Member of the Surbana Jurong Group

Port of Townsville Channel Upgrade

Reclamation Integrity Plan

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Glossary

The glossary of terms presented in Table 1 provides a summary of some of the key words and terms used in this document.

Table 1: Glossary of Terms

TERM	DEFINITION
Bathymetry	Seabed levels
Borehole	A hole that is bored into the ground to take a soil sample and enable analysis of the different soil types beneath the surface
Bund	An embankment of material that has been designed to contain another material
Cohesive soils	Very fine particle soils e.g. clay and silt
Design life	The period for which the structure has been designed to fulfil specified performance criteria
Dual Frequency Echosounder	A device that measures the distance between it and the seabed. The device emits pulses of energy and measures the time taken for it to reflect back to the device sensor. This is done with two different frequencies of energy to measure the difference between the “True Bottom” and the “Apparent Bottom”, with the difference being the thickness of liquified or very soft or very loose sediments.
Factor of Safety	In the context of this document, the safety margin against bund instability is expressed as the ratio of resisting and destabilising forces and/or moments
Geobag	A sand filled and sealed geotextile bag
Geophysical survey	In the context of this document, a geophysical survey is a technique that is used to determine sub-surface geological layers and features over a large spatial area
Geotechnical	Relating to the engineering performance of the ground and earth materials
Geotextile	Permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain the soil
Head	The height of retained water. In the context of this project it is the difference between the open coast tide level in Townsville and the reclamation compartment water level.
Hydraulic stability	The stability of a structure when subjected to forces from waves, tides and currents
Integrity	To hold together under loading, including own weight, without breaking or deforming excessively
Joint probability	A statistical measure of two discrete events occurring at the same time e.g. a specific wave height and tide level. This is normally expressed as an annual probability of exceedance (e.g. 1%) or an average return period (e.g. 1 in 100 years).
Liquefaction (soil)	Loss of strength/stiffness in response to shaking during an earthquake
Metocean	Wind, wave, tide, current and climate conditions
Non-cohesive soils	Granular soils, e.g. sand

TERM	DEFINITION
Numerical modelling	Computer generated simulation of a real-life environment to determine the response of an object or system to different scenarios.
Paleochannel	An ancient inactive water course that has been filled by younger sediments, creating a linear feature of deeper soft soils than the surrounding profile
Physical modelling	Physical modelling is a smaller or larger physical copy of an object and its environment. The geometry of the model is either a larger or smaller scaled version of the real-life object and its environment. The physical model is used to simulate an object's response to different scenarios.
Reclamation	The use of material (usually soils) to create land for future use
Seismic	Relating to earthquakes. Can also refer to the transmission of motion or sound wave energy though earth.
Topography	Land levels

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Executive Summary

The Port of Townsville Limited (the Port) is seeking to increase the capacity of its existing shipping channel through dredging activities to increase the width along the channel. The construction of a new rock wall bund has been selected to provide a new reclamation area, which will be used to safely accommodate the dredge material. Given that Townsville is located in an active cyclone region and the rock wall bund construction is a significant undertaking, substantial design effort has been completed to achieve a robust design, in line with recognised industry standards and guidelines.

In order to comply with its requirements under Conditions 8 and 10 of the *Environment Protection and Biodiversity Conservation* (EPBC) Act Approval No. 2011/5979; the Townsville Port Expansion Project, Coordinator-General's evaluation report on the Environmental Impact Statement (September 2017) and the Operational work for Tidal Works – Townsville Port Expansion Project Rock Wall and Reclamation Works (2002-21277 SPD) Conditions 2 and 5, the Port via its design consultants, has developed this Reclamation Integrity Plan. This document presents the methodology that the Port will be adopting to ensure the integrity of the rock wall bunds and reclamation area remains fit for the intended purpose of ensuring that any release of sediment (dredge reclamation material) from the reclamation area into tidal waters is minimised in accordance with the approval requirements over its design life. The overall methodology takes a risk-based approach, considering the identified risks and how these are to be mitigated by ensuring that adequate site investigations, design, construction practices, construction quality verification, monitoring and maintenance are all undertaken, in compliance with the relevant standards, guidelines and recognised industry standards. This Plan has been produced in parallel with site investigation, design works and construction works and therefore it covers work already undertaken as well as future proposed elements of the Plan.

A risk assessment has been completed to identify the hazards that could affect the short and long-term integrity of the rock wall bund during its construction and longer-term operational life. The risk assessment process also identifies mitigation actions that will be applied during the design, construction and operational phases, which will reduce or eliminate the probability of the hazards occurring. This Reclamation Integrity Plan presents the key risks, mitigation actions and an overview of the methodology that has been adopted to implement the mitigation actions in the design, construction, ongoing monitoring and maintenance of the rock wall bund.

The rock wall bund design process is based on good quality data that provides a sufficient level of detail and covers the physical extent of the proposed works. The data includes bathymetry, geotechnical, geophysical, wave heights, environmental factors (e.g. adverse weather events), tide levels, rock quality and geotextile properties.

Industry recognised standards, guidelines and quality adherence processes have been followed in the design and during the construction process to achieve the bund structure performance criteria. These criteria include a 50-year design life and rock wall bund stability criteria for a 200-year average recurrence interval (ARI) storm event for minor damage and a 500-year ARI storm event for intermediate damage. Geotechnical stability design criteria include minimum factors of safety (FOS) of 1.1, 1.2 and 1.5 for seismic, temporary conditions (i.e. before reclamation fill placement) and permanent conditions (i.e. following reclamation fill placement) respectively. Settlement criteria and the parameters for cohesive (e.g. clays) and non-cohesive (e.g. sands) materials have also been carefully selected in line with recognised industry standards.

A hydrographic survey has been undertaken to obtain seabed level data to inform the detailed design of the rock wall bund structure and to provide data for the geophysical survey, numerical modelling and physical modelling.

A geophysical survey has been undertaken to determine whether significant paleochannels are present beneath the proposed rock wall bund; provide information about the location of different types of soil that are present beneath the proposed rock wall bund and determine the thickness and distribution of very soft sediments present beneath the proposed rock wall bund. No paleochannels have been identified in the vicinity of the proposed rock wall bund.

Furthermore, a vibracoring investigation was completed in 2020, immediately prior to construction of the rock wall bund to provide further information regarding the nature and depth of soft sediments and the level of stiff clay under the rock wall bund, in particular along the eastern and western sections of the rock wall bund, where no previous geophysical investigations had been undertaken.

Numerical modelling has been completed to assess the interaction of storm tides and waves at the Port, typically under cyclonic weather conditions. The purpose of the numerical modelling is to accurately determine the range of different wave heights at the rock wall bund structure, as a key design input, taking into consideration the independent events of astronomical tide and storm surge. This methodology is consistent with recognised industry standards for the design of such a rock wall bund and reclamation and provides increased certainty and level of accuracy in relation to design wave conditions. The design of the rock armourstone for the rock wall bund has been assessed based on recognised industry standards, desktop calculations and supported by hydraulic numerical modelling and physical modelling. The physical modelling has been completed in a 2-D flume and a 3-D tank to accurately assess:

- The impact of breaking waves at the rock wall bund structure.
- Potential scour (erosion of the seabed) at the toe (bottom) of the rock wall bund.
- A review of the rock wall bund to verify it is adequately designed for overtopping events.
- The hydraulic stability of the primary armourstone, secondary armourstone and underlying core rock during temporary and permanent construction stages and the associated risk.

A geotechnical assessment has been undertaken to assess the overall stability of the rock wall bund and the potential settlement of the underlying seabed material. This assessment has been based on a ground model that integrates a desk study (geology, seabed depth, subsurface soil profiles etc.), geophysical studies and borehole data. Slope stability analysis has been completed to include construction and maintenance traffic loads, reclamation material loads and seismic (earthquake) loading. A settlement assessment has been undertaken to predict settlement of the subsurface soil below the rock wall bund. The settlement and overall stability assessments identified the requirement for the construction contractor to displace the top layer of soft sea bed Holocene clay material, until the rock is founded on the lower, stiffer layer of sea bed material, to mitigate the settlement and associated stability risk.

A detailed specification for rock materials has been developed to ensure that the rock that is supplied for the construction of the rock wall bund has the required properties to ensure the constructed rock wall bund performs in accordance with the design criteria. The grading of the rock wall bund layers, including primary armourstone, secondary armourstone and core rock has been designed in accordance with industry defined 'filter rules', to ensure:

- Rock within the layers does not filter out between the voids within the structure
- Small particles within the founding material do not wash or 'pipe' out through the structure.

As part of the rock wall bund design, a suitably designed filter fabric has been specified, which is called a geotextile. The geotextile is required to ensure that any release of sediment (dredge reclamation material) from the reclamation area into tidal waters is minimised. The design and specification for the geotextile in the rock wall bund includes the following:

- filtering properties to minimise clay and silt fines flowing through the rock wall bund
- installation requirements to ensure it is secured, including in weather events, and is not damaged during installation
- The geotextile is installed to extend from the crest down to below the toe of the structure and is overlapped in accordance with industry guidelines to ensure the geotextile forms a continuous layer along the full length of the rock wall bund.

As part of the quality systems of the project, Inspection Test Plans (ITPs) have been developed and implemented to ensure that the rock has been delivered to site in accordance with the requirements of the rock specification.

The construction methodology has been developed in accordance with industry recognised standards, to minimise or eliminate the following risks: poor geotechnical founding conditions; impacts of extreme water level and wave conditions; the ability to safely operate machinery in a tidal environment; and minimise the release of sediment (dredge reclamation material) from the reclamation area into tidal waters. The construction methodology comprises a staged construction, each of which have been assessed for geotechnical and hydraulic stability of the rock wall bund. A quality ITP for the construction of the rock wall bund has been developed and implemented to ensure that all aspects of construction of the rock wall bund comply with the design.

Monitoring of the rock wall bund has been undertaken during the construction and operational phases. The monitoring plan was developed prior to the construction phase to ensure that robust measures are implemented over the life of the structure.

Maintenance of the rock wall bund will comprise the activities that are required on a periodic basis after construction to ensure that the rock wall bund performs to an acceptable standard during its design life. The maintenance program will therefore include: inspection and monitoring of the environmental conditions and structural response; an appraisal of monitoring data to assess compliance of the performance with predetermined standards; actions in response to non-conformances, if any; and repair or replacement of elements of the rock wall bund due to minor damage or displacement of rock during the design life.

1. Introduction

1.1. Project Background

The Port of Townsville Limited (the Port) is seeking to increase the capacity of its existing shipping channel through dredging activities to increase the width along the channel. Due to the legislative requirements of both the Commonwealth and Queensland Governments, the option of offshore placement for dredge material generated by the channel upgrade works is prohibited. An onshore dredge material receival facility is required to contain this material, which also offers the Port long-term options to expand its existing usable area for port logistics activities.

The construction of a new rock wall bund has been selected to provide a new reclamation area, which will contain material placed within the reclamation area and ensure that any release of sediment to tidal waters is minimised in accordance with the State Government development approval conditions. Given that Townsville is located in an active cyclone region and the rock wall bund construction is a significant undertaking, substantial design effort is required to achieve a robust design, in line with industry recognised standards and guidelines. Well planned construction works, rigorous construction quality verification and ongoing monitoring and maintenance will also be required in order to ensure the integrity of the rock wall bund and reclamation area.

1.2. Legislative overview

The Port Expansion Project (PEP) was the subject of an Environmental Impact Statement (**EIS**) and a further Additional Information to the Environmental Impact Statement (**AEIS**), submitted in support of Commonwealth and State project approval applications.

The following approvals have been obtained for the PEP and the Channel Upgrade (CU) Project, as Stage 1 of the PEP.

1.2.1 Commonwealth Approvals

EPBC Approval No. 2011/5979 was issued on 5 February 2018.

Appendix A lists the conditions from this approval that are relevant to this plan.

1.2.2 State Approvals

The Coordinator-General's Evaluation Report on the Environmental Impact Statement for the Townsville Port Expansion Project was issued in September 2017 (and all associated development approval / permits and environmental authorities).

The State Government's State Assessment and Referral Agency (SARA) response conditions, as amended on 22nd April 2021, issued under the Planning Act 2016 (see Appendix A).

1.3. Site Extent

The rock wall bund is located within the approved tenure area on the north-eastern side of the existing Port seawall as shown in Figure 1. The eastern extent of the tenure boundary shown in Figure 1 was extended after the rock wall bund detailed design was completed.

The reclamation for the CU Project represents Stage 1 (initial first stage) of PEP and covers an area of approximately 62ha.

Figure 1: Site Location

1.4. Why is a Reclamation Integrity Plan Required?

In order to comply with its requirements under Conditions 8 and 10 of the EPBC Approval No. 2011/5979, the Port must develop and implement a Construction Environmental Management Plan (CEMP) that includes measures to mitigate impacts to Matters of National Environmental Significance (MNES) from the construction of the reclamation area. The CEMP consists of the following set of documents:

- Stormwater, Sediment & Erosion Control Plan
- Site Monitoring Plan
- Tailwater Monitoring Plan
- Reclamation Integrity Plan
- Acid Sulfate Soil and Contamination Management Plan

The CEMP must be prepared in accordance with the Department's Environmental Management Plan Guidelines and include a program to monitor the integrity of the reclamation area, including monitoring locations, methods, and frequency (Condition 10e). The Port is complying with this clause by developing this Reclamation Integrity Plan.

Furthermore, the Port is required to comply with the State Government's State Assessment and Referral Agency (SARA) response conditions, that include the requirement for:

- The development to be carried out generally in accordance with the approved general arrangement drawings.
- The external revetment walls as shown on the plans in Condition 1 must be designed and constructed to contain material placed within the reclamation area and ensure that any release of sediment to tidal waters is minimised.

This document presents the methodology that the Port is adopting to ensure that the integrity of the rock wall bund and reclamation area is maintained throughout the duration of its design life. The overall methodology adopts a risk-based approach, considering the identified risks and how these are mitigated by ensuring that adequate site investigations, design, construction practices, construction quality verification, monitoring and maintenance are all undertaken, in compliance with the relevant standards, guidelines and accepted industry recognised standards. This Plan has been produced in parallel with site investigations and design analysis and therefore some of the proposed mitigation actions have already been undertaken.

This Plan presents potential risks to the integrity of the rock wall bund and the reclamation area over the design life, along with the proposed mitigation action methods.. Some discussion is also provided in this Plan regarding the filtration and retainment of reclamation material fines by the rock wall bund. This information is presented in the sequence in which the rock wall bund has been designed and will be constructed and operated, to enable the reader to follow the sequence of methods and mitigation actions, as they will be applied through the following key stages of the overall methodology:

- Performance criteria and standards
- Design data collection
- Assessment of the geotechnical and metocean (waves, tides and currents) conditions
- Design of the stability and integrity of the rock wall bund
- Materials and construction quality criteria
- Monitoring and maintenance

2. Risk and Mitigation Actions

The rock wall bund has been designed and constructed to contain material placed within the reclamation area and ensure that any release of sediment to tidal waters is minimised in accordance with the Port's approvals. A risk assessment has been completed to identify the hazards that could affect the short and long-term integrity of the rock wall bund during its construction and longer-term operational life. The risk assessment process also identifies mitigation actions that have been and will be applied during the design, construction and operational phases, which will reduce or eliminate the probability of the hazards occurring.

