APPENDIX K

Onshore pond and reclamation engineering design

APPENDIX K

Onshore pond and reclamation engineering design

SYNOPSIS

Independent technical specialist
Royal Haskoning DHV
28 October 2016

Hay Point sustainable sediment management assessment approach

AVOID OR REDUCE

- *Where do sediments come from?* *Appendix C*
- *Where do sediments accumulate in the port area?* *Appendix D, E*
- *What effect will this have on the port?* *Appendix F, G*
- *Can this be managed without dredging?* *Appendix H*

REUSE OR RECYCLE

- *What are the engineering qualities of the material?* *Appendix J*
- *Can the material be used beneficially?* *Appendix I*

ALTERNATIVES TO AT SEA

- *What are the environmental values to consider on land and at sea?* *Appendix L*
- *What are the details of onshore containment alternatives?* *Appendix K*
- *How do all the disposal alternatives compare?* *Appendix B*

Purpose of study:

Guided by accepted US Army Corps engineering standards, the purpose of this study was to describe onshore pond and reclamation storage options (for maintenance dredge material) in the context of predicted maintenance dredging requirements, to inform a comparative analysis. In particular, NQBP was interested in understanding how an initial volume of approximately 200,000m^3 of maintenance dredge material would be managed/stored if brought onshore.

Broad study approach:

Using sediment budget, beneficial re-use options and Environmental Values and constraints assessment information from other Hay Point SSMA studies, the 'Onshore Pond and Reclamation Engineering Design' study involved two key components:

i) Develop concept plans for the four sediment storage options for the Port of Hay Point maintenance dredge material, including reclamations to the north of Mackay Harbour and Half Tide Tug Harbour and onshore ponds at Mackay and Dudgeon Point.

ii) Conduct a comparative assessment of the four sediment storage options considering concept plan requirements, cost, greenhouse gas (GHG) emissions and potential water quality impacts in to identify a preferred storage option/s.

Methodology:

An initial site selection assessment was undertaken to identify potentially available areas for the reclamations and onshore ponds at the four nominated locations. Available constraints information was reviewed, along with the 10-year port development Master Plan for the Port of Hay Point.

A dredging assessment was then undertaken looking at:

- **Dredge volumes** – using recent bathymetric survey data
- **Physical properties of the dredge material** – using the 2016 Advisian report at Appendix J
- **Dredging rates** – considering the type of dredger, distance between dredging and relocation areas and the dredge sediment properties

- **Dredging vessels** – TSHD Brisbane was assumed the most appropriate vessel given it currently undertakes maintenance dredging across Queensland ports and has historically undertaken maintenance dredging at the Port of Hay Point
- **Infrastructure requirements for the dredge material** – considered the distance from the dredger to the reclamation areas or onshore ponds
- **Future use.**

Concept plans for each of the storage options/locations were subsequently prepared. In preparing the concept plans, the following design criteria was considered:

- In-situ dredge volumes
- Total settled volume of sediment and water
- Compactability of dredge material
- Pond wall height
- Total pond area
- Secondary pond requirements
- Target TSS discharge concentrations
- Pond lining requirements.

Reclamation options considered total area required and protection via rock wall structures using material from local quarries, with a design based on numerical model results for a 50-year Average Recurrence Interval (ARI) cyclonic event.

Each storage option was then compared on the basis of the above key concept plan considerations and associated costs, GHG emissions and potential water quality impacts. A Rough Order of Magnitude (ROM) cost model was developed to identify and compare costs for each option. Scope 1, 2 and 3 GHG emissions were calculated for each option using internationally recognised accounting methods from the World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD) 2015. Lastly, water quality impacts were assessed through the modelling of a failure event, using the existing calibrated and validated Hay Point/ Mackay Hydrodynamic Model.

Key findings

After preparing concept plans for each of the four maintenance dredge material onshore/reclamation disposal options, and undertaking a comparative assessment of these options considering design criteria, cost, GHG emissions and water quality impacts, the following key findings were made:

- There were positives and negatives associated with each of the four options considered.
- The Mackay Onshore Pond option on the whole was predicted to be the cheapest, have the lowest GHG emissions and a low impact on water quality, however additional work and costs would be required to enable the site to hold future maintenance dredge material.
- Onshore ponds have lower costs than reclamation to store initial volumes, however the costs become comparable over a 20 to 25-year period.
- None of the options are expected to result in water quality impacts away from the sites, however the level of confidence reduces for reclamations over the life of the rock wall revetment structures.

Key study findings may be summarised as follows, noting these account for future use considerations:

Storage Option	Suitable area (ha)	Bund Wall Height (m)	Total Cost ($ mill)	Total Scope 1,2 & 3 GHG emissions (CO2e- tonnes)	Max Sediment Concentrations at source (mg/L)
Reclamation north of Mackay Harbour	20 ha	N/A	$32 M	19,485	7.8
Reclamation north of Half Tide Tug Harbour	20 ha	N/A	$44.4 M	24,774	12.8
Mackay Onshore Pond	20 ha	4m	$18.6 M	4,886	2.15
Dudgeon Point Onshore Pond	50 ha	3m	$28.3 M	7,421	1.3

REPORT

Port of Hay Point

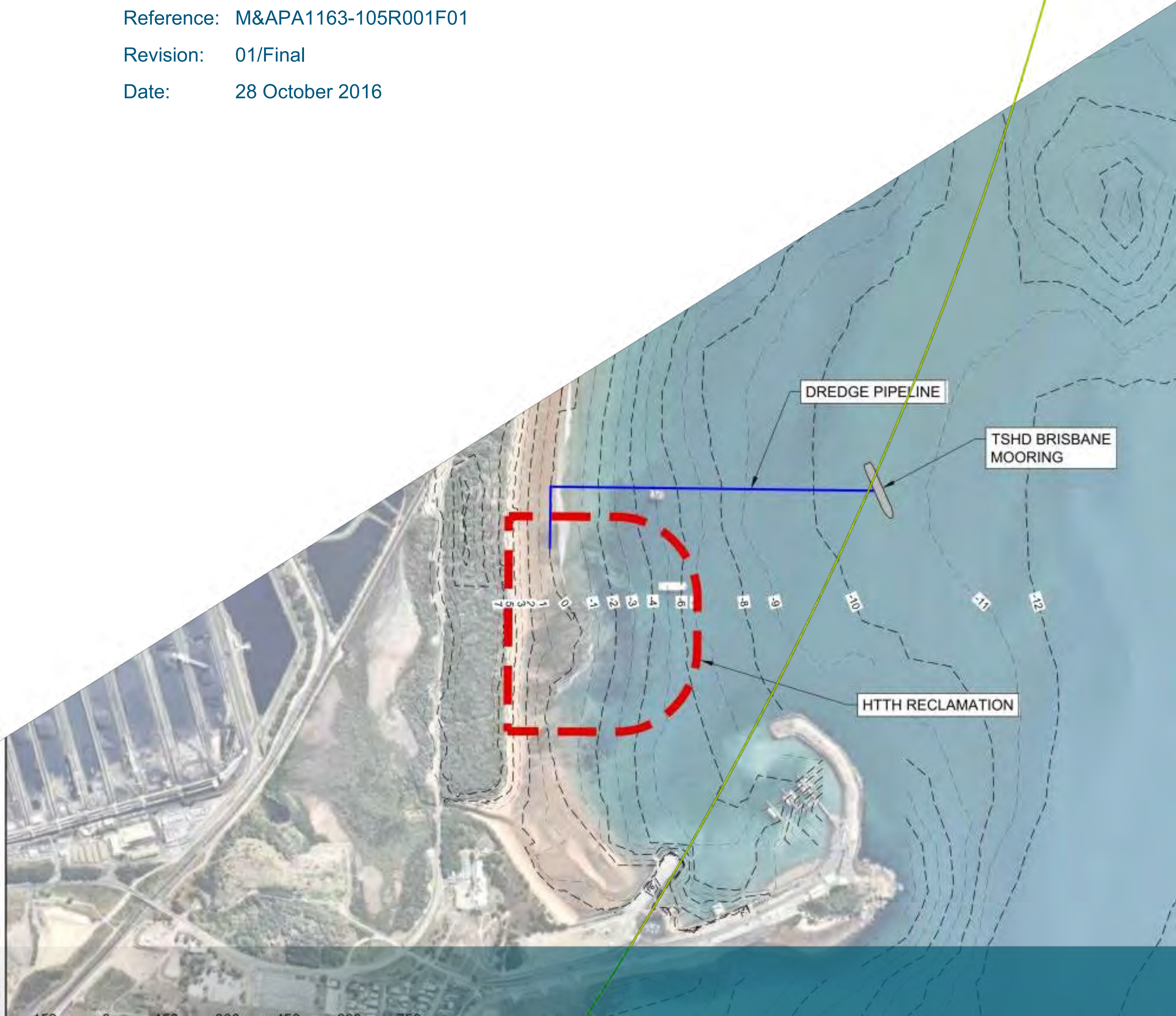
Onshore Pond and Reclamation Engineering Design

Client: North Queensland Bulk Ports Corporation

Reference: M&APA1163-105R001F01

Revision: 01/Final

Date: 28 October 2016



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Executive Summary

North Queensland Bulk Ports Corporation (NQBP) commissioned Haskoning Australia Pty Ltd, a company of Royal HaskoningDHV (RHDHV), to develop concept designs for reclamations and onshore ponds to potentially store an initial quantity of sediment (200,000m^3 of in-situ volume) and quantities of future sediment (200,000m^3 of in-situ volume every five years) from maintenance dredging at the Port of Hay Point. This study forms part of a larger investigation being undertaken by NQBP which focuses on sustainable sediment management at the port.

This report addresses the following aims:

1. to develop reclamations and onshore pond concept designs for the storage of maintenance dredging material at the following locations:
    - reclamations to the north of Mackay Harbour and to the north of Half Tide Tug Harbour (HTTH); and
    - onshore ponds at Mackay and Dudgeon Point.
2. to undertake a comparative assessment of the developed options considering the cost, greenhouse gas (GHG) emissions and any potential water quality impacts.

The results of the comparative assessment of the four sediment storage options can be summarised as follows:

- the cost estimates show that expected costs range from $18 million to $45 million, with the Mackay onshore pond option having the lowest cost and the HTTH reclamation option having the highest cost;

- the onshore pond options have lower costs than the reclamation options to contain the initial 200,000m^3 of in-situ maintenance dredged material. However, when the additional costs for future maintenance dredging campaigns are considered, the costs for the onshore and reclamation options become comparable over a 20 to 25 year period;

- despite the Mackay options having higher relative GHG emissions for the dredging component of the work compared to the Dudgeon Point and HTTH options, they have lower overall emissions. This is due to the the Mackay onshore site being relatively flat while the Dudgeon Point onshore option requires significant cut and fill to level it prior to installation of the onshore pond and the Mackay reclamation being able to use the existing northern breakwater of Mackay Harbour;

- none of the options are expected to result in water quality impacts away from the sites. The level of confidence for this is lower for the reclamation options relative to the onshore pond options due to the risk of failure of the geotextile layer in the reclamation options over the life of the structures; and

- based on the comparative assessment there are positives and negatives associated with each of the options. The Mackay onshore option is predicted to have the lowest GHG emissions, be the cheapest option, have low impacts on water quality but additional work and cost would be required to enable the site to hold future maintenance dredging material in addition to the existing maintenance dredging requirement of 200,000m^3 of in-situ volume.

1 Introduction

North Queensland Bulk Ports Corporation (NQBP) commissioned Haskoning Australia Pty Ltd, a company of Royal HaskoningDHV (RHDHV), to develop concept designs for reclamations and onshore ponds to potentially store an initial quantity and future quantities of sediment from maintenance dredging at the Port of Hay Point. This study forms part of a larger investigation being undertaken by NQBP which focuses on the sustainable sediment management at the port.

The aims of this investigation are:

1. to develop reclamations and onshore pond concept designs for the storage of maintenance dredging material at the following locations:
    - reclamations to the north of Mackay Harbour and to the north of Half Tide Tug Harbour; and
    - onshore ponds at Mackay and Dudgeon Point.
2. to undertake a comparative assessment of the developed options considering the cost, greenhouse gas (GHG) emissions and potential water quality impacts.

1.1 Project Background

In October 2006 NQBP completed the development of a departure channel and apron area for shipping at the Port of Hay Point. The capital works involved dredging in the order of 9 million m^3 of sediment from the seabed, and included:

- a ship manoeuvring apron area approximately 500 m wide adjacent to the existing berths (labelled Apron in **Figure 1**); and
- a departure channel from the apron to the sea approximately 9,500 m long. The first 500 m of the channel is 500 m wide, after which it tapers to a width of 300 m (labelled Departure Channel in **Figure 1**).

Over the last 10 years there has also been capital dredging for new berths at both the Dalrymple Bay Coal Terminal (DBCT) and Hay Point Coal Terminal (HPCT) facilities (**Table 1** and **Figure 2**) consisting of:

- December 2005: 400,000 m^3 was removed for the DBCT Berth 4; and
- end of 2011: 275,000 m^3 was removed for the HPCT Berth 3.

Maintenance dredging has been undertaken periodically at the Port of Hay Point, with two campaigns since the 2006 capital dredging (**Table 1**). The maintenance volume dredged in 2004 approximately represents the biennial maintenance dredging requirement prior to the capital dredging. Based on historical dredged volumes the maintenance requirement increased significantly since the capital dredging in 2006 (volumes in 2008 and 2010 were approximately double the volume in 2004). However, the maintenance dredging requirement over the initial years immediately after capital dredging is typically significantly larger than the ongoing requirement due to channel and slope stabilisation processes.

It is also important to note that these post 2006 maintenance campaigns did not return all areas to the design depth. The 2008 campaign was an opportunistic campaign focused on a specific area, while the 2010 campaign was planned to be a full maintenance campaign to return all areas to their design depths but due to industrial action by the dredge crew the campaign was stopped early and never completed. Since 2012 it has not been possible to undertake maintenance dredging due to a two year delay in the approval of the dredging permit and a subsequent appeal lodged on the approval. Due to the timescales associated with the legal proceedings and the permit durations, the permits were revoked at the request of NQBP in July 2015.

Siltation has been ongoing in areas of the apron, channel and berths at Hay Point since the 2010 maintenance dredging resulting in areas of shallowing. As a result, the declared depths at some areas of the port have been reduced by the Harbour Master (**Table 2**) and specific navigational requirements have been adopted at the Port for safety reasons. For example; the vessels at all berths have to be loaded during the rising tide, and sail prior to high tide with the aim of being halfway along the channel at high tide to prevent the risk of a fully laden vessel having insufficient under keel clearance and grounding. This has resulted in operational inefficiencies with significant economic ramifications, and has the potential to jeopardise safety (e.g. if a fully laden vessel breaks down in the berth or channel and there is insufficient time for tug vessels to move the vessel to deeper water prior to low water).

A recent bathymetric investigation undertaken by RHDHV (2016a) calculated that the existing maintenance dredging requirement, based on the most recent bathymetric survey carried out in October 2015, was 205,800 m^3. The areas where the majority of siltation had occurred were the north area of the apron and the berths. Future increases in the maintenance dredging requirement have been predicted by RHDHV (2016b), with an estimated maintenance dredging requirement of 220,000 m^3 to 270,000 m^3 every five years (range due to uncertainty associated with the occurrence and impact of tropical cyclones).

Measures to reduce siltation at the Port of Hay Point were investigated by RHDHV (2016c). The study identified that maintenance dredging is the only feasible option to manage the existing maintenance dredging requirement and that maintenance dredging is the lowest GHG emission and most cost effective solution to manage ongoing siltation at the port. The study also noted that other approaches to manage the ongoing siltation such as use of a drag bar at the berths could be adopted to significantly reduce the ongoing siltation at the port, but that the GHG emissions from this would be higher than those for maintenance dredging.

Table 1: Historic in-situ dredging volumes (m^3) at the Port of Hay Point since 2004.

Year	Maintenance Dredging Volumes (m^3)	Capital Dredging Volumes (m^3)
2004	98,900	0
2005	0	400,000
2006	0	9,000,000
2007	0	0
2008	192,294	0
2009	0	0
2010	216,070	0
2011	0	275,000
2012	0[1]	0
2013	0[1]	0
2014	0[1]	0
2015	0[1]	0

[1] Since the last maintenance dredging approval for the Port of Hay Point expired at the end of 2011, further maintenance dredging has not been possible due to delays and complications with a new permit.

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Table 2: Details of dredged areas in the Port of Hay Point (MSQ, 2013 and 2015).

Location	Design Depth (m below LAT)	2016 Declared Depth (m below LAT)	Length (m)	Width (m)
Departure Channel	14.9	14.7	10,000	500 – 300
Apron	14.9	14.7	4,500	500
HPCT Berth 1	16.6	16.4	343	61
HPCT Berth 2	16.7	16.8	366	61
HPCT Berth 3	19.0	18.6	460	70
DBCT Berth 1	19.6	18.1	425	71
DBCT Berth 2	19.6	18.0	425	71
DBCT Berth 3	19.0	17.9	450	71
DBCT Berth 4	19.0	18.0	450	71

1.2 Port of Hay Point

The Port of Hay Point is located on the central east coast of Queensland, approximately 15 km south of Mackay, and it is one of the largest coal export ports in the world. It is located close to the neighbouring communities of Louisa Creek, Salonika Beach and Half Tide Beach, and is comprised of two separate export terminals, DBCT and HPCT which service mines in the Central Bowen Basin of Queensland. The limits of the port extend 1.75 km offshore of the berths, 3.75 km to the south of HPCT Berth 3 and 7.5 km to the north-west of DBCT Berth 4 (**Figure 1** and **Figure 2**). The port lies within the Great Barrier Reef World Heritage Area (GBRWHA) but is excluded from the Great Barrier Reef Marine Park (GBRMP).

The port has a dredged departure channel, apron and seven berths; these are shown in hydrographic charts AUS249 and AUS250 in **Figure 1** and **Figure 2**, respectively. Details of the initial design depths and the existing declared depths, as well as the dimensions of the dredged areas of the port, are provided in **Table 2**.

1.3 Report Structure

The report herein is set out as follows:

- site selection is detailed in **Section 2**;
- details of the maintenance dredging, including an overview of the sediment properties, is provided in **Section 3**;
- the concept designs are provided in **Section 4**;
- a comparison of the concept options in terms of costs, GHG emissions and potential water quality impacts is presented in **Section 5**; and
- a summary of the findings is provided in **Section 6**.

Unless stated otherwise, levels are reported to Australian Height Datum (AHD).

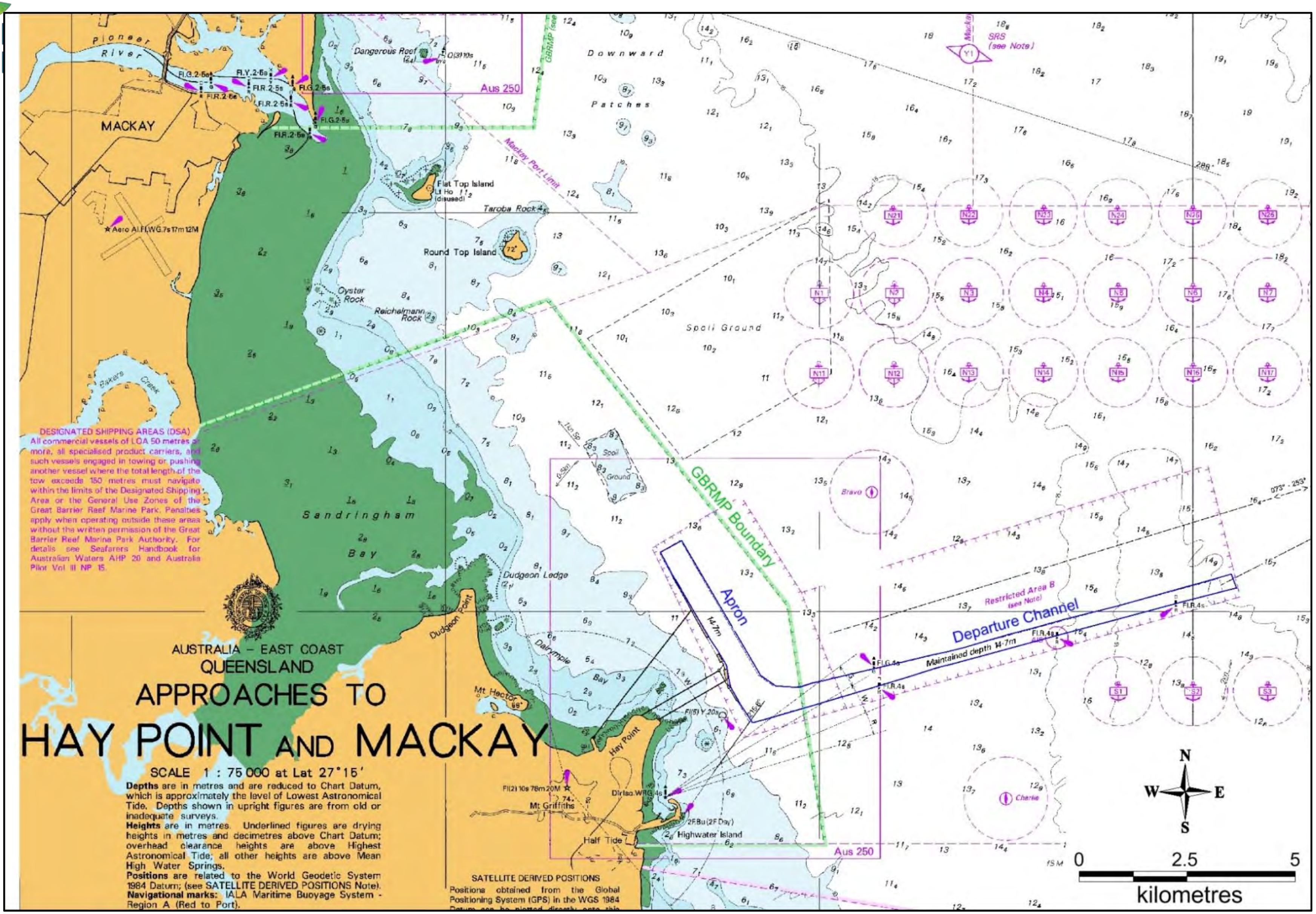

Figure 1: Location of Hay Point Port relative to the GBRMP. Note: the dredged areas are represented by the blue outline and depths are relative to LAT.

