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Tauranga City Council

Mauao Base Track Remediation Design
Revetment Detailed Design Report

July 2018

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

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1. Introduction

1.1 Background

In April 2017 a series of storms occurred in the Tauranga region, resulting in a landslide on the south western corner of Mauao which destabilised the walking track, known as the 'base track', above the slip area. A temporary track was installed by Tauranga City Council (TCC), however consists of many steps and is not practical for community members with limited mobility. A new section of track is required to increase the amenity and access to Mauao for all.

After an options development process to determine the most appropriate alignment of the new section of the track, TCC considered five options. The preferred option selected by TCC consists of a new track at the base of Mauao. To enable the track to be located here, a coastal protection revetment structure is required to elevate the path and protect the base of Mauao from ongoing wave impacts that may cause further erosion and destabilisation of the area.

1.1.1 Location

Mauao is north of Tauranga, the location of the old base track and the landslide affected area are presented in Figure 1, where the realigned base track is also shown.

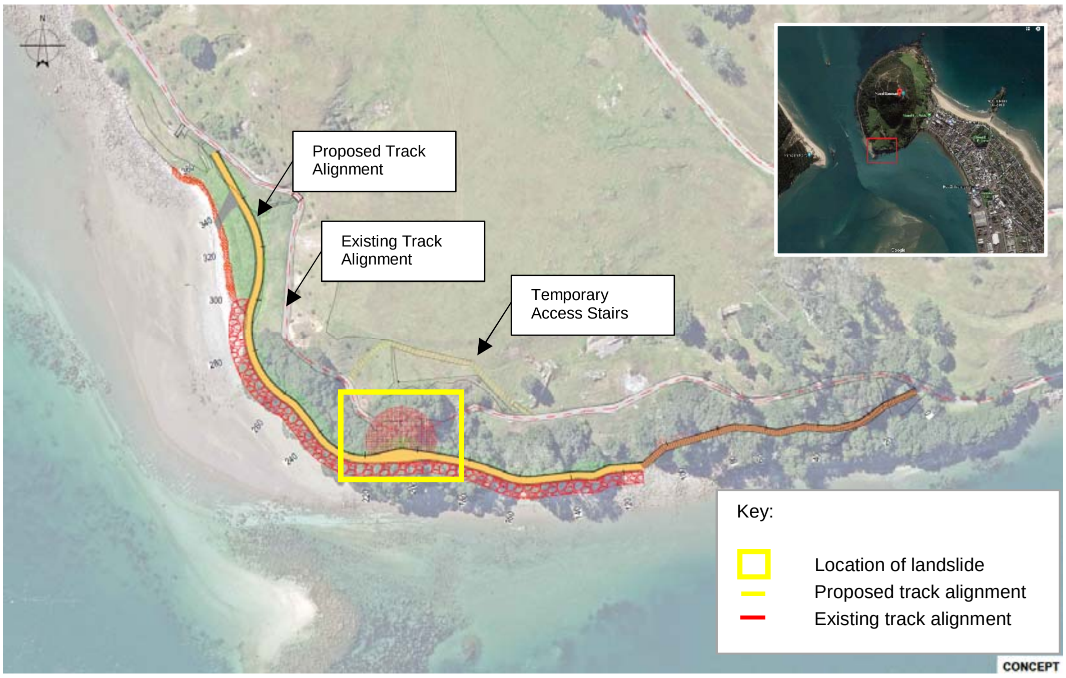

Figure 1 Location of landslide and the proposed new track alignment (Image: Google)

1.2 Purpose of this Report

The purpose of this report is to present the design criteria, assumptions, guidelines, and considerations associated with the design of the coastal revetment where the new base track will be founded on.

1.3 Scope and Limitations

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2. Design Basis

The purpose of the coastal protection structure is two-fold – to elevate the path above the beach and daily tides, as well as protect the foot of the slopes from wave processes that may increase the risk of undermining and further landslides.

2.1 Design Requirements

2.1.1 Design life

The industry standard design life for a rock revetment structure is 50 years. This typically represents an acceptable balance between the uncertainty and risk due to future environmental conditions (particularly climate change and sea level rise) and the construction costs associated with an extended design life.

2.1.2 Standard of protection

The industry standard of protection for a revetment structure is to a 1 in 100 year annual return interval (ARI) event, or 1% annual exceedance probability (AEP). That is, a storm of magnitude that is statistically expected to occur once every hundred years, or has a 1% chance of occurring in any one year.

The revetment location is perceived as low to moderate risk, in that, it will not be protecting any 'built' public or private property, and there are already significant operational restrictions in place. During large storm events, the track is closed, thereby reducing the risk to the community. Therefore, a reduction in the standard of protection is possible, with recognition that the lower the standard of protection, the higher likelihood that the structure may need maintenance or remediation following large events. To this end, overtopping discharge limits associated with the design structure will be governed by structural integrity rather than pedestrian safety.

2.2 Local Coastal Processes

2.2.1 Tides and datums

Mauao has a semi-diurnal tidal regime, meaning it has two high and two low tides daily. Within Tauranga Harbour two datums are commonly used, Chart Datum (CD) and mean sea-level Moturiki Datum (MSL). Tidal planes are presented in both datums for information, however, the elevations presented in this report are in m MSL.

Table 1 Tidal planes (LINZ Nautical Almanac 2017/2018)

Tidal Plane	Metres CD (m CD)	Metres MSL (m MSL= RL)
LAT	-0.05	-1.14
MLWS	0.14	-0.95
MLWN	0.49	-0.60
MSL	1.09	0.00
MHWN	1.67	0.58
MHWS	1.94	0.85
HAT	2.13	1.04

2.2.2 Bathymetry

Bathymetric information was received from the Port of Tauranga Limited (PoTL). PoTL conducts regular maintenance dredging, therefore the bathymetry is surveyed regularly using multi-beam technology.

The data shows intertidal depths of approximately -1 m MSL, dropping to approximately -20 m MSL in the dredged channel adjacent to the project site.

The nearshore depths will be used to inform the design wave and current (shear stress) calculations to check the rock armour stability.

2.2.3 Wind

The predominant wind direction in the Tauranga region is relatively constant. Winds from the west and southwest sector have the highest speeds and frequency of occurrence, as shown in Figure 2. A design wind speed of 40 km/hr from the southwest has been adopted in subsequent wave calculations.

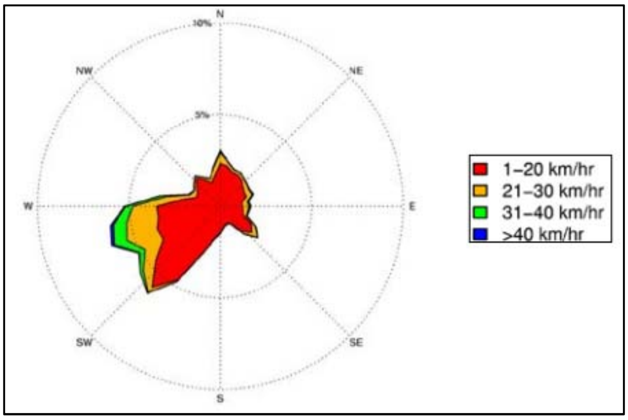

Figure 2 Wind rose at Tauranga Airport (source: NIWA – the Climate and Weather of Bay of Plenty, 3rd edition, Figure 10)

2.2.4 Water levels

Changes in water level in the channel and harbour are generally attributed to normal astronomical tides. Extreme weather events occasionally induce a storm tide, which goes above normal astronomical tides.

Based on the NIWA coastal calculator, a 1% AEP storm tide gives a 1.6 m MSL water level between the period of 2004-2012 relative to MVD-53 baseline. Combined with projected sea level rise (SLR) over 50-year horizon of 0.4 m, the design water level is derived as 2.0 m MSL, as summarised in Table 2.

Table 2 Design water levels (NIWA, 2017)

	1% AEP Design Water Level (m MSL)
Offshore	1.6
Offshore + 0.4 m SLR	2.0

2.2.5 Waves

The wave climate on the southern and western sides of Mauao and within Tauranga Harbour is dominated by fetch limited wind generated waves. This means the size of the wave is limited by the distance over water the wind has to blow. The longest fetch that will have an effect the site is from the southwest with a fetch length of approximately 7.5 km.

Swell waves from offshore have some impact on the northern and western sides of Mauao, but under ambient conditions the wave energy dissipates as it enters the restricted harbour entrance. Occasionally tropical lows and cyclones generate larger swell that is able to penetrate the harbour entrance. Through refraction and diffraction processes at Mauao these swells are occasionally able to impact the south western shoreline of Mauao. Consequently, swell heights corresponding to various return periods were investigated. The values are based on the NIWA calculator at the offshore location, and are applied with refraction and diffraction coefficients to transform the offshore wave to a location adjacent to Mauao. Table 3 summarises the wave transformation.

Table 3 Wave heights corresponding to different AEP events

AEP	Offshore Wave Heights H_0 (m)	Design Wave Height at Site[1] (m)
63.2%	4.50	1.61
18.1%	5.56	1.78
9.5%	5.95	1.79
5%	6.31	1.79
2%	6.74	1.79
1%	7.04	1.79

Characteristics of the waves are important inputs into the revetment design process as, combined with other factors, they dictate the size of the rock armour required for the structure. It is noted that ship/boat wakes are not considered to be dominant factor in determining the rock size at the site due to speed restrictions, therefore they have been ignored.

The design standard adopted for the wave climate is a 1% AEP event. Table 4 summarises the design wave condition to be based on for the revetment design.

Table 4 Design wave conditions

	Design Wave Height (m)	Peak Period T_p (sec)
Wind Wave	0.58	2.8
Swell	1.79	9.75[2]

2.2.6 Currents

Current velocities through the navigation channel will be another factor requiring consideration in the design, in addition to wave climate. The PoTL monitors current speeds and directions in real-time for port operations. However, this information only provides a snapshot of the currents in time, and does not have historic information on the past.

An alternative source of information is obtained in the PoTL Port Information for Ship's Masters. Based on this information, current velocity at the port entrance reaches 3 knots in neap tides, and up to 4.5 knots in spring tides. Subsequently, current velocity of 4.5 knots in the direction of the port entrance orientation is assumed as the design value.

2.3 Overtopping Threshold

CIRIA (2007) and EurOtop (2016) propose various critical overtopping discharge thresholds to protect people, nearby property and for the structural integrity of the structure itself. In the context of Mauao Base Track, GHD understands that the track would be closed from public

[1] Depth limited wave from 9.5% AEP onwards

[2] 90th percentile wave period estimated from Bay of Plenty Regional Council buoy data between 2004 and 2017, then applied with relevant diffraction coefficient

access during adverse weather conditions. Therefore, an overtopping discharge of **200 ℓ/s/m** was adopted as the preferred overtopping threshold, which is the maximum recommended threshold before overtopping may cause damage to a paved promenade.

It is noted however that a paved promenade may not be considered suitable given the aesthetics of the existing track. In the event that an unsealed path is proposed, consideration should be given to the increased maintenance requirements as discussed in Section 3.3.

3. Revetment Geometry

3.1 Revetment Slope

A slope of 1V:1.5H is proposed in the design to minimise the footprint of the structure. A typical revetment section similar to the Mauao Base Track design is shown in Figure 3 as an example.

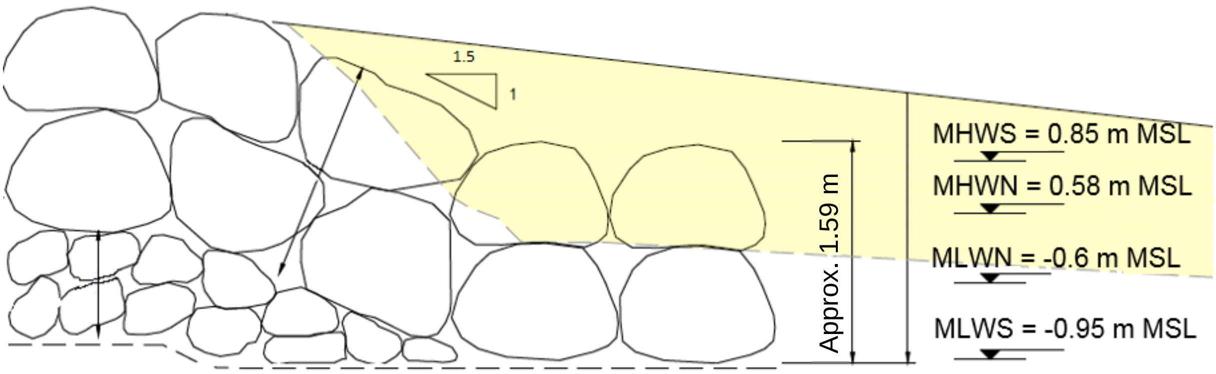

Figure 3 A typical revetment section example

A slope stability assessment will be carried out prior to issue of the design for construction.

3.2 Rock Sizing

Based on the wave climate and design standards, the rock sizes proposed for the project with a rock density of 2,600 kg/m^3 are:

- Class I – armour layer: M_{50} = 1,300 kg and a layer thickness of 1.59 m
- Class II – underlayer: M_{50} = 160 kg and a layer thickness of 1.19 m

In addition, the following details should be incorporated into the revetment:

- A layer of Texcel 900R geotextile or equivalent beneath the underlayer to reduce the fine material in the backfill being washed out
- Adequate fill material to form up the revetment slope (quarry run, or additional thickness of Class II under layer rocks)

Considering the purpose of the structure and the site condition, the rock sizes were calculated using the van der Meer equation with a damage number S_d = 4. A S_d = 4 damage number implies that potentially more frequent maintenance may be expected, with hydraulic instability unlikely.

At where the revetment terminates, i.e. at chainages 300, 340 (opening for the concrete ramp), and 360 as indicated in Figure 4, it is suggested to locally increase the rock sizes in a 5~10 m run section due to the likelihood of wave focusing. In accordance with industry practice, the following rock sizes are proposed at these locations:

- Class III – armour layer: M_{50} = 1,700 kg and a layer thickness of 1.74 m
- Class IV – underlayer: M_{50} = 200 kg and a layer thickness of 1.31 m

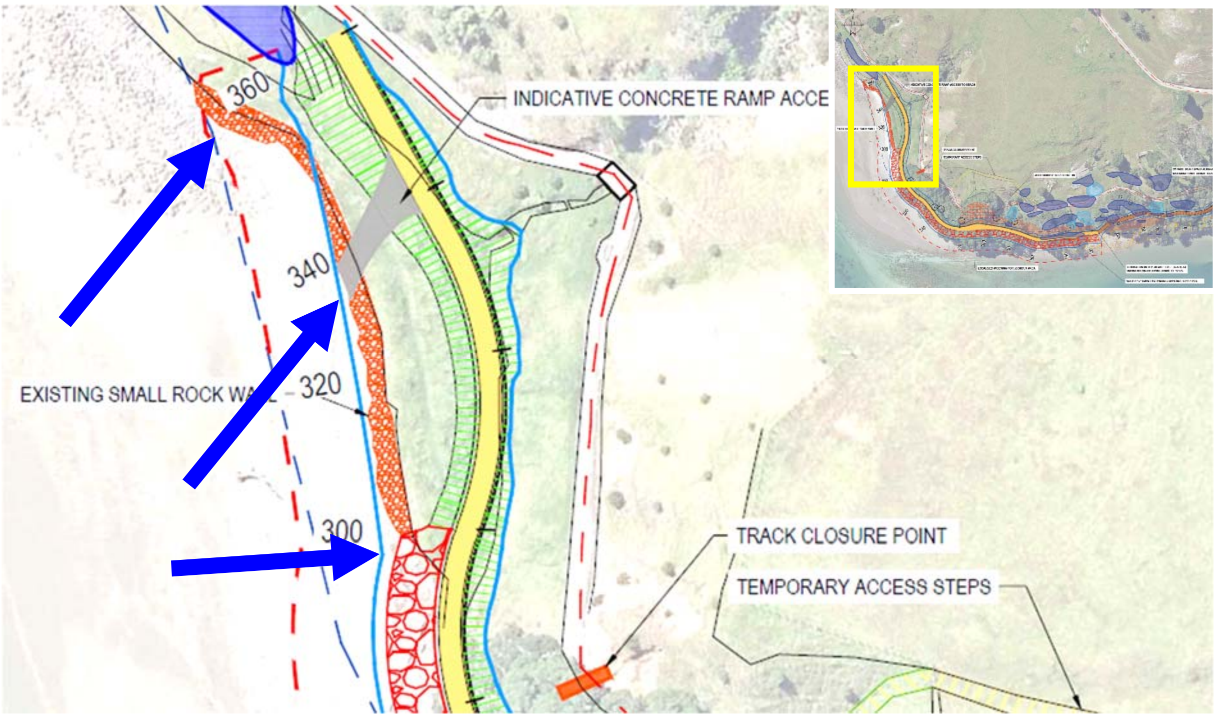

Figure 4 Locations where enlarged armour rocks are required

As the project developed, an opportunity was identified to elevate the picnic area (between chainage 300 to 360) to the same level as the base track in order to achieve a consistent crest level against wave overtopping; this would require approximately 1 metre of backfill material.

To protect the elevated area from wave impact, the proposed revetment geometry between chainage 120 to chainage 300 could be extended to chainage 360. In the event that the revetment is extended through the picnic area, it will no longer be necessary to increase the size of the armour rocks at chainages 300 and 340 since the revetment termination point would be at chainage 360. It would however be necessary to increase the size of the rocks to those described above at chainage 360 from approximately chainage 355.

To minimise the encroachment of revetment footprint onto the existing beach, the revetment between chainage 300 and 360 could maintain the seaward extent of the existing rock protection, with the structure extending back into the picnic area by approximately 1.2 m.

At the time of this report was being prepared, no decision has been made whether to further explore this opportunity.

3.3 Crest Elevation

The crest elevation of the revetment at +3.0 m MSL was set as the starting point in accordance with the preferred option endorsed by TCC in Tonkin & Taylor's option report. In order to adhere to such a crest elevation whilst meeting the design conditions nominated, it would be necessary to adopt a 1V:2H slope with a minimum crest width of 2.1 m – an equivalent to three armour rocks wide.

Following consideration of the various project outcomes and drivers, it was considered that the optimum design solution comprised a revetment geometry at a 1V:1.5H slope with crest elevation of +3.0 m MSL. This approach considered a balance between the following aspects

- Overtopping rates
- Crest elevation preference
- Hydraulic stability of the revetment

- Footprint/encroachment into the CMA
- Cultural/aesthetic impacts
- Material quantities and associated construction costs

3.3.1 Frequency of overtopping

Formal analysis of the overtopping frequency has not been undertaken within the current scope of engagement. A formal analysis requires complex analysis to overlay the cumulative frequency of water level, wave climate (height, period and direction), structure slope, armour rock size, and overtopping rates.

A preliminary estimate is however possible using the 2017 water level records at the A Beacon. Based on the records, three to four times in the past year the freeboard between the water surface and the crest reduced to a level of high risk although no exceedance occurred. Nonetheless, with a strong wind or strong wave condition during such elevated water levels waves are likely to overtop the crest. Weighing in the likelihood of sea level rise, the frequency of this sporadic overwash will increase yearly.

The implication of such to the design is that whilst the rock armour would remain stable, an unsealed track would require resurfacing following major storm events. If this is considered unacceptable, potential improvements may include raising the crest elevation (to reduce the frequency of damage) or sealing the track with suitable pavement material.

3.4 Toe Detail

The project site is understood to consist of a large boulder field overlain by a veneer of sand. Given the ground condition, the toe of the revetment is proposed to be placed on top of the boulder field by removing the overlaying sand, then backfilling the excavated sand to match the existing beach surface. As a minimum, a two-rock wide toe width is adopted in the design.

4. Safety in Design

A Safety in Design (SiD) Registry has been prepared for the revetment detailed design. The SiD Registry documents common risks associated with revetment design, construction and operation. Refer Appendix A for the SiD Registry.

5. References

- CIRIA. CUR, CETMEF (2007), the Rock Manual – the use of rock in hydraulic engineering 2nd edition, ref: C683
- EurOtop (2016), Manual on wave overtopping of sea defences and related Structures. An overtopping manual largely based on European research, but for worldwide application. Second Edition. Authors: J.W. van der Meer, N.W.H. Allsop, T. Bruce, J. DeRouck, A. Kortenhaus, T. Pullen, H. Schüttrumpf, P. Troch and B. Zanuttigh. www.overtopping-manual.com
- Formentin S.M., Zanuttigh B. and Van der Meer J.W. (2017), A Neural Network TOOL for predicting wave reflection, overtopping and transmission, Coastal Engineering Journal, 59, No. 2 (2017), 1750006, 31 pp.
- Goda (2010), Random Seas and Design of Maritime Structures, 3rd Edition
- LINZ Nautical Almanac 2017/2018
- Navionic online nautical charts
- NIWA Coastal Calculator
- NIWA – the Climate and Weather of Bay of Plenty, 3rd edition
- Zanuttigh B., Formentin S.M., and Van der Meer J.W. (2016), Prediction of extreme and tolerable wave overtopping discharges through an advanced neural network, Ocean Engineering, 127, 7-22.

Appendices

Appendix A – Safety in Design Registry

HSE040 Safety in Design Risk Assessment

Notes: *Designs with significant quantities of dangerous goods may require detailed risk assessments under Dangerous Goods or Major Hazard legislation
* Most industrial processes will require an industry specific assessment, e.g. HAZOP and/or Quantitative Risk Assessment for facilities that have chemical or high-pressure processes under Dangerous Goods or Major Hazard legislation.

Design Life Cycle:	Investigation and Design	Setup, Construction and Commissioning	Operation	Maintenance	Disposal		**Date:**	11/07/2018	**Revision No:**	0
Job Name:	Mauao Base Track Revetment Design		**Job No:**	21/27021	**Client**	Tauranga City Council	**Design:**	[redacted] s 7(2)(a) – Priva		
People involved in Risk Assessment:	[redacted] s 7(2)(a) – Privacy									

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	Initial Risk Rating L	Initial Risk Rating RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating C	Residual Risk Rating L	Residual Risk Rating RR	Comments
	Investigation and Design	Instability	The rock may not achieve the mass required for stability consideration	N/A	C- Severe	3 – Possible	Moderate	- Consult with quarries and adopt the rock property that they can produce - Adjust rock spec to meet quarries' capability prior to construction	GHD/BM	Prior to construction		A – Minor	2 – Unlikely	Negligible	
	Investigation and Design	Uncertainties in design wave climate	The design wave climate was transformed to project site from NIWA's wave measurement ~60km offshore using diffraction diagrams and shoaling calculator. Accuracy might not be as good as using a numerical model	N/A	C- Severe	3 – Possible	Moderate	- A safety factor is built into the rock sizing - Regular inspection on the revetment and vigilant maintenance program to repair damages on revetment	GHD/BM/TCC	Design and operation		B - Major	2 – Unlikely	Negligible	
	Maintenance	Instability	Opens up void for wave to impact the underlayer, leads to structural failure	N/A	C- Severe	3 – Possible	Moderate	- In the rock spec the contractor is required to place the armour layer with a certain arrangement to achieve interlocking - Two layers of armour rocks - Regular inspection on the revetment and vigilant maintenance program to repair damages on revetment	BM/TCC/Contractor	Prior to construction		B - Major	3 – Possible	Low	To reduce rock sizes, a higher damage number (S_d=4) was made in the design
	Maintenance	Instability	Slope failure	N/A	C- Severe	3 – Possible	Moderate	- Undertake slope stability analysis on the revetment	GHD	Prior to construction		C- Severe	2 – Unlikely	Low	
	Maintenance	Instability	Revetment settles due to toe scour	N/A	B - Major	4 – Likely	Low	- Found the revetment toe on firm bedrock/boulder field where possible - Make allowance for settlement in crest height determination	GHD/BM	During construction		B - Major	2 – Unlikely	Negligible	
	Operation	Overtopping	Base track pavement (crushed rubble) damage by overtopping	N/A	B - Major	4 – Likely	Low	- Increase the crest elevation in accordance with design guidelines - Adopt different type of pavement system (e.g. grouted, or concrete pavement) - Consider physical modelling to provide further certainty on overtopping during design events - Ensure structure and structure periphery are able to cope with occasional saline inundation (e.g. galvanised stainless steel fittings etc)	GHD/BM	Prior to construction		A – Minor	2 – Unlikely	Negligible	
	Operation	Overtopping	Pedestrian injury from overtopping jet	N/A	C- Severe	3 – Possible	Moderate	- Close the base track for access during adverse weather	TCC	During operation		A – Minor	3 – Possible	Negligible	
	Investigation and Design	Instability	Due to the revetment alignment and opening for the concrete ramp, waves focus at chainages 300, ~340, and 360. Armour rock may be undersized	N/A	C- Severe	3 – Possible	Moderate	- Increase M_{50} of the armour rock around chainages 300, 340, and 360 - Two-layer armour system - Contractor to place rocks in accordance with requirements in the spec	GHD/BM/TCC/Contractor	Prior to construction		B - Major	3 – Possible	Low	

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2127021-25554/https://projects.ghd.com/oc/Sydney/mauaobasetrackremedi/Delivery/Documents/2127021-RPT-1_Revetment DDR.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date

[redacted] s 7(2)(a) – Privacy

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