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Tauranga City Council

Mauao Base Track Remediation Design

Revetment Detailed Design Report

October 2018

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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

This report: has been prepared by GHD Pty Ltd for Tauranga City Council and may only be used and relied on by Tauranga City Council for the purpose agreed between GHD and the Tauranga City Council as set out in Section 1.2 of this report.

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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. To this end, overtopping discharge limits associated with the design structure will be governed by structural integrity rather than pedestrian safety.

2.1.3 Maintenance requirements

Due to access issues for heavy plant, the client has requested a ‘low to no’ maintenance structure for the duration of the design life. This requirement is likely to increase the required standard of protection of the revetment structure.

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 (m 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.

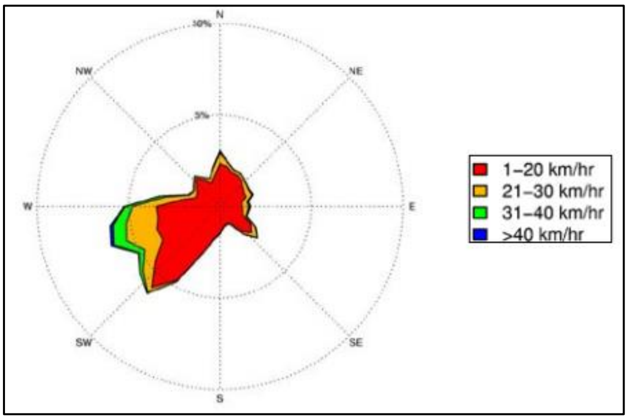

Figure 2 Wind rose at Tauranga Airport (source: NIWA – the Climate and Weather of Bay of Plenty, 3rd edition, Figure 10)

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 ex-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 not been considered in the design.

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 real-time, and does not have historic information.

An alternative source of information is obtained from 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, property, and paved surfaces. In the context of Mauao Base Track, GHD understands that the track would be closed from public access during adverse weather

[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

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. This value is also taken informally as a discharge that may potentially affect the structural stability of a rock revetment structure, through a process of outflanking caused by excessive ‘green water’.

It is noted however that a paved promenade is not an option for this location, due to cost limitations and tying into the aesthetics of the existing track. An unsealed path is likely to be the preferred track surface, with ongoing maintenance requirements relating to track resurfacing requiring consideration by TCC.

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 is shown in Figure 3.

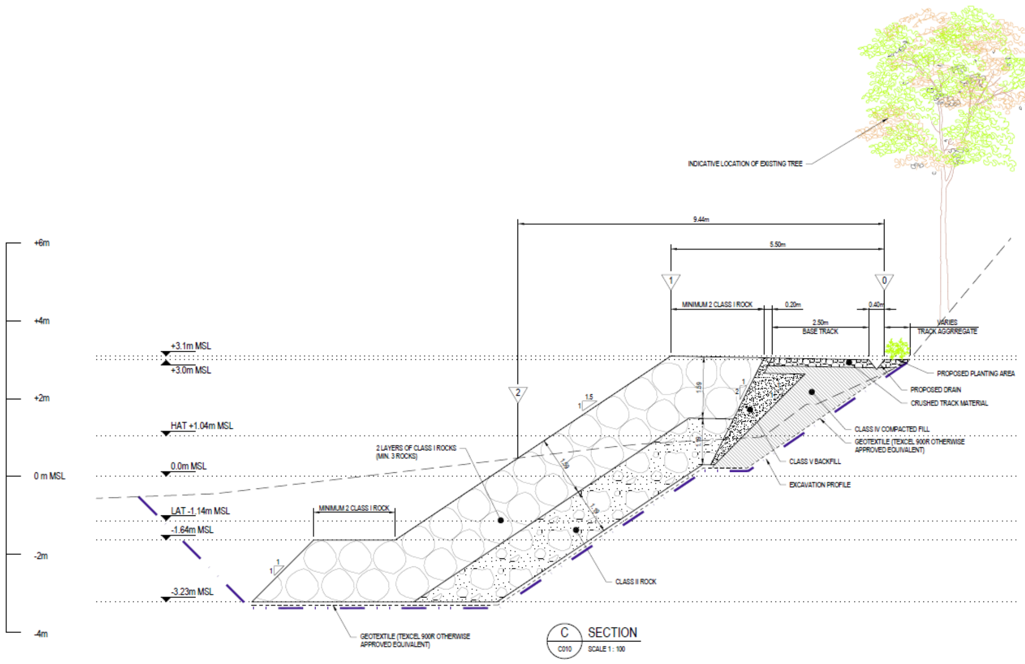

Figure 3 A typical revetment section

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 from washing 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 instability unlikely.

At where the revetment terminates, i.e. at chainage 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

The underlayer of this armour will be Class II as specified previously.

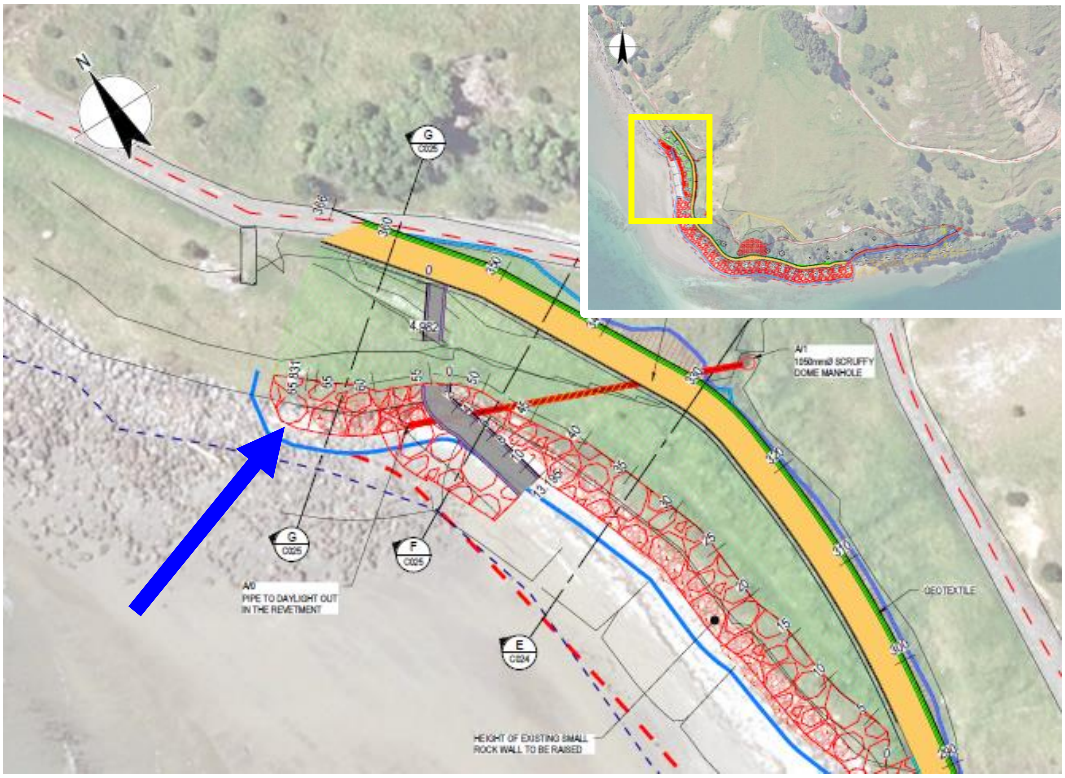

Figure 4 Locations where enlarged armour rocks are required

As the project developed, an opportunity was identified to elevate the picnic area (between chainage 290 to 360), depending on the volume of backfill material available. In response, the crest elevation of the revetment varies from 3.1 m MSL at the southern end near chainage 290, to 2.8 m MSL at northern end.

To minimise the encroachment of the 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 horizontally back into the picnic area by approximately 2 m.

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, which would significantly increase the footprint of the structure.

Following consideration of the various project requests and drivers, it was considered that the optimum design solution comprised a revetment geometry at a 1V:1.5H slope with crest elevation of +3.1 m MSL. This approach considered a balance between the following aspects

- Crest elevation and width preference
- Hydraulic stability of the revetment
- Footprint/encroachment into the Coastal Marine Area (CMA) (for consenting)
- Cultural/aesthetic impacts
- Material quantities and associated construction costs

3.4 Overtopping Considerations

TCC should therefore be aware that the structure can be considered as having a standard of protection against overtopping potentially less than a 1% AEP, and the steepening of the slope without increasing the crest width, has increased the overtopping potential beyond that of the target discharge of 200 **ℓ/s/m**. This may increase the long term maintenance requirements of the structure to more than the requested 'low to no' maintenance regime.

3.4.1 Frequency of overwashing

A preliminary estimate of the overwashing potential under ambient conditions was undertaken using the 2017 water level records at the A Beacon.

Based on the records, the freeboard between the water surface and the crest reduced to a level of high risk three to four times in the past year (2017) although no exceedance occurred. Present day HAT is at 1.04 m MSL; with the 100 year SLR estimate included then the water elevation is projected to be 1.94 m MSL. The crest of the revetment in the current design is 3.4 m MSL for the base track, which is 1.46 m higher than the HAT + 100 year SLR and is considered sufficient for freeboard under normal ambient conditions. With regard to the design extreme water level for 50 years of 2.0 m MSL with 50 years of SLR and of 2.5 m MSL with 100 years SLR, the revetment freeboard equates to a minimum of 0.9 m, which again is considered within acceptable limits for the proposed structure subject to acceptance of the overtopping discharge rates described in Section 3.4.

With sea level rise and storm wave action, the frequency of the sporadic overwashing will increase through time. 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.

3.5 Toe Detail

The project site is understood to consist of a large boulder field on the southern side of Mauao, overlain by a veneer of sand. The western side is sandy, and the presence and depth of the boulders beneath is uncertain. The design toe depths are determined to minimise scour, however are unlikely to be achievable on the southern side, and potentially on the western side. Therefore, an alternative toe detail of the revetment is proposed to be placed on top of the boulder field by removing the overlaying sand, placing the rock, 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. Where no boulders are present, or they are present at depth, the design toe to the full depth is to be the preferred arrangement.

3.6 Slope Stability

A slope stability assessment has been undertaken, the results are presented within the Geotechnical Report (GHD, 2018) and summarised in Table 5.

Table 5 Summary of Slope Stability Factors of Safety

	Acceptable FoS	FoS Achieved		
		Design toe depth	Alternate toe depth	Eroded beach profile
High tide	1.5	1.9	1.6	1.5
Low tide	1.5	1.7	1.5	1.5

3.7 Beach Access Ramp

A beach access ramp is provided at approximately chainage 55 of the picnic area. It is proposed to adopt pre-fabricated concrete box culverts to form the access ramp, for pedestrian access only. The selection of the box culvert ramp is due to the site restrictions and constructability issues.

Dimensions of the box culvert were taken from a prospective supplier’s product brochure to ensure product availability. It is expected that requirement on the sub-grade for the box culvert shall be in accordance with the supplier’s specification.

The ramp is designed to reach a top elevation a minimum of 1 m below the existing beach surface. In the event the boulder field is encountered, the boulders shall be excavated to allow for the placement of box culvert, and the boulders could be reused to form the scour protection around the box culvert.

4. Coastal Impacts

The coastal processes and geomorphology of the Mauao area and channel are not likely to be significantly modified or impacted due to the revetment structure. The structure lines the edge of the Mauao base track in parallel to the shoreline, rather than protruding into the channel or harbour. Therefore, it will be similar to the existing foreshore which consists of a boulder field overlain by sand. The changes and/or disturbance to the sediment regime is more likely to be during construction, rather than operation. The design calls for sediments excavated to be re-placed back to the natural profile after construction.

The northern and southern extents of the project site are held by natural boulders, therefore the accretion of sediment between these points is likely to remain stable in the short term. Under future increases in normal tides due to SLR and more frequent storm tide events, there may be lowering of sand elevations at the toe of the structure, potentially increasing scour risks.

There is low likelihood that the positioning of the structure will impact the hydrodynamics of the channel or harbour. Only during construction would we expect there be any impacts, likely increases in turbidity etc, however there’s a very low likelihood of changes to circulation patterns or flood and ebb flows.

5. Safety in Design

A Safety in Design (SiD) Register has been prepared for the revetment detailed design. The SiD Register documents common risks associated with revetment design, construction and operation, but excludes issues related to geotechnical and footpath design.

Refer Appendix A for the SiD Register.

6. 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 Register

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:**	28/09/2018	**Revision No:** 3
Job Name:	Mauao Base Track Revetment Design	**Job No:**	21/27021	**Client**	Tauranga City Council		**Design:**	s 7(2)(a) - Privacy [redacted]	
People involved in Risk Assessment:	s 7(2)(a) - Privacy [redacted]								

risk number:	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
1	Investigation and Design	Instability	The rock may not achieve the right density or mass required for stability	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	
2	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 is not 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	Prior to construction		B - Major	2 – Unlikely	Negligible	
3	Investigation and Design	Instability associated with #1 and #2	Opens up voids for wave to impact the underlayer, can lead 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 good placement density - Two layers of armour rocks - Regular inspection of the revetment and maintenance program to repair any damages	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
4	Investigation and Design	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	
5	Investigation and Design	Instability	Revetment settles due to toe scour. An alternate toe has been proposed where the design toe depth is unachievable. Toe will be founded on the existing boulder field material.	N/A	D – Critical	3 – Possible	Significant	- Found the revetment toe on firm bedrock/boulder field where possible - dig out and replace as much sand as possible. - Make allowance for settlement in crest height determination	GHD/BM Contractor/TCC	Prior to construction		B - Major	2 – Unlikely	Negligible	
6	Operation	Overtopping	Base track pavement (crushed rubble) damage by overtopping	N/A	B - Major	5 – Almost Certain	Moderate	- 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	GHD/BM TCC	Prior to construction		A – Minor	2 – Unlikely	Negligible	
7	Operation	Overtopping	Base track pavement (crushed rubble) damage by overtopping	N/A	C- Severe	5 – Almost Certain	Significant	- Ensure structure and structure periphery are able to cope with occasional saline inundation (e.g. galvanised stainless steel fittings etc) - Top up track material after storm events as necessary	TCC	During operation		C- Severe	3 – Possible	Moderate	
8	Operation	Overtopping	Pedestrian injury from overtopping green water	N/A	C- Severe	3 – Possible	Moderate	- Track weather, storm and tide forecasts to alert to a possible extreme event - Ensure the base track is closed during adverse weather - Add signage noting risks	TCC	During operation		A – Minor	3 – Possible	Negligible	
9	Operation	Community/public interaction/access	Pedestrian injury from scaling the revetment	N/A	D – Critical	3 – Possible	Significant	- Track signage stating people are not to scale the rock revetment - use the pedestrian access points	TCC	During operation		C- Severe	3 – Possible	Moderate	
10	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 specifications	GHD/BM/TCC/Contractor	Prior to construction		B - Major	3 – Possible	Low	
11	Maintenance	Community/public interaction/access	settlement of the revetment and track surface	n/a	C- Severe	5 – Almost Certain	Significant	Track maintenenace and topping up of track material as structure settles, to ensure an even stable track. Particularly the transition between the boardwalk and revetment track surfaces.	TCC	During operation		B - Major	2 – Unlikely	Negligible	

risk number:	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			Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating			Comments
					C	L	RR					C	L	RR	
12	Setup, Construction and Commissioning	Access/egress, access ways, entrances/gates	use of a barge to bring in plant and materials	n/a	D - Critical	4 - Likely	Significant	Contractor to work with TCC to ensure safe work practices during construction.	TCC/Contractor	During construction		C- Severe	3 - Possible	Moderate	
13	Setup, Construction and Commissioning	Instability	Instability of upper slopes above work areas during construction and operation	n/a	D - Critical	3 - Possible	Significant	Contractor to work with TCC to ensure a safe work area during construction.	TCC/Contractor	During and after construction		C- Severe	3 - Possible	Moderate	
14	Setup, Construction and Commissioning	Commissioning	Lack of understanding of marine construction practices through lack of marine construction experience	n/a	E- Catastrophic	4 - Likely	Extreme	Thorough review of contractor ability and experience prior to commission. These will be costly, difficult and complex construction works. Will require close monitoring of works and careful planning.	TCC/BM/GHD	Prior to and during construction		C- Severe	3 - Possible	Moderate	
15	Setup, Construction and Commissioning	Construction safety	Hazards during excavations and constructions	n/a	D - Critical	4 - Likely	Significant	Structures are designed with constructability and contractor safety in mind. Contractors to submit work method statements (WMS) for client and designer review prior to commencing works.	TCC/Contractor/GHD/BM	Prior to construction		B - Major	3 - Possible	Low	
16	Investigation and Design	Manual mixing of concrete	Personnel injury if need to mix concrete on site to form the beach access ramp	n/a	D - Critical	4 - Likely	Significant	- Use adeqaute machine to mix the concrete on site - Use pre-fabricated concrete units, to remove the need for in situ mixing	GHD/Contractor/TCC	Prior to construction		A - Minor	1 - Very Unlikely	Negligible	
17	Investigation and Design	Quality of concrete	Concrete used for the box culvert not suitable for marine applicatoin	n/a	B - Major	3 - Possible	Low	- Box culvert supplier shall comply with design specification - Box culvert supllier to ensure the concrete used for fabricating the box culvert meets relevant marine code - Box culvert supplier shall provide certiciate of concrete used to demonstrate compliance	Contractor	Prior to construction		A - Minor	2 - Unlikely	Negligible	
18	Investigation and Design	Lateral load from revetment	Lateral load from revetment might exceed box culvert capacity	n/a	C- Severe	3 - Possible	Moderate	- Box culvert supplier to consider the lateral load, and add adeqaute reinforcement to the side walls of the box culvert - Contractor to 'place' rocks when working around the box culvert. 'Dropping' of rocks shall be prohibited	Contractor	During construction		B - Major	2 - Unlikely	Negligible	
19	Operation	Fall from height	Pedestrian fall from the beach access at the top of the ramp	n/a	D - Critical	4 - Likely	Significant	- Provide hand rail on the beach access - Set up warning sign at the start of beach access ramp	Contractor/TCC	Prior to construction		D - Critical	2 - Unlikely	Moderate	
20	Operation	Trip hazard	Pedestrian got tripped by the handrail towards the end of the beach surface	n/a	C- Severe	3 - Possible	Moderate	- Terminate the hand rail at where the ramp surface intersects with the existing beach level, so the hand rail would remain visible and would not be buried too deep - Set up warning sign at the start of beach access ramp	Contractor/TCC	Prior to construction		A - Minor	1 - Very Unlikely	Negligible	
21	Setup, Construction and Commissioning	Overloading of ramp	Construction vehicle travelled on the ramp, overloading the box culvert	n/a	C- Severe	3 - Possible	Moderate	- Contractor to be made aware that no vehicular access is allowed on the beach access ramp, unless box culvert supplier confirmed/granted vehicular access - The box culverts shall be 'placed', not 'dropped'	Contractor	During construction		A - Minor	2 - Unlikely	Negligible	
22	Operation	Trip hazard	Large pore spaces bewteen rocks and culverts, where pedestrian's foot might be trapped	n/a	B - Major	2 - Unlikely	Negligible	- Provide kick plate on the hand rail - Set up warning sign at the start of beach access ramp	Contractor/TCC	Prior to construction		A - Minor	1 - Very Unlikely	Negligible	

GHD

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2127021-9741/https://projects.ghd.com/oc/Sydney/mauaobasetrackremedi/Delivery/Documents/2127021-RPT-4_Revetment DDR.docx

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