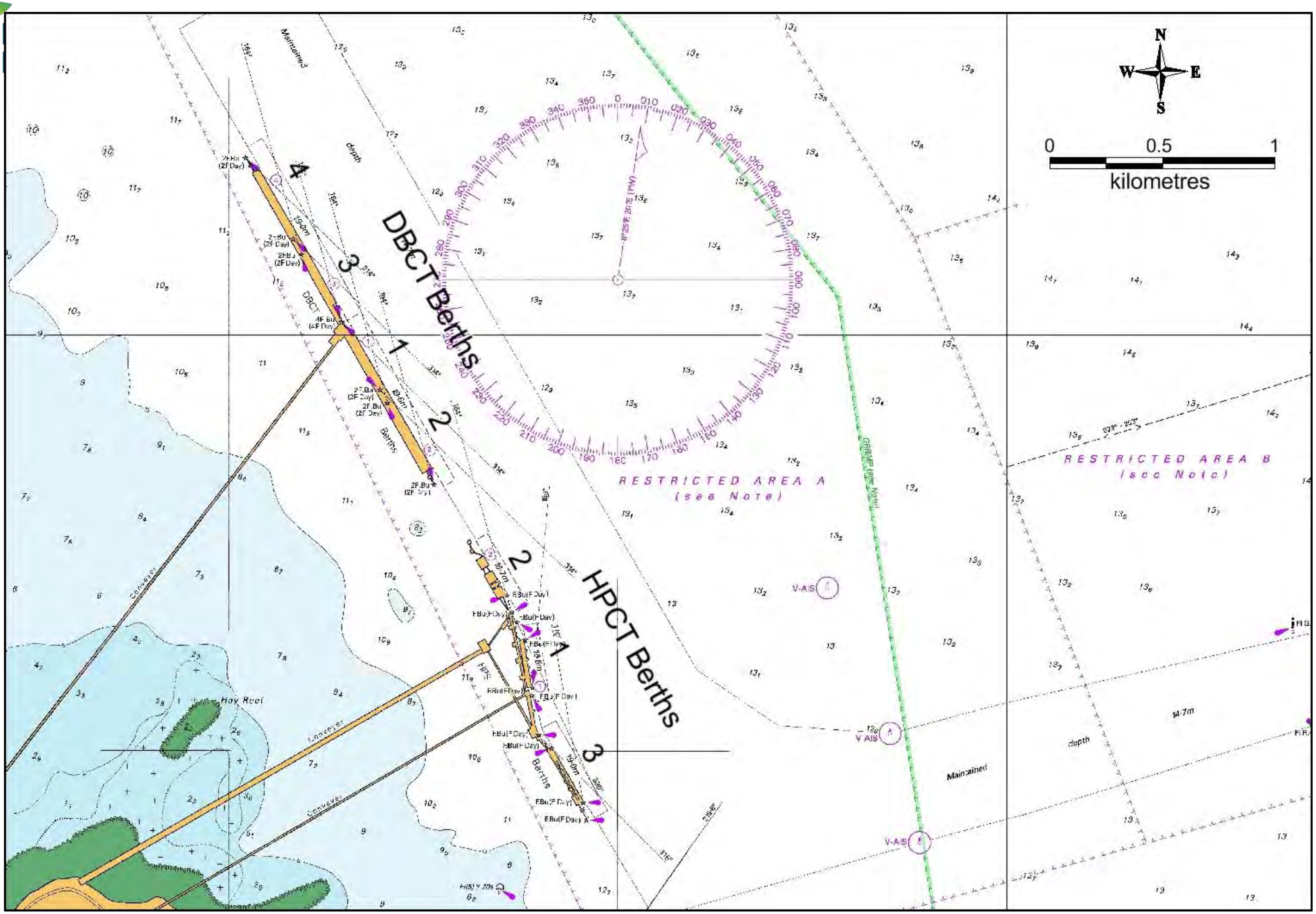

Figure 2: Configuration of the berths, apron and channel at Hay Point Port. Note: depths are relative to LAT.

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2 Site Selection

A site selection assessment is required to identify potentially available areas for the proposed onshore ponds and reclamation areas. As part of the assessment, available constraints information has been reviewed along with the 10 year port development master plan for the Port of Hay Point (Aurecon, 2012).

2.1 Selection Considerations

The relevant constraint and master planning information is discussed in the following sections for each of the four proposed sites.

2.1.1 Mackay Reclamation Area

The land use information for the Port of Mackay identifies a 20 hectare area adjacent to the existing north harbour wall as proposed future strategic port land (**Figure 3**). The land directly adjacent to this area is currently vacant but its future use is listed as being for port operations. There are also a number of advantages of adopting a location directly adjacent to Mackay Harbour:

- the construction costs would be reduced as the reclamation could make use of the existing north wall of the harbour;
- construction would be simplified as there would already be access available along the existing harbour wall for plant to allow construction of the other walls;
- a temporary mooring for the dredger could be setup within Mackay Harbour, ensuring calm conditions for the pumping out of dredged material from the hopper of the dredger and only a short distance for pumping; and
- by combining the structure with the existing harbour structure there would be no additional interruption to the longshore drift of sand as would occur if the structure was separate to the existing harbour.

As such, this location is proposed as a suitable option for a reclamation area at Mackay.

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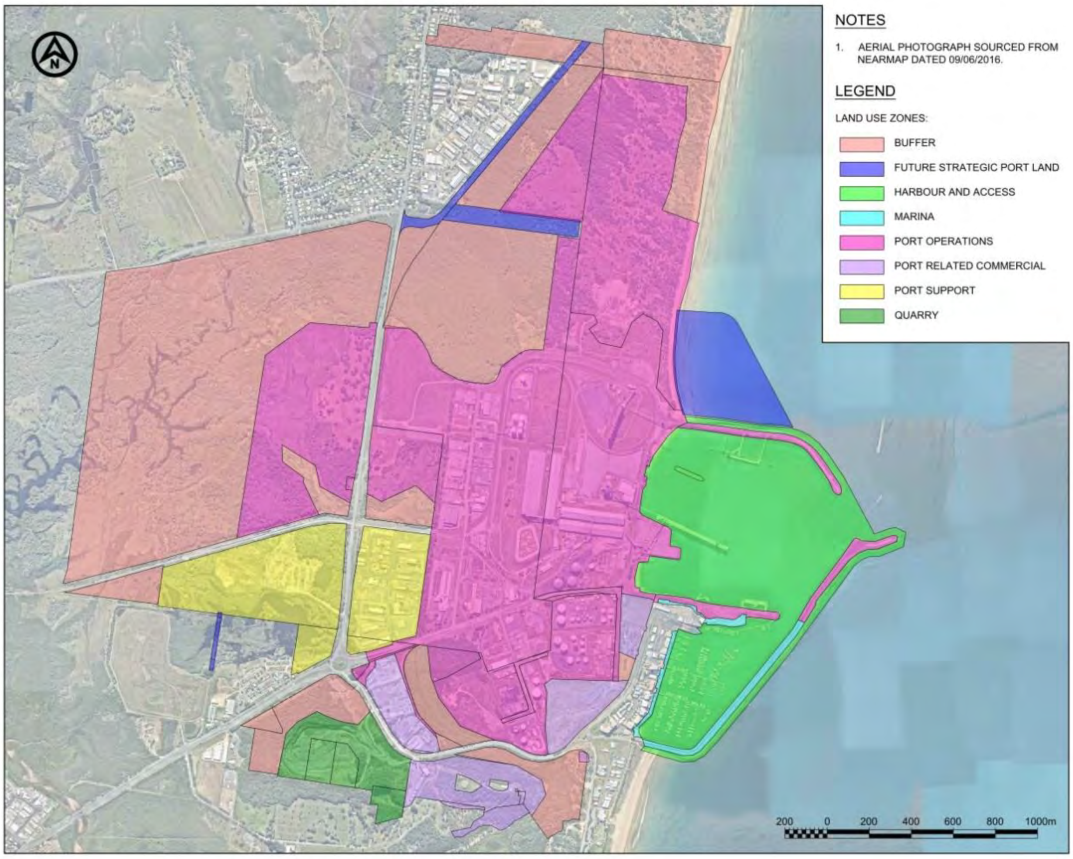

Figure 3: Land use information around the Port of Mackay.

2.1.2 Half Tide Tug Harbour Reclamation Area

The Port of Hay Point 10 year development Master Plan identifies three new reclamation areas which would be laydown areas within the Half Tide Tug Harbour (**Figure 4**). The proposed areas are located immediately to the south of the existing creek which drains into the harbour. This creek is a constraint and must remain open as it acts to convey stormwater discharge from the existing port terminals. Relocating the entrance of the creek is not considered to be a realistic option. The area to the south of the creek is not sufficiently large for the proposed volume of material that the reclamation is required to contain and so the reclamation would need to be located to the north of the creek outlet. There is an area to the north of the creek outlet with a rock bed which would reduce any settlement of the rock walls during construction.

The approximate location shown in **Figure 5** is proposed as a suitable option for a reclamation area at Half Tide Tug Harbour.

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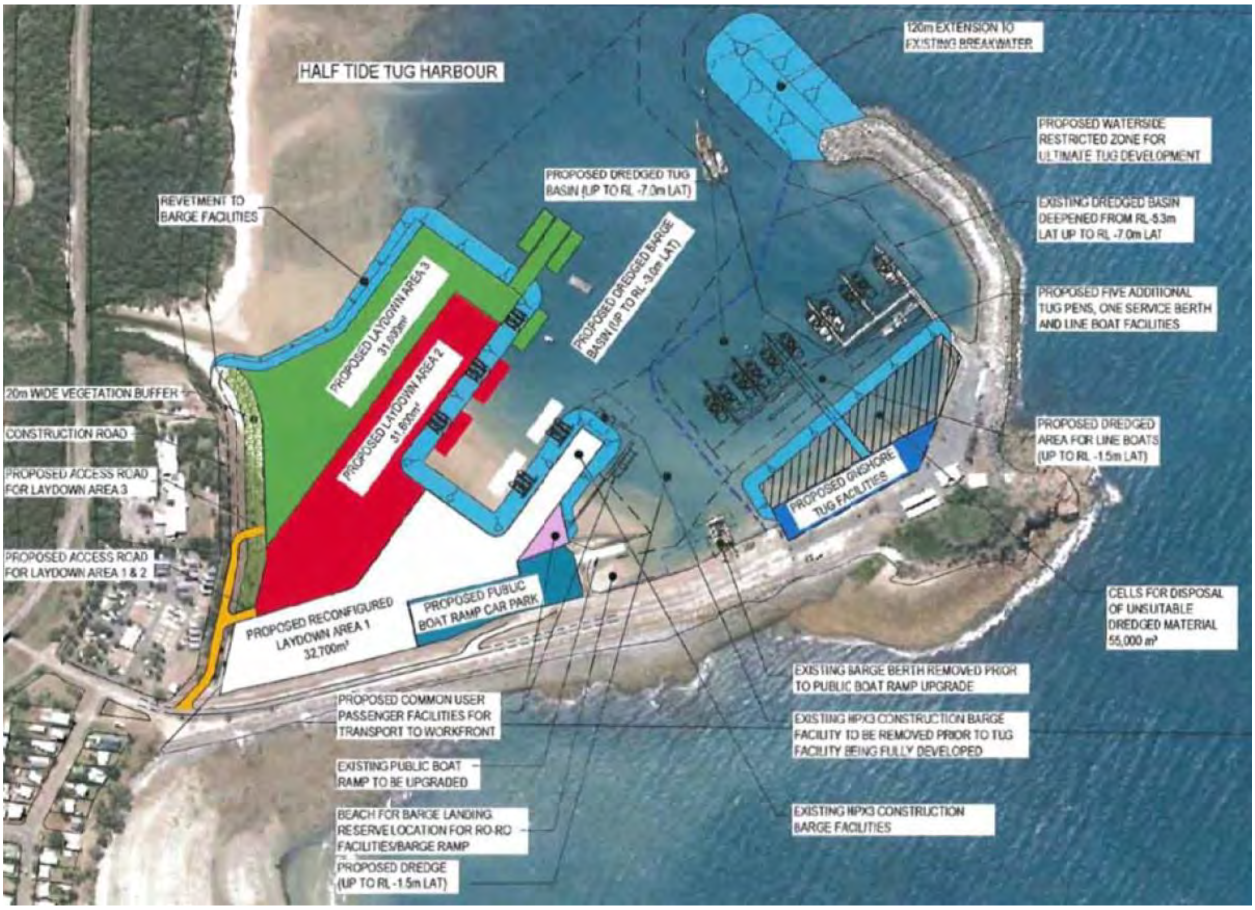

Figure 4: Reclamation at Half Tide Tug Harbour shown in the Port of Hay Point Ten Year Development Master Plan (Aurecon, 2012).

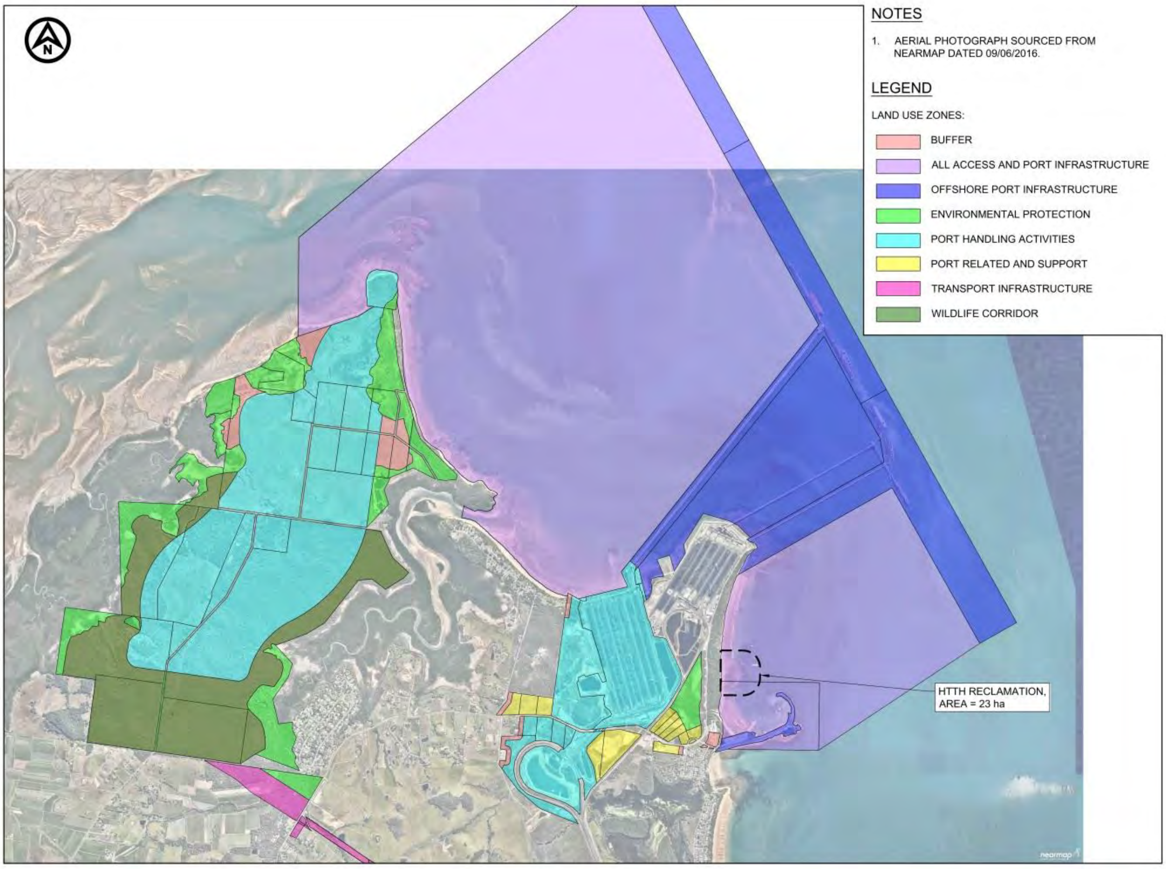

Figure 5: Land use and constraint mapping at Dudgeon Point and HTTH and the proposed location of the HTTH reclamation.

2.1.3 Mackay Onshore Pond

A constraints analysis at the Port of Mackay of the undeveloped Strategic Port Land (SPL), which is owned by NQBP, and the Australian Maritime Safety Association (AMSA) site on Slade Road was undertaken by GHD (2011). The assessment considered the following constraints:

- environmental constraints including flora, fauna, habitat, acid sulphate soils, contaminated land, flood prone areas, groundwater and surface water and erosion prone areas;
- conservation status of habitats;
- social or cultural heritage; and
- engineering constraints.

The assessment identified four areas as unconfined growth opportunities (**Figure 6**). Out of these four locations site 1, to the west of Slade Road, is the preferred location for the onshore ponds as this area is relatively flat and the furthest from the existing port and so less likely to be required for other port development infrastructure. Based on the land use mapping of the area this location is approximately 44 hectares in area, although the small buffer around the creek at the south end of the site effectively means only the area to the north with a reduced area of 32 hectares would be suitable for an onshore pond. The location shown in **Figure 7** is proposed as a suitable area for an onshore pond at Mackay.

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Figure 6: Port of Mackay future growth areas (GHD, 2011).

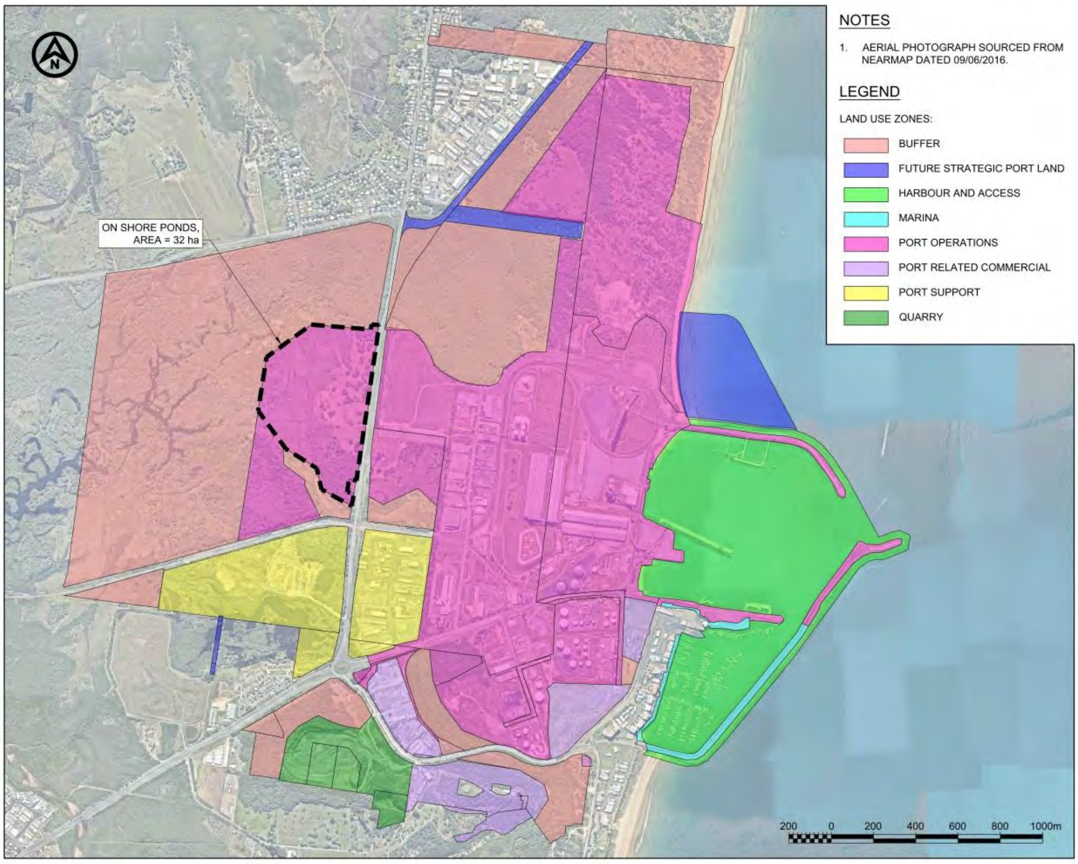

Figure 7: Land use information around the Port of Mackay and the proposed onshore pond location.

2.1.4 Dudgeon Point Onshore Pond

Based on the land use information provided by NQBP there are a number of constraints at Dudgeon Point, which include environmental protection areas, buffer areas and wildlife corridors (**Figure 5**). In addition, there are areas where the land is not available for onshore ponds; these include an area that has been leased and a saltpan area which has been identified as a possible area for future remediation measures (**Figure 8**). There are also land elevation considerations within the possible area, with the small area to the north being of lower elevation and relatively flat while the larger area to the south is of higher elevation and has more variation in the elevation. The location shown in **Figure 8** is proposed as a suitable area for an onshore pond at Dudgeon Point. Due to the variable elevation in this area significant cut and fill will be required for the onshore pond.

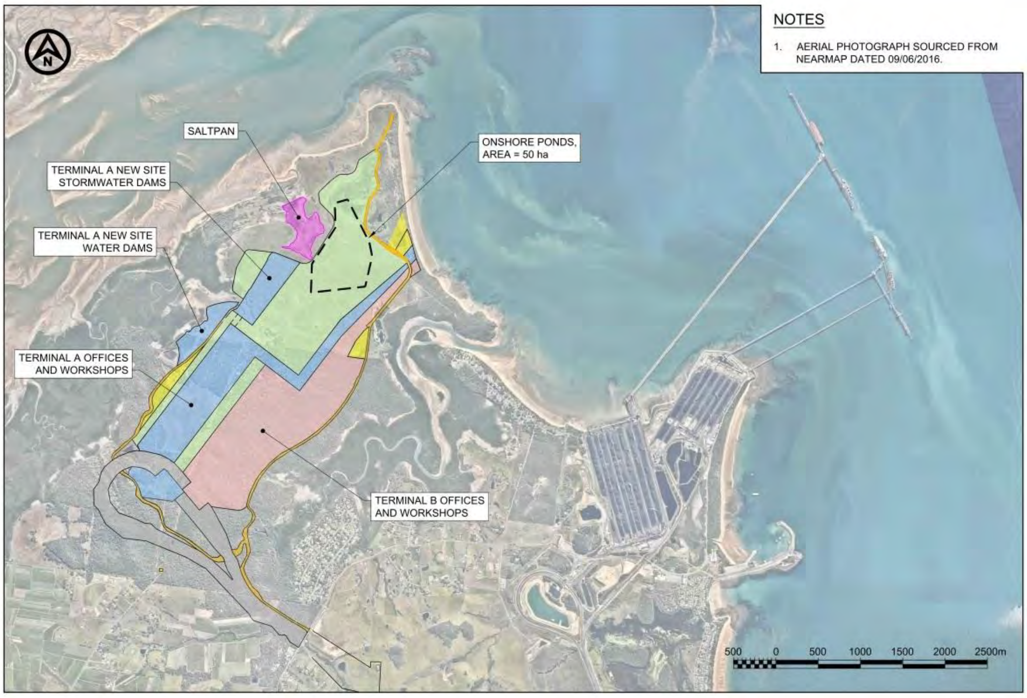

Figure 8: Future proposed terminal locations, saltpan constraint and proposed onshore pond location.

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3 Dredging Assessment

The maintenance dredge material would need to be dredged and transported to the proposed onshore and reclamation sites. This section details the dredging and material transportation associated with the four options.

3.1 Material Description

3.1.1 Volumes

Detailed investigations into the existing and likely future maintenance dredging requirements at the Port of Hay Point were undertaken by RHDHV (2016a and 2016b). A summary of the requirements is provided below:

- based on the most recent bathymetric survey carried out in October 2015 the existing maintenance dredging requirement was found to be 205,800 m^3; and
- the future maintenance dredging requirement has been estimated to be between 220,000 and 270,000 m^3 every five years if no sedimentation reduction measures are adopted. If sedimentation reduction measures are adopted this value could be significantly reduced (RHDHV, 2016c).

3.1.2 Physical Properties

Detailed sediment sampling was undertaken as part of the sustainable sediment management project at the Port of Hay Point (Advisian, 2016). When the sediment sampling results are considered for the areas where regular siltation has occurred they show that the sediment which has been accreting is predominantly fine grained (approximately 90% silt and clay) with small quantities of sand (approximately 10%). It is also important to note that samples from the north end of the berths are not representative of the sediment throughout the berths. These areas are regularly subject to propeller wash which would erode most silt and clay sized sediment, leaving the coarser sand sized sediment behind.

As the sediment from maintenance dredging is predominantly fine grained, when used for reclamation areas it will not have a suitable strength for industrial land where heavy load-bearing occurs. As such, the demand for reclaimed land of low strength adjacent to the Half Tide Tug Harbour or Mackay Harbour is unknown, although ground improvement measures could be undertaken to provide desired strengths.

3.2 TSHD Brisbane

Trailing Suction Hopper Dredgers (TSHD) have typically undertaken the majority of the maintenance dredging at Queensland Ports as they are the most suitable type of dredger. They have high production rates, can operate in offshore areas and heavily trafficked areas, have an internal hopper allowing temporary storage, transport and disposal of dredge material away from the dredging site, and are well suited to dredging soft unconsolidated sediment typically associated with maintenance material.

The TSHD Brisbane (‘Brisbane’) was specifically designed for the maintenance dredging of Queensland Ports and has been the equipment of choice of the Queensland ports to undertake maintenance dredging programs since it was commissioned in 2000. As the ‘Brisbane’ currently undertakes the maintenance dredging at the ports located within Queensland and has historically undertaken the maintenance dredging at the Port of Hay Point, it has been assumed that this vessel would be used for any maintenance dredging required.

The 'Brisbane' is equipped with dredge automation control and navigation systems. The hopper capacity is 2,900m³ and dredge material can be pumped ashore or disposed at sea through bottom dump valves. The pumping system consists of 2 x 750kw Warman pumps, capable of pumping dredge material at least 1500 metres from the mooring location. Pumping distances of 2500 metres can be achieved depending on the characteristics of the material, and the addition of booster pumps on the discharge line can further increase the achievable pumping distances. The shore disposal operation can be undertaken at berth or from a mooring through a floating pipeline.

To minimise the turbidity resulting from dredging the vessel is also equipped with a low turbidity hopper loading system and under keel discharge of overflow waters through an anti-turbidity ('green') valve. The hopper can also be pumped dry to maximise efficiency in the non-overflow dredging mode.

3.3 Dredging Approach

3.3.1 Dredging Rates

The average rate that a dredger relocates material over the duration of a dredging campaign is often referred to as the dredging rate. The dredging rate is dependent on a number of variables including the dredging vessel, the distance between the dredging and relocation areas and the type of material. In order to calculate comparative dredging rates for the four options a number of assumptions had to be made:

- an in-situ volume of maintenance material of 1,500 m^3 per load for the 'Brisbane';
- a total time of 1.25 hours for dredging to fill the hopper;
- vessel steaming speed of 10 knots when fully laden and 12 knots when empty;
- an allowance of 1 hour to moor up and connect to the pipeline and to de-connect after;
- an allowance of 1 hour to pump a full hopper load ashore;
- operational downtime of 10% (i.e. working for approximately 21.5 hours per day, 150 hours per week);
- sailing distances of 4.5 km from the dredging area to the mooring location for the HTTH reclamation and Dudgeon Point onshore sites; and
- sailing distances of 18.5 km from the dredging area to the mooring location for the Mackay reclamation and onshore sites.

Based on these assumptions the dredging rates have been calculated with the dredge durations shown in **Table 3**. The table shows that the dredge durations are the same for the Mackay options, with the dredging and pumping ashore expected to take approximately 31 days to complete. Similarly, the dredge durations for the HTTH reclamation and Dudgeon Point onshore sites are the same, with the dredging and pumping ashore expected to take approximately 23 days to complete.

Table 3: Dredging durations for the four options.

	Mackay Reclamation	HTTH Reclamation	Mackay Onshore	Dudgeon Point Onshore
Time Dredging (hrs)	172	172	172	172
Time Steaming to Mooring (hrs)	137	34	137	34
Time Pumping (hrs)	274	274	274	274
Time Steaming to Dredge Area (hrs)	114	29	114	29
Total Time (days)	**32**	**24**	**32**	**24**

3.3.2 Infrastructure

To determine the infrastructure required to pump ashore it is important to understand the distance that the vessel would be from either the reclamation area or onshore pond. The ‘Brisbane’ has a fully laden draft of 6.25m and with a 1m allowance for under keel clearance the vessel requires depths of at least 7.25m below LAT at the pump out location. Based on the depths detailed in the Admiralty Charts the proposed mooring location for the TSHD Brisbane, with a depth of at least 7.25m below LAT, is shown in **Figure 9** to **Figure 12** for each of the options. The resultant pipeline distances for the four options are detailed in **Table 4**. The pumping distances for the two reclamations would be less than 1km, while for the onshore sites they would be around 2km. Through discussions with the Port of Brisbane (who own and operate the ‘Brisbane’) we understand that for maintenance dredging material it is expected that a pumping distance of 2km should be achievable without the need for a booster station.

Table 4: Pumping distances for the four locations.

Site	Required Pumping Distance (km)
Mackay Reclamation	0.25
HTTH Reclamation	0.75
Mackay Onshore	1.9
Dudgeon Point Onshore	2.1

For all four cases the following temporary infrastructure would be required for the duration of the dredging and pumping:

- pump out coupling to allow the pipeline to attach to the nozzle mounted on the bow of the ‘Brisbane’. The coupling would be attached to a floating line which would connect to the submerged pipeline;
- submerged pipeline to transport the dredged material to the reclamation area/onshore pond location. This is typically a steel pipeline with a diameter of 650mm which is assembled on the beach and then dragged out to its installed location; and
- mooring for the ‘Brisbane’ to hold the vessel into position without swinging during pumping. This could either be through pick up moorings or by using a small tug to hold the vessel while pumping.

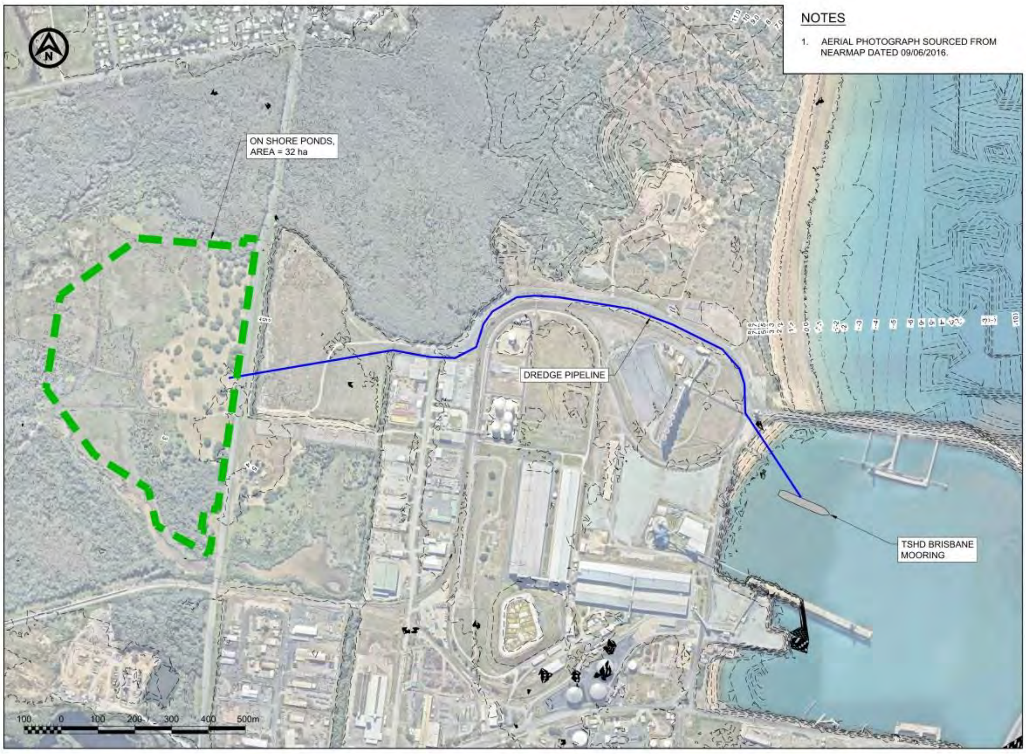

Figure 9: Indication of TSHD Brisbane mooring and pipeline for the Mackay Onshore option.

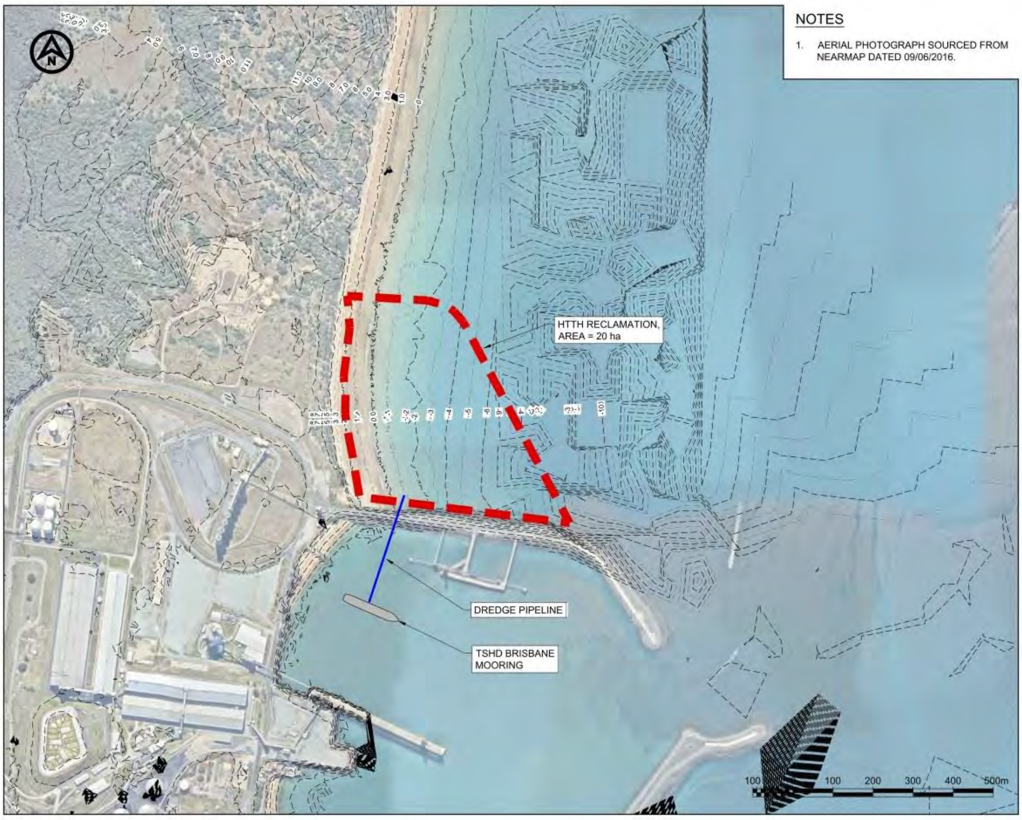

Figure 10: Indication of TSHD Brisbane mooring and pipeline for the Mackay reclamation option.

Figure 11: Indication of TSHD Brisbane mooring and pipeline for the Dudgeon Point Onshore option.

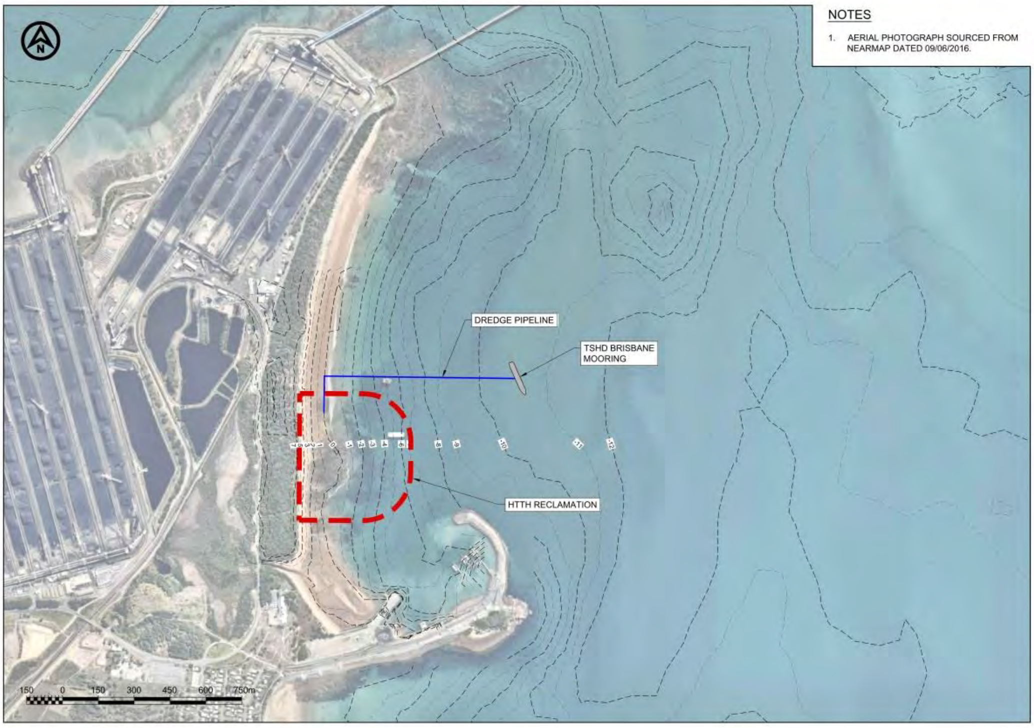

Figure 12: Indication of TSHD Brisbane mooring and pipeline for the HTTH reclamation option.

4 Concept Design

The estimated in-situ dredge volume is approximately 200,000 m^3. The material that will be dredged will be predominantly silt and clay (estimated to be 90% of total dredge volume). In order to achieve a consistency that can be pumped ashore, a large volume of water is included in the dredge slurry. For the type of material to be dredged, it is estimated the total settled volume of sediment plus water would be a factor of approximately 4 times the in-situ volume. This means that if 200,000 m^3 of in-situ volume is dredged, the dredge slurry after dredging and pumping may occupy an immediate settled volume of approximately 800,000 m^3. This is one of the main driving factors with regard to the pond size required.

Design drawings for each of the concept design options are provided in **Appendix B**, the following sections provide details and justification for the concept designs.

4.1 Pond/Reclamation Configuration

4.1.1 Mackay Reclamation Area

The Mackay Reclamation covers an area of approximately 20 hectares and the rock wall is approximately 860 m in length. At the seaward extent the seabed level is approximately -9 m AHD. At the landward end of the rock wall the ground level is approximately +4 m AHD. The average seabed slope over the site is approximately 1v:45h.

4.1.2 Half Tide Tug Harbour (HTTH) Reclamation Area

The HTTH Reclamation covers an area of approximately 20 hectares and the rock wall is approximately 1250m in length. Along the seaward extent the seabed level is approximately -6m AHD. At the landward end of the rock wall the existing ground level is approximately +5m AHD. The average seabed slope over the site is approximately 1v:40h.

4.1.3 Mackay Onshore Pond

The Mackay onshore site is constrained by existing roads to the east and south, and by wetlands to the north and west. The site is approximately 31.5 hectares in area and is relatively flat with a ground level of approximately +2.5 m AHD.

Due to the limited land available at Mackay it is necessary to maximise the use of the land and have the pond occupy as much of the site as possible. A minimum buffer of 10 m between the site boundary and the bund walls is included to allow for ease of construction and a water drainage system around the perimeter of the pond. Along the eastern boundary a buffer of 20 m is included to allow for road access and water drainage. Including consideration for buffer zones and bund wall construction, both internal and external, the resulting pond area is approximately 20 hectares.

The pond has been sized to accommodate all of the dredge slurry (i.e. approximately 800,000 m^3). This means that a minimum bund wall height of 4 m is required. In addition to a potential 4 m slurry height, a freeboard of 1 m is also included. The freeboard allows for a safety margin in terms of actual volume pumped into the pond, additional capacity to accommodate a potential increase in water level due to rainfall, and also prevents overtopping of small wind waves that may form within the pond.

4.1.4 Dudgeon Point Onshore Pond

The Dudgeon Point onshore site is constrained by existing and proposed port developments and also by environmental constraints. The site is approximately 180 hectares in size and consists of a rectangular area in the south-west of approximately 150 hectares and a triangular area to the north-east of approximately 30 hectares. The rectangular area has ground levels ranging from +5 m to +30 m AHD. The triangular area has an average ground level of approximately +5 m AHD.

For the Dudgeon Point site the pond has been sized to achieve a minimum area of 40 hectares. Including allowance for bunds and buffer areas, the total site is therefore approximately 50 hectares. In order to accommodate a dredge slurry volume of approximately 800,000 m^3 the bund walls would need to be 3 m high. This includes allowance for a 1 m freeboard.

4.2 Target Discharge Concentration

A representative target total suspended solids discharge concentration of <50 mg/l has been adopted based on previous approvals for similar projects as this is thought to be a realistic concentration for the tailwater concentrations. In order to achieve a discharge concentration of <50 mg/l for the pond options, there needs to be sufficient settling of solids within the pond area between the intake position and the outfall location. The intake refers to the location where the dredge material enters the primary pond and the outfall refers to the location where the supernatant flows out of the secondary pond.

The reclamation options are designed on the basis that sediment will settle out in the reclamation area and the supernatant water will be able to flow through the porous rock wall. The use of a geotextile layer within the rock wall construction will restrict fine material from flowing through the rock wall (see **Section 4.4**).

4.2.1 Onshore Pond Options

As the dredge material flows through the ponds, the solids will settle out leaving a relatively clear supernatant to be discharged at the outfall. The rate at which the solids settle is referred to as the settling rate. Settling rate is related to the size, shape and density of the particles. Finer materials, such as silts and clays, take longer to settle out and will therefore take longer to achieve the target discharge concentration than dredge slurry containing predominantly sand particles. However, fine grained sediments can be subject to flocculation, the sticking together of grains due to short range attractive forces, which results in increased settling velocities.

Assuming an average settling rate, it is possible to adopt an empirical approach based on the USACE (1987) to calculate a required flow path length between the intake and outfall to achieve the target discharge concentration. The flow path must, however, be sufficiently wide to prevent high velocities that could result in resuspension of solids. For both the Mackay option and the Dudgeon Point option, the internal bund walls have been configured to maximise the flow path whilst maintaining a suitable width. This approach provides a high level indication of the discharge concentration to assist in the concept design stage of the study. Additional settling tests and detailed modelling during the detailed design stage would be required to better understand the discharge concentration.

The Mackay option has a total flow path length of approximately 900 m with basin width ranging from approximately 150 m to 250 m. The calculated discharge concentration based on USACE (1987) is ≈50 mg/l.

The Dudgeon Point option has a flow path length of approximately 1500 m with a basin width ranging from approximately 200 m to 350 m. The calculated discharge concentration based on USACE (1987) is ≈25 mg/l.

Both options include the use of an internal bund wall. In addition to being a means of achieving a longer flow path, the use of an internal bund wall also provides a more efficient use of a bund wall as it supports ponds on either side, and it is used to divide the pond into primary and secondary settling ponds. Also, by dividing the pond into two areas greater operational control can be achieved.

Although the ponds have been sized according to a theoretical flow path length needed to achieve a target discharge concentration, this approach is based on an assumed settling rate and limited information regarding sediment characteristics. Further testing could be undertaken to refine settlement parameters with values derived from settling tests performed on site sediments. It has therefore been necessary to adopt a conservative approach with regards to the pond design. This conservative approach that has been adopted is to provide a pond that has sufficient capacity to accommodate the full 800,000 m^3 dredge slurry volume.

4.3 Operational Considerations

It is assumed that the time between future maintenance dredging campaigns will be approximately five (5) years and that each maintenance dredging campaign will require an in-situ volume of approximately 200,000 m^3 to be dredged.

During the dredging activity and in the five (5) years between maintenance dredging campaigns, it is assumed that the onshore ponds will be managed as follows:

- Dredge material will be pumped into the primary settling pond through an intake pipeline. Overflow between the primary pond and the secondary pond will be managed through the use of a weir box (see **Section 4.5.1**) to retain a high percentage of solids in the primary pond;
- The discharge from the secondary pond will also be managed through the use of a weir box. The overflow through the weir box will be adjusted to ensure that the target discharge concentration is achieved. Sampling and testing would be undertaken as part of an Environmental Management Plan to demonstrate compliance. It is likely that a total suspended solids (TSS) versus turbidity relationship would be developed to facilitate monitoring/compliance. Provided the target discharge concentration is met, discharging of the supernatant can then proceed with the overflow to be directed back towards the ocean;
- As the water level in the ponds drop due to discharging of supernatant and through evaporation, the ratio of sediment to water will gradually increase. The objective is to achieve a dry material that can be mechanically handled and which has sufficient bearing capacity to accommodate an excavator or similar type of plant travelling over it. Use of an amphibious excavator should also be considered. The deeper the slurry, the longer it will take to dry out. It is therefore generally recommended that the slurry should be no more than 0.5m thick to promote natural drying out. For both the Mackay option and the Dudgeon Point option, where the slurry will likely initially be 4 m and 2 m thick respectively, additional measures may be needed to promote the drying out process. The measures that are proposed include a horizontal drainage system along the base of the ponds (see **Section 4.4.2**).
- Once the material is sufficiently dry to be mechanically handled, there are a number of options that can be considered, including:
    a) Removing the dry material from the pond to create sufficient capacity for the next maintenance dredging campaign. A site for disposing of the dry material, or reuse option would need to be identified.
    b) Increasing the height of the bunds using the dredged material to increase the capacity of the pond (see **Figure 13**). The effectiveness of this approach is dependent on the engineering quality of the dredge material. Considering that the material to be dredged is predominantly

silt and clay, it is expected the quality would need to be improved by adding imported material.

c) Construct a new pond for each maintenance dredging campaign. In addition to there being limited land available to implement this approach, it will also prove to be a costly exercise and as such is not considered realistic.

- Commence with the next round of maintenance dredging.

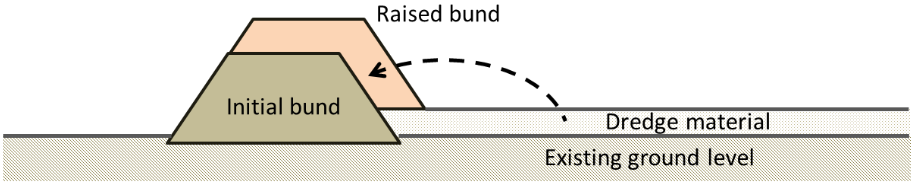

Figure 13: Raising the bund height using dredged material.

Due to the natural bed level at the proposed reclamation areas they have a relatively large volume capacity up to the proposed crest level (detailed in **Section 4.4.1**). For both reclamations it has been assumed the geotextile layer would extend to an elevation of up to 6.5 m above AHD and that the reclamations could be filled up to this level with dredged material. In the five (5) years between dredging campaigns it has been assumed that the dredged material would consolidate, with the volume reducing to approximately 1.5 times the initial in-situ volume. The total volume capacity up to 6.5 m above AHD of the Mackay reclamation is approximately 2 Mm^3 and of the HTTH reclamation is approximately 1.7 Mm^3. Based on these volumes the Mackay reclamation is estimated to have capacity for approximately five (5) maintenance dredging campaigns, while the HTTH reclamation is estimated to have capacity for approximately four (4) maintenance dredging campaigns. Once the reclamations are full with maintenance dredged material the remaining volume capacity of the reclamations (approximately 1.3 Mm^3) could be filled with material with good engineering properties. Prior to adding a material that has good engineering properties, it may be necessary to undertake deep soil mixing of the dredged material (e.g. adding cement or the like to improve engineering properties). This would improve the load bearing of the reclamation, however further detailed geotechnical assessment is required to determine the exact measures to be implemented.

4.4 Bund/Wall and Base Design

4.4.1 Reclamation Options

The reclamation options will be protected by a rock wall structure. The rock wall design is based on numerical model results for a 50 year ARI cyclonic event and an assumed water level approximately equivalent to a 50 year ARI (which due to the large tides in the area is only just above HAT).

The design wave condition for each site, based on the results of numerical modelling, is presented in **Table 5**. A detailed description of the spectral wave model is provided in **Appendix A**.

As a sensitivity check, peak wave periods of 8 seconds and 12 seconds have also been considered as part of the rock wall design.

Table 5: Design wave conditions.

Site	Significant Wave Height, Hs (m)	Peak Wave Direction, Dir (deg N)	Peak Wave Period, Tp (sec)	Water Level (m AHD)
Mackay Reclamation	5.2	90	9.5	3.47
HTTH Reclamation	4.6	80	9.4	3.80

The rock wall is designed based on a maximum overtopping discharge of 50 l/s/m. As per EurOtop (2007) this is the maximum acceptable discharge to prevent damage to the crest and rear slope if both are well protected.

The primary armour layer has been sized according to the van der Meer (1988) approach for a two-layer armoured slope. This approach results in the following key dimensions presented in **Table 6**.

Table 6: Rock wall design.

Site	Primary Armour Rock, M_{50} (tonnes)	Seaward Slope (cot α)	Leeward Slope (cot α)	Primary Armour Crest Height (m AHD)
Mackay Reclamation	12	2	1.5	+11.3
HTTH Reclamation	9	2	1.5	+10.3

The crest of the core material is 6 m wide. This is to ensure sufficient width for access by construction equipment.

To prevent the loss of fines from the reclamation through the rock wall, a filter layer is to be incorporated into the core material. The filter layer will consist of a geotextile material placed along the rear slope of the core with 0.5 m thick stone layer either side to prevent damage to the geotextile.

To prevent the geotextile from becoming detached from the rock wall, the filter layer will be weighed down by additional core material and primary armour rock.

For the purposes of a concept design, it is assumed that the seaward slope, crest and lee slope of the rock wall will all be protected with the same size primary armour rock. Further design optimisation, such as the possible inclusion of a concrete wave wall and cap and also optimised rock armour requirements for the lee slope, should be considered as part of future design input.

Limited site data suggests that the two reclamation sites are underlain by rock material just beneath the seabed surface.

4.4.2 Onshore Options

The earth mound bund for the onshore ponds will be constructed using material from the site. Following site clearance, earthworks will be undertaken to create a level platform and to stockpile material for the bund formation. The bunds will be constructed with a 1v:3h slope and a crest width of 6 m. The 6 m crest width is to ensure that sufficient width is provided for construction vehicles.

To prevent the flow of water through the bund, and the potential risk of the bund failing, the bunds are to be lined. For the purposes of concept design it is assumed that the bunds will be lined with a geosynthetic clay liner (GCL). See additional details provided in **Appendix B** and **Appendix C**.

The GCL acts as a containment barrier and will ensure that the ponds retain the dredge slurry.

The ponds will contain two weir boxes, one in the internal bund and one to control the tailwater discharge (**Figure 14**). A weir box typically consists of vertical boxes, or shafts, on either side of the bund wall. The shafts extend from the base of the pond to a height above the maximum dredge slurry level. The shafts are connected by means of a pipeline. Each shaft consists of a section where panels can be added and removed. These panels are typically steel plates of thickness 5 – 10mm. By removing or adding panels, the dredge slurry overflow level can be easily managed. The use of panels on the outflow side allows for flow velocities to be controlled, but care needs to be taken to ensure that the weir box does not become clogged with sediment.

Figure 14: Example weir box with two 800mm pipelines (source: Boskalis).

As mentioned in **Section 4.3**, horizontal drainage will be included to promote the drying out process. The horizontal drainage system will consist of a 200 mm thick stone layer placed over the base of each pond over the GCL. Over the stone layer is a permeable geotextile which will allow water to flow through, but not fines. A series of drainage pipes will be installed at the same level as the stone layer at a fall of 2% through the bund to a water drainage system that runs around the perimeter of the pond. See **Figure 15**.

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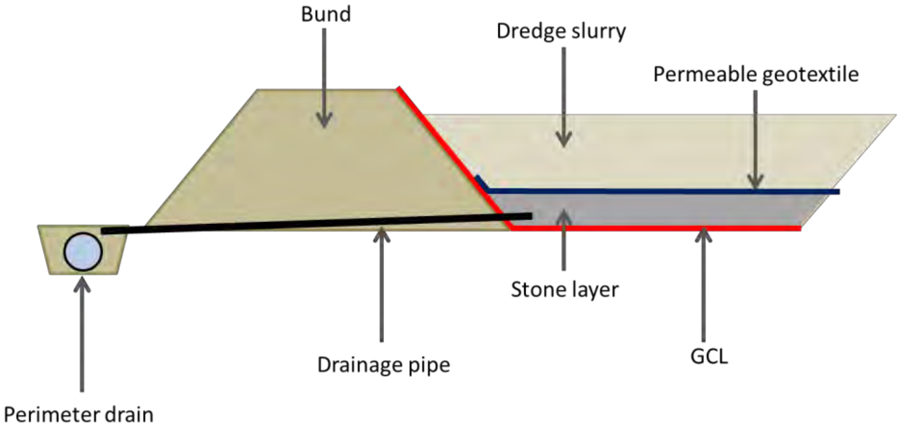

Figure 15: Schematic showing bund and drainage system.

The bunds have also been designed with consideration of vehicle access during construction and also for future maintenance requirements. Access roads are provided at a slope of 1v:10h. For the majority of the crest a 6 m wide crest has been adopted. At designated passing areas the width increases to 20 m.

The GCL is available in various grades depending on the shear strength requirements. For the base of each pond, where the required shear strength will be relatively low, an X800 grade GCL is assumed. Along the bund slopes, where shear strength will be an important factor, an X2000 grade GCL is assumed. Further information on the GCL is provided in **Appendix C**.

For the permeable geotextile to be placed over the stone layer, a grade A34 Bidim is assumed. Further information on the Bidim is provided in **Appendix C**.

The stone layer is assumed to consist of <70 mm stone.

All drainage pipes are assumed to be HDPE. For the purposes of concept design it is assumed that drainage pipes will be installed at 100 m centres around the outer perimeter. This will need to be checked as part of future design input.

To prevent piping around the edges of the drainage pipes, and the risk of pipes moving, it is recommended that the pipes be anchored using concrete collars, or similar, and that the collars should be sufficiently dimensioned to prevent piping along the outer side of the drainage pipe. This is to be addressed further as part of future design input.

4.4.3 Freeboard and Rainfall Considerations

The bunds for the onshore ponds have been designed with a freeboard of 1 m.

For the Mackay Onshore option this equates to a spare capacity of 200,000 m^3 (approximately 20 hectares x 1 m). For the Dudgeon Point Onshore option this equates to a spare capacity of 400,000 m^3 (approximately 40 hectares x 1 m).

Based on rainfall statistics for Mackay airport for the period 1950 to 2016, annual average precipitation is 1536 mm. Monthly average rainfall is shown in **Table 7**.

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Table 7: Rainfall and evaporation statistics for Mackay airport.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Annual
Mean rainfall (mm)	245	167	88	64	35	34	25	34	80	128	310	354	1564
Evaporation, mean (mm)	450			350			600			600			2000
Rainfall – evaporation	+50 mm			-220 mm			-460 mm			+190 mm			-440 mm

Source: Bureau of Meteorology

Based on the rainfall data provided above, it would be preferential to undertake the dredging works during May / June. With an average net precipitation over summer of approximately 200 mm and an average net annual evaporation rate of approximately 440 mm, the 1 m freeboard is considered sufficient to accommodate the average annual rainfall.

In addition to this, a review of the latest IFD Design Rainfall Depths (BoM, 2016) has been undertaken for the Mackay/Hay Point Area (see **Table 8** for Hay Pt IFD Table). From this it can be seen that the 1.0 m design freeboard can accommodate up to a 7 day (168 hour) 5% AEP rainfall event assuming no outflow. Under normal operating conditions, considering an outflow similar to that occurring during dredging (i.e. does not consider the additional driving head as the freeboard volume is taken up), the design freeboard is not expected to be exhausted up to and including a 7 day, 1% AEP rainfall event.

This assessment does not consider any attenuating effects of the basins or any specific requirements for on-site detention. It is assumed that any requirements to demonstrate no net increase in runoff from the site will be addressed holistically at the detailed design stage.

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Table 8: Hay Point IFD Table.

IFD Design Rainfall Depth (mm)

Issued: 21 September 2016

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).

	EY	Annual Exceedance Probability (AEP)					
Duration	**1EY**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**
1 min	2.9	3.2	4.2	4.8	5.5	6.2	6.8
2 min	5.0	5.6	7.5	8.7	9.9	11.5	12.7
3 min	7.1	7.9	10.5	12.2	13.9	16.0	17.6
4 min	8.9	10.0	13.2	15.3	17.4	20.0	21.9
5 min	10.6	11.9	15.7	18.2	20.6	23.6	25.8
10 min	17.4	19.4	25.5	29.4	33.1	37.7	41.1
15 min	22.4	25.0	32.7	37.7	42.4	48.4	52.7
30 min	32.6	36.4	47.8	55.3	62.3	71.3	77.9
1 hour	44.8	50.3	66.9	77.9	88.4	101.9	111.9
2 hour	59.5	67.4	91.7	107.9	123.4	143.7	158.9
3 hour	69.8	79.6	110.0	130.3	150.0	175.8	195.2
6 hour	91.2	105.5	150.2	180.6	210.4	249.9	280.1
12 hour	119.4	139.8	205.2	250.9	296.7	358.9	407.8
24 hour	155.8	183.9	277.3	345.6	416.3	516.1	597.6
48 hour	199.9	237.0	365.2	463.5	569.2	725.1	857.8
72 hour	228.0	270.7	421.1	538.9	667.8	861.5	1029
96 hour	248.1	295.1	461.4	592.5	736.8	954.9	1145
120 hour	263.4	313.9	492.5	633.0	787.1	1019	1221
144 hour	275.4	329.2	517.8	664.6	824.5	1063	1269
168 hour	285.2	342.1	539.0	690.0	852.5	1092	1295

4.5 Construction Approach

4.5.1 Reclamation Options

The rock walls for the reclamation options will be constructed using rock material sourced from local quarries. For each of the proposed reclamation sites two quarry sites have been considered, specifically:

- Mt Bassett quarry (<5km from Mackay Reclamation site / 50km from HTTH Reclamation site);
- Quarries in the vicinity of Farleigh (20km from Mackay Reclamation Site); and
- Quarries in the vicinity of Nebo (80km from HTTH Reclamation site).

The rock will be delivered to site by 40 tonne capacity dump trucks. The rock will be end-tipped and the rock wall will be formed using bulldozers and excavators. A mobile crane will be used to ensure that the primary armour rock is placed according to the design profile, particularly at the lower extremities of the rock wall near the toe.

The estimated durations and number of plant required for each component of the rock wall construction is as presented in **Table 9**.

Table 9: Assumed construction duration and plant requirements.

Site	Place core material	Geotextile installation	Armour material (upper reaches)	Armour material (lower reaches)
Mackay Reclamation	14 - 16 weeks	12 weeks	5 weeks	9 weeks
	Bulldozer (x2) Dump truck (x5 - 6) Excavators (x2)	Excavators (x2)	Bulldozer (x2) Dump truck (x5) Excavator (x2)	Dump truck (x2 - 3) Mobile crane (x1)
HTTH Reclamation	23 - 25 weeks	12 weeks	8 weeks	12 weeks
	Bulldozer (x2) Dump truck (x6 - 8) Excavators (x2)	Excavators (x2)	Bulldozer (x2) Dump truck (x6 - 8) Excavator (x2)	Dump truck (x3 - 4) Mobile crane (x1)

The main difference between the Mackay Reclamation option and the HTTH Reclamation option is the distance from the site to the quarry, and the number of dump trucks required to achieve a suitable construction rate.

All construction activities are assumed to be undertaken 10 hours per day, Monday to Friday, and 5 hours per day on Saturdays.

4.5.2 Onshore Options

Following site clearance, bulk earthworks will be undertaken on a cut-and-fill basis to create a platform for the ponds. The earthworks will also include stockpiling of material for the bund formation.

Once the platform has been established, the bunds will be constructed and the drainage pipelines will be installed.

Once the bunds have been constructed they will be lined.

The estimated durations and number of plant required for each component of the rock wall construction is presented in **Table 10**.

Table 10: Assumed construction duration and plant requirements.

Site	Site preparation	Earthworks	Bund formation	Liner installation
Mackay Onshore	2 weeks	4 weeks	4 weeks	3 weeks
	Bulldozer (x2) Dump trucks (x3) Excavator (x2)	Bulldozer (x2) Dump trucks (x3) Excavator (x2) Scraper (x2) Grader (x1) Roller compactor (x1) Water truck (x1)	Bulldozer (x2) Dump trucks (x3) Excavator (x2) Trencher (x3) Roller compactor (x1) Water truck (x1)	Excavator (x2)
Dudgeon Point Onshore	4 weeks	16 weeks	4 weeks	3 weeks
	Bulldozer (x2) Dump trucks (x3) Excavator (x2)	Bulldozer (x2) Dump trucks (x3) Excavator (x2) Scraper (x2) Grader (x1) Roller compactor (x1) Water truck (x1)	Bulldozer (x2) Dump trucks (x3) Excavator (x2) Trencher (x3) Roller compactor (x1) Water truck (x1)	Excavator (x2)

The main differences between the Mackay Onshore option and the Dudgeon Point Onshore option is the size of the site that needs to be cleared and the volume of earthworks needed to create a working platform.

As with the reclamation options, all construction activities are assumed to be undertaken 10 hours per day, Monday to Friday, and 5 hours per day on Saturdays.

5 Design Comparison

To enable a comparison between the four maintenance dredge material disposal options considered, the relative cost, GHG emissions, potential tailwater impacts and capacity for future maintenance dredging material are detailed in this section.

5.1 Cost Estimates

Table 11 provides a summary of the rough order of magnitude (ROM) costs associated with each option. A breakdown of the cost estimate is provided in **Appendix D**. The ROM costs for the rock wall construction represents the average cost between the two quarry locations considered. The ROM costs show that the onshore options are significantly lower cost than the reclamation options, with the cost of the rock required for the reclamations resulting in them being more expensive. The Dudgeon Point onshore pond option is significantly more expensive than the Mackay onshore option due to the extensive earthworks required to level the site prior to construction of the ponds and because a larger pond area was adopted to try and improve the drying out of the sediment to allow future reworking or removal to be more straightforward.

Table 11: ROM cost estimate

	Mackay Reclamation	HTTH Reclamation	Mackay Onshore	Dudgeon Point Onshore
Site preparation			$ 60,000	$ 100,000
Earthworks & bund formation			$ 4.9 million	$ 10.6 million
Rock wall construction	$ 18 million	$ 26.6 million		
Weir boxes			$ 100,000	$ 100,000
Geotextiles	$ 180,000	$ 180,000	$ 3.4 million	$ 4.3 million
Perimeter drainage			$ 0.9 million	$ 1.4 million
Miscellaneous			$ 200,000	$ 200,000
P&Gs	30%	30%	30%	30%
Contingencies	20%	20%	20%	20%
Subtotal	$ 28.5 million	$ 41.8 million	$ 15.1 million	$ 25.7 million
Dredging	$ 3.5 million	$ 2.6 million	$ 3.5 million	$ 2.6 million
TOTAL (excl. GST)	$ 32 million	$ 44.4 million	$ 18.6 million	$ 28.3 million

5.2 GHG Emissions

An assessment of the Greenhouse Gas (GHG) emissions from the dredging activity and construction works was made for each solution.

The GHG emissions assessment was undertaken in accordance with the internationally recognised methodology outlined in the GHG Protocol (WRI & WBCSD, 2015). The GHG Protocol defines three groups of GHG emissions that arise from an organisation's operational entity:

- **Scope 1 emissions**: "direct" GHG emissions arising from each of the solutions, such as those associated with fossil fuel consumption by vessels during transport and construction activity;
- **Scope 2 emissions**: account for "indirect" GHG emissions from the production of electricity and gas (i.e. off site and usually by third parties) consumed by plant and equipment as part of the solutions; and
- **Scope 3 emissions**: are indirect emissions arising from supporting activities (e.g. work upstream and/or downstream, the activities of sub-contractors and ancillary travel associated with a project) associated with the solutions. Scope 3 emissions are voluntary and an organisation can take a decision on the materiality of such activities before deciding to spend effort on calculating them for inclusion in a GHG footprint, or excluding them.

This GHG assessment has considered Scope 1 emissions and has also provided high level estimates for Scope 3 emissions for each of the disposal options (note that none of the options result in Scope 2 emissions). The findings of the GHG assessment are summarised in **Table 12**, and further detail is provided in **Appendix E**. The GHG Scope 1 emissions from construction plant for the reclamations are for the average emissions between the two quarry locations considered. The table shows that the Mackay Onshore option is predicted to have the lowest GHG emissions out of the four options, this is because the site is relatively flat, while the Dudgeon Point onshore option requires significant cut and fill effort to prepare the site for the onshore pond. The reclamation options result in much higher Scope 3 emissions due to the large quantities of rock material used in the construction.

Table 12: GHG emission estimates.

Option	Scope 1 CO_2e Emissions (Tonnes)			Scope 3 Emissions (CO_2e Tonnes)	Total Scope 1 + Scope 3 Emissions (CO_2e Tonnes)
	CO_2e Emissions from Dredging	**CO_2e Emissions from Construction Plant**	**Total Scope 1 CO_2e Emissions**	**Embodied Emissions from Construction Materials**	
Mackay Reclamation	1,183	2,433	**3,616**	15,869	**19,485**
HTTH Reclamation	795	4,160	**4,955**	19,819	**24,774**
Mackay Onshore	1,183	1,663	**2,846**	2,040	**4,886**
Dudgeon Point Onshore	795	4,200	**4,995**	2,426	**7,421**

5.3 Water Quality Impacts

A sediment transport model was setup using the existing calibrated and validated, RHDHV Hay Point/ Mackay Hydrodynamic Model detailed in **Appendix E**. A series of nested computational grids were developed to ensure a sufficient spatial resolution near the proposed tailwater release locations and reclamation locations. As the reclamations have been designed to contain all of the dredged material without the need for a tailwater release, a partial failure (tear) of the geotextile layer which acts to contain the fine grained dredged material in the reclamation has been simulated. As such, the model was setup to simulate the fate of sediment plumes from the following scenarios:

- Mackay onshore pond tailwater release into Barnes Creek, which subsequently drains into the Pioneer River;
- Dudgeon Point onshore pond tailwater release into the salt pan on the northern foreshore of Dudgeon Point;
- Mackay Reclamation geotextile layer failure of the eastern bank; and
- Half Tide Tug Harbour Reclamation geotextile layer failure of the eastern bank.

Table 13 provides an overview of the assumed discharge of sediment from the tailwater discharge and reclamation failures that were simulated. The onshore pond tailwater discharges were developed based on the dredging approach discussed in **Section 3.3**. The tailwater discharge would commence once the ponds have filled up to the weir box levels (after approximately five days) and would continue discharging until after cessation of the dredging. Therefore, for the total dredging duration of 31 and 23 days for Mackay Onshore Pond and Dudgeon Point Onshore Pond, respectively, a total slurry mix (sediment + water) volume of 66,167 m^3 per day (Mackay) and 94,025 m^3 per day (Dudgeon Point) was estimated. This results in tailwater discharge rates of 0.77 m^3/s at Mackay and 1.1 m^3/s at Dudgeon Point with an assumed suspended sediment concentration (SSC) of 50 mg/L. For the simulations of embankment failure of the reclamation sites, a constant release of 1,000 mg/L per second was assumed.

The model was used to simulate the release of sediment over a 14 day duration, which, as the SSC in the study area were shown to not increase over time, can be assumed to be representative of the entire discharge period.

Table 13: Overview of simulated sediment input scenarios.

	Mackay Onshore Pond	Dudgeon Pt Onshore Pond	Mackay Reclamation	HTTH Reclamation
Discharge (m^3/s)	0.77	1.1	1	1
Concentration (mg/L)	50	50	1,000	1,000
Simulation duration (days)	14	14	14	14

The results from the plume modelling have been processed to provide a statistical representation of the plume over the 14 day simulation period. The 95th percentile SSC is shown for the four options in **Figure 16** to **Figure 19** and a summary of the maximum SSC adjacent to the release locations and 2km away is provided in **Table 14**. It is important to understand that the percentile plots do not provide an instantaneous representation of the plume at a specific time, rather they represent the concentration in each model grid cell for which concentrations were below for 95 percent of the simulation period. The results show that the SSC from the tailwater release are very low, with maximum SSC over the 14 day simulation period of less than 1mg/l predicted 2km away from the release point. As expected, for the reclamation scenario the SSC are higher, with maximum SSC over the 14 day simulation period of up to 2mg/l predicted 2km away from the release location.

Various statistical measures of the predicted SSC at sensitive receptors identified by NQBP (shown in **Figure 20**) for the four scenarios are detailed in **Table 15**. The tailwater release discharge from the onshore options is not predicted to result in a measureable increase in SSC at any of the sensitive receptors (increase of less than 1mg/l). The reclamation failure scenarios are predicted to result in very small increases in SSC at Victor Islet and Hay Reef for the HTTH reclamation and at Slade Islet for the Mackay reclamation. However, the median increase in SSC at all of these locations is less than 1mg/l and so it is questionable whether the increases would be measureable.

Table 14: Summary of maximum concentrations at surrounding points to the discharge location.

	Maximum SSC (mg/L)				
	Source	**2km North**	**2km East**	**2km South**	**2km West**
Mackay Onshore Pond	2.15	*Land*	0.0	0.1	*Land*
Dudgeon Pt Onshore Pond	1.3	0.0	0.1	*Land*	0.4
Mackay Reclamation	7.8	*Land*	1.0	1.5	*Land*
HTTH Reclamation	12.8	0.6	1.1	2.2	*Land*

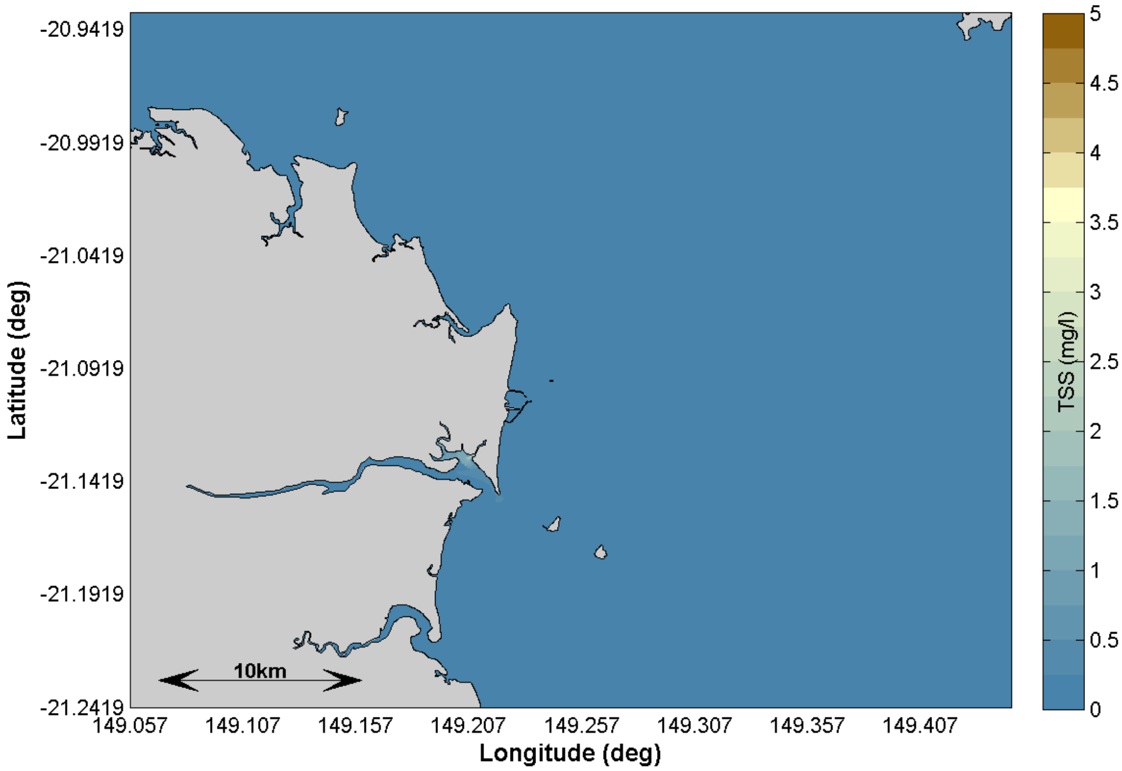

Figure 16: 95th percentile SSC from the tailwater release at the Mackay Onshore location.

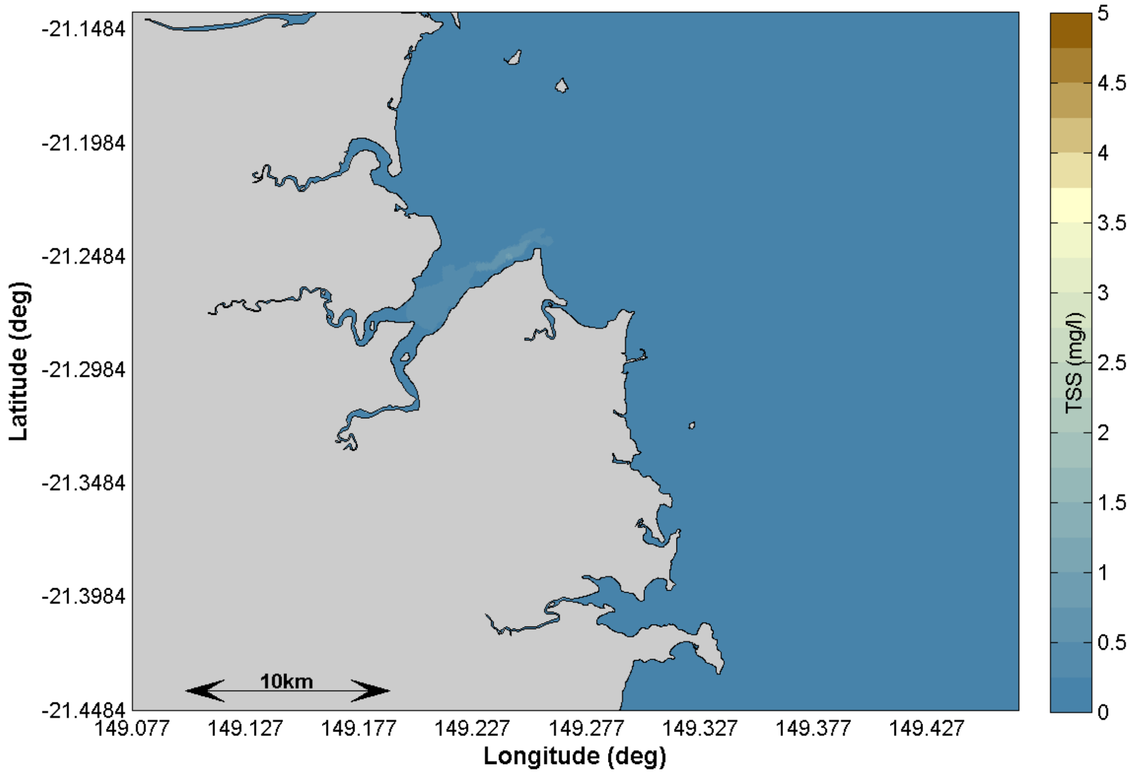

Figure 17: 95th percentile SSC from the tailwater release at the Dudgeon Point Onshore location.

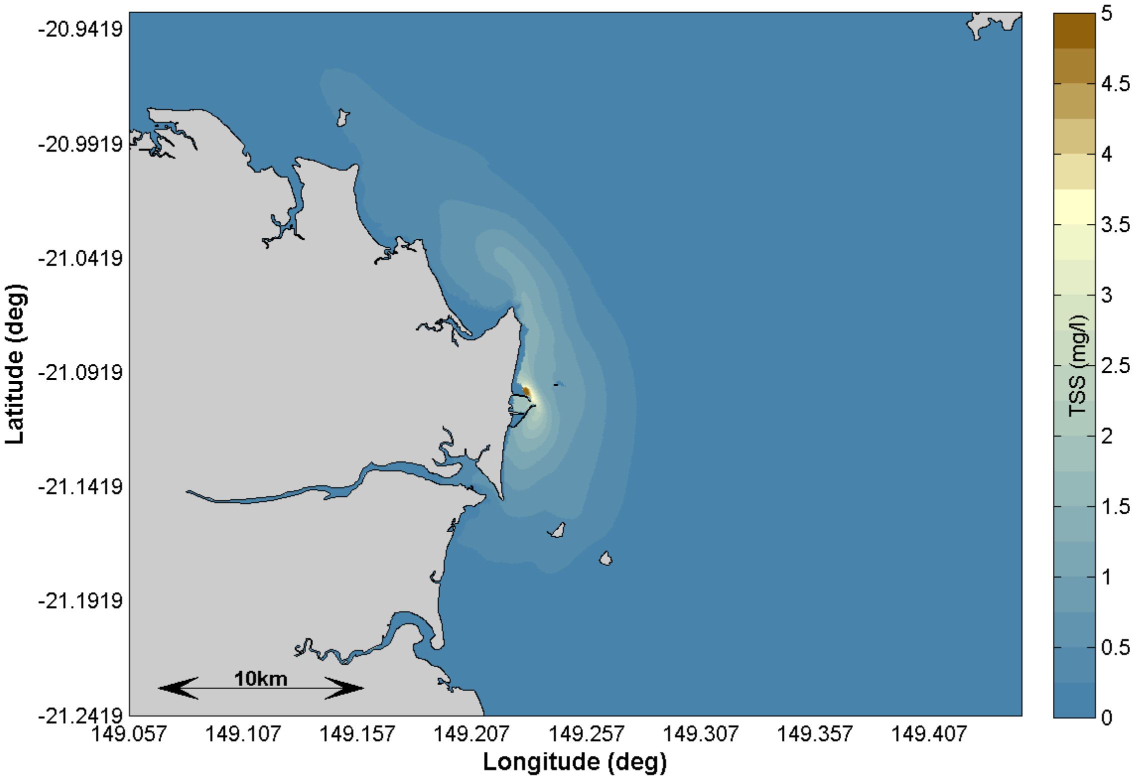

Figure 18: 95th percentile SSC from the reclamation failure at Mackay.

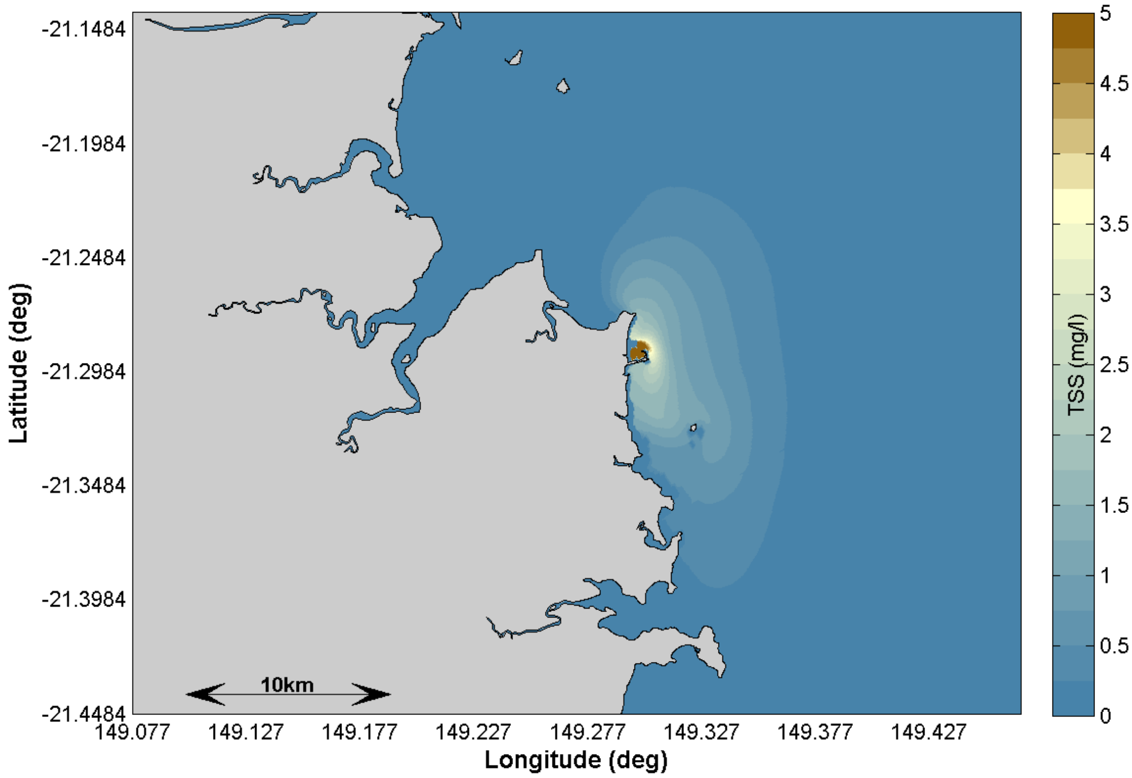

Figure 19: 95th percentile SSC from the reclamation failure at HTTH.

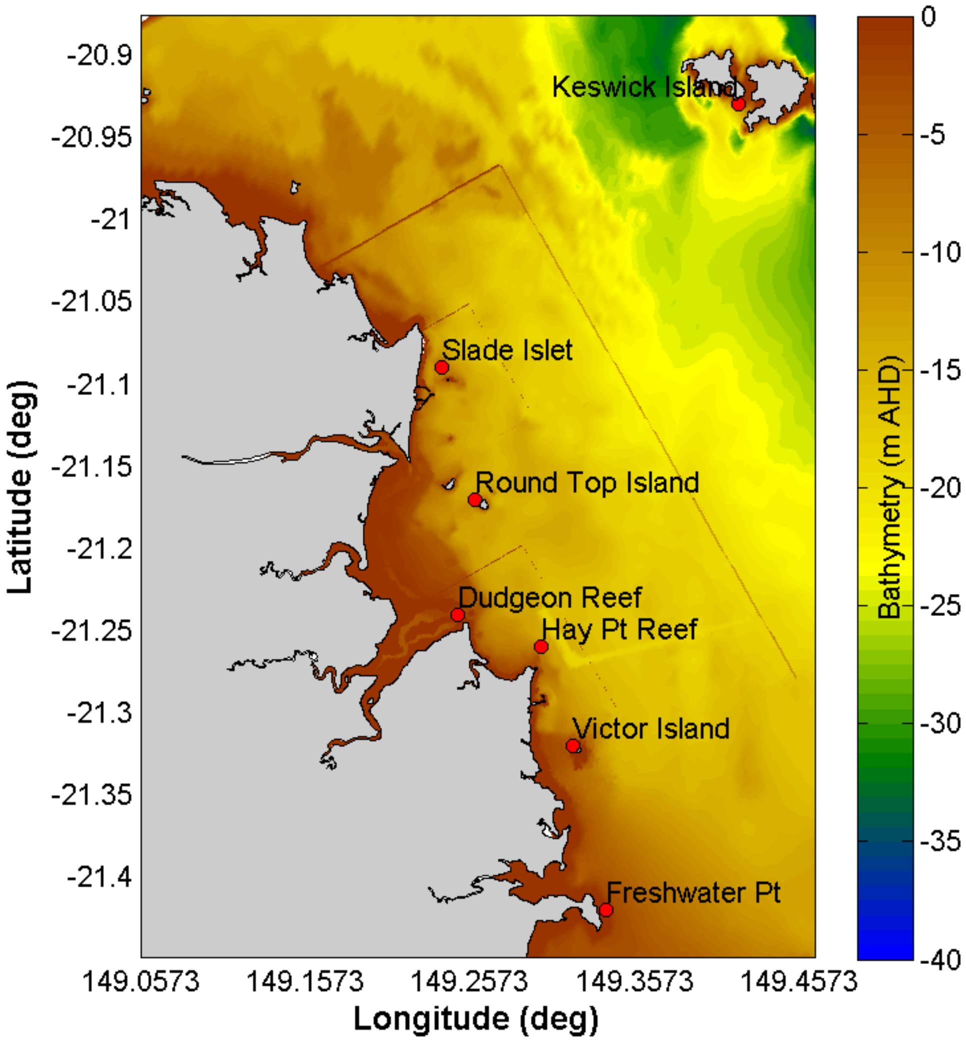

Figure 20: Bathymetry of model domain and sensitive receptor locations identified by NQBP.

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Table 15: Statistical summary of modelled suspended sediment concentrations at sensitive receptors.

Mackay Onshore Pond Tailwater Discharge SSC (mg/l)							
	Freshwater Point	Victor Island	Hay Reef	Dudgeon Pt Reef	Round Top Island	Slade Islet	Keswick Island
95th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Count	2017	2017	2017	2017	2017	2017	2017
Dudgeon Point Onshore Pond Tailwater Discharge SSC (mg/l)							
	Freshwater Point	Victor Island	Hay Reef	Dudgeon Pt Reef	Round Top Island	Slade Islet	Keswick Island
95th %	0.0	0.0	0.0	0.2	0.0	0.0	0.0
80th %	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Median	0.0	0.0	0.0	0.1	0.0	0.0	0.0
20th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Count	2017	2017	2017	2017	2017	2017	2017
Mackay Reclamation Failure Scenario SSC (mg/l)							
	Freshwater Point	Victor Island	Hay Reef	Dudgeon Pt Reef	Round Top Island	Slade Islet	Keswick Island
95th %	0.0	0.0	0.0	0.1	0.1	1.1	0.0
80th %	0.0	0.0	0.0	0.0	0.1	0.9	0.0
Median	0.0	0.0	0.0	0.0	0.0	0.8	0.0
20th %	0.0	0.0	0.0	0.0	0.0	0.5	0.0
5th %	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Count	2017	2017	2017	2017	2017	2017	2017
Half Tide Tug Harbour Failure Scenario SSC (mg/l)							
	Freshwater Point	Victor Island	Hay Reef	Dudgeon Pt Reef	Round Top Island	Slade Islet	Keswick Island
95th %	0.2	1.1	1.1	0.0	0.0	0.0	0.0
80th %	0.1	0.7	0.8	0.0	0.0	0.0	0.0
Median	0.0	0.4	0.3	0.0	0.0	0.0	0.0
20th %	0.0	0.2	0.1	0.0	0.0	0.0	0.0
5th %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Count	2017	2017	2017	2017	2017	2017	2017

5.4 Future Use

Both of the onshore pond concept designs have been configured to contain the volume from a single maintenance dredging campaign, approximately 200,000m^3 of in-situ volume. Two future options are considered realistic for the ponds to enable them to contain additional volume of material from future campaigns:

- remove the dry material from the pond to create sufficient capacity for the subsequent maintenance dredging campaign. A suitable site for disposing of the dry material, or a reuse option for the material would be required; or
- increase the height of the bunds to increase the capacity of the pond. It is possible that some of the dry material could be used to increase the bund heights, although additional imported material would be expected to be required to improve the quality of the sediment.

It is difficult to estimate the cost for these options at this stage, but it is expected that the costs would be between $4 million (to remove material from the site) and $6 million (to raise the bund levels) per maintenance dredging campaign. Further explanation of these costs are provided in **Appendix D**.

Due to the large tidal range in the area and the relatively high cost for construction of the reclamations, they have been configured to have sufficient capacity to contain material from additional maintenance dredging campaigns. The HTTH option should have sufficient capacity to contain the volume from four maintenance dredging campaigns (assuming each future campaign is 200,000m^3 of in-situ volume), while the Mackay option should have sufficient capacity to contain the volume from five maintenance dredging campaigns. Once these capacities have been reached the only options available for future volumes would be to either remove some of the dredged material or to construct a new reclamation adjacent to the existing reclamation.

5.5 Summary

A summary of the comparative analysis is provided in **Table 16**.

Table 16: Comparative analysis summary

Location	Cost	GHG emissions (CO_2e tonnes)	Water Quality Impacts	Future Use
Mackay Reclamation	$32 M	19,485	Low (medium confidence)	Capacity for 5 campaigns (25 yrs)
HTTH Reclamation	$44.4 M	24,774	Low (medium confidence)	Capacity for 4 campaigns (20 yrs)
Mackay Onshore	$18.6 M	4,886	Low (high confidence)	No capacity, additional cost of $2-6 million/campaign
Dudgeon Point Onshore	$28.3 M	7,421	Low (high confidence)	No capacity, additional cost of $2-6 million/campaign

Table 16 indicates the following:

- the costs for the onshore pond options are lower than the reclamation options for the initial 200,000m^3 of in-situ maintenance dredged material. However, when the additional costs for future maintenance dredging campaigns are considered the onshore and reclamation option costs become comparable over a 20-25 year duration;

- the Mackay Onshore option results in the lowest GHG emissions out of the four options, this is due to the sourcing of rock resulting in high Scope 3 emissions for the reclamation options and the Mackay site is relatively flat, while the Dudgeon Point onshore option requires significant cut and fill to level it prior to installation of the onshore pond. The Mackay Reclamation option is predicted to have lower GHG emissions than the HTTH Reclamation as it is able to utilise the existing breakwater of Mackay Harbour, significantly reducing the construction required; and

- none of the options are expected to result in water quality impacts away from the sites. The level of confidence for this is lower for the reclamation options relative to the onshore pond options due to the risk of failure of the geotextile layer over the life of the structures.

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6 Conclusions

This assessment has investigated four options to potentially store existing (200,000m^3 of in-situ volume) and future sediment (200,000m^3 of in-situ volume every five years) from maintenance dredging at the Port of Hay Point. Concept designs for reclamations at Mackay and HTTH along with onshore ponds at Mackay and Dudgeon Point have been developed. Based on the concept designs a comparative assessment of the developed options has been undertaken considering the cost, greenhouse gas (GHG) emissions and potential water quality impacts

The results of the comparative assessment of the four options can be summarised as follows:

- the cost estimates show that expected costs range from $18 million to $45 million, with the Mackay onshore pond option being the cheapest and the HTTH reclamation being the most expensive;

- the onshore pond options have lower costs than the reclamation options to contain the initial 200,000m^3 of in-situ maintenance dredged material. However when the additional costs for future maintenance dredging campaigns are considered, the costs for the onshore and reclamation options become comparable over a 20 to 25 year period;

- despite the Mackay options having higher relative GHG emissions for the dredging component of the work compared to the Dudgeon Point and HTTH options, they have lower overall emissions. This is due to the the Mackay onshore site being relatively flat while the Dudgeon Point onshore option requires significant cut and fill to level it prior to installation of the onshore pond and the Mackay reclamation being able to use the existing northern breakwater of Mackay Harbour; ;

- none of the options are expected to result in water quality impacts away from the sites. The level of confidence for this is lower for the reclamation options relative to the onshore pond options due to the risk of failure of the geotextile layer in the reclamation options over the life of the structures; and

- based on the comparative assessment there are positives and negatives associated with each of the options. The Mackay onshore option is predicted to have the lowest GHG emissions, be the cheapest option, have low impacts on water quality but additional work and cost would be required to enable the site to hold future maintenance dredging material in addition to the existing maintenance dredging requirement of 200,000m^3 of in-situ volume.

7 References

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Appendix A Wave Modelling

Note / Memo

Haskoning Australia PTY Ltd.
Maritime & Aviation

To: NQBP
From: Heiko Loehr and Justin Cross
Date: 21 September 2016
Copy:
Our reference: M&AN001D01
Classification: Project related

Subject: Design Conditions, Rock Sizing and Overtopping

Hay Point & Mackay Wave Model

A spectral wave model for the Mackay region was setup to transform extreme offshore wave conditions to the seaward rock wall of two proposed reclamations (adjacent to Mackay Harbour and Half Tide Tug Harbour).

The spatial resolution of the computational grids used in the model is detailed in **Table 1** and the grid configuration and bathymetry shown in **Figure 1**.

Table 1: Spatial resolution of computational model grids used in this study.

	Regional Grid	Nearshore Grid	High-resolution Hay Point	High-resolution Mackay
Model resolution	550m	180m	60m	60m

As the spectral wave model will be used to transform extreme cyclonic wave conditions from offshore to nearshore it is necessary to demonstrate that the model is capable of representing this type of condition. Measured wave conditions were available at both the Mackay and Hay Point waverider buoys (WRB) for the period when TC Dylan impacted the area in January 2014. This event therefore provides an ideal period to validate the model as the Mackay WRB can be used to represent offshore wave conditions while the Hay Point WRB can be used to demonstrate that the model can transform these offshore conditions to a nearshore location.

The spectral wave model was therefore validated for a 4-day period over TC Dylan in January 2014. In order to validate the model for these extreme wave conditions at the Hay Point WRB (nearshore site) it was necessary to include wave generation by local winds. The local winds were from the Mackay weather station and were scaled to represent the over water wind conditions. **Figure 2** shows the time-series validation for two wave buoy sites within the study site. It can be seen that the wave model is capable of reproducing the measured time-series.

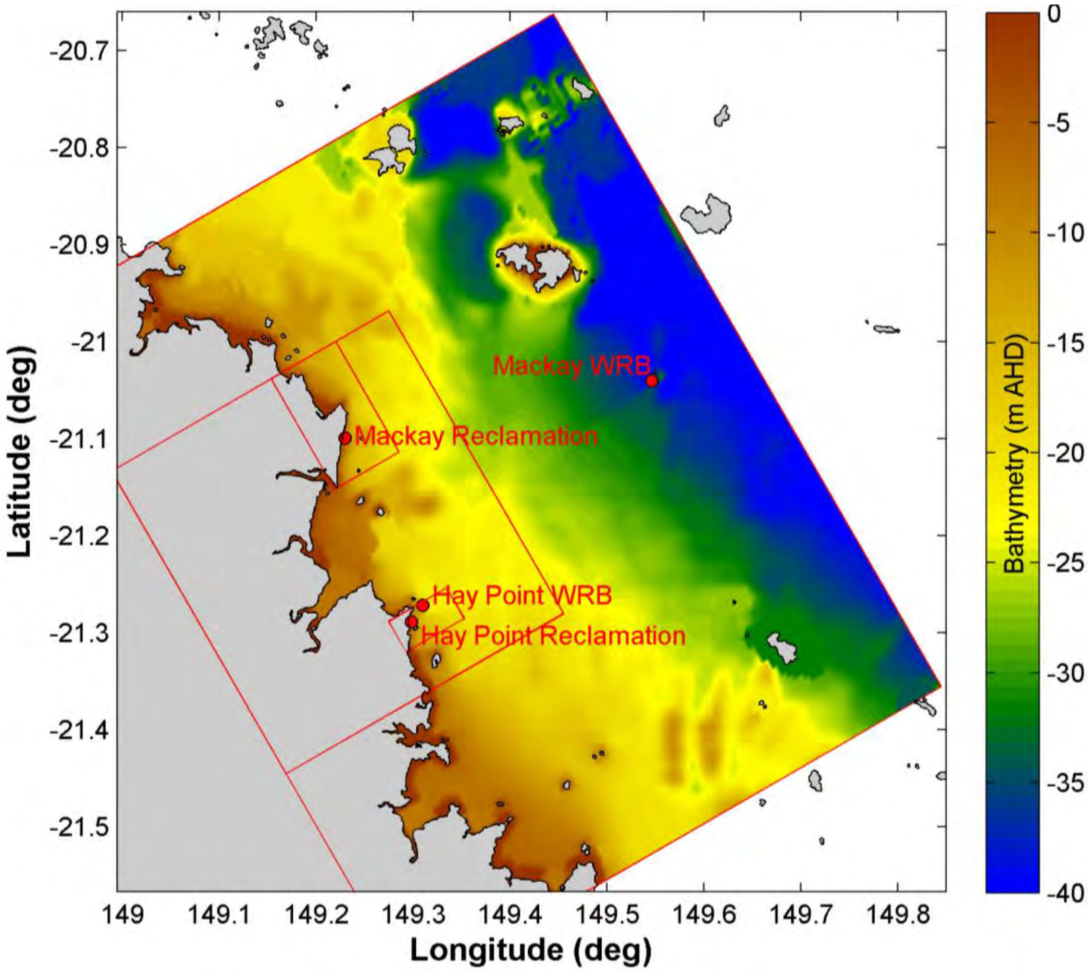

Figure 1: Overview of various model grids and bathymetry used in this study.

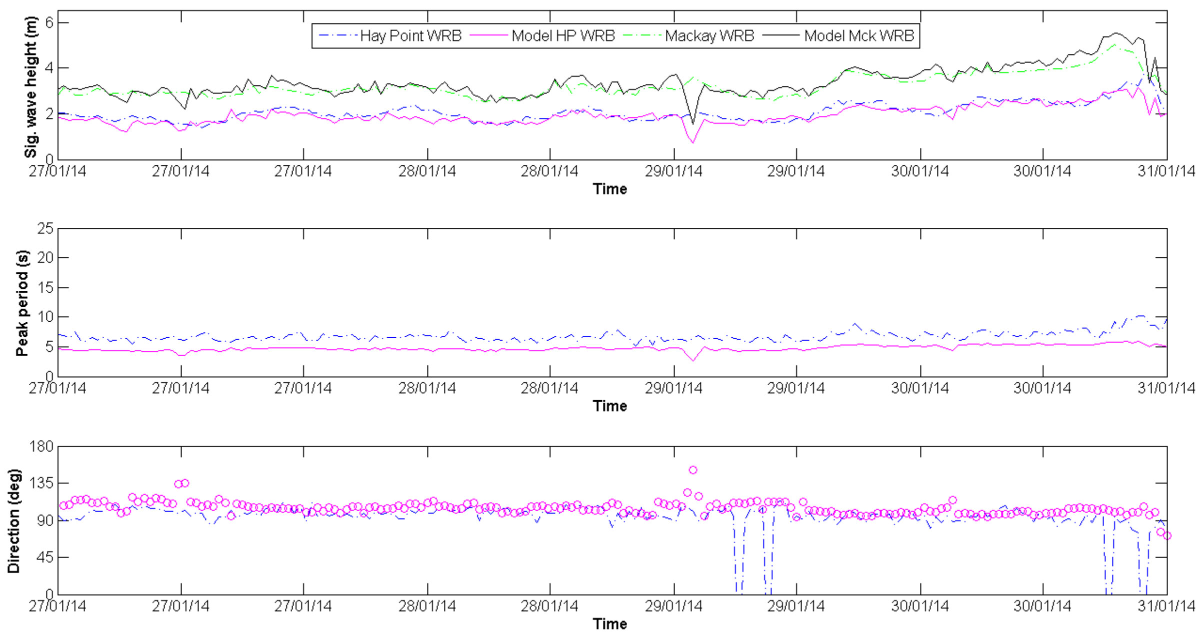

Figure 2: Comparison of modelled and measured time-series of TC Dylan event (4-days).

Wave data between 1993 and 2015 from the Mackay WRB was processed to predict the offshore extreme conditions. The calculated offshore extreme wave conditions are detailed in **Table 2**. To define a wave direction for extreme waves a 3m significant wave height threshold was applied to the measured waves recorded at the Mackay WRB and the average wave direction for these waves was calculated. The average wave direction for extreme waves at the Mackay WRB was calculated to be 105 degrees.

Table 2: Calculated offshore extreme wave conditions based on the Mackay WRB data.

Event	Hs (m)	Tp (s)
5 year ARI	4.05	9
10 year ARI	4.72	10
25 year ARI	5.82	11
50 year ARI	6.79	12
100 year ARI	7.86	13

Note: Tp is based on the average steepness relations for the largest wave conditions measured.

As noted during the model validation process to represent the nearshore extreme wave conditions it is important for the model to also include wave generation due to local winds. The wind conditions for a 50 year ARI event were taken from Harper (1999) for Mackay (**Figure 3**).

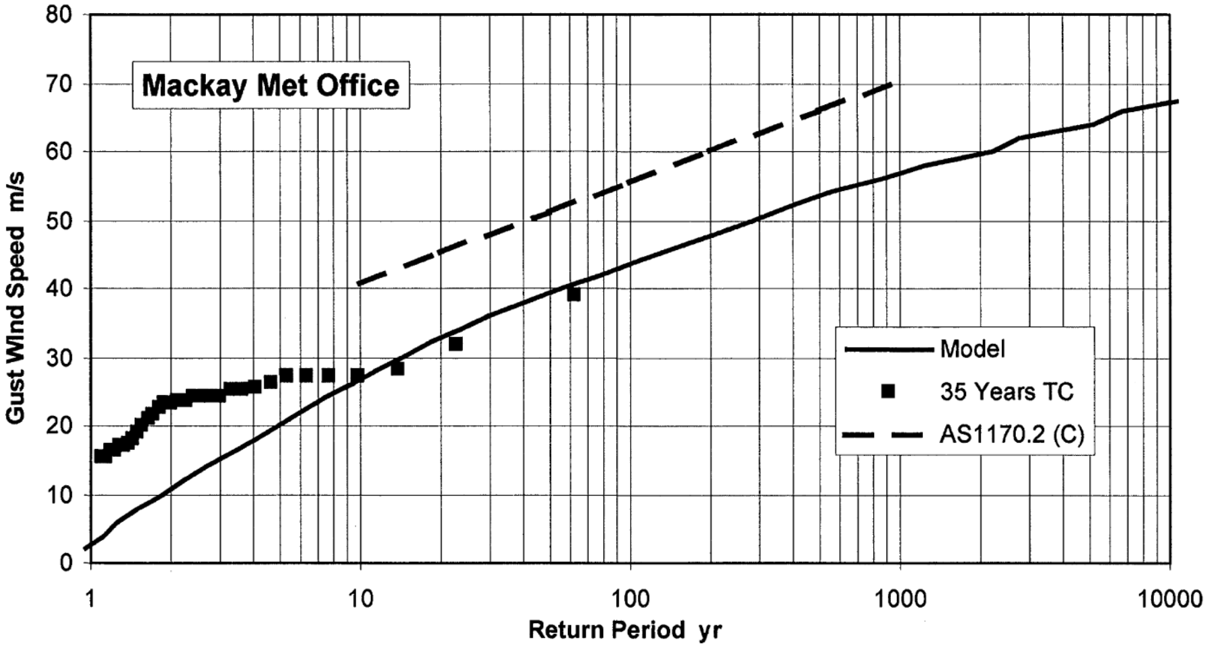

Figure 3: Modelled and measured extreme wind conditions (Harper, 1999).

To determine the nearshore design wave heights at the proposed reclamation sites, the measured 50 year ARI conditions from the Mackay wave buoy were transformed to the nearshore using the RHDHV spectral wave model. **Figure 5** shows the spatial distribution of significant wave heights for the 50 year ARI at Mackay and Hay Point.

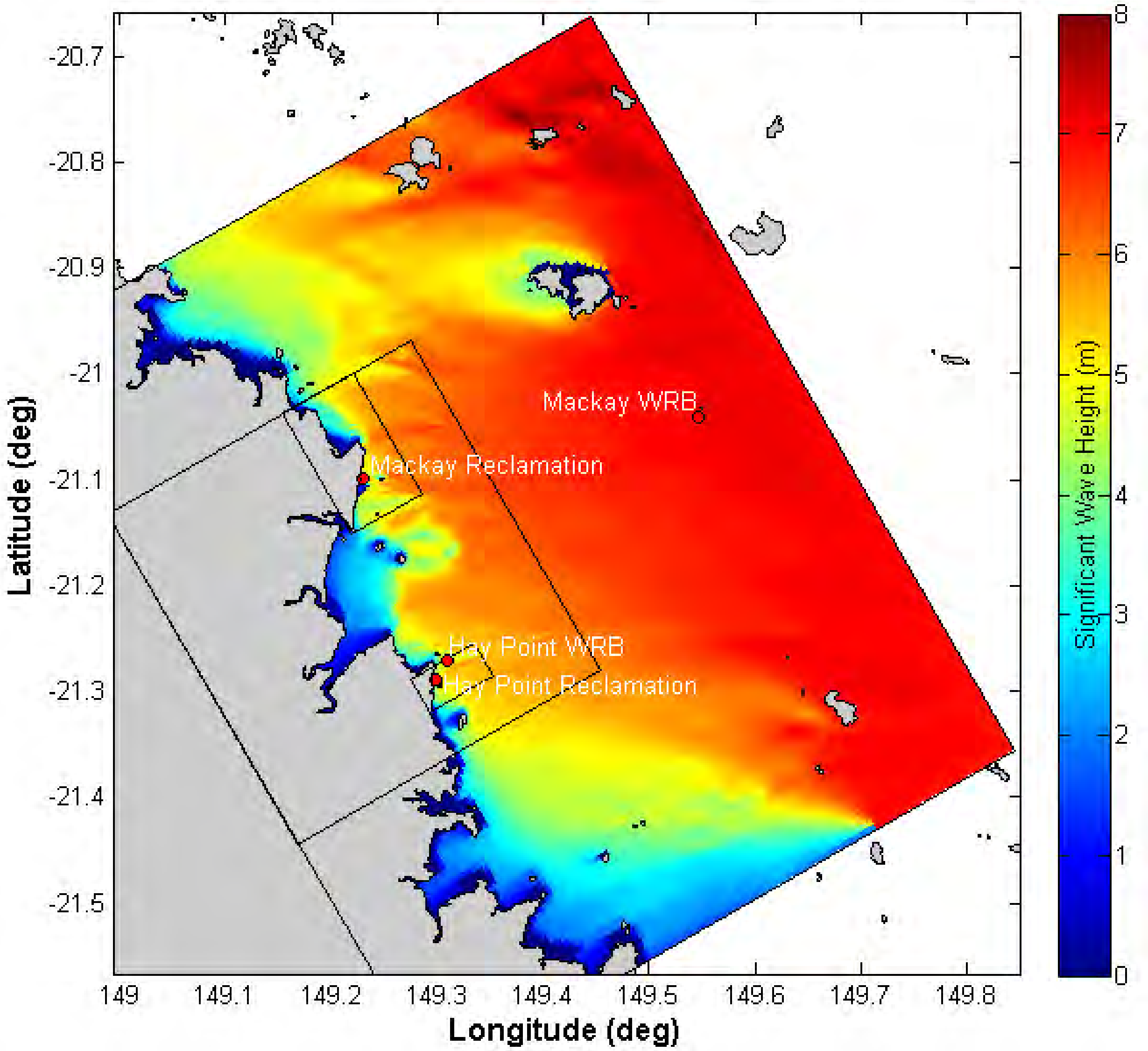

Figure 4: Significant wave height in meters over the model domain for a 50 year ARI event. The squares show the nested grids.

The model results for the 50 year ARI wave event at the Mackay and Hay Point reclamation sites are presented in **Figure 5** and **Table 3**. It is interesting to note the wave sheltering which occurs at the Hay Point WRB during an extreme wave event due to the dredged apron and departure channel at the Port of Hay Point.

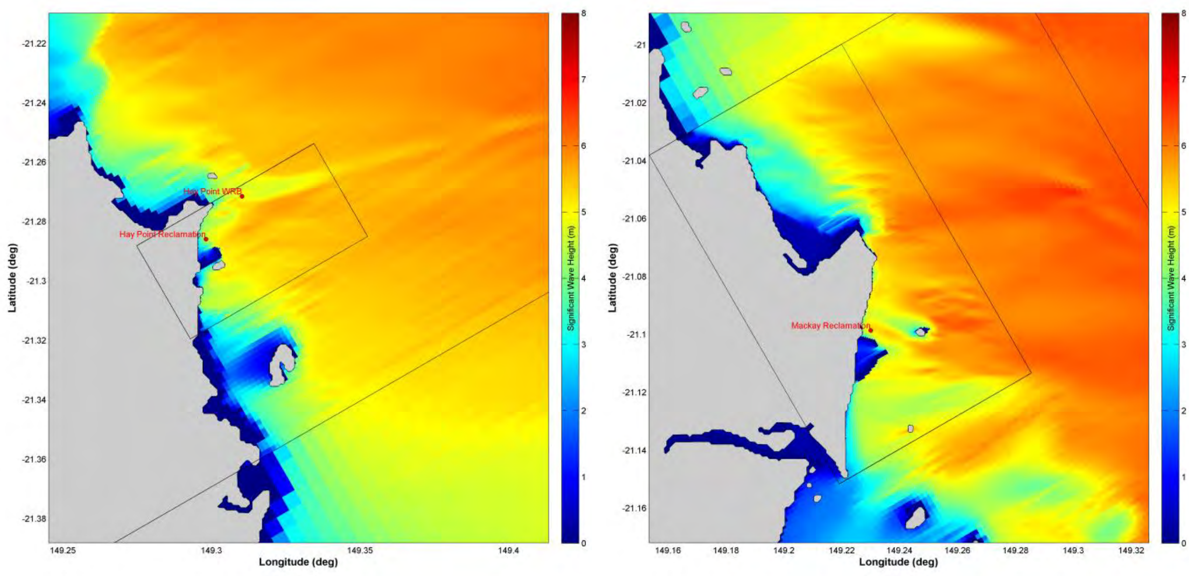

Figure 5: Significant wave height in meters near the reclamation areas at Hay Point (left) and Mackay Harbour (right) for the 50 year ARI event. The squares show the high-resolution nested grid extents.

Table 3: Design conditions at the two reclamation sites.

	Hay Point	Mackay
Significant Wave Height (m)	4.6	5.2
Peak Direction (deg)	80	90
Peak Period (s)	9.4	9.5
HAT Water Level (m AHD)	3.8	3.47

Overtopping Estimates

Due to the relatively large tidal range at Mackay and Hay Point the tide plus storm surge level during an extreme event is similar to the HAT level (Hardy et al., 2004). As such, the Mackay and Hay Point (Sarina Beach) HAT levels have been used for the overtopping calculations.

Overtopping estimates were calculated using the deterministic approach from EurOtop (2007) for the following structure type:

- Rock revetment with 1 in 2 slopes; and
- 2 layers and permeable core.

The crest freeboard was adjusted to ensure the overtopping results were below a maximum overtopping discharge of 50 l/s/m which EurOtop (2007) notes as the maximum acceptable discharge to prevent damage to the crest and rear slope if both are well protected. The final results from the overtopping estimates are provided in **Table 4**.

Table 4: Summary of overtopping calculations for the two proposed reclamation sites.

	Hay Point	Mackay
Significant Wave Height (m)	4.6	5.2
Design Water Level (m AHD)	3.8	3.5
Crest freeboard (Rc) (m, relative to SWL)	3.9	4.9
Seaward Slope (cot α)	2	2
Overtopping discharge (q) (l/s/m)	**48.6**	**46.8**

Rock Sizing

A summary of the results obtained using the Van De Meer (1988) equation is provided in **Table 6**. It is noted that the rock density used in the rock sizing equations is based on typical rock density information but may differ to the local quarry rock. The damage factor defines the level of damage that is acceptable for the structure, e.g. a damage factor of 1 or less defines no damage (only some settlement may be expected in that case, see **Table 5**). A damage factor of 4 has been adopted for the rock sizing calculations in this study.

Table 5: Design values of the damage parameter, S_d, for armourstone in a double layer (CIRIA, 2008).

Slope (cotα)	Damage level		
	Start of damage	Intermediate damage	Failure
1.5	2	3-5	8
2	2	4-6	8
3	2	6-9	12
4	3	8-12	17
6	3	8-12	17

Table 6: Summary of Van der Meer (1988) estimation of minimum rock armour size D50 for emerged breakwaters for a series of wave periods.

Return Period	Hay Point 50-year ARI (H_s = 4.6m)				Mackay Harbour 50-year ARI (H_s = 5.2 m)			
Peak Period (s)	**8**	**10**	**12**	**14**	**8**	**10**	**12**	**14**
H_s (m)	4.6	4.6	4.6	4.6	5.2	5.2	5.2	5.2
Slope, Cot(α)	2	2	2	2	2	2	2	2
Damage Factor (S_d)	4	4	4	4	4	4	4	4
Rock density (kg/m^3)	2,750	2,750	2,750	2,750	2,750	2,650	2,650	2,650
Water density (kg/m^3)	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025
Sea bed level (m)	-6	-6	-6	-6	-10	-10	-10	-10
Duration of storm (hours)	6	6	6	6	6	6	6	6
Weight (t)	**6**	**7**	**9**	**11**	**8**	**9**	**12**	**15**
D50 (m)	**1.28**	**1.36**	**1.50**	**1.60**	**1.40**	**1.50**	**1.65**	**1.75**

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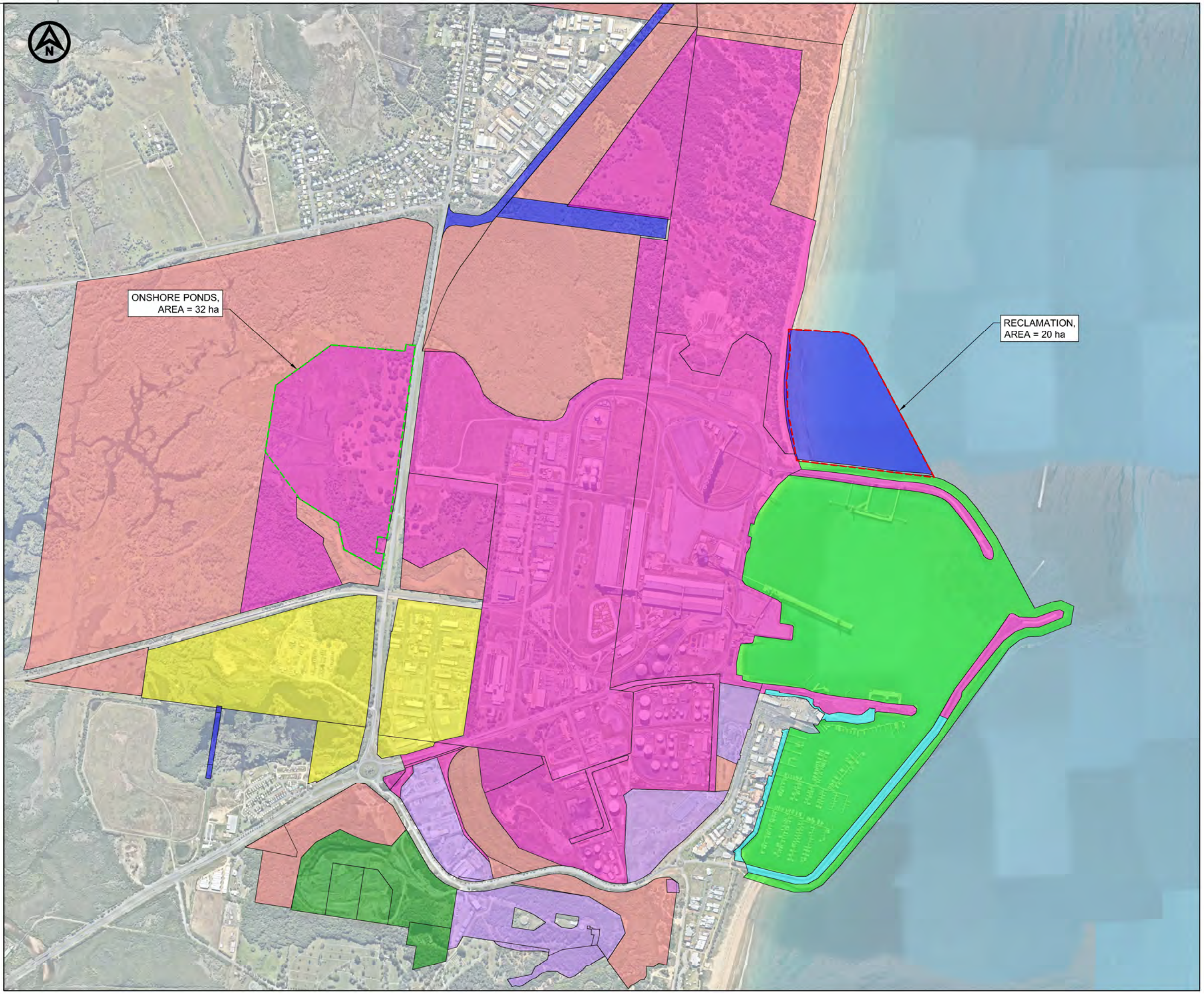
Appendix B Design Drawings

DRAWING No. PA1163/MA/1001

DO NOT SCALE



NOTES

1. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.

LEGEND

LAND USE ZONES:

- BUFFER
- FUTURE STRATEGIC PORT LAND
- HARBOUR AND ACCESS
- MARINA
- PORT OPERATIONS
- PORT RELATED COMMERCIAL
- PORT SUPPORT
- QUARRY

PROPOSED:

- ONSHORE PONDS AREA
- RECLAMATION AREA

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT

NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT:

HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE:

MACKAY
PROPOSED DREDGE DISPOSAL OPTIONS OVERVIEW

HASKONING AUSTRALIA PTY LTD
SYDNEY

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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163

AUTOCAD REF. PA1163-MA-MACKAYV3

SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/1001 | REVISION A

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

150 0 150 300 450 600 750m

1:7500 (A1) 1:15000 (A3)

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1163 - HAY POINT BATHYMETRY MODELLING\E02 WORKING DRAWINGS\PA1163-MA-MACKAYV3.DWG 9/21/2016 12:57 PM

DRAWING No. PA1163/MA/1011 | **DO NOT SCALE**

DETAIL PLAN
1:5000 (A3)

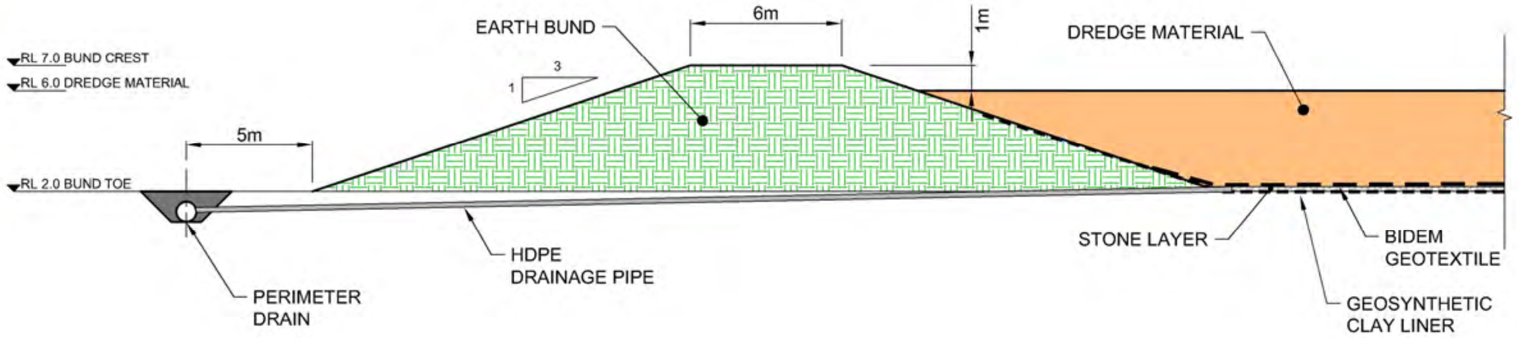
LEGEND

EARTHWORKS:

- CUT
- FILL

NOTES

1. ALL LEVELS ARE SHOWN RELATIVE TO AHD.
2. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.
3. TOPOGRAPHIC CONTOURS PRODUCED FROM LIDAR (2015), PROVIDED BY NQBP.



SECTION A TYPICAL SECTION
1:300 (A3)

AUSTRALIAN HEIGHT DATUM | **NOT FOR CONSTRUCTION**

200 0 200 400 600 800 1000m
1:10000 (A1) 1:20000 (A3)

200 0 200 400 600 800 1000m
1:10000 (A1) 1:20000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT: HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE: MACKAY ONSHORE PONDS DETAIL PLAN AND TYPICAL SECTION

HASKONING AUSTRALIA PTY LTD
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AUTOCAD REF. PA1163–MA–MACKAY

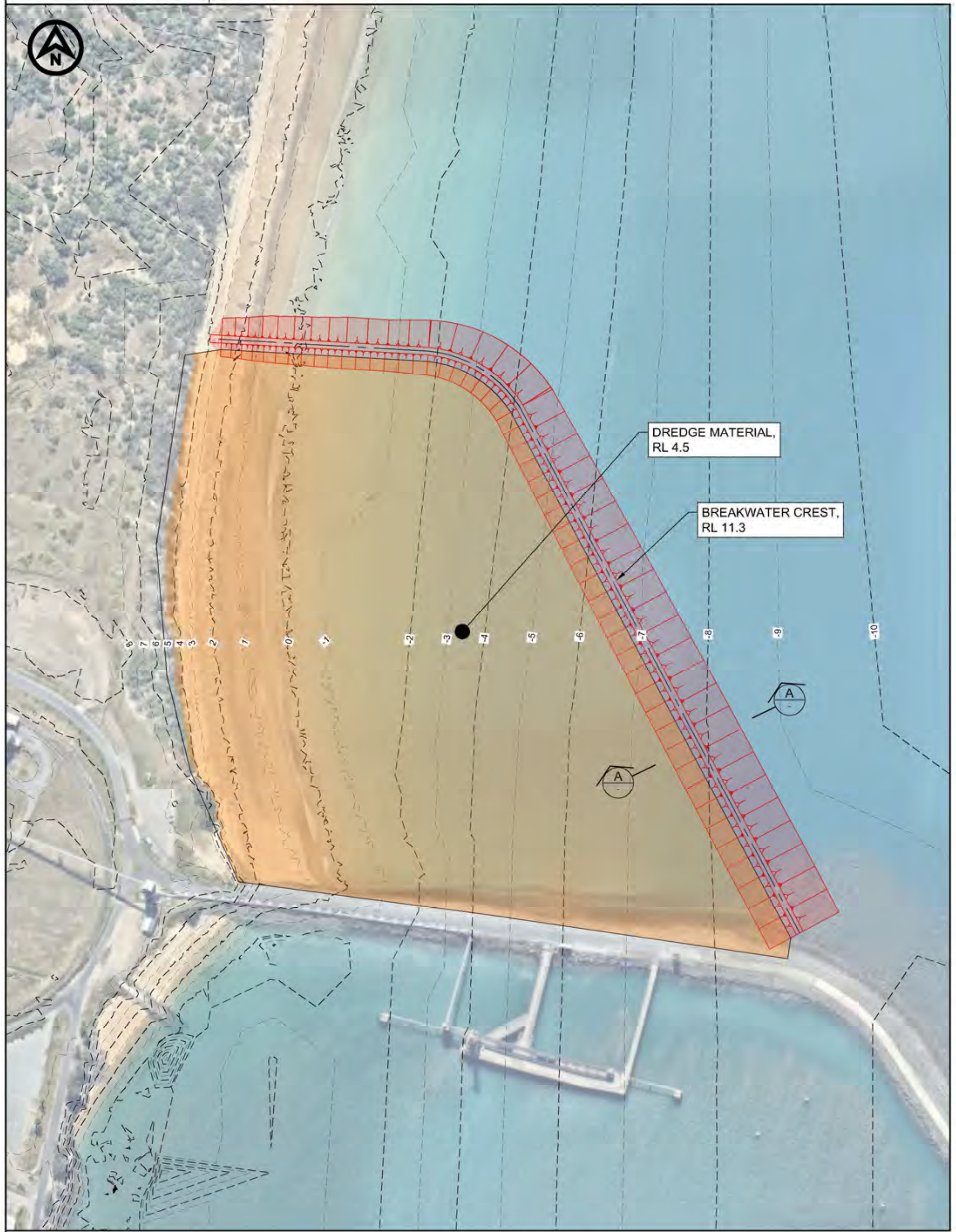
SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/1011 | REVISION A

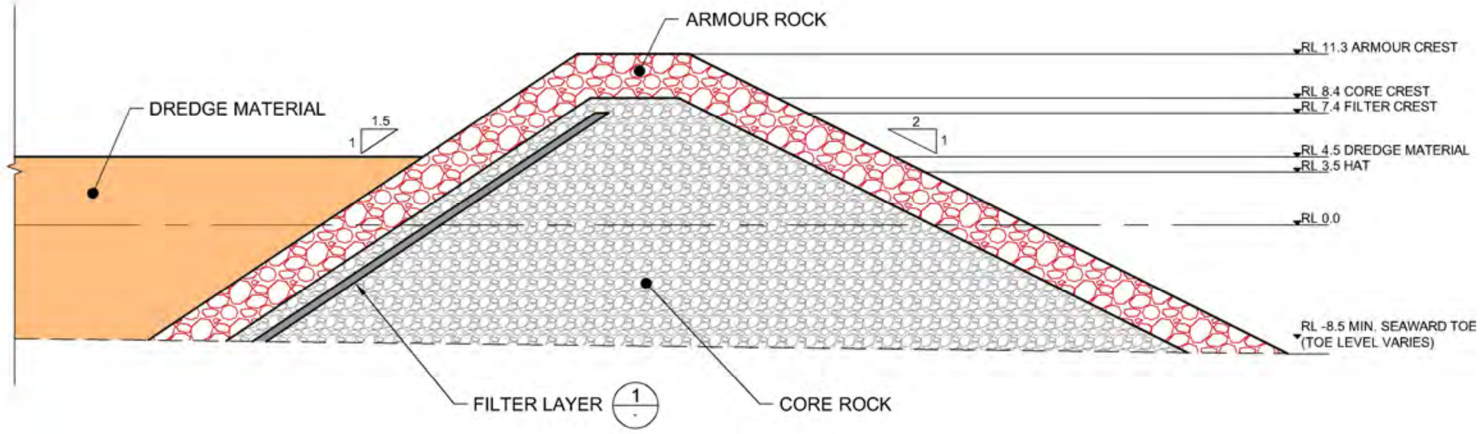
DRAWING No. PA1163/MA/1021 | DO NOT SCALE

NOTES

1. ALL LEVELS ARE SHOWN RELATIVE TO AHD.
2. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.
3. TOPOGRAPHIC CONTOURS PRODUCED FROM LIDAR (2015), PROVIDED BY NQBP.



DETAIL PLAN
1:5000 (A3)



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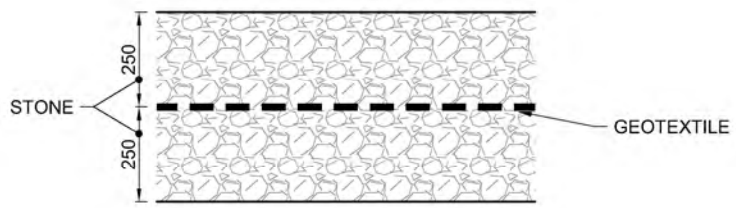
1:500 (A3)



DETAIL 1 FILTER LAYER
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REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT: HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE: MACKAY RECLAMATION DETAIL PLAN AND TYPICAL SECTION

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SYDNEY
Royal HaskoningDHV
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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163
AUTOCAD REF. PA1163-MA-MACKAY
SCALE AT A1 AS SHOWN
DRAWING No. PA1163/MA/1021 | REVISION A

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

50 0 50 100 150 200 250m
1:2500 (A1) 1:5000 (A3)

5 0 5 10 15 20 25m
1:250 (A1) 1:500 (A3)

400 0 400 800 1200 1600 2000mm
1:20 (A1) 1:40 (A3)

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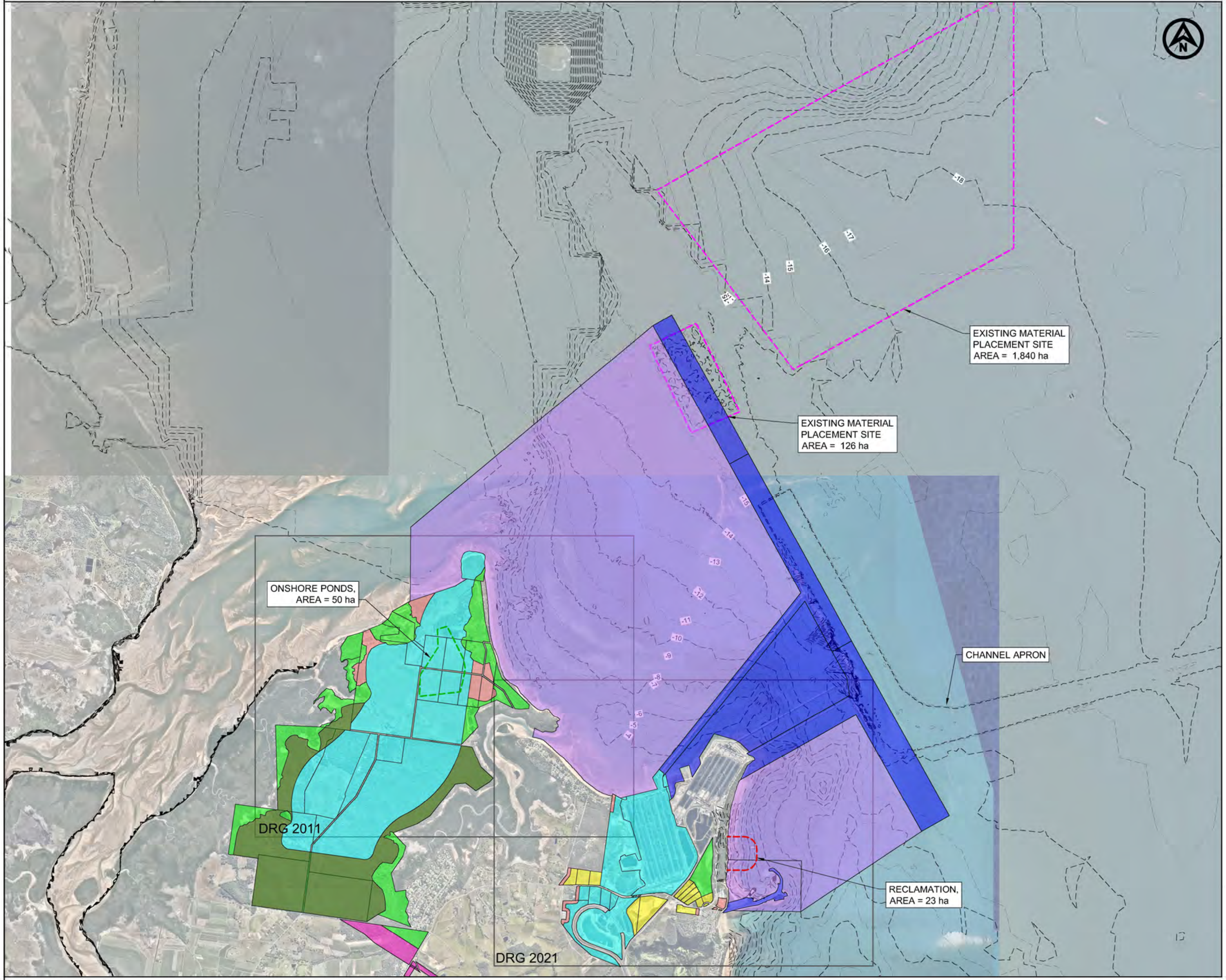
DRAWING No. PA1163/MA/2001 | **DO NOT SCALE**



NOTES

1. ALL LEVELS ARE SHOWN RELATIVE TO AHD.
2. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.
3. BATHYMETRIC CONTOURS PRODUCED FROM COMBINED STATE WIDE BATHYMETRIC DATA.

LEGEND

LAND USE ZONES:

- BUFFER
- ALL ACCESS AND PORT INFRASTRUCTURE
- OFFSHORE PORT INFRASTRUCTURE
- ENVIRONMENTAL PROTECTION
- PORT HANDLING ACTIVITIES
- PORT RELATED AND SUPPORT
- TRANSPORT INFRASTRUCTURE
- WILDLIFE CORRIDOR

PROPOSED:

- ONSHORE PONDS AREA
- RECLAMATION AREA
- OFFSHORE DISPOSAL

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT: HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE: DUDGEON POINT PROPOSED DREDGE DISPOSAL OPTIONS OVERVIEW

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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163

AUTOCAD REF. PA1163-MA-DUDGEONPT

SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/2001 | REVISION A

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

600 0 1,000 2,000 3,000m
1:30,000 (A1) 1:600 (A3)

DRAWING No. PA1163/MA/2011 | **DO NOT SCALE**

NOTES

1. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT:

HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE:

DUDGEON POINT ONSHORE PONDS DEVELOPMENT CONTRAINTS

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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163

AUTOCAD REF. PA1163-MA-DUDGEONPT

SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/2011 | REVISION A

AUSTRALIAN HEIGHT DATUM | **NOT FOR CONSTRUCTION**

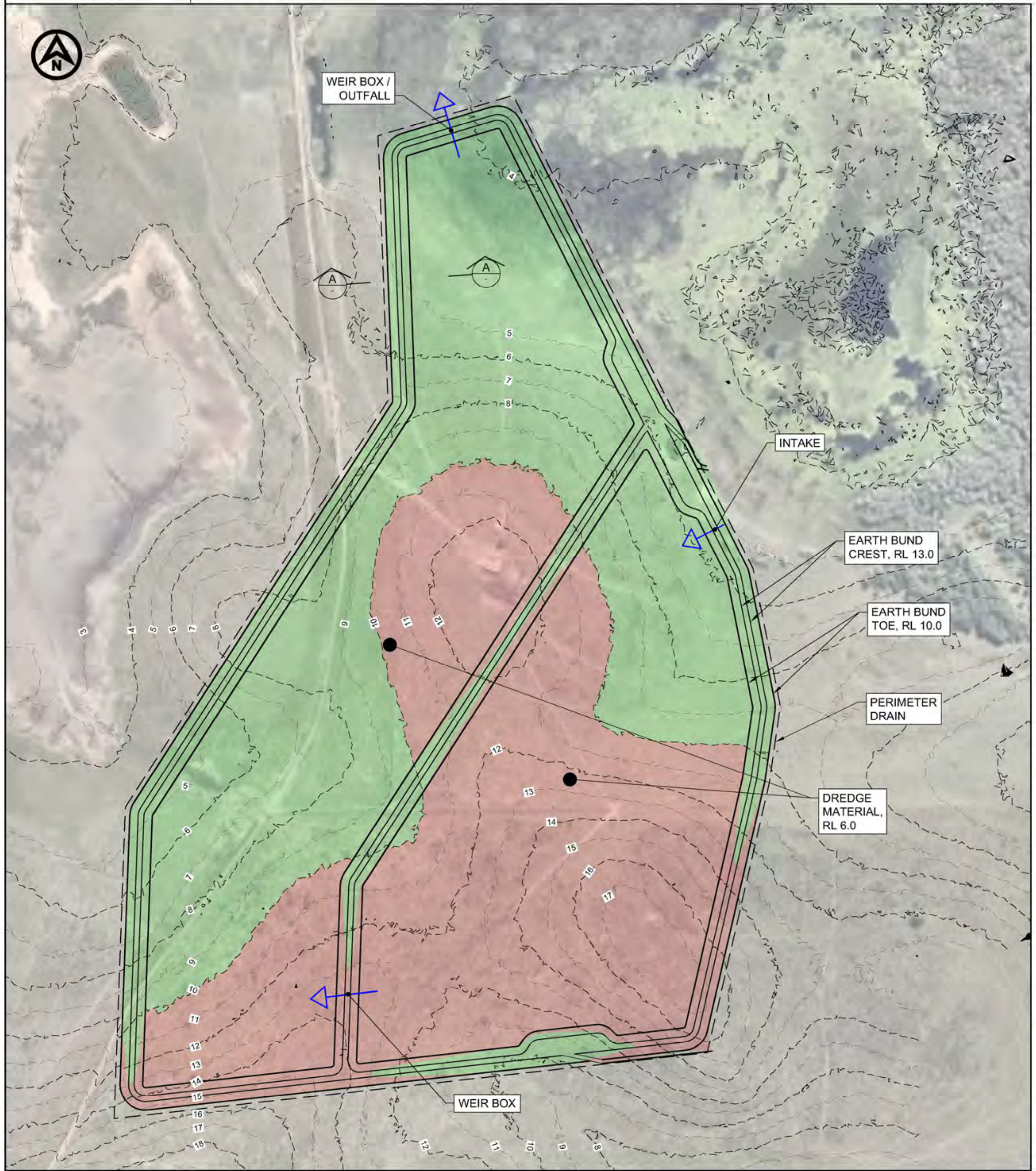
200 0 200 400 600 800 1000m

1:10000 (A1) 1:20000 (A3)

\\HKA-SERVER\PUBL\C\CURRENT JOBS\~PA1163 - HAY POINT BATHYMETRY MODELLING\E02 WORKING DRAWINGS\PA1163-MA-DUDGEONPT.DWG 9/21/2016 12:51 PM

DRAWING No. PA1163/MA/2012

DO NOT SCALE



DETAIL PLAN

1:5000 (A3)

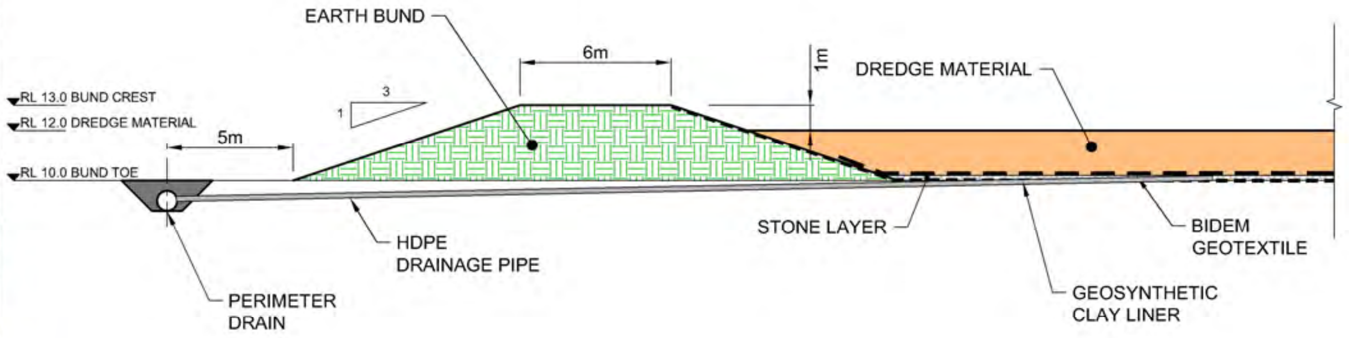
LEGEND

EARTHWORKS:

- CUT
- FILL

NOTES

1. ALL LEVELS ARE SHOWN RELATIVE TO AHD.
2. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.
3. TOPOGRAPHIC CONTOURS PRODUCED FROM LIDAR (2015), PROVIDED BY NQBP.



SECTION A TYPICAL SECTION

1:300 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT: HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE: DUDGEON POINT ONSHORE PONDS

HASKONING AUSTRALIA PTY LTD SYDNEY

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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163

AUTOCAD REF. PA1163-MA-DUDGEONPTV2

SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/2012 | REVISION A

AUSTRALIAN HEIGHT DATUM **NOT FOR CONSTRUCTION**

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3 0 3 6 9 12 15m — 1:150 (A1) 1:300 (A3)

DRAWING No. PA1163/MA/2021 **DO NOT SCALE**

NOTES

1. ALL LEVELS ARE SHOWN RELATIVE TO AHD.
2. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.
3. TOPOGRAPHIC CONTOURS PRODUCED FROM LIDAR (2015), PROVIDED BY NQBP.
4. BATHYMETRIC CONTOURS PRODUCED FROM COMBINED STATE WIDE BATHYMETRIC DATA.

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT: HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE: DUDGEON POINT RECLAMATION OVERVIEW

HASKONING AUSTRALIA PTY LTD SYDNEY

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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163

AUTOCAD REF. PA1163-MA-DUDGEONPT

SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/2021 | REVISION A

AUSTRALIAN HEIGHT DATUM **NOT FOR CONSTRUCTION**

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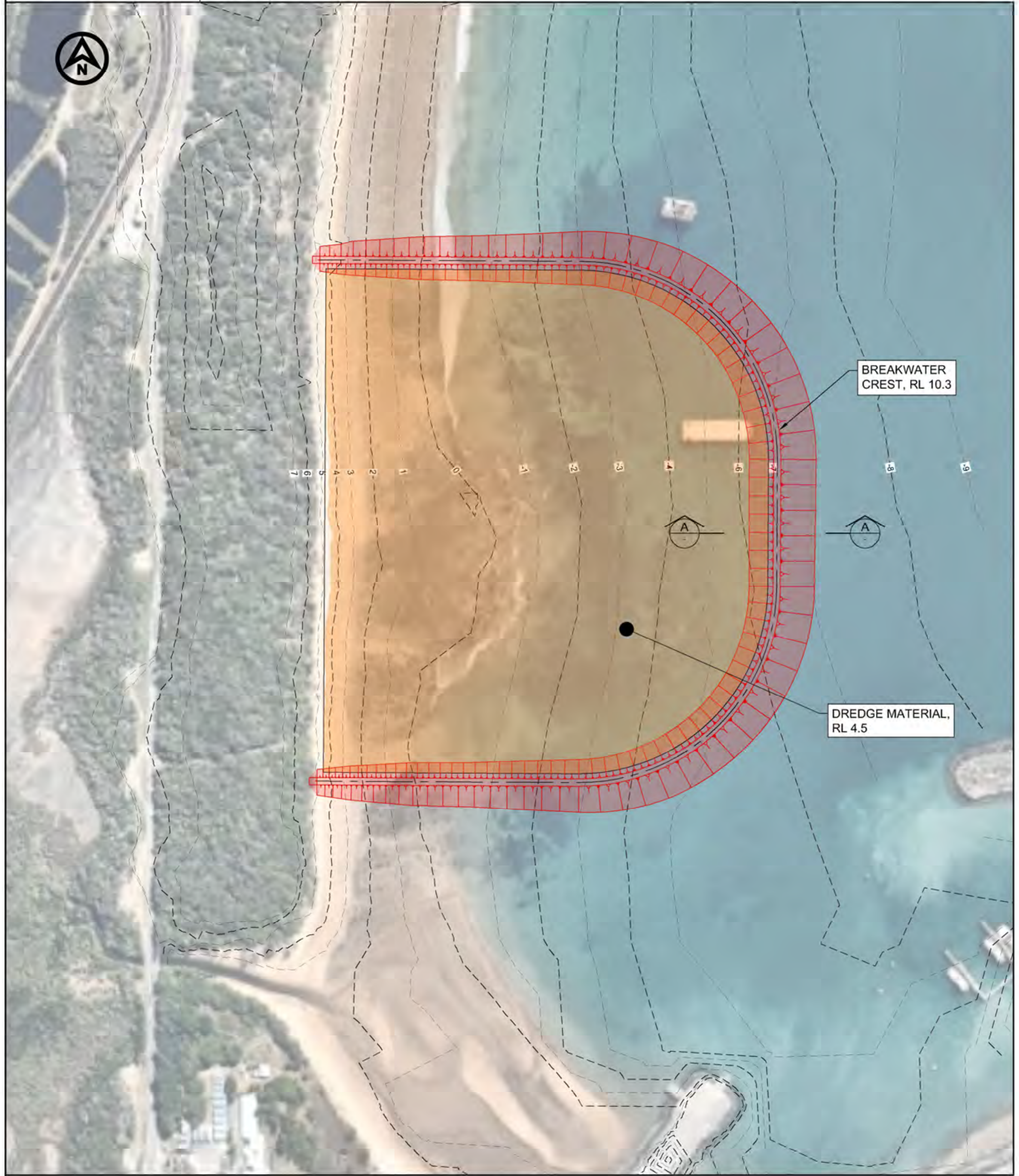
1:10000 (A1) 1:20000 (A3)

DRAWING No. PA1163/MA/2022

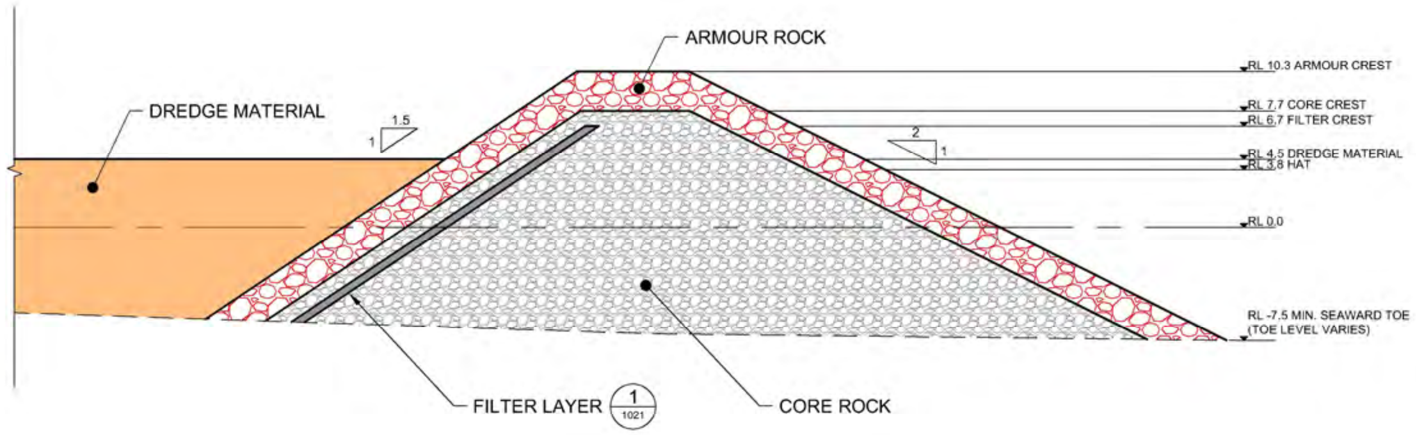
DO NOT SCALE



DETAIL PLAN
1:5000 (A3)

NOTES

1. ALL LEVELS ARE SHOWN RELATIVE TO AHD.
2. AERIAL PHOTOGRAPH SOURCED FROM NEARMAP DATED 09/06/2016.
3. TOPOGRAPHIC CONTOURS PRODUCED FROM LIDAR (2015), PROVIDED BY NQBP.
4. BATHYMETRIC CONTOURS PRODUCED FROM COMBINED STATE WIDE BATHYMETRIC DATA.



SECTION A TYPICAL SECTION
1:500 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	23.09.2016	ISSUED FOR REVIEW	BAM	JC	

REVISIONS

CLIENT: NORTH QUEENSLAND BULK PORTS CORPORATION

PROJECT: HAY POINT DREDGE DISPOSAL OPTIONS

DRAWING TITLE: DUDGEON POINT RECLAMATION DETAIL PLAN AN TYPICAL SECTION

HASKONING AUSTRALIA PTY LTD
SYDNEY

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DRAWN BAM | DATE 21/09/2016 | JOB No. PA1163

AUTOCAD REF. PA1163-MA-DUDGEONPT

SCALE AT A1 AS SHOWN

DRAWING No. PA1163/MA/2022 | REVISION A

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

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1:2500 (A1) 1:5000 (A3)

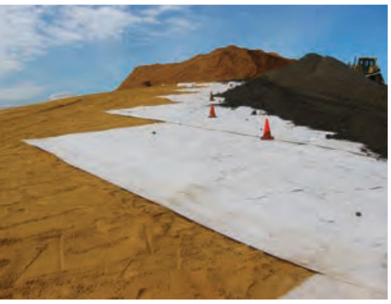
5 0 5 10 15 20 25m
1:250 (A1) 1:500 (A3)

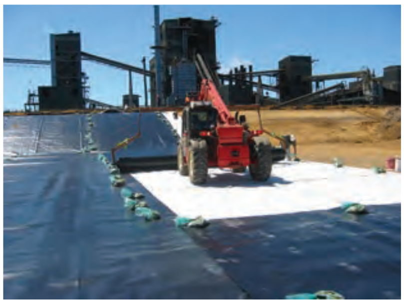
Appendix C GCL and Bidim Details

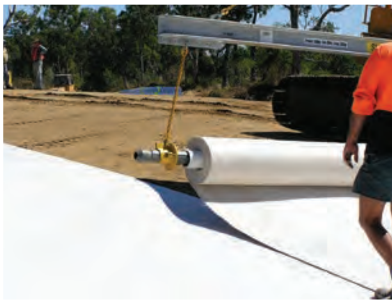
ELCOSEAL®

Geosynthetic Clay Liners

General Brochure







QUALITY - SUPPORT - EXPERTISE

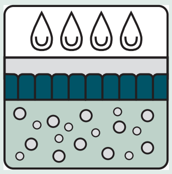
GEOFABRICS®

A Geosynthetic Clay Liner (GCL) is a geosynthetic composite, engineered for environmental containment applications. GCLs consist of a layer of high-quality sodium bentonite powder sandwiched between two or more layers of durable geotextiles, reinforced by needle-punching to improve confinement and internal shear strength.

ELCO**SEAL**® GCLs provide the equivalent hydraulic protection as a one metre thick layer of compacted clay. To ensure the waste being contained is compatible with the lining system, Geofabrics can perform compatibility testing through our Geosynthetic Centre of Excellence.

ELCO**SEAL**® GCLs allow landfills and other waste containment structures (such as tailings dams) to be built faster and more cost effectively when compared to traditional lining systems.

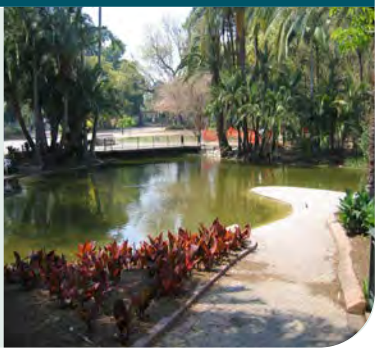
FUNCTIONS

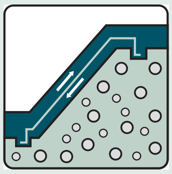


Rapid Sealing

When in contact with water or other liquids, ELCO**SEAL**® GCLs rapidly hydrate to create a containment barrier equivalent to a one metre thick layer of compacted clay.

The rapid sealing performance of the ELCO**SEAL**® GCLs are derived from the increased surface area of the powdered sodium bentonite clay used in the ELCO**SEAL**® GCL.

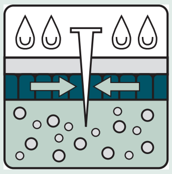




Shear Resistance

To resist the high shear stresses generated by the long, steep slopes within a landfill or tailings dam, ELCO**SEAL**® GCLs use high tenacity polypropylene fibres that are needle punched through the thickness of the GCL.

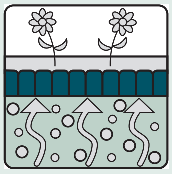
The design of a stable lining system requires consideration of the shearing stresses applied to the ELCO**SEAL**® GCL.



Self Healing

ELCO**SEAL**® GCLs can self-heal around holes, punctures or protrusions. In the ELCO**SEAL**® GCL, the sodium bentonite clay is confined vertically by the thermally locked geotextile layers but can swell laterally around the puncture.

The self-healing nature of ELCO**SEAL**® GCLs is important when considering the leakage from any installation damage.



Gas Containment

ELCO**SEAL**® GCLs are used in conjunction with gas collection systems to prevent the migration of gases from landfills or contaminated sites.

TYPICAL APPLICATIONS

LANDFILLS

The hydraulic sealing performance of the ELCO**SEAL**® GCLs allows it to completely or partially replace the traditional thick layers of compacted clay in landfill liners and caps. The strength of the ELCO**SEAL**® GCLs allows it to resist high shear forces along the steep slopes within landfills.

The ELCO**SEAL**® Manufacturing Quality Assurance program is rigorous, complying with the very high requirements of the Victorian EPA Best Environmental Practice Management guidelines for landfills.

MINING

ELCO**SEAL**® GCLs are widely used in tailing ponds and mine closures or rehabilitation projects. ELCO**SEAL**® GCLs reduce the contaminant transport to assist mining companies achieve environmental compliance for their waste containment structures.

The Geosynthetic Centre of Excellence regularly tests mining waste or liquor for mining companies to ensure compatibility is achieved with the ELCO**SEAL**® GCL lining system, thereby reducing risk for the mine operator and allowing efficient design of the lining system.

SECONDARY CONTAINMENT

The ease of installation and reliable pipe penetration construction process encourage the use of ELCO**SEAL**® GCLs as a secondary containment barrier in above ground impoundments. ELCO**SEAL**® GCLs resist the leakage of hydrocarbons into the surrounding environment should the tank rupture.

PONDS AND DAMS

The low permeability, high internal shear strength and easy installation process enables ELCO**SEAL**® GCLs to provide excellent liquid containment, such as in reservoirs, irrigation canals, as well as ponds and lagoons.

VERTICAL CONTAINMENT

The high mechanical and internal shear strength of the ELCO**SEAL**® GCL allows it to be used as a vertical cut-off barrier, preventing the lateral movement of liquids. A common application is adjacent to irrigation canals.

ADVANTAGES OF ELCOSEAL® GCLs

Reduced Risk	Compared to traditional compacted clay liners, ELCO**SEAL**® GCLs reduce the risk on a landfill or waste containment project through several means, including: • Compatibility testing at the Geosynthetic Centre of Excellence ensuring the site specific liquor or waste will be contained by the lining system. • Strict Manufacturing Quality Assurance provides a higher level of consistency in the lining layer. • Laboratory support is provided for the construction QA process for ELCO**SEAL**® GCLs.
Enhanced Performance and Reliability	ELCO**SEAL**® GCLs have been manufactured in Australia for over 20 years, and used widely around Australia and internationally. The proven performance stems from various manufacturing features, including: • Consistent low permeability performance. • Proven edge sealing techniques. • The powdered bentonite clay allowing instant sealing.
Cost Benefits	ELCO**SEAL**® GCLs offer engineers a number of economic benefits over traditional compacted clay layers or alternative lining systems, including: • Simpler installation processes, reducing the time required to construct a landfill cell or waste containment structure. • Simple overlaps along the edges removes the need for specialist installation crews. • Supply of ELCO**SEAL**® GCL rolls to specific roll lengths allows a single roll to be installed down a slope, reducing the installation time and wastage. • By removing the need for 1m thick compacted clay layers, the ELCO**SEAL**® GCL increases the void spacing within the landfill.

ELCOSEAL® GCL RESEARCH AND DEVELOPMENT

Through our Geosynthetic Centre of Excellence, Geofabrics is committed to pursuing research and development of ELCO**SEAL**® GCLs in various in-situ environments. For information or a tour of the Geosynthetic Centre of Excellence, please contact the Technical Department at the Geosynthetic Centre of Excellence on (07) 5594 8600.

SUPPORTING LITERATURE

Datasheets and Specifications	• ELCO**SEAL**® GCL Technical Data Sheet • ELCO**SEAL**® LX Laminated GCL Technical Data Sheet • Geosynthetic Clay Liner Model Specification
Installation Guidelines	• ELCO**SEAL**® GCL Installation Guidelines • ELCO**SEAL**® LX Laminated GCL Installation Guidelines
OH&S	• ELCO**SEAL**® Material Safety Data Sheets • ELCO**SEAL**® GCL Spreader Bar Safe Usage Guidelines
Technical Notes	• Bentonite Technical Notes - ELCO**SEAL**® GCL Technical Notes
Quality Assurance	• Manufacturers Quality Assurance & Control for ELCO**SEAL**® GCL • ELCO**SEAL**® GCL Construction Quality Assurance Checklist
Other	• ELCO**SEAL**® GCL Project List

AUSTRALIA	**MELBOURNE** (03) 8586 9111	**SYDNEY** (02) 8785 8800	**NEWCASTLE** (02) 4951 2688	**COFFS HARBOUR** (02) 6653 5706	**PERTH** (08) 6305 0561	**ADELAIDE** (08) 8162 5855
	BRISBANE (07) 3279 1588	**TOWNSVILLE** (07) 4774 8222	**BUNDABERG** (07) 4155 9968	**GOLD COAST** (07) 5594 8600	**HOBART** (03) 6273 0511	**DARWIN** 0407 523 669
NEW ZEALAND	**AUCKLAND** (64 9) 634 6495	**HAMILTON** (021) 732 178	**NAPIER** (021) 916 736	**CHRISTCHURCH** (64 3) 349 5600		

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ELCOSEAL®

Geosynthetic Clay Liners

Technical Data Sheet

QUALITY - SUPPORT - EXPERTISE

GEOFABRICS®

Issue Date August 2015

Specifications

ELCOSEAL® Geosynthetic Clay Liners – MARV and Typical Values

ELCOSEAL® is a New Generation Geosynthetic Clay Liner (GCL) made from quality polypropylene geotextiles and premium grade sodium bentonite powder mined in Australia. ELCOSEAL® GCL's are fibre-reinforced by needle-punching the composite across the entire surface area of the product. Unique to this product, the high tenacity fibres are then thermally-locked to ensure high long-term shear strength.

PROPERTY		TEST METHOD	MQC[1] FREQUENCY	UNITS	ELCOSEAL® GRADE			
					X800	X1000	X2000	X3000
GCL Hydraulic Properties								
Hydraulