slope	2.575	-0.5400	0.1150
Total section	1.544	-0.230	0.053

The range of the rock armour was calculated between 450-750 kg.

Overtopping Mean Discharge

Sm-1,0 (wave steepness at toe) <0.01 , Rc>0

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 10^{-0.50} \cdot exp\left(\frac{R_c}{\gamma_f \cdot \gamma_\beta \cdot H_{m0} \cdot (0.33 + 0.022 \cdot \xi_{m-1,0})}\right)$$

Negative Freeboard for submerged sections (Hughes and Nadal 2009), Rc <0

$$q_{overflow} = 0.54\sqrt{g.\ |-Rc^3|}$$

q= mean overtopping discharge per meter structure width,

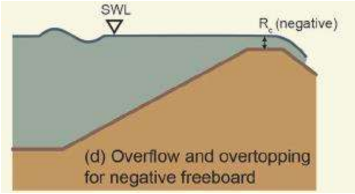
Hm0= significant wave height,

ξm-1,0 = surf similarity or Iribarren number,

γf= surface roughness factor,

$\gamma\beta$= oblique wave factor,

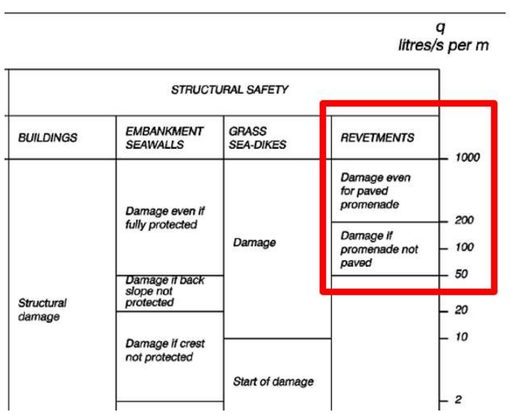
Rc= overflow depth

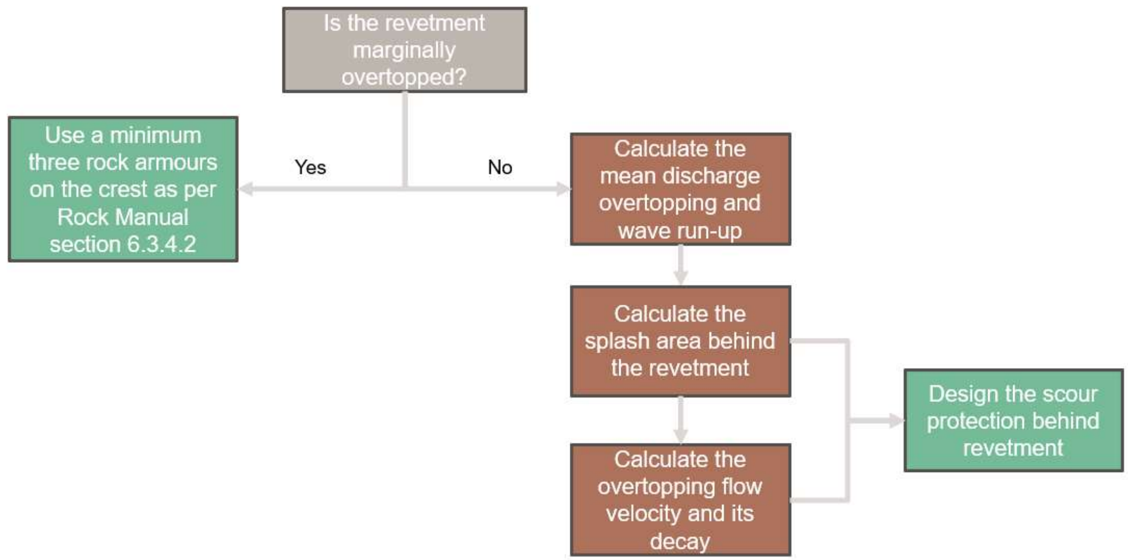


Overtopping discharge exceeds 100 l/m/s

Low-crest revetment concept design

Non-overtopped structures, waves mainly affect the stability of the front slope, while in the case of overtopped structures the waves do not only affect the stability of the front slope, but also the stability of crest and rear slope.





Revetment crest design flow-diagram

Low-crest revetment concept design

Splash area

The splash area on the land was calculated using Cox and Machemehl's method (1986)

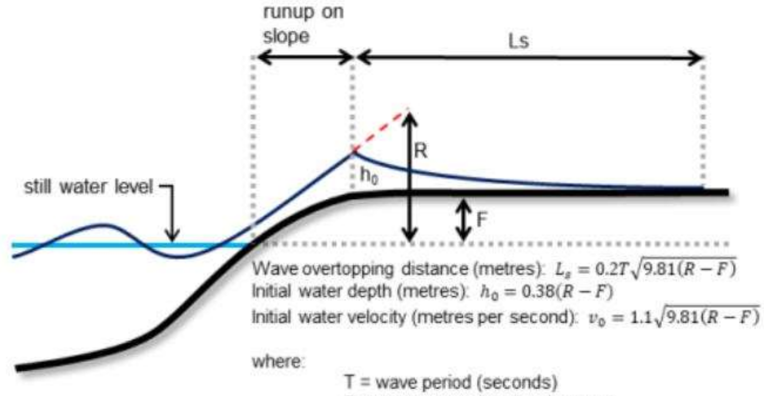
$$L_s = 0.2\,T\sqrt{9.81(R-F)}$$

T = wave period(s); Tm-1,0 can be used

R = wave run-up level (m) and

F = crest level relative to SWL(m).

Splash area approximately 10m



$$T_p = 1.1\,T_{m\text{-}1.0}$$

$$R_{u2\%}/H_s = A\xi + B$$

Mean energy period $T_E = T_{m\text{-}1,0} = T_{-10}$

Low-crest revetment concept design

Overtopping flow velocity

In order to design the scour protection behind the revetment, velocity on crest of the revetment was estimated using the formula given in EurOtop 2018

$$\frac{v_{front}}{\sqrt{gH_{mo}}} = c_u\sqrt{\frac{R_{u\,max}}{H_{mo}}}$$

cu = stochastic variable;=1 for normal distribution

Ru max = maximum run-up of all waves in a sea state

Hm0 = significant wave height.

Vfront=4.4m/s

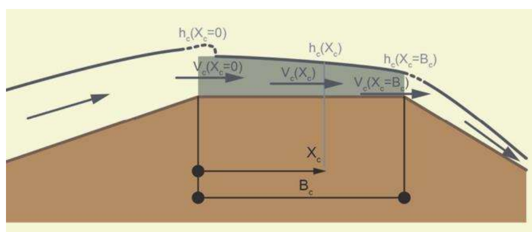
Flow velocity decay

The decay of flow velocity along the crest is a function of the distance from the seaward edge:

$$v_{2\%}(x_c)/v_{2\%}(x_c = 0) = exp\left(-1.4x_c/L_{m-1,0}\right)$$

Where Lm-1,0 = spectral wavelength in deep water

Flow velocity 10m from the seaward edge= 4 m/s



Low-crest revetment concept design

Crest design

The area behind rock revetment designed using concrete slab and grouted rock.

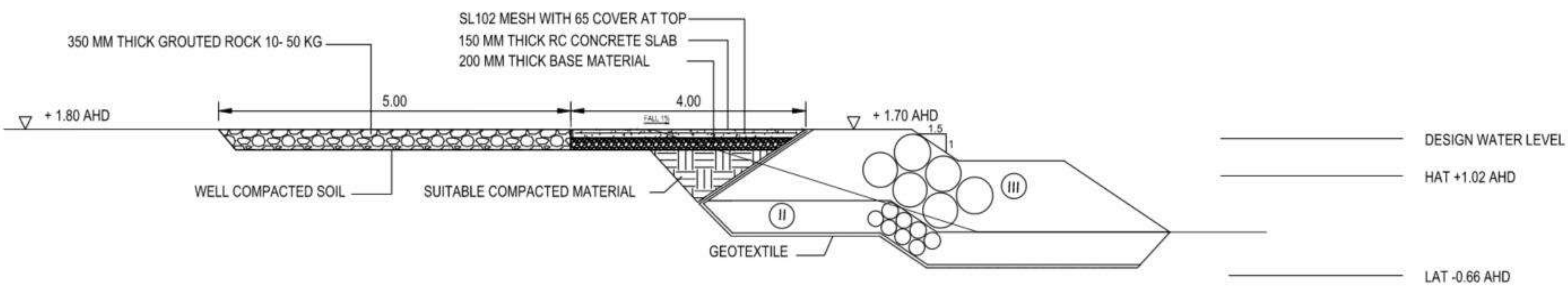
Reno mattress could be considered in next stage of design as it could improve the health and diversity of the natural habitat by providing soil and seeds in the rock voids

Goal 11 of sustainability development

To meet the Goal 11 of United nations sustainability development goal, Sustainable cities and communities:

Safe access: Safety in Design (Design to consider signage to warn pedestrians against activities on the revetment during storm events).

Reduction of the adverse effects of natural disasters by constructing revetment and scour protection on the crest



Conclusion

- Low-crested structures may be used for protection in areas where horizontal visibility is a requirement, e.g. for aesthetic purposes.
- For low-crested structures a part of the wave energy can pass over the revetment. Therefore, the size or mass of the material at the front slope of such a low-crested structure might be smaller than on a non-overtopped structure.
- In the case of overtopped structures the waves do not only affect the stability of the front slope, but also the stability of crest.
- These structures generally allow significant wave overtopping and the erosion behind the structure is a concern.
- Splash area behind the revetment needs to be designed against scouring.

Thank you