The identified hazards that could have a detrimental impact on the integrity of the rock wall bunds are presented in Table 2. A summary of the mitigation actions for each hazard are also presented along with a reference to the relevant section of this report, where a more detailed description of the mitigation action methodology is presented. The assessed mitigated risk rating for each hazard is also presented, having been assessed utilising the risk management guidelines within the Port's Quality Management System (risk tables reproduced in Appendix B).

Table 2: Identified Hazards and Mitigation Actions

RISK ID	IDENTIFIED HAZARD	RESULTING CONSEQUENCE	MITIGATION ACTIONS	MITIGATED RISK RATING	REPORT SECTION
	Design Hazards and Risks				
1	Inaccurate design wave and tide conditions at the rock wall bund, leading to an inadequate design and failure of the integrity of the rock wall bund	• Release of reclamation material into the marine environment • Rock wall bund remediation and environmental impact costs	• Carry out numerical modelling to define inshore design wave parameters, up to a 0.2% annual exceedance probability * • Carry out hydraulic stability design in accordance with accepted standards* • Carry out physical modelling to confirm and refine the hydraulic stability design* • Carry out hydraulic numerical modelling to assess the flow of water through the bund and geotextile over the range of tide levels (February 2021)*. • Independent review of the design by Jentsje Van der Meer who is a Professor of Coastal Engineering, based at Deltares*	Low (rare)	Section 3.1 Section 4.2 Section 5 Section 6.2 Section 6.3
2	Global failure of rock wall bund due to embankment geotechnical instability	• Release of reclamation material into the marine environment • Rock wall bund remediation and environmental impact costs	• Undertake adequate ground investigation work* • Design the rock wall bund with an adequate factor of safety against embankment failure* • Ensure construction is carried out in accordance with the design and recognised industry standards.	Low (Rare)	Sections 3.2, 3.4.3, 3.4.4 and 3.5 Section 4.3 and 4.4 Section 7 Section 8 Section 10.3

3	Unforeseen geotechnical conditions due to insufficient geotechnical investigation data along the rock wall bund alignment	• Unforeseen conditions not considered in the design and construction, leading to potential failure of the rock wall bund or construction delays	• Obtain further geotechnical information (e.g. vibracoring prior to commencing construction) * • Geotechnical ground truthing required during construction stage to verify design investigations and assumptions*	Rare (unlikely)	Section 4.4 and 7.4.1 Section 10.3
4	Fine sediments being released to the marine environment due to filter layers not being adequate	• Release of reclamation material into the marine environment • Marine water quality issues leading to negative impacts • Remediation and environmental costs	• Ensure an adequate geotextile specification is selected to minimise specified reclaimed material from passing through the rock wall bund* • The geotextile is to have adequate strength to mitigate the risk of damage during placement and construction of the rock wall bund* • Undertake dry trials of geotextile strength due to machinery loading and rock placement (June 2020)* • Ensure that the geotextile is placed in accordance with the manufacturer's recommendations, with suitable overlap, it extends below the toe of the rock wall bund, and it is 'anchored' onto the rock wall bund to ensure it is held in position during and following construction.* • Appropriate quality controls (including optional diving inspections, where rectification works are	Medium (Possible)	Section 3.6 Section 10.1 Section 11

			required) are undertaken prior to the geotextile being placed and covered* • Prioritise placement of clay lining at rear of the rock wall bund. • Monitor rear slope of rock wall bund for rock and geotextile movement. Implement maintenance recommendations, where required.		
5	Fine sediments being released to the marine environment through the interface between the tailwater discharge pipe and the rock wall bund.	• Release of reclamation material into the marine environment • Marine water quality issues leading to negative impacts • Remediation and environmental costs	• Ensure the tailwater discharge pipe is adequately designed and 'keyed' into the rock wall bund* • The discharge system is to contain a weir box configuration that contains controls (e.g. boards) that can be raised to allow sediment laden water to be retained within the reclamation area. • The tailwater discharge pipe is designed to withstand appropriate hydrostatic pressures* • Geotextile interface design to provide continuity of geotextile between the rock wall bund and the tailwater discharge pipe to minimise sediment release paths (e.g. bespoke geotextile connection details and clamps) (March 2021)*	Rare (low)	Section 3.6 Tailwater Management Plan

			• Bulk dredged material is to be placed against the rear slope of the rock wall bund early in the reclamation process.		
6	Project design criteria not being clearly communicated and understood by relevant stakeholders	• Rock wall bund does not comply with project specific criteria leading to subsequent impact on the design and construction integrity.	• Prepare a Basis of Design report prior to completing the design, which clearly sets out the criteria and standards upon which the design is based* • Ensure that relevant stakeholders review the Basis of Design report prior to completion of the design*	Low (Unlikely)	Section 3
7	Earthquake forces impact on the integrity of the rock wall bund design	• Ground motion affects the stability of excavations and, groundwater movements • Ground motion affects construction safety.	• Adopt appropriate design standards during the design*	Low (Unlikely)	Section 3.2.1 Section 3.2.2 Section 3.4.3 Section 8.1.2
Construction Hazards and Risks					
8	Poor construction of the rock wall bund leads to loss of integrity due to extreme wave conditions	• Release of reclamation material into the marine environment • Rock wall bund remediation and environmental impact costs	• Ensure construction is carried out in accordance with the design and recognised industry standards. • Ensure adequate monitoring and surveillance during rock wall bund construction* • Good quality control over materials to be incorporated into the rock wall bund construction works*	Low (rare)	Section 9 Section 10 Section 11
9	Rock wall bund bridges over paleochannel filled with soft material, causing loss of sediment under the rock wall bund	• Release of reclamation material into the marine environment	• Carry out geophysical investigations focussed on identifying paleochannels within the rock wall bund footprint. *	Low (Rare)	Section 4.3 Section 7.4.1 Section 10.3

		• Rock wall bund remediation and environmental impact costs	• Paleochannel (if found to be present, based on current studies considered very unlikely) infill material will be reduced through displacement of softer material or other means* • Undertake vibracoring to reduce the risk of paleochannels not being identified (March 2020)*		
10	The end use of the reclamation area is unknown	• Future construction on reclamation area adversely affects the stability of the rock wall bund	• Ensure that appropriate assumptions for future development are included in the Basis of Design* • Ensure that future development designers for the reclamation area are aware of the rock wall bund Basis of Design parameters • Prepare civil design (surface falls, drainage, access areas, etc) for implementation upon completion of filing	Low (Unlikely)	Section 3
11	Lifting, separation or damage to the geotextile at the interface of the rock wall bund and reclamation fill	• Release of reclamation material into the marine environment • Rock wall bund remediation and environmental impact costs	• Design details and construction methodology to ensure that the geotextile is not damaged and if so, it is replaced prior to completing construction* • Ensure the selected geotextile has adequate strength to minimise risk of damage during construction, provides adequate filtration has ample durability, and is constructed	For Phase 1 works above the buttress, Medium (Likely) For Phase 3-4 works, Low (Unlikely)	Section 10.1 Section 10.5

			strictly in accordance with supplier recommendations * • Ensure installation requirements include measures to ensure it is secure in poor weather events* • Design and construct rock buttress on the rear slope of the rock wall bund to stabilise geotextile above the level of the anticipated water levels within the reclamation compartment (April 2021). For geotextile above the rock buttress, monitor and maintain the rock and geotextile until clay lining and reclamation has been placed*		
12	Damage to partially constructed rock wall during extreme weather events	• Rock wall bund remediation and environmental impact costs	• Schedule rock wall construction so that most of the rock wall construction without armouring occurs in the dry season* • Construction methodology to be implemented to minimise risk of damage to the core and secondary armourstone during construction. This will be managed by the Contractor through a combination of appropriate weather forecasting, rock stockpile management and contingency and flexibility in working methods to provide rock wall bund stability*	For Phase 1 works above the buttress, Medium (Possible) For Phase 3 works, Medium (Possible)	Section 10

			• Implement pre-determined risk mitigation strategies for ensuring the integrity of the works in progress and the protection of the rock wall bund and landward infrastructure. This would typically include forecasting weather, having sufficient stockpiles of larger rock and sequencing construction with flexibility*		

* indicates action completed at time of writing.

Risk of Failure of this Plan:

A risk for the project is the risk of this Reclamation Integrity Plan not being successfully implemented. To address this risk, the Port has engaged an experienced design consultant for the design. This design consultant will also provide RPEQ certification of the rock wall bund construction in accordance with tidal works approval conditions.

Additionally, the Port has engaged a rock wall bund construction contractor based on a detailed tender process, with selection of the contractor based on its capability and experience to perform the construction works and demonstration of successful completion of similar works.

Two key risks to the success of the Reclamation Integrity Plan, and how these risks are mitigated, are:

Funding to implement:

A key risk to the implementation of the program will be sufficient funding to support the works to complete all actions. The Port has committed to ensuring the rock wall is constructed appropriately, with significant funding committed to ensure sufficient design testing and confirmation is carried out prior to commencing construction. Further to these works that have been completed, the Port has also committed within the project budget, sufficient resources to support the integrity monitoring during and post construction of the works. Noting that the design and construction of the rock wall will require engineering certification, the Port is committed to devoting required resources to the implementation of this plan.

Weather:

Given the rock wall bund construction will occur in the marine environment, weather conditions and extreme weather events pose a significant risk to the integrity of the rock wall bund construction. Recognising this, the rock wall bund construction commenced after the 2019-2020 wet/cyclone season. This approach mitigated the risk by ensuring that the majority of the rock wall bund construction occurred in the period of the year where there was low potential for severe weather, protecting the constructed wall when there was no armouring in place. While total construction period will include construction of the Phase 1 works (see Section 10) in the 2020-21 cyclone season, the construction sequencing was scheduled by the contractor to provide as much protection to the core rock as was practical.

Additionally, post severe weather event monitoring has been incorporated into this integrity plan to ensure that an integrity review is undertaken soon after any events that occur during the construction period.

3. Design Basis

This section sets out the data, standards and methodology for determining the design basis and also presents the key performance criteria that will be achieved to mitigate risks, through the application of the proposed methodology.

3.1. Data

The rock wall bund design process is based on good quality data, that provides a sufficient level of detail and covers the physical extent of the proposed works, in order to mitigate the risks presented in Table 2.

The rock wall bund design is based on the data sets presented in Table 3.

Table 3: Design Data Sets

DATA TYPE	DATA SOURCES	WHAT WILL THIS DATA TELL US?	HOW WILL THIS MITIGATE RISK?
Bathymetry (seabed levels)	Hydrographic survey data (see Section 4.2)	This enables us to model how waves and their energy change as they move inshore to the proposed rock wall bund location. This data has been used to determine an accurate existing seabed level at the proposed rock wall bund site	This data enables us to more accurately predict what size the waves will be at the rock wall bund and therefore produce a rock wall bund design that retains its integrity over the design life of the structure.
Geotechnical	Borehole data (see Section 7.4)	This data enables the type and strength of the ground conditions to be determined in individual locations in the vicinity of the rock wall bund	This data confirms the accuracy of the geophysical data and enables the geotechnical risks associated with the strength and stability of the ground conditions beneath the rock wall bund to be mitigated.
Geotechnical	Vibracoring data (see Section 7.4.1)	This data will provide further information regarding the nature and depth of soft sediments and the level of stiff clay under the footprint of the rock wall bund.	This data will provide greater confidence in the stiff clay layers, particularly along the eastern and western sections of the rock wall bund, where no previous geophysical investigations had been undertaken.
Geophysical	Geophysical survey data (see Section 4.3)	The data enables the type and strength of the ground conditions to be determined along a continuous section of seabed below the rock wall bund	This data enables the geotechnical risks associated with the strength and stability of the ground conditions beneath the rock wall bund to be mitigated. This data also enables the potential presence of paleo channels to be identified.

DATA TYPE	DATA SOURCES	WHAT WILL THIS DATA TELL US?	HOW WILL THIS MITIGATE RISK?
Wave heights	Offshore wave modelling (See Section 5)	The size, direction, energy and frequency of waves at offshore locations have been used to model how waves and their energy change as they move inshore to the rock wall bund location.	This data enables us to more accurately predict what size the waves will be at the rock wall bund and therefore produce a rock wall bund design that retains its integrity over the design life of the structure.
Tide levels	Tide gauge data (See Section 5)	The frequency and magnitude of different tide levels.	This data enables us to more accurately predict what the tide levels will be at the rock wall bund and therefore produce a rock wall bund design that retains its integrity over the design life of the structure. For modelled reclamation compartment water levels, see Section 6.3
Rock quality	Quarry	It will confirm whether the rock will retain its integrity during construction and over the design life of the rock wall bund	Only appropriately sized rock that will retain its integrity over the design life will be used, thereby mitigating the risk of failure of the rock wall bund
Geotextile properties	Suppliers	The filtration properties (including the size of the fines that can pass through), how the geotextile is to be placed, how it is to be held in position prior to filling, how long the geotextile will last and its resistance to potential damage during construction.	Only durable geotextiles that are installed and appropriately secured as per the design and manufacturer specifications will be used. Only geotextiles that minimise specified reclaimed material from passing through the rock wall bund over its design life will be used.

3.2. Standards and Guidelines

The rock wall bund design is based on the following recognised industry standards, guidelines and conference papers.

3.2.1 Standards

- British Standard, BS6349-1:2000, Maritime structures – Part 1: Code of practice for general criteria.
- Standards Australia, AS4997-2005, Guidelines for the design of maritime structures.
- Standards Australia. (2007). AS1170.4-2007. Structural Design Actions - Earthquake Loading, 1-61.
- Standards Australia. (2008).AS4678 - 2008 Earth-retaining structures. Sydney, NSW, Australia.

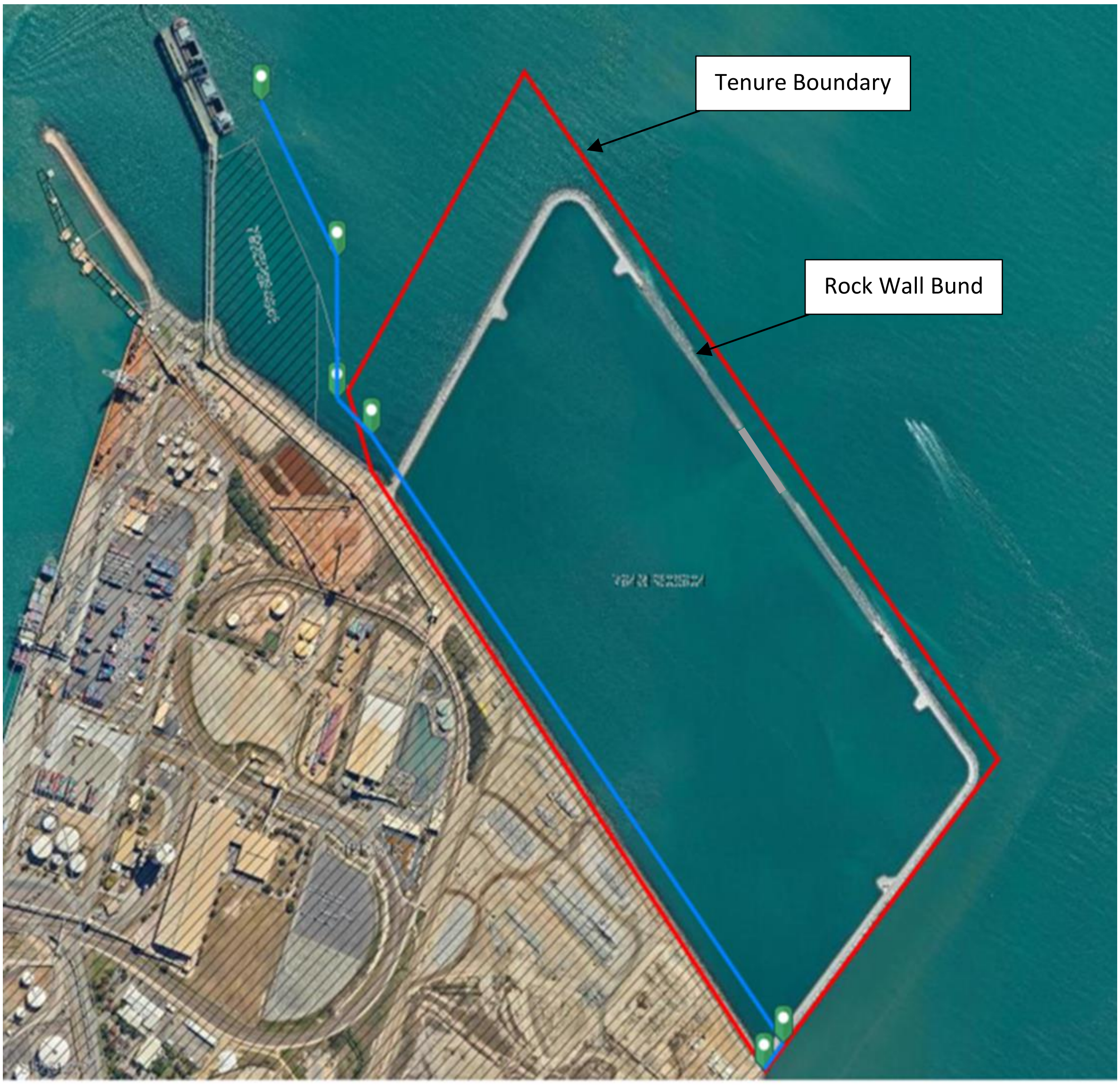
3.2.2 Guidelines and Papers

- Battjes, A. Groenendijk, H. (2000), Wave Height Distribution on Shallow Foreshores, Coastal Engineering, Vol. 40, Issue 3, pp161-182.
- CERC (1984) Shoreline Protection Manual. Vol 1 & 2, CERC Dept. of the Army, U.S. Army Corps of Engineers, Washington.
- CIRIA (2007), C683 The Rock Manual.
- Department of Environment and Heritage Protection (2013), (now known as Department of Environment and Science), Operational Policy, Building and Engineering Standards for Tidal Works, Queensland Government
- Engineers Australia (2012), The National Committee on Coastal and Ocean Engineering, Coastal Engineering Guidelines for working with the Australian coast in an ecologically sustainable way, 2nd Edition, p.34-37.
- Goda (2010), Random Seas and the Design of Maritime Structures, 3rd Edition.
- Schüttrumpf, H. (2003) Wave Overtopping Flow on Sea Dikes. PIANC-Bulletin. H. 114. p.7-23.
- Shore Protection Manual (SPM), (1984). 4th ed., 2 Vols, U.S Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, U.S. Government Printing Office, Washington, D.C.
- US Army Corps of Engineers (USACE) (2006), Coastal Engineering Manual (CEM).
- Van der Meer, JW; Allsop, NWH; Bruce, T; De Rouck, J; Kortenhaus, A; Pullen, T; Schüttrumpf, H; Troch, P and B Zanuttigh (2016), EurOtop, Manual on wave overtopping of sea defences and related structures, an overtopping manual largely based on European research, but for worldwide application, pre-release version, October.
- Van Gent, MRA; van den Boogaard, HFP; Pozueta, B and JR Medina (2007), "Neural network modelling of wave overtopping at coastal structures", Coastal Engineering, Vol. 54, pp. 586-593

3.3. Geometry

The Port has secured an agreement for a perpetual lease over land below the high-water mark for the construction of the rock wall bund. The rock wall bund is to be constructed within this 64.9ha tenure area shown in general layout Figure 2 (red line). The northern section of rock wall bund will be approximately 1075m long and the eastern and western sections of the rock wall bund will be approximately 550m long. This footprint complies with Approval Condition 8a.

Figure 2: Rock wall bund Tenure Area



3.4. Rock Wall Bund Structure Performance Criteria

3.4.1 Design Life

A 50-year design life up to 2070 has been adopted for the rock wall bund structure in accordance with:

- Australian Standard (AS) 4997-2005, Guidelines for the design of maritime structures, for 'normal maritime structures'.
- Building and engineering standards for tidal works, by Department of Environment and Heritage Protection, now known as Department of Environment and Science.

3.4.2 Rock Stability Performance Criteria

Based on AS 4997-2005, 'Guidelines for the Design of Maritime Structures', the design is governed by the most conservative outcome of the following two design events:

- A design event with a 0.5% annual exceedance probability (AEP), equivalent to a 200-year average recurrence interval (ARI) storm event, combined with a damage factor (Sd) of 2 (initial damage). Initial damage is defined as 0 to 5% of rock armourstone units displaced during the design event, where displacement is defined as armourstone displacing by a distance of one rock diameter. Only the upper layer of armourstone (primary armourstone) is assumed to be displaced in this scenario. The intention of the adoption of this design event is to ensure that only minor damage is incurred in a 200-year ARI event.
- A design event with a 0.2% annual exceedance probability (AEP), equivalent to a 500-year average recurrence interval (ARI) storm event, combined with a damage factor (Sd) of 6 (intermediate damage). Intermediate damage is defined as armourstone units displaced without causing exposure of the lower levels of rock armourstone or core layer to direct wave attack. Only the upper layer of armourstone is assumed to be displaced in this scenario. This design event is adopted in order to ensure that the rock wall bund will not fail in a 500-year ARI event.

Due to the staged construction of the rock wall bund and reclamation works, it is anticipated that a temporary intermediate rock wall bund (Phase 1 works, see Section 10.1 and Figure 10) will be constructed prior to completion of the reclamation work. Following completion of the reclamation work, the final rock wall bund design will be completed (Phase 4, see Section 10.1 and Figure 11) which includes additional rock at the crest of the rock wall bund (rear crest scour protection), to mitigate the risks associated with scour and overtopping in accordance with the above design events. The intermediate rock wall bund is a temporary design. The intermediate rock wall bund crest is expected to remain stable (minor rock movement in the order of 0-5%) for wave parameters (measured at the Townsville Wave Rider Buoy) comprising a significant wave height (Hs) of less than 2.5m and a peak wave period of 9 seconds, in combination with water levels of less than +2.9mLAT. The rear crest scour protection (Phase 4) is to be constructed by the reclamation contractor upon completion of the reclamation works (Phase 3), which is expected to be completed within 3 years of the completion of the rock wall bund construction. The probability of stated wave parameters being exceeded in the first 18 months, 2 years and 3 years following completion of the intermediate bund construction works is 7.5%, 10% and 14% respectively.

Following any of these design events, the Port will maintain the rock wall bund in accordance with the Port procedures for rock wall maintenance, to reinstate the full integrity of the rock wall bund.

3.4.3 Geotechnical Stability Design Criteria

The stability design criteria adopted for design of the rock wall bund includes the following:

- Cohesive materials (e.g. clay) in the foundations are modelled for short-term (i.e. temporary condition) and long term (i.e. permanent condition) behaviour.
- For non-cohesive materials (e.g. sand), drained strength parameters are used for temporary and permanent conditions.
- A loading across the top of the embankment is adopted for construction and maintenance traffic.
- The primary method for slope stability analysis is undertaken using industry accepted software to derive a factor of safety.
- The minimum factors of safety (FOS) of 1.1, 1.2 and 1.5 for seismic, temporary conditions (i.e. before reclamation fill placement) and permanent conditions (i.e. following reclamation fill placement), respectively.
- Based on the anticipated subsurface conditions it is expected that no foundation materials will liquefy during the design earthquake event.

3.4.4 Settlement Design Criteria

Settlement performance criteria for such rock wall bunds are generally governed by the limiting criteria of other structures (e.g. pipes, pavements or piles) within the rock wall bund, or by minimum crest height requirements relating to the reclamation volume.

However, within the current rock wall bund design, there is only one additional structure to be considered. This structure is a tail water discharge pipe that will be used for short term temporary works. The tail water discharge pipe will be constructed entirely within the rock wall bund and therefore due to the relatively small size of this structure, differential settlement is not considered to be an issue.

Consequently, the settlement design criteria adopted for the overall rock wall bund is 250mm over the first 25 years after construction. This criterion has been used to determine the crest height of the rock wall bund in order to retain the required reclamation volume over the design life of the structure and to inform the maintenance specification.

3.5. Geotechnical Parameters

A desktop study of the regional geology of the Port of Townsville has been undertaken using the data available through the publicly accessible Department of Natural Resources, Mines and Energy website.

The representative geotechnical soil parameter values that have been used in the design of the rock wall bund are based on laboratory data collected for the PEP EIS and AEIS historical laboratory test data (collected over several years by the Port), published data and previous experience. For cohesive materials (e.g. clay), a critical stage of the construction of a rock wall bund, in terms of stability, is during and immediately after construction. The water pressure in low permeability clays is instantaneously built up in response to the weight of the rock wall bund. At this stage, the soil is temporarily in an undrained condition and its stability is dominated by the undrained or short-term shear strength of the soil. The values adopted within the design were established by considering historical laboratory test results, past experience and published data.

When cohesive materials are subjected to permanent or long-term loading, drained strength parameters are used.

For non-cohesive materials (e.g. sand), drained strength parameters are used for temporary and permanent conditions, as the materials are deemed to act in a drained manner when loaded/unloaded. At the time of completing the detailed design, there were no direct laboratory tests available for the strength parameters of the non-cohesive materials on the site, hence the adopted design values have been derived based on past experience and published data.

3.6. Fines Filtration and Containment

As part of the rock wall bund design, a suitably designed filter fabric has been specified, which is called a geotextile. The geotextile is required to ensure that any release of sediment to tidal waters is minimised in accordance with the State Government development approval conditions. The design and specification for the geotextile in the rock wall bund includes the following:

- filtering properties to minimise clay and silt fines to flow through the rock wall bund
- permeability to allow water to flow through the geotextile
- installation requirements to ensure it is secured, including in weather events, and is not damaged during installation
- durability that is appropriate for the design life of the rock wall bund
- The geotextile is installed to extend below the toe of the structure and is overlapped in accordance with industry guidelines to ensure the geotextile forms a continuous layer.

Industry has advanced the manufacture of non-woven geotextiles for both strength and filtration performance considerably in past decades. The CU project specifies a heavy duty non-woven geotextile that is suitable for the rock wall bund.

The geotextile is covered with a smaller rock to ensure the fabric is not damaged during construction but is also secured in place. Site based trials have been undertaken to demonstrate that the geotextile is not damaged during i) placement of rock in accordance with the drawings and specification, and ii) vehicles passing at a horizontal distance of greater than 1m from the geotextile.

The interface between the geotextile on the rear slope of the rock wall bund and the tailwater discharge pipe has been designed to minimise fine reclamation material from being washed from the reclamation area and through the rock wall bund. This has been achieved by using a bespoke fabricated geotextile sheets, formed like a top hat, which has been clamped around the perimeter the tailwater discharge pipe. The brim of the top hat geotextile extends in a perpendicular direction to overlap with the geotextile on the rear slope of the rock wall bund.

4. Hydrographic, Geophysical and Vibracoring Surveys

4.1. Introduction

A detailed and accurate hydrographic survey of the seabed has been carried out to:

- Inform the detailed design of the rock wall bund structure.
- Provide data for the geophysical survey.
- Provide input data to the metocean numerical modelling and to define the design wave conditions.
- Provide an input to the physical modelling of the rock wall bund structures, which is required to fully understand the response of the structures to the design wave and tide events.

A variety of geophysical survey methods have been applied to:

- Determine whether significant paleochannels are present beneath the proposed rock wall bund.
- Provide information about the location of different types of soil that are present beneath the proposed rock wall bund.
- Determine the thickness and distribution of soft sediments present beneath the proposed rock wall bund.

4.2. Hydrographic Survey

- A bathymetric survey of the reclamation area and Port channels has been undertaken by the Port (see Figure 3). The survey was undertaken by Australian Hydrographic Surveys in November 2018, to a Maritime Safety Queensland Class C level of accuracy.

The relatively high-resolution bathymetric survey is a key input into the following design activities:

- Numerical modelling and rock wall bund stability analysis
- Design of the rock wall bund
- Calculating material quantities
- Geotechnical stability analysis

Figure 3: Bathymetric survey at the proposed reclamation site

4.3. Geophysical Survey

4.3.1 Methodology

Marine Navigation and Positioning

The geophysical investigation used a data acquisition, navigation and positioning system (Hypack), which was controlled from a series of laptop computers installed on the survey vessel. This system enabled the surveyor to accurately survey pre-defined geophysical survey lines. The navigation equipment provided the vessel operator with a real-time indicator of whether the vessel needed to move left or right to remain on the survey lines, which aided the accuracy and the quality of the survey.

The average height of the vessel above the previously surveyed seabed was determined using tide information provided by The Tide Unit, Marine Safety Queensland (MSQ), from the tide gauge located at Berth 1 Pump House.

Marine Seismic Refraction Testing

Marine Seismic Refraction Testing (MSRT) provides information on the seismic wave velocity distribution of the soils in place on the site. This information can be compared with borehole testing data in order to form a 3-dimensional model of the distribution of different soil types on the site.

The MSRT system was towed at a sufficient level above the seabed, to improve the quality of the information recorded and to avoid marine hazards, such as rapid changes in the seabed level and seafloor obstructions.

Initial trials on-site ensured the MSRT system was towed at the required depth for the vessel speed, with on-board computers receiving navigation and seismic records. The vessel was operated at between 3 and 5 knots.

The MSRT data was acquired at a 62.5µs sample interval (i.e. 16,000 samples per second) using one digital seismograph and the data was stored on the on-board computers for processing.

Sub Bottom Profiling by Single Channel Seismic Reflection.

Sub-Bottom Profiling (SBP) provides an indication of any sudden changes in the soil strength across the surveyed site. This technique can be useful for locating the interface between two geological units such as:

- The interface between soft, compressible Holocene clays and older Pleistocene clays, which are much firmer and less compressible.
- Any rapid change from soil to rock.

The SBP system uses a surface towed seismic source (boomer), which sends out seismic pulses. The reflected seismic pulses were detected by a 4.5m long group of hydrophones, which was also towed near the water surface.

The SBP system was controlled in conjunction with the navigation system, which enabled the investigation line locations to be accurately tracked from the vessel. The SBP seismic information was recorded in accordance with accepted recognised industry standards, including digital file formatting.

The seismic reflection information was observed by the geophysical contractor on the vessel for quality assurance purposes.

Dual Frequency Echosounder (DFE)

A Dual frequency echosounder (DFE) was used to measure the distance from the echosounder to the seabed by measuring the time for a pulse of energy to travel to the seabed and back. A DFE survey can provide valuable information in relation to the thickness of soft sediment on the seabed. The higher frequency energy pulse detects the level of the top of the sediment, while the lower frequency energy pulse penetrates the 'softer' sediment and is reflected from firmer material below. The difference between the depth readings from the two frequencies gives an indication of the thickness of soft sediment.

The DFE equipment was set up on the vessel with transmission frequencies including 200KHz and 30KHz with a beam angle of 8 and 19 degrees respectively.

4.3.2 Results

The results of the geophysical survey are reported in Geophysical Study - Channel Upgrade Project – Channel Widening and Reclamation Area Revision 3 (SMEC, 11/03/19).

4.3.3 Paleochannel Assessment

The conclusion of the paleochannel assessment is that no paleochannels have been identified within the vicinity of the rock wall bund, or reclamation, to the extent of the investigations completed.

4.4. Vibracoring Investigation

Subsequent to the geophysical survey and immediately prior to construction of the rock wall bund, a vibracoring investigation was completed along the footprint of the rock wall bund between 9th to 13th March 2020. The vibracoring investigation comprised: sixty-three (63) vibracore locations to assess foundations conditions at the proposed rock wall bund; in situ testing and sampling of soil and preparation of a factual geotechnical report presenting the results of the geotechnical investigation.

Vibracores were advanced vertically (i.e. at 90°) to the existing seabed using a solid 6.0 m vibracore tube with a 40mm inner diameter. The depth to the seabed, depth at which the coring stopped and time were recorded at the time of sampling. Once the vibracore tube would not penetrate any deeper into the seabed, the samples were hydraulically extracted into plastic sleeves and stored for logging.

Engineering logs of vibracore samples, in situ test results and explanatory notes defining the terms and symbols used in their preparation were recorded and the outputs are presented in SMEC report 30032296-RPT-003.

5. Numerical Metocean Modelling

5.1. Scope

Numerical metocean modelling has been completed to assess the interaction of storm tides and waves at Port of Townsville, typically under cyclonic weather conditions. The purpose of the numerical modelling was to accurately determine the probability of different wave heights arriving at the rock wall bund structure, as a key design input, taking into consideration the independent events of astronomical tide and storm surge. This methodology is consistent with recognised industry standards for the design of rock wall bund structures and provides increased certainty and levels of accuracy in relation to design wave conditions.

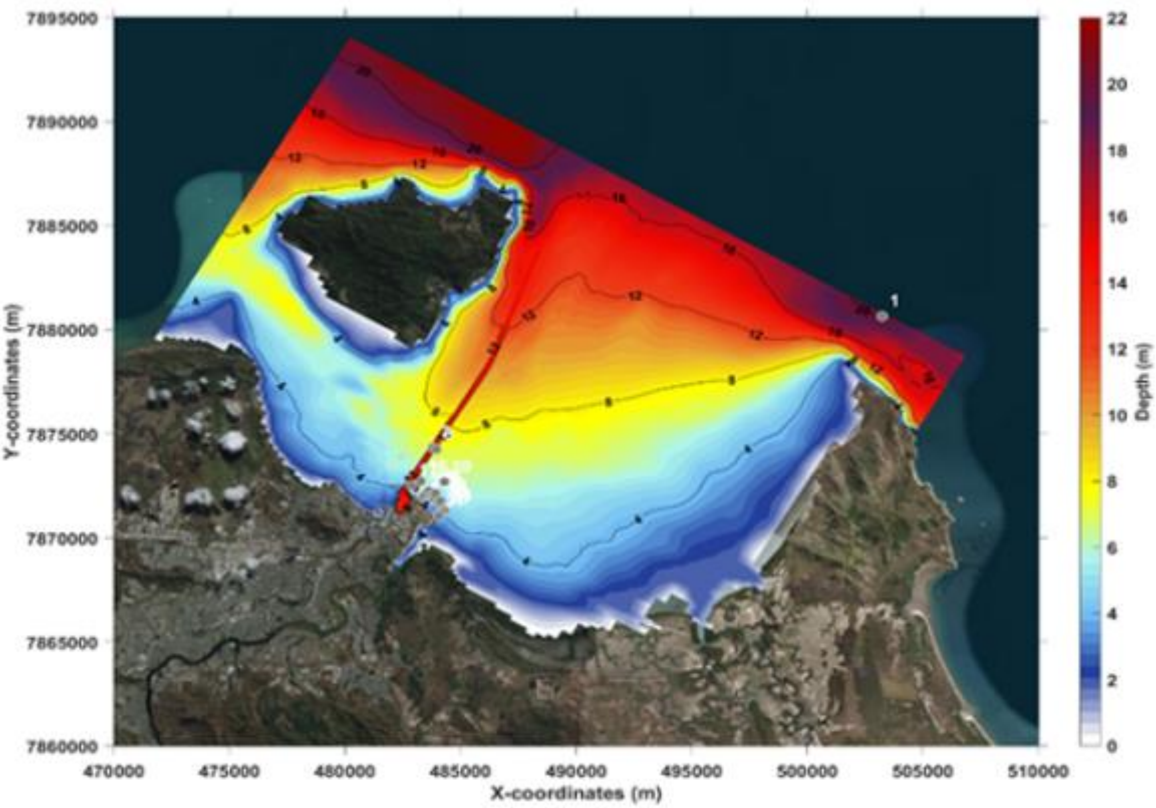
The overall methodology that was adopted for numerical metocean modelling comprises:

1. An artificial cyclone track dataset has been developed for Townsville using a probability model, which has been used as the basis of a joint probability assessment of waves and storm water levels, with annual exceedance probability (AEP) up to 0.1% or a 1 in 1000-year Average Recurrence Interval (ARI). The joint probability assessment has been used as the basis for the structural and hydraulic design of the rock wall bund, with the significant wave height (Hs) nominated as the primary design parameter.
2. A joint probability assessment has been undertaken of combined waves and water levels. Within the assessment, the largest Hs value of a specific probability has been used to characterise the event. The outcome of the joint probability assessment was a graph of Hs and total water level values with the same joint probability, which forms a curve. A family of joint probability curves has been presented, each with its own AEP of 2%, 1%, 0.2% and 0.1%(cyclonic). The AEP events are based on a joint probability of total water level (astronomical tide plus storm surge) and wave height (Hs).
3. The deliverables include a time series of data for Hs, peak wave period (Tpeak) and total water level for the 6 hours preceding the highest Hs value occurring and up to 3 hours after the highest Hs value occurs.
4. A sea level rise allowance has been adopted for up to 2070, in accordance with current Queensland government guidelines.
5. For each AEP event, wave height distribution parameters have been determined at specific output locations along the rock wall bund.
6. Using the related parameters from the model relationships, the corresponding wave period parameters and wave direction have been developed.
7. The validation process comprised a comparison of extreme events through statistical analysis of measured wave height and water level (Cape Cleveland) versus the numerically modelled results.
8. Sensitivity analysis of future climate change has been modelled, with respect to tropical cyclone (TC) intensity and frequency.
9. Non-TC storm tide hazards are known to influence Townsville AEPs up to approximately 0.5%. A non-cyclonic storm tide hazard analysis has been undertaken. This has been achieved by analysing long-term tide gauge data during time periods that are not impacted by TC events, up to a 0.1% AEP.
10. An assessment has been undertaken on the ‘known/anecdotal’ interaction effects of the shipping channel and local bathymetry on the wave parameters.

5.2. Numerical Model Summary

The modelled bathymetry, with depth relative to LAT datum, is presented in Figure 4.

Figure 4: Bathymetric modelled surface



A summary of the nearshore bathymetry and the modelling output location points are provided in Figure 5 and Figure 6. The modelling output location points are points of design interest that have been set to capture data for design consideration and comparison. Modelling output point reference numbers are shown adjacent to each point of interest, which are located around the perimeter of the rock wall bund and at other key locations.

Figure 5: Nearshore bathymetric modelled surface and numerical modelling output points

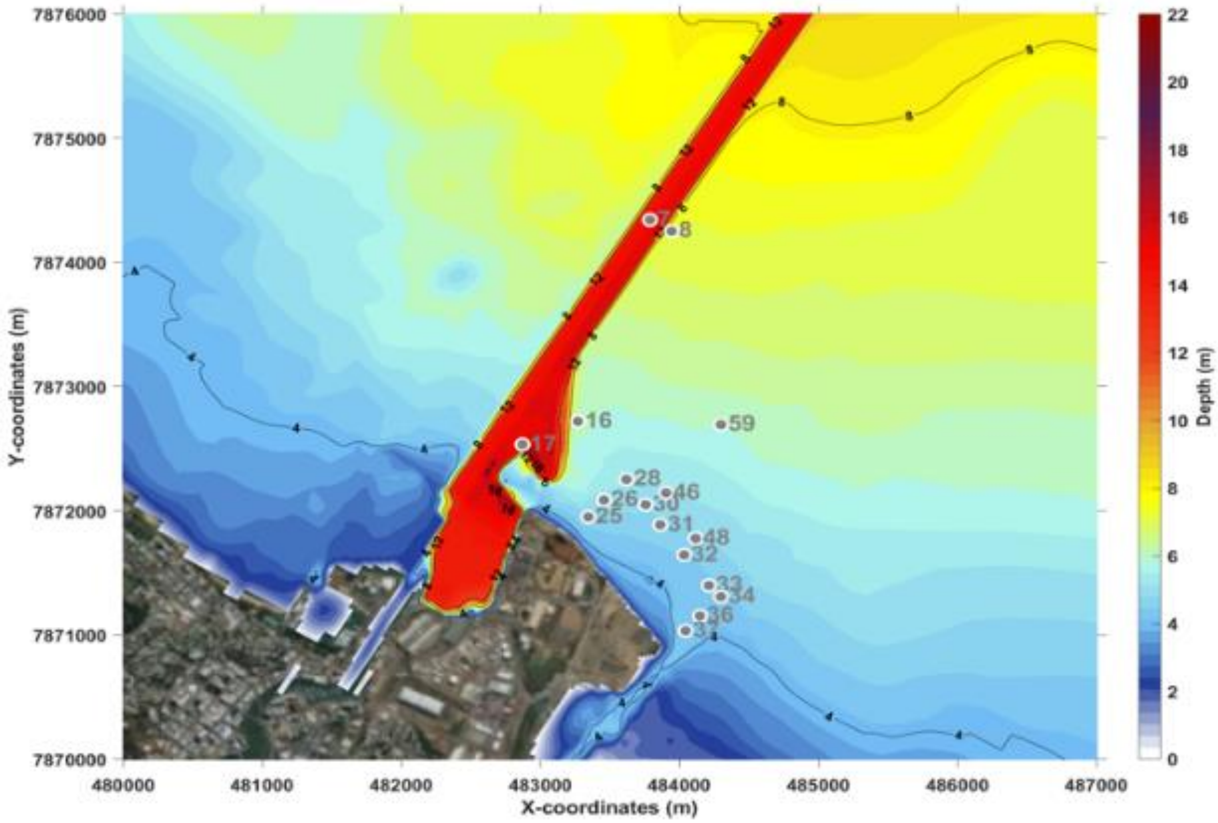
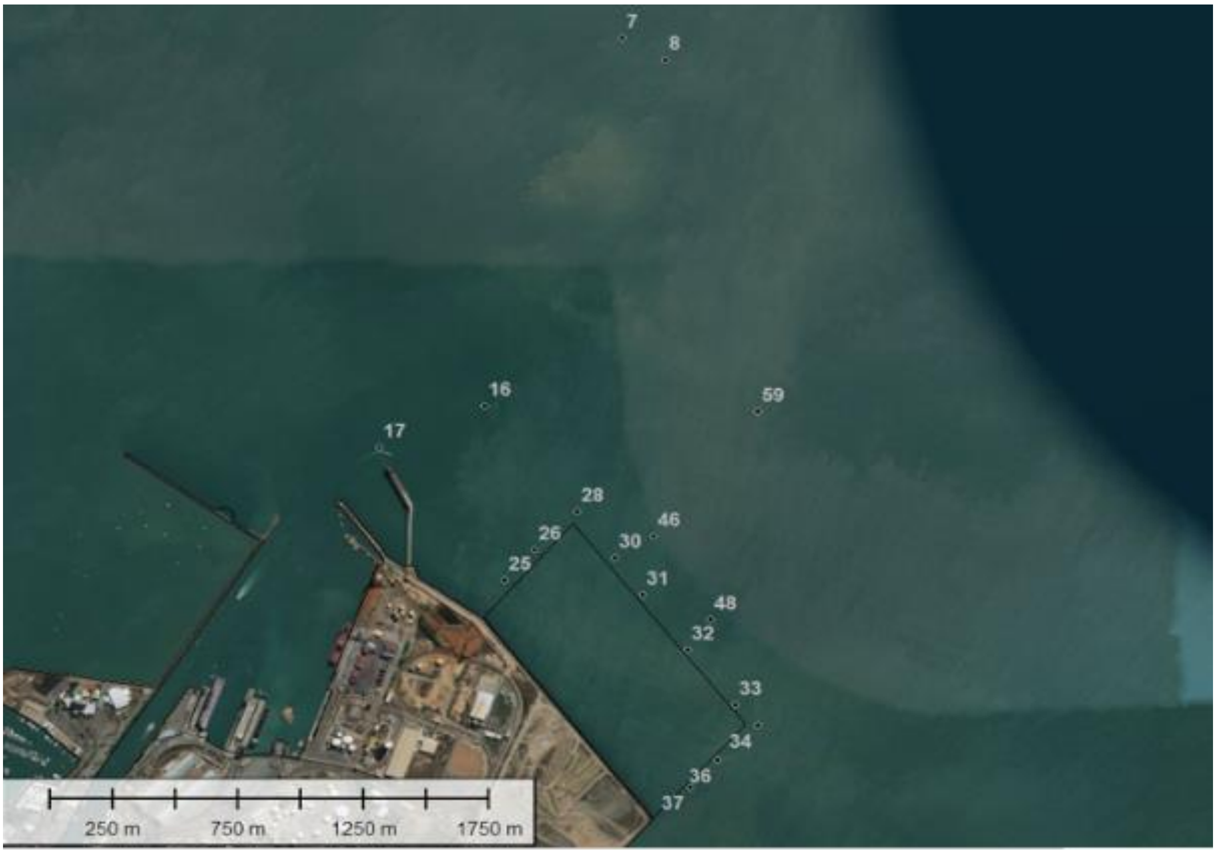


Figure 6: Numerical modelling output points



6. Hydraulic Stability Design

6.1. Design Methodology

An analytical model has been developed for the design of rubble mound and rock wall bund structures (based on Van Der Meer equations), which has been applied to determine the primary armourstone size. Calculations have been undertaken in accordance with the performance criteria set out in Section 3.4.

Rock wall bund crest design calculations have been undertaken to determine the anticipated volume (per second and per linear length of rock wall bund) of water that flows over the rock wall bund (known as overtopping) during the design storm events. The rock wall bund toe design has been undertaken in accordance with guidance from the CIRIA Rock Manual and other industry guidelines. These design outputs have been verified through physical modelling, in accordance with recognised industry standards.

6.2. Physical Modelling

Physical modelling has been undertaken by a professional research laboratory, using 2-dimensional flume and 3-dimensional large basin physical model testing. Physical modelling of the rock wall bund structure is proposed to:

- Accurately assess the impact of breaking waves at the rock wall bund and confirm the calculated rock size for stability.
- Investigate the potential reflection and focusing effects due to the geometric arrangement of the channel in relation to the surrounding infrastructure, including the proposed reclamation.
- Identify the potential risk for scour at the rock wall bund toe.
- Assess the overtopping rate, overtopping distribution and overtopping jet velocity.
- Assess permanent and temporary rock wall bund construction stages. This approach enables optimisation of the crest design for the permanent case and informs risk management practices during construction.

The physical modelling work comprises:

- 3-dimensional large basin (see 3d large basin model in Figure 7);
- 2-dimensional flume (see 2d model in Figure 8);
- Quasi 3-dimensional testing (see quasi 3d model in Figure 9).

The purpose of the 3-dimensional large basin physical model testing is to:

- Accurately determine extreme wave heights at the structure, prior to the waves breaking onto the rock wall bund structure.
- Model wave reflection and focusing effects due to the channel, natural bathymetry, and surrounding infrastructure, including the proposed reclamation.

The 2-dimensional and quasi 3-dimensional flume testing assesses rock stability (at a greater scale leading to greater level of accuracy and verification), current velocities along the rock wall bund toe, average overtopping volumes, overtopping jet velocities and the extent of overtopping at the rock wall bund crest.

Figure 7: CU 3d large basin model by WRL (rock wall bund on right hand side of photograph)

Figure 8: Rock wall bund of 2d model by WRL

Figure 9: Quasi-3d large model by WRL

6.3. Hydraulic Numerical Modelling

A hydraulic numerical model was developed in February 2021 to assess the flow of water through the bund and geotextile over the range of tide levels that were anticipated to be experienced in a typical year and throughout the construction process (i.e. from 0.0m LAT to +4.1mLAT). The purpose of this assessment was to support analysis of the stability of the rear slope of the rock wall bund and the design of a rock buttress at the rear of the rock wall bund to keep the geotextile in place, prior to and during the reclamation works.

The model was run to assess several different scenarios including:

- Scenario 1 - Rock wall bund lined with geotextile along the eastern, western and northern sections of the rock wall bund
- Scenario 2 – Scenario 1 with the clay placed on the rear of the western section of the rock wall bund (approximately 25% of the overall rock wall bund length).
- Scenario 3 – Scenario 1 with the clay placed on the rear of the western and northern sections of the rock wall bund (approximately 75% of the overall rock wall bund length).
- Scenario 4 – Scenario 1 with the clay placed on the rear of the northern section of the rock wall bund (approximately 50% of the overall rock wall bund length).

The modelling identified that a head of water (a difference between the open coast tide level and the water level inside the reclamation compartment) would form when the geotextile was placed in Scenario 1, with the magnitude of the head increasing as clay is progressively placed on the rear of the rock wall bund (i.e. from Scenario 2 to Scenario 4) (see Table 4).

Table 4: Predicted Head Across CU Rock Wall Bund Relative to LAT.

SCENARIO	CLAY LINING EXTENT (M)	PREDICTED HEAD AT +4.1MLAT	PREDICTED HEAD AT +3.6MLAT	PREDICTED HEAD AT +3.0MLAT
1	0	1.5	1.2	0.8
2	550	1.5	1.2	0.8
3	1625	2.0	1.5	0.95
4	1075	1.8	1.4	0.9
Fully Clay Lined*	2177	2.1	1.6	1.0

* Assumed, not modelled

This data was used to determine the quantity of rock that needed to be placed on the rear slope of the rock wall bund to prevent the geotextile from moving. Geotechnical analysis was undertaken to determine the quantity of rock, which is described in Section 8.1.2.

7. Geotechnical Assessment

7.1. Introduction

To assess the overall stability of the rock wall bund and the settlement of the underlying sea bed material, it was necessary to create a ground model that integrates a desk study (geology, seabed depth, subsurface soil profiles etc.), geophysical and borehole data.

Factual investigation data from relevant geotechnical reports, which specifically related to the Port of Townsville CU project, were compiled into a single database. This digitised dataset and its corresponding reports, were used in conjunction with knowledge of the surrounding area to develop a geotechnical model for the proposed site.

A geophysical assessment and vibracoring investigation were carried out across the marine area of the CU project including the area of the proposed rock wall bund to further progress the geotechnical model of subsurface materials (see Sections 4.3 and 4.4).

7.2. Geology

In order to develop an appropriate geotechnical model for the reclamation area, a desktop review of the regional geology of the Port of Townsville was undertaken using the spatial data available through the publicly accessible Department of Natural Resources, Mines and Energy information. The geological conditions of the proposed dredging and reclamation areas have been inferred as similar to the geology of onshore areas near to the site.

Appendix C presents an extract from the geological map published by Department of Natural Resources, Mines and Energy for the reclamation area, together with a legend depicting the different geological units referenced therein

7.3. Geophysical Assessment

A geophysical assessment was undertaken to collect data on the different soil types below the seabed and their corresponding properties. This information was required for the geotechnical assessment of the rock wall bund. A more detailed description of the geophysical assessment is presented in Section 4.3 of this report and therefore the following information is only a summary:

- Seismic compression wave information was recorded along longitudinal lines of the rock wall bund site using the Marine Seismic Refraction Testing (MSRT) method. This data has been used to form a 3-dimensional model of the distribution of different soil types on the site.
- Single channel seismic reflection information was recorded using a sub-bottom profiling system. This survey method is used to identify any sudden changes (i.e. sharp interfaces) in the soil strength across the site.
- A dual frequency echosounder survey has been undertaken to determine the thickness of soft sediment layers on the seabed.
- Seismic and dual frequency echosounder data has been collected in accordance with recognised industry standards.
- The geophysical information has been analysed in conjunction with geotechnical data.

As shown in Appendix D of this report, the lines completed were parallel to the shoreline. REC-1 was recorded generally along the northern rock wall bund of the reclamation area and REC-2 was recorded approximately 150m landwards from REC-1.

7.4. Borehole Data Analysis

A dataset was compiled from historical factual geotechnical investigations. A total of eight boreholes are in the vicinity of the rock wall bund and reclamation area.

These boreholes include:

- Port of Townsville Log BH141
- Port of Townsville Log BH145
- Port of Townsville Log BH151
- Port of Townsville Log BH153
- Port of Townsville Log BH168
- Port of Townsville Log BH267
- Port of Townsville Log BH268
- Port of Townsville Log BH269

The proximity of these boreholes to the proposed bund locations are shown in Appendix D.

7.4.1 Vibracore Data Analysis

Sixty-three (63) vibracores were taken along the footprint of the rock wall bund immediately prior to construction to inform the detailed design and construction of the rock bund wall and:

- Identify variation in the level of stiff clay layers along the length of the rock wall bund
- Reduce the risk of paleochannels not being identified

The location of the vibracores in relation to the rock wall bund are shown in Appendix D.

7.5. Geotechnical Model

Based on consideration of the information presented in Sections 7.2 *to* 7.5*, the geotechnical model for near surface geological conditions was inferred to comprise Holocene age alluvial deposits. These deposits consisted of sand and very soft to firm compressible cla*ys. This layer was generally underlain by Pleistocene age stiff to very stiff clay/silt materials over medium dense to dense sands and/or hard clays. Interbedded clays and sands were typically encountered below these materials as shown in Table 5.

Table 5: Inferred Ground Conditions

UNIT	BASE OF UNIT (M LAT)
Soft Clay	-3.8 m LAT
Stiff to Very Stiff Clay	-9.3m LAT
Medium Dense to Dense Sands	-15.2m LAT
Interbedded Very Stiff to Hard Clays and Sands	-60m LAT

8. Geotechnical Design

8.1. Slope Stability

8.1.1 Introduction

Slope stability assessments have been undertaken to mitigate the risk of geotechnical failure of the rock wall bund. General stability assessments were undertaken, based on geophysical data (SMEC, 2019), and supplemented by borehole data. Geophysical data from this report indicated that the location of REC-1, corresponded to the alignment of the rock wall bund running in a north-west to south-east direction. This data was used to identify the different geotechnical conditions likely to be encountered on site.

8.1.2 Slope Stability Assessment

Stability assessments have been carried out for the rock wall bund using Slope/W software, adopting limit equilibrium methods to achieve a minimum factor of safety (FOS) of 1.1, 1.2 and 1.5 for seismic, temporary conditions (i.e. before reclamation fill placement) and permanent conditions (i.e. following reclamation fill placement), respectively.

The expected soil conditions for the stability assessments were based on a geotechnical model (as described in Section 7).

Uniformly distributed live loading was adopted at the top of the rock wall bund for both short term and long-term loading conditions. This uniformly distributed live loading has been adopted to represent loads applied by construction and maintenance traffic on the top of the rock wall bund . The analysis incorporated a minimum setback distance of 1m from the face of the rock wall bund as an assumed construction safety offset (i.e. a distance from the edge of the rock wall bund in which construction traffic will not operate for safety reasons).

As a conservative approach and in the absence of any information regarding the expected reclamation fill material composition, the design was based on the assumption that this material is soft clay. It is likely the dredge material will have a range of consistencies from very soft to hard but its behaviour will be governed by the weakest materials.

Seismic loading analysis has been undertaken within the stability checks of the proposed rock wall bund. The behaviour of soil structures that are subjected to earthquake loading is often modelled using pseudo-static analysis, whereby the earthquake loading is represented by an equivalent static horizontal force. This force is often quoted in proportion to the weight (i.e. force) of the soil structure in terms of gravity, g (m^2/s) i.e. acceleration (or seismic) coefficient. An earthquake design acceleration has been applied to the rock wall bund stability modelling in accordance with AS1170.4 (Standards Australia, 2007). An earthquake design acceleration has been determined based on equation 8.2 (2) of AS1170.4. The design pseudo-static acceleration used in the stability modelling was assumed to be half of the peak ground acceleration (Kramer, 1996).

Based on the assessed subsurface conditions, there is considered to be a low probability that foundation materials will liquefy during the design earthquake event. Also, Townsville is located in a region with low probability of significant seismic events. As such it is considered that a detailed assessment is not required due to the low probability of an earthquake event, and the properties of the underlying geotechnical conditions.

The stability analysis of the construction stages is presented in Section 10.

A separate stability assessment was undertaken in March 2021, following commencement of the construction works, for the rock on the rear slope of the rock wall bund that is located above the geotextile. This rock is referred to as a buttress. The buttress is required to maintain stability of the geotextile and overlying rock, when there is a difference between the open coast tide level and the water level inside the reclamation compartment (also known as head) (see Section 6.3). This is a temporary works scenario that was required prior to placement of the reclamation material on the rear slope of the rock wall bund. Geotechnical modelling was undertaken using PLAXIS software for differing head values to determine the geometry of the buttress rock that would be required to maintain the stability of the geotextile and rear slope of the rock wall bund, based on the range of tide levels that were anticipated to be experienced in a typical year and throughout the rock wall bund construction process.

8.2. Settlement Assessment

8.2.1 Introduction

Settlement predictions depend on several factors including design criteria and timelines, fill placement, geological conditions and geotechnical parameters. These factors influence the settlement during loading, the residual settlement, and therefore the final crest height.

Fill placement and timelines for construction will be determined by the construction contractor. Total settlements (rather than only consolidation estimates for clay soils) are considered appropriate based on the level of geotechnical information available for use in the assessment (including consolidation data), and the limited thickness of soft material that will be present below the rock wall bund after construction.

8.2.2 Settlement

The finite element modelling package PLAXIS 2D was used to predict settlement of the subsurface profile below the rock wall bund.

Stability analyses of the rock wall bund design have indicated that the stability is highly sensitive to the top layer of the subsurface profile, which has a shear strength of less than 50kPa. However, due to the minimal thickness of the soft layer and method of rockfill placement, the impact of any remaining soft material should be limited. This was a similar observation made in the existing eastern reclamation rock wall bund constructed in the 1980s, that has never experienced instability.

The input geometry for the model assumes a three-layered subsoil profile with the rock wall bund on top. The core rock, secondary armourstone and primary armourstone layers have been delineated within the rock berm modelled in accordance with the current proposed design.

Model geometry was sufficiently extended in the horizontal directions so that there is no interference with the results. The influence of model depth on the predicted settlement was mitigated by running the model with a depth of 33m (maximum depth of the closest borehole to the rock wall bund).

9. Rock Size and Quality

9.1. Introduction

A detailed specification for rock materials has been developed to ensure that the supplied rock has the required properties to ensure the constructed rock wall bund performs in accordance with the design. The major properties are:

- Density – important for hydraulic stability against wave attack
- Shape – important for good interlocking for hydraulic stability against wave attack
- Durability properties – to ensure that the rock is durable in the environment over the rock wall bund structure design life
- Grading within each rock material type – important in ensuring adequate filtering such that lower and smaller rocks are not pulled out of the rock wall bund through the upper layers of larger rocks (e.g. it is important the secondary armourstone and core rock is graded such that it cannot be pulled through the primary armourstone layer)

9.2. Rock Grading Design

The grading of the rock wall bund layers, including primary armourstone, secondary armourstone and core rock has been undertaken in accordance with well-established industry 'filter rules', to ensure:

- Rock is not able to pass between the voids of the upper layer of rock within the rock wall bund.
- Small particles within the founding material do not wash or 'pipe' out through the rock wall bund.

The risk of small particles within the founding material 'piping' out through the rock wall bund structure is considered extremely low. Notwithstanding this, the risk has been mitigated as follows:

- An assessment of shear stress at the seabed versus the shear strength of the founding calculations has been undertaken.
- A geotechnical performance specification has been developed for the preparation of the seabed and founding rock wall bund formation level. Insitu verification of the founding material is incorporated into the geotechnical performance specification.

9.3. Rock Specification

The primary armourstone, secondary armourstone and core rock will be required to satisfy the following criteria in relation to rock wall bund stability and durability:

- Rock will comprise individual stones, which are either igneous or metamorphic in origin, which are dense, sound, resistant to abrasion and free of cracks, cleavage planes, seams and other defects, which would result in breakdown of the rock in the environment of the site of the works.
- Rock will be rough and angular.
- The ratio of the maximum dimension of any rock to the minimum dimension, measured at right angles to the maximum dimension will not exceed 2.5.
- All rock will be unweathered and free from damaging minerals such as expansive clay minerals.
- The water absorption will not exceed 3% when determined by relevant methods described in AS1141 Section 6 or AS4133.2.
- Rock will show no signs of stress-relief.

9.4. Quality Management

Inspection test plans and processes for the rock quality have been developed and will be implemented to ensure that the rock is delivered to site in accordance with the requirements of the rock specification. The rock quality requirements include the following:

- Quality management procedures
- Detailed Inspection and Testing Plans (ITPs)
- Documentation and record keeping requirements to ensure auditability and traceability

The quality testing requirements have been developed in accordance with the recommendations of the CIRIA Rock Manual.

10. Construction

10.1. Overall Construction Methodology and Sequencing

The construction methodology was developed based on the following key constraints:

- Geotechnical founding conditions
- Exposure to both ambient and extreme water level and wave conditions
- Ability to safely operate machinery in a tidal environment
- Rock wall bund structure containment of the dredge material

The rock wall bund comprises five different types of rock, as follows:

- Core rock – this is generally smaller pieces of rock (see green shaded area in Figure 10)
- Secondary armourstone – this rock is larger than the core rock but smaller than the primary armourstone. This material is placed above the core rock (see yellow shaded area in Figure 10) and is designed so that core rock cannot pass through the secondary armourstone.
- Primary armourstone- this is the largest rock on the structure and is placed above the secondary armourstone (see orange shaded area in Figure 10). Primary armourstone is designed so that only initial damage to the structure occurs during the design event and so that secondary armourstone cannot pass through it.
- Ballast rock – this rock is smaller than the core rock and has been selected to reduce the risk of damage to the geotextile during the construction phase (see blue shaded area in Figure 10). The ballast rock is designed so that it does not pass through the core rock.
- Buttress rock – this rock has been selected to add weight and stability to the rock and geotextile on the rear slope of the rock wall bund (see purple shaded area in Figure 10).

Large continuous (overlapping) sheets of geotextile (non-woven needle punched staple fibre) are placed within a 'sandwich' of ballast rock on the rear slope of the rock wall bund to protect it on both sides. The ballast rock and buttress rock also anchor and secure the geotextile in place, to minimise fine reclamation material from being washed from the reclamation area and through the rock wall bund.

The following construction phases (and sub-phases) are presented in Figure 10 (Phase 1 and Phase 3) and Figure 11 (Phase 4), noting that the rock wall bund illustrations are conceptual illustrations to convey the indicative construction method. Reference should be made to the rock bund wall construction contractor's method statement and the final issue of the construction drawings for specific rock wall bund detail. Each of the sub-phases has been assessed in the design for both hydraulic and geotechnical stability:

- Phase 1 – Construct Rock Wall Bund (see Figure 10)
  - Phase 1.1 – construct the core rock (green area) using ground verification and quality test checks to ensure that minimal or no soft material is present as per the detailed design
  - Stage 1.2 - place the secondary armourstone (yellow area) and the primary armourstone (orange area) up to the top of the rock wall bund slope
  - Stage 1.3 – place ballast rock then overlay geotextile and secure in position as per the design and extend the geotextile from the top of the crest to below the rear toe of the rock wall bund to provide a continuous filter system over the full height of the rock wall bund. Cover geotextile with ballast and then core rock (blue area)
  - Stage 1.4 – construct the rock buttress (purple area)
- Phase 2 – Construct dredge material receival facility
- Phase 3 – Placement of the Dredge Material (see Figure 10)
  - Phase 3.1 – Placement of dredge material will occur upon commencement of the dredge campaign in the following priority areas to mitigate the release of fine material:
    - Tie-ins at the eastern and western sections of the rock wall bund, as shown on drawing 30032296-GE-SME-01-271 rev B
    - Along the back of the rock wall bund, immediately adjacent to the dredge material receival facility, as shown on drawing 30033794-TS-SME-01-101.
- Phase 4 – Construct rear crest scour protection (see Figure 11)
  - Phase 3.1 – Place geotextile over reclamation material, whilst ensuring a continuous overlap with the Stage 1 geotextile and cover with ballast rock (brown area)
  - Phase 3.2 – Place secondary armourstone over ballast rock (red area)
  - Phase 3.3 - Construct the primary armourstone at the crest of the rock wall bund

Figure 10: Phase 1 Construction (Phase 3 in grey)

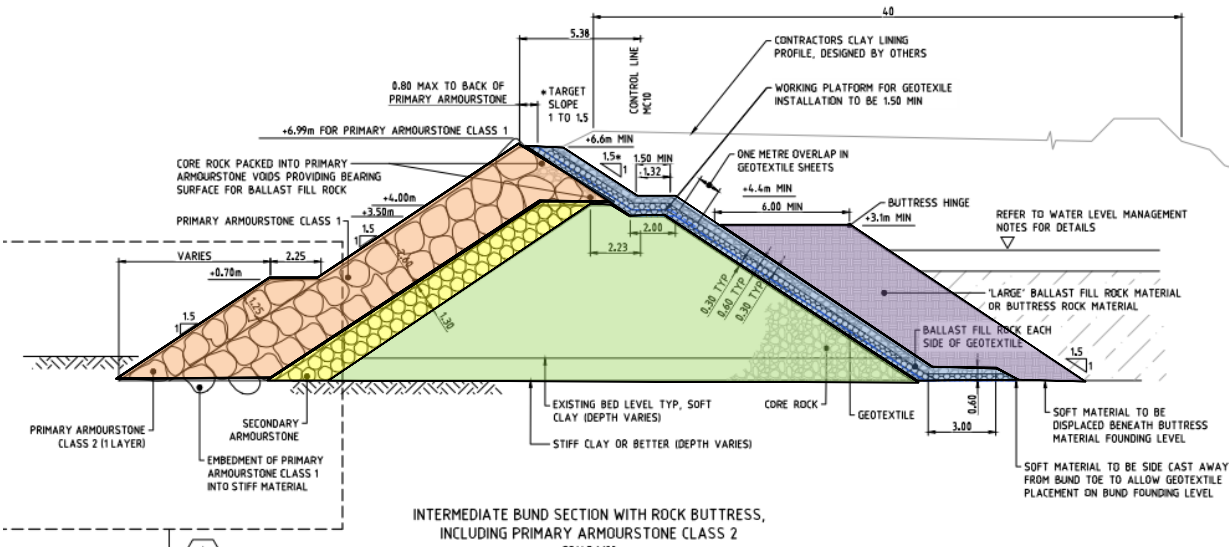
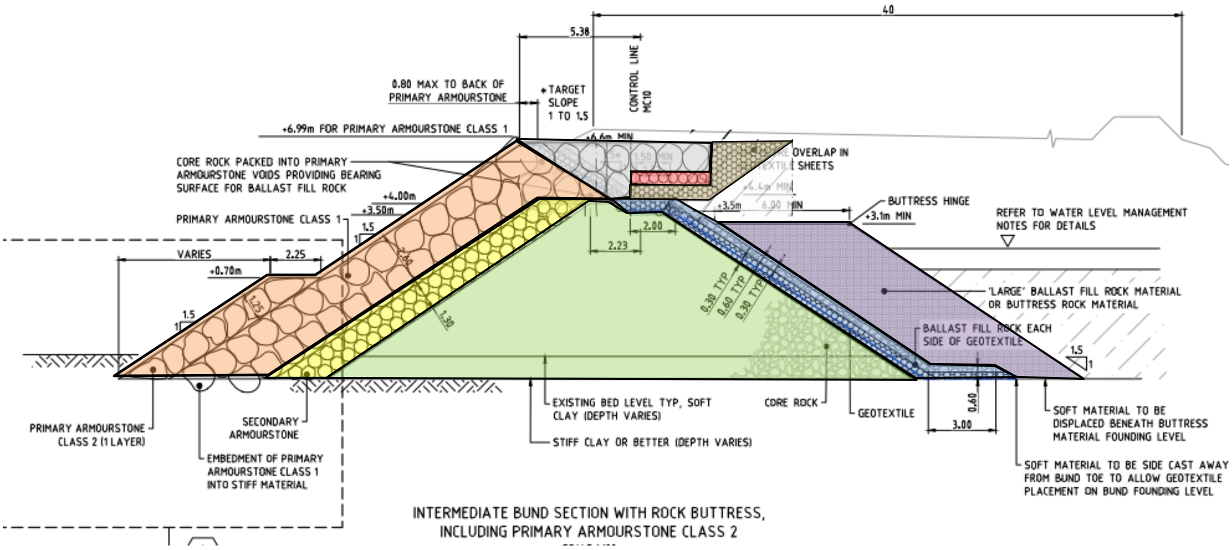


Figure 11: Phase 4 Construction



10.2. Rock Placement Methodology

Correct rock placement is a critical factor to ensure:

- The integrity and containment of the dredged fill.
- Performance of the rock wall bund structure during extreme conditions.

The methodology follows industry recognised standards and aims to minimise the risks as outlined in Table 2, during the rock wall bund construction and operational phases.

To reduce the risk of loss of integrity of the core, secondary armourstone or primary armourstone, the maximum distance between the construction of core rock and the two layers of secondary armourstone has been managed by the Contractor through a combination of appropriate weather forecasting, rock stockpile management and contingency and flexibility in working methods to provide rock wall bund stability. This approach reduces the risk of the more mobile core rock being washed out during construction, leading to potential loss of integrity.

In the event of extreme weather, the construction contractor implemented pre-determined risk mitigation strategies for ensuring the integrity of the works in progress and the protection of the rock wall bund and landward infrastructure. The construction contractor ensured that all contingencies were in place for mitigation at all times, including sufficient quantity of onsite stockpiled secondary and primary armourstone.

The construction of the secondary and primary armourstone was required to comply with the following criteria:

- Place armourstone to the lines and levels and batters shown on the construction drawings.
- The armourstone must be individually placed to achieve a dense, fully interlocked armoured slope, so that each armourstone is securely held in place by adjacent armourstone. Placing must commence at the toe and proceed upwards towards the crest. Armourstones must be lowered into place individually and must not be placed so that they obtain their stability from frictional resistance on one plane alone.
- End-tipping of armourstone is not permitted in any instance.
- Armourstone must be placed so that it is touching at least three other rocks. The finished armourstone layer must be at least two armourstones thick and smaller pieces of rock (i.e. core or in the case of the primary armourstone layer, using secondary rock) must not be used to fill holes or to support larger rocks to achieve the required profile.
- Armourstone must be placed in such a way as to minimise the risk of breaking individual rocks. The placement method must also cause minimum disturbance or dislodgement of underlying layers.
- All rock placement must minimise any vibration to surrounding areas.

10.3. Geotechnical Construction Methodology

To ensure integrity of the rock wall bund structure in both the construction and operational phases, ground truthing of subsurface conditions was required to ascertain bed and founding levels.

The construction contractor was required to submit a Works Method Statement (WMS) for these ground truthing and verification activities for approval prior to construction.

The ground truthing and verification of founding levels was conducted systematically as the rock wall bund was constructed.

10.4. Construction Quality Management and Verification

A set of Inspection Test Plans (ITPs) to manage quality was developed and implemented to ensure that all aspects of construction of the rock wall bund complied with the design. These quality ITPs were reviewed by RPEQ engineers before implementation.

The quality checks were developed and implemented in collaboration with the Port acting in the role of the Principal Contractor in accordance with the requirements of the technical specification for the works and ensure compliance and suitability. The quality documentation included the following matters:

- Quality management procedures
- Detailed Inspection and Testing Plans (ITPs), including witness and hold points
- Documentation and record keeping requirements to ensure auditability and traceability

The quality documentation was developed in accordance with the recommendations of the CIRIA Rock Manual.

The Port's Works Engineer and the design consultant reviewed the quality of the works by general surveillance, attendance at all witness points and hold points and by carrying out audits on the implementation of the quality documentation.

Inspection & Test Plans (ITPs) identifying the tests, frequencies, rejection criteria and responsibilities were prepared as part of the quality documentation. At the commencement of the rock wall bund construction, the construction contractor constructed a test panel, 25 metres in length. Construction was required to be accordance with the technical specification and in accordance with the construction contractor's approved work method statement (WMS). The test panels demonstrate the quality of placing of all materials within each stage.

The construction contractor was required to survey cross sections of each layer or element on a two-metre grid to provide evidence that the completed works comply with the placing tolerance nominated in the specification. The construction contractor was required to make any adjustments to the completed rock layer necessary to comply with the technical specification before practical completion of the rock wall bund is granted and the rock wall bund is approved by RPEQ as being constructed in accordance with the design intent, drawings and specifications.

10.5. Geotextile Repair Methodology

10.5.1 Geotextile

During Rock Wall Bund Construction and Above the Reclamation Level

Where defects (e.g. insufficient geotextile overlap or damage) are observed in the geotextile during the construction of the rock wall bund, the geotextile must be either replaced (if pragmatic to do so), patched over with an additional geotextile sheet, or patch repaired using sand filled geotextile bags (geobags).

If geobags are used, the geobag should be founded on stable rock to prevent the geobag from sliding and covered with ballast rock to mitigate the risk of damage to the geobag.

The geotextile is not overlaid with a buttress above a level of +3.1mLAT but it is overlaid with a layer of core rock. If the geotextile becomes unstable above the buttress (+3.1mLAT) due to tidal pressure on the highest of spring tides and/or elevation of the tide due to storm surge, the Port will maintain the geotextile and overlaid core rock to achieve the integrity of the as-constructed geotextile overlap.

Following placement of the clay lining and reclamation material (Phase 3), the stability of the geotextile and overlaid rock above +3.1mLAT will increase. For the Phase 4 rear crest scour protection works, the Phase 1 and 3 geotextile above +3.1mLAT will be replaced with a new sheets of geotextile which maintains the integrity and function of the geotextile from the toe to the crest of the rock wall bund. The new sheets of geotextile will be overlaid with primary and secondary armourstone.

Post Rock Wall Bund Construction and Below the Reclamation Level

Following completion of the rock wall bund construction and commencement of the reclamation works, if there is evidence of potential defects in the geotextile (e.g. piping of clay), the potential source is to be identified through a visual inspection, UAV survey and / or an optional diver survey.

Upon identification of the potential source, the reclamation material is to be excavated at the location of the source and geotextile remedial works are to be undertaken, comprising geobag (or similar) installation to reinstate the integrity and continuity of the geotextile.

10.5.2 Rock

The core rock at the rear of the Phase 1 (intermediate) rock wall bund above +3.1mLAT and the buttress rock may be mobilised by overtopping volumes from the ocean side of the rock wall bund and wind generated waves within the reclamation compartment, prior to the rock wall bund being fully lined with clay by the reclamation contractor. The Port will maintain the rear slope of the rock wall bund, generally to as-constructed position and profiles.

11. Monitoring

11.1. Monitoring Plan

Monitoring of the rock wall bund is required during the construction and operational phases. The monitoring plan has been developed prior to the construction phase and will ensure that robust measures are implemented over the life of the structure. The monitoring plan herein is additional to monitoring by the construction contractor, who will undertake surface observations and underwater surveys to confirm construction compliance.

11.2. Purpose and Objectives

Rock structures respond to the action of waves and tides in the form of changes in the shape of the structure. These changes may occur due to the movement of rock or changes in the geotechnical conditions beneath the structure.

A regular monitoring program of the rock wall bund structure and the environment enables the Port to plan repairs and respond in a timely manner. Deterioration of rock structures often occurs gradually and therefore may not be noticed without a monitoring plan in place. By setting out a plan that enables comparison of measurements at consistent locations over time, a structural monitoring program allows these changes to be identified at an early stage and therefore enables appropriate maintenance activities to be carried out.

This monitoring plan is designed to:

- Conduct the monitoring in a consistent manner, which meets the requirements of the appropriate environmental approvals and any standards
- Identify trends across a range of parameters
- Identify areas of potential concern, which may require maintenance or design adaptations; and
- Establish a temporal and spatial dataset to inform discussions with regulators and provide supporting information for ongoing performance.

11.3. Monitoring Locations

Reclamation integrity monitoring will be conducted at several monitoring locations (Figure 12) regularly spaced around the rock wall bund structure. Indicative global positioning system (**GPS**) co-ordinates for all monitoring locations are included in Table 6 and will be updated as the rock wall bund is constructed. Monitoring may be conducted at other locations, as required for complaint investigation, incident monitoring, if environmental conditions change, or based on field observations of the nominated locations and additional locations requested (see Section 11.4 and Table 7).

Table 6: Monitoring Locations

LOCATION NAME	INDICAVITE LOCATION: EASTING	INDICATIVE LOCATION: NORTHING
RI01	483900	7870899
RI02	484036	7871038
RI03	484186	7871209
RI04	484030	7871420
RI05	483866	7871651
RI06	483710	7871876
RI07	483514	7872153
RI08	483371	7871945
RI09	483254	7871776

Figure 12: Monitoring Site Location

11.4. Methodology & Frequency

When conducting monitoring, assessments are focused on reviewing the performance and condition of the rock wall bund and reclamation during and following construction. In effect, monitoring entails reviewing the performance of the rock wall bund and reclamation against the potential risks as identified in Table 2and the relationships between these risks and the monitoring actions are presented in Table 7. Typical observations and assessments for the rock wall bund and reclamation include:

- Settlement of the rock wall bund both during construction and ongoing for several years. While small consolidation settlement is expected due to the limited 'soft' material directly below the rock wall bund, the total settlement is estimated to be in the order of 250mm or less. By conducting surveys at several locations around the rock wall bund, the survey results will enable the Port to ensure that this design estimation is not exceeded. If periodic surveys indicate that more than 250mm has occurred, the Port can place rock at the rock wall bund crest during maintenance activities, to ensure that the height of the rock wall bund is kept to the design specifications.
- Monitoring for potential piping holes or turbidity in the water, should filtering layers be damaged or not installed correctly. While this is considered to be low risk due to the quality testing and compliance requirements within the technical specification, daily observations will be undertaken during the construction of the reclamation works, and in response to varying weather events, in accordance with recognised industry standards. Following completion of the reclamation works, periodic inspections (minimum of 6 months during periods of low background turbidity and following larger spring tides) will be undertaken for the next two years. This monitoring will enable the Port to implement repairs early, should they be required.
- Stability of the rock wall bund. Reviews of rock wall bund movement or visual observations of cracking in the rock armourstone provides indication that the wall may potentially be under early signs of stress. This is undertaken during the Port's maintenance activities and allows the Port to implement corrective actions early.

There are two principal types of monitoring that can be undertaken; measurement of the structure and measurement of the environmental conditions (i.e. wind, waves and tides) to assist with observations to address the above.

The types of structural monitoring and measurement that will be taken include:

- Surveying nine points on the structure on a well-established grid.
- Outer surface description.
- A survey and record of the position of individual rocks, including unstable rocks, new voids (holes) in the structure and exposure of secondary armourstone / core rock / geotextile. This includes UAV, land based and underwater surveys using hydrographic surveying with an angled beam to provide a 3-d image of the rock wall bund.
- A survey and record of the condition of individual rocks, including fractures and breakages.

The types of additional monitoring and measurement that will be undertaken include:

- Water level – e.g. data from a nearby tide gauge.
- Wind climate – e.g. wind meter.

During the construction phase, visual observations have been conducted by the Port in accordance with the ITP and any necessary repairs have been undertaken by the construction contractor. A survey will be conducted 6 months after the end of the Phase 1 rock wall bund construction and on an annual basis for the next three years in accordance with Table 7. Additional surveys will be undertaken following every severe weather event. Following the initial three years after construction of the rock wall bund, it will be included with the other rock wall bund assets within the Port of Townsville and monitored for condition every 1-2 years.

Table 7: Monitoring Program aspects and risk linkages

MONITORING ASPECT	RISK/HAZARD TO MEASURE	METHOD	FREQUENCY	TRIGGER	MITIGATION ACTION
Settlement of rock wall bund	1, 2, 6, 7, 8, 12	Surveying at 9 locations	6 Monthly	250mm of settlement	Maintenance of wall by installing more rock at crest
Piping/release of sediment through rock bund wall	2, 4, 9, 11	Visual observation	Daily	Visual observation of turbidity in the water (beyond natural background levels) Subsidence of reclamation material	Diver survey to assist with identification of the location of the source Site visual and UAV survey to assist with identification of the location of the source. Geotextile remedial works (e.g. geobag installation over defect if deemed appropriate) (see Section 10.5).
Stability of rock wall bund	1, 3, 6, 7, 8, 12	Survey of position of individual rocks – land based topographic survey	6-monthly via UAV survey and UAV photogrammetry for above waterline and hydrographic survey below waterline	Every 6 months	Undertake survey comparison to identify rock movements and rock breakage
		Survey of position of individual rocks and the seabed – hydrographic survey	6-monthly via UAV survey for above waterline and hydrographic survey below waterline	Every 6 months	Undertake survey comparison to identify rock movements and seabed scour
		Visual survey of condition of individual rocks	6-monthly via UAV survey for above waterline and hydrographic survey below waterline	Every 6 months	Undertake survey comparison to identify rock movements

11.5. Reporting

The Port will produce an annual summary of the monitoring results from this monitoring plan. Copies of all report(s) will be kept on-site and will be available for regulatory inspection. If requested by the regulators, all monitoring data and information related to this monitoring plan will be submitted within 30 business days of the request, or within a timeframe agreed by the relevant regulator in writing.

11.6. Continuous Improvement

This Reclamation Integrity Plan is a "living document" which requires review at least annually during the construction phase and amendment, as necessary to ensure it remains up to date and relevant, whilst allowing for new or changing environmental risks and mitigation actions to be addressed. Feedback systems will be in place for the duration of the CU Project to enable this plan to be updated and responsive to learning from any incidents, complaints and ongoing monitoring results and to reflect knowledge gained. Other triggers for review may include:

- Changes in operations or management
- Changes in environmental legislation and/or policies
- New technologies / innovation relevant to applied monitoring methods and mitigation actions that provide innovative means of executing activities.

Changes to this plan may be developed and implemented in consultation with relevant regulators and other stakeholders over time. All changes are to maintain the approval conditions and be approved by the CU Project Management before implementation.

Information from this plan will be used to assist with improving the control measures in the Construction Environmental Management Plan where relevant and required.

As noted in Section 11.5, an annual summary of the monitoring results will be produced that will identify the results found and an interpretation of the results in relation to the integrity of the rock wall bund construction. Where the monitoring identifies the need for revised management actions, the CEMP will be revised to incorporate the adaptive management arrangements. This may include the assessment of any monitoring program modifications needed also.

As per Condition 38 of the EPBC Act Approval (EPBC 2011/5979), any changes to this Monitoring Plan, or any of the Management Plans as a result of the outcomes of the reclamation integrity monitoring will be notified to the Department.

12. Maintenance

12.1. Maintenance Manual

Maintenance of rock structures comprises the activities that are required on a periodic basis after construction, to ensure that the rock wall bund continues to perform to an acceptable standard during its design life.

Following construction of the rock wall bund, the Port will maintain the rock wall bund in accordance with the Port procedures for rock wall maintenance.

13. Conclusions

In order to comply with the requirements of its Approval Conditions, the Port has developed, inter alia, a Reclamation Integrity Plan to demonstrate that the key risks associated with the proposed reclamation rock wall bund have been assessed and that recognised industry standards will be applied to mitigate or eliminate these risks throughout the 50-year design life of the structure.

The overall methodology takes a risk-based approach and considers the identified risks (Section 2) and how each of these will be mitigated by ensuring that adequate site investigations, design, construction practices, construction quality verification, monitoring and maintenance are all undertaken, in compliance with the relevant guidelines and recognised industry standards.

The proposed risk mitigation methodologies presented in this Reclamation Integrity Plan have and will be adopted to manage the construction and operational risk associated with the Port of Townsville's CU reclamation rock wall bund.

Appendix A EPBC and SARA Approval Conditions Reference Table

EPBC Approval Conditions

Ref	Cond. No.	Condition Requirement	Plan Reference	Demonstration of how the plan addresses the condition requirement
1	8a	The reclamation area does not exceed 110 hectares at **stage** 1 of the action in accordance with Appendix B;	1.3 3.3 11	Section 1.3 and 3.3 establish the size of the reclamation area for the CU Project (stage 1 reclamation). Section 11 details the monitoring plan that will include geospatial identification of the boundary of the reclamation area.
2	8b	The reclamation area does not exceed 152 hectares in total, in accordance with Appendix C; and	1.3 3.3 11	Section 1.3 and 3.3 establish the size of the reclamation area for the CU Project (stage 1 reclamation). Section 11 details the monitoring plan that will include geospatial identification of the boundary of the reclamation area.
3	8c	The design, materials and methods of construction for the reclamation area must prevent water quality impacts from leaching material through the bund wall, release of tailwater and storm-water run-off.	9 10 11.4	Section 9 and 10 provides an overview of the rock size and quality requirements, along with the construction methodology that demonstrates the wall is fit for purpose. Section 11.4 details the monitoring approach for determining if there is any leaching, piping etc of material from through the rock wall bund.
4	10a	The person taking the action must submit a Construction Environmental Management Plan (CEMP) for the Minister's approval, which includes measures to mitigate impacts to MNES from the construction of the reclamation area before the commencement of the action. The person taking the action must not commence the action unless the Minister has approved the CEMP. The CEMP must be prepared in accordance with the Department's Environmental Management Plan Guidelines and include at least the following: clearly defined objectives and performance criteria to mitigate impacts to MNES from the construction of the reclamation area and the placement of dredge material in the reclamation area;	3	Section 3 details the design basis, standards and performance criteria associated with the rock wall construction and design to ensure it meets a fit for purpose design.
5	10b	details on the design, materials, and methods to be used for constructing the reclamation area, that meet best practice and/or recognised industry standards;	3 10	Section 3 details the design basis, standards and performance criteria associated with the rock wall construction and design to ensure it meets a fit for purpose design. This includes identification of recognised industry standards.

Ref	Cond. No.	Condition Requirement	Plan Reference	Demonstration of how the plan addresses the condition requirement
				Section 10 provides an overview of the construction methodology for the rock wall that demonstrates the wall will be fit for purpose.
6	10e	A program to monitor the integrity of the reclamation area, including monitoring locations, methods, and frequency;	11	Section 11 details the monitoring plan for the rock wall bund / reclamation area integrity, include monitoring approaches, locations and frequencies.
7	10g	Management measures to maintain the integrity of the reclamation area in the case of extreme weather events;	5, 6, 8, 9, 10, 11, 12.	The rock wall bund has been designed in accordance with recognised industry standards, including numerical and physical modelling of the impact of extreme weather events and design peer reviews by international experts. The impact of extreme weather events on the reclamation area will be monitored and any observed or surveyed damage will be repaired, to maintain the integrity of the rock wall bund and reclamation area.

SARA Approval Conditions

Ref	Cond. No.	Condition Requirement	Plan Reference	Demonstration of how the plan addresses the condition requirement
1	1	The development must be carried out generally in accordance with the following plans: a) External Bund Wall General Arrangement Sheet 1 of 2, prepared by SMEC dated 24th January 2020, reference 30032296-GE-SME-01-101 and revision A b) External Bund Wall General Arrangement Sheet 2 of 2, prepared by SMEC dated 28th January 2020, reference 30032296-GE-SME-01-102 and revision B	1.3 3.3 11	Section 1.3 and 3.3 establish the size of the reclamation area for the CU Project (stage 1 reclamation). Section 11 details the monitoring plan that will include geospatial identification of the boundary of the reclamation area.
2	2	The development must be carried out generally in accordance with the Townsville Port Expansion Project Additional Information to the Environmental Impact Statement prepared by Aecom and BMT WBM dated October 2016, in particular:	1.4	The Reclamation Integrity Plan is an appendix to the approved Construction Environmental Monitoring Plan (CEMP), which requires a program to monitor the integrity of the reclamation area, including monitoring locations, methods, and frequency. The CEMP has been

Ref	Cond. No.	Condition Requirement	Plan Reference	Demonstration of how the plan addresses the condition requirement
		a) Section 2 Project Description; and b) Appendix B2 Construction Environmental Monitoring Plan		developed generally in accordance with the requirements of the Environmental Impact Statement.
3	5	The external revetment walls as shown on the plans in Condition 1 must be designed and constructed to contain material placed with the reclamation area and ensure that any release of sediment to tidal waters is minimised.	3, 4, 5, 6, 7, 8, 9, 10, 12	The rock wall bund has been designed in accordance with recognised industry standards, including numerical and physical modelling of the impact of extreme weather events and design peer reviews by international experts. The impact of extreme weather events on the reclamation area will be monitored and any observed or surveyed damage will be repaired, to maintain the integrity of the rock wall bund and reclamation area to minimise the release of sediment to tidal waters.

Appendix B Extract from POT442 – Risk Management Guidelines

ANNEXURE A – QUALITATIVE MEASURES OF CONSEQUENCE OR IMPACT

	Rank	Operations (Trade)	Financial Loss	Asset Loss	Interruption to Services	Reputation, Image & Political Implications	Performance	Criminal Penalty	Information Security	Safety	Health	ENVIRONMENT	
												Nature & Extent of Potential / Actual Environmental Harm	Frequency, Intensity, Duration, Offensiveness of Activity
1	Insignificant	Insignificant impacts on operations and trade. No navigation closures. Insignificant delays.	$0 - $50K	Little or no impact on assets	< ½ day	Unsubstantiated, low impact, low profile or no news items. No political implications.	Up to 5% variation to KPI	Pecuniary	Can be dealt with by routine operations.	Minor temporary – irritation, first aid treatment required.	Reversible health effects of concern.	Environmental Nuisance resulting in insignificant impacts on the natural receiving environment, plants and/or wildlife. No impact on community or business.	Low frequency / intensity / duration activity (days). No substantiated offensive amenity impacts on surrounding area.
2	Minor	Minor impact on operations and trade. No navigation closure but minor revenue loss due to loading or unloading delays.	$50K - $500K	Minor loss or damage to assets	½ - 1 day	Substantiated, low impact, low news profile. Minor political implications resulting in minor local media attention.	5 -10% variation to KPI	Pecuniary	May threaten the efficiency or effectiveness of some aspect of the infrastructure but would be dealt with internally.	Minor temporary – medical treatment required.	Severe reversible health effects of concern.	Environmental Nuisance resulting in minor adverse impacts on or unreasonable interference with the natural receiving environment, plants and/or wildlife, but noticeable effect on amenity. Minimal impact on community or businesses.	Minor frequency / intensity / duration activity carried out during normal operating hours over a short term (weeks). Minor amenity impacts experienced within surrounding area with potential to trigger complaints.
3	Serious	Temporary navigation closure or prolonged restriction of navigation.	$500K - $5m	Major damage to assets	1 day – 1 week	Substantiated, public embarrassment, moderate impact, moderate (local) media attention. Political implications resulting in directions given by the shareholding Ministers.	10-25% variation to KPI	Imprisonment	Would not threaten the infrastructure but would mean that the program could be subject to significant review or changed ways of operating.	Major permanent – loss of body part or function.	Short term health problems or irreversible health effects of concern.	Actual or potential Material Environmental Harm resulting in noticeable adverse or unreasonable impact on the natural environment, plants and/or wildlife within surrounding area. Noticeable impact on community or businesses.	Medium frequency / intensity / duration activity carried out for a significant period of time on most days or over a period of months. Adverse amenity impacts on community giving rise to multiple/sustained substantiated complaints.
4	Major	Temporary closure of a navigation channel affecting movements to the port for several days. Ensuing loss of trade.	$5m - $10m	Significant loss of assets	1 week – 1 month	Substantiated, public embarrassment, high impact, high (local and national) news profile, third party actions. Political implications resulting in state/ national inquiry.	25-50% variation to KPI	Imprisonment	May threaten the survival or continued effective functioning of the infrastructure or project and require top-level management intervention.	Major permanent– single fatality, total blindness, quadriplegia.	Health impacts, long term/chronic health problems or life threatening or disabling illness.	Material Environmental Harm resulting in significant adverse or unreasonable impact on the natural receiving environment, plants and/or wildlife over an extensive area as a result of the duration or magnitude or nature of impact. Extended disruption/impact to community or businesses. Potential exists to remedy the impact if the activity is ceased or impact is reversible.	High frequency / intensity / duration activity carried out during most hours of the day or impact is long term (years). Significant adverse impacts on community.
5	Catastrophic	Port closes, navigation seriously disrupted for an extended period. Serious and long term loss of trade.	>$10m	Complete loss of assets	> 1 month	Substantiated, public embarrassment, very high multiple impacts, high widespread (national and international) news profile, third party actions. Political implications resulting in state/ national inquiry. Significant national and worldwide attention from governments and media condemning activity.	>50% variation to KPI	Imprisonment	May threaten the survival of not only the infrastructure but also the business, possibly causing major problems for clients.	Multiple fatalities	Long term, permanent or irreversible health problems. Chronic health affects too many people.	Serious Environmental Harm resulting in irreversible, high or widespread adverse impact on the natural receiving environment/high conservation or special significance area. Severe and protracted disruption/impact to community or businesses. Irreversible loss of amenity experienced.	Permanent high frequency / intensity / duration activity carried out 24/7. Serious adverse impacts on community.

ANNEXURE B – QUALITATIVE MEASURE OF LIKELIHOOD

Level	Descriptor	Description	Ongoing Activities	Projects
1	Rare	May only occur in exceptional circumstances	Unlikely in the life of the facility	0.1% chance
2	Unlikely	Could occur at some time	Once in 20 years	1% chance
3	Possible	Might occur at some time	Once in 5 years	10% chance
4	Likely	Will probably occur in most circumstances	Once per year	50% chance
5	Almost Certain	Expected to occur in most circumstances	Many times per year, continuous	99% chance

ANNEXURE C – RISK EVALUATION FACTORS

	Consequence	**Insignificant**	**Minor**	**Serious**	**Major**	**Catastrophic**
Likelihood	***Score***	***1***	***2***	***3***	***4***	***5***
Rare	***1***	**L** ***1***	**L** ***2***	**L** ***3***	**L** ***4***	**M** ***5***
Unlikely	***2***	**L** ***2***	**L** ***4***	**M** ***6***	**M** ***8***	**S** ***10***
Possible	***3***	**L** ***3***	**M** ***6***	**M** ***9***	**S** ***12***	**H** ***15***
Likely	***4***	**L** ***4***	**M** ***8***	**S** ***12***	**H** ***16***	**E** ***20***
Almost Certain	***5***	**M** ***5***	**S** ***10***	**H** ***15***	**E** ***20***	**E** ***25***

Appendix C Geological Plan

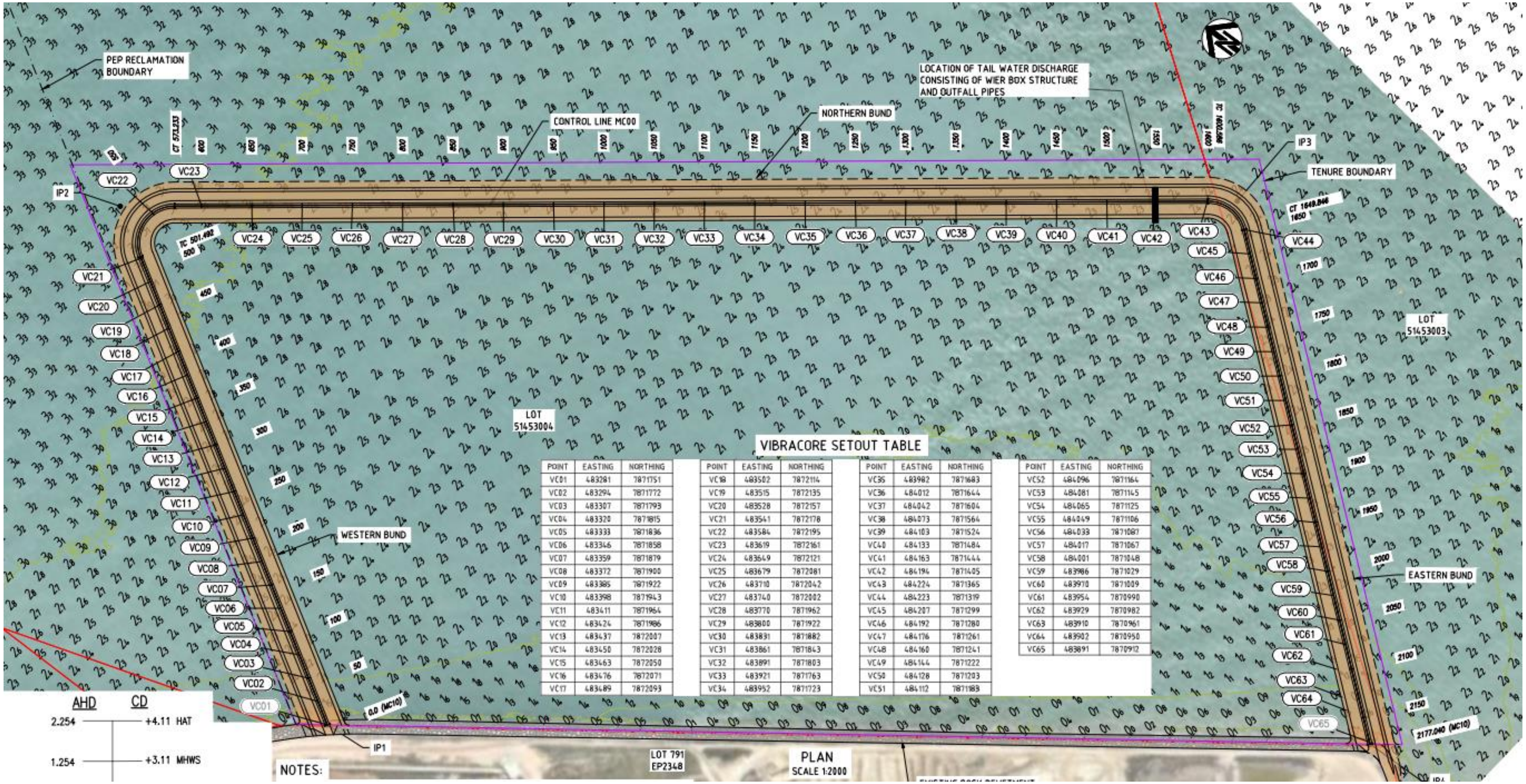
FIGURE TITLE	REGIONAL GEOLOGY OF PROPOSED RECLAMATION SITE	DATE	22-03-2019
APPENDIX	D		
PROJECT NO.	30032296	PROJECT TITLE	PORT OF TOWNSVILLE CHANNEL CAPACITY UPGRADE PROJECT
PAGE SIZE	A3		
CREATED BY	LG	SOURCES	DEPARTMENT OF NATURAL RESOURCES, MINES AND ENERGY (2018)

Member of the Surbana Jurong Group

SMEC AUSTRALIA PTY LTD
ABN 47 065 475 149

Appendix D Investigation Locations Plan

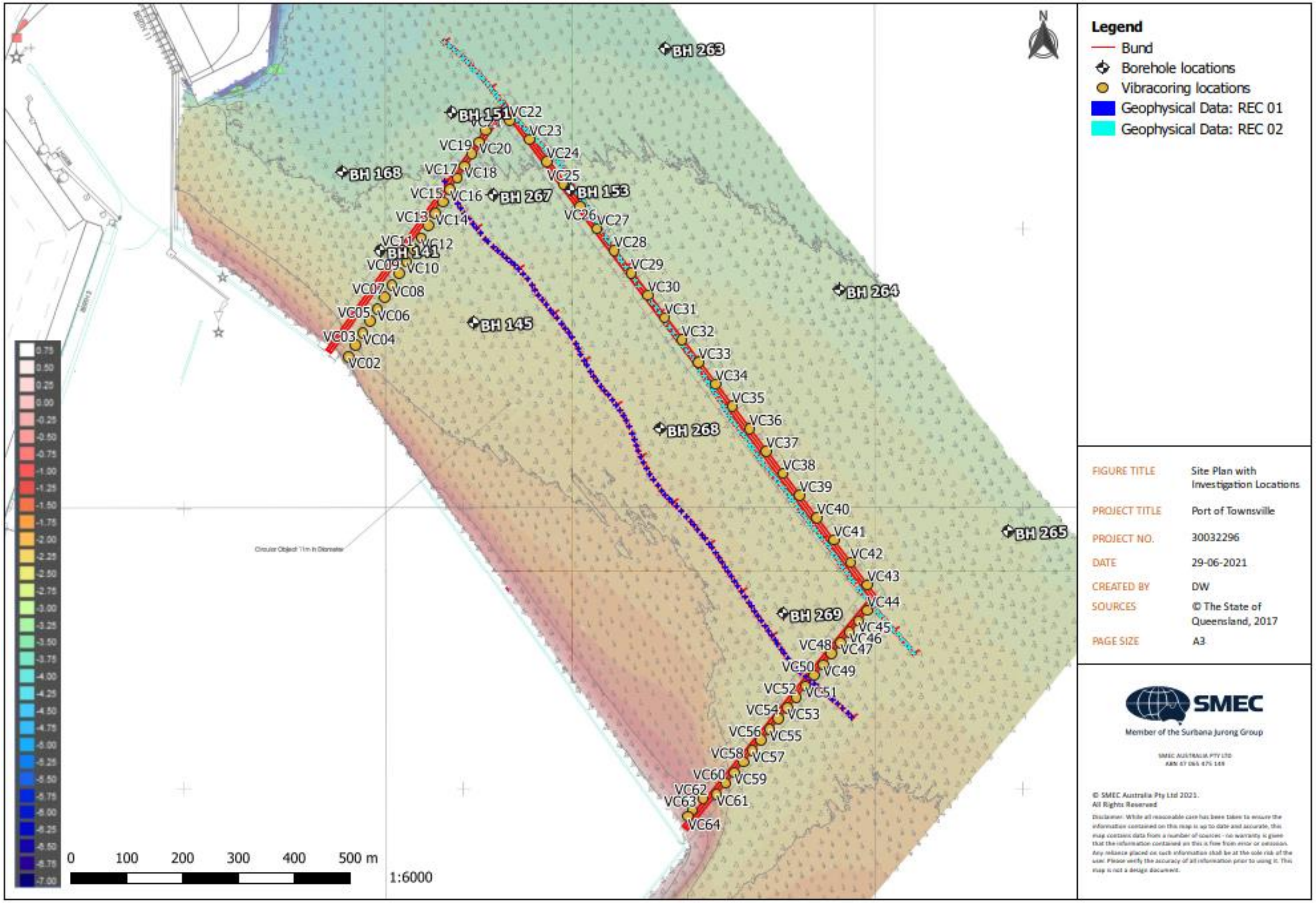
Vibracore Survey Locations (VC01 – VC64)



VIBRACORE SETOUT TABLE

POINT	EASTING	NORTHING
VC01	483281	7871751
VC02	483294	7871772
VC03	483307	7871793
VC04	483320	7871815
VC05	483333	7871836
VC06	483346	7871858
VC07	483359	7871879
VC08	483372	7871900
VC09	483385	7871922
VC10	483398	7871943
VC11	483411	7871964
VC12	483424	7871986
VC13	483437	7872007
VC14	483450	7872028
VC15	483463	7872050
VC16	483476	7872071
VC17	483489	7872093
VC18	483502	7872114
VC19	483515	7872135
VC20	483528	7872157
VC21	483541	7872178
VC22	483584	7872195
VC23	483619	7872161
VC24	483649	7872121
VC25	483679	7872081
VC26	483710	7872042
VC27	483740	7872002
VC28	483770	7871962
VC29	483800	7871922
VC30	483831	7871882
VC31	483861	7871843
VC32	483891	7871803
VC33	483921	7871763
VC34	483952	7871723
VC35	483982	7871683
VC36	484012	7871644
VC37	484042	7871604
VC38	484073	7871564
VC39	484103	7871524
VC40	484133	7871484
VC41	484163	7871444
VC42	484194	7871405
VC43	484224	7871365
VC44	484223	7871319
VC45	484207	7871299
VC46	484192	7871280
VC47	484176	7871261
VC48	484160	7871241
VC49	484144	7871222
VC50	484128	7871203
VC51	484112	7871183
VC52	484096	7871164
VC53	484081	7871145
VC54	484065	7871125
VC55	484049	7871106
VC56	484033	7871087
VC57	484017	7871067
VC58	484001	7871048
VC59	483986	7871029
VC60	483970	7871009
VC61	483954	7870990
VC62	483929	7870982
VC63	483910	7870961
VC64	483902	7870950
VC65	483891	7870912

Relative locations of the rock wall bund, historic boreholes, geophysical surveys and vibracores.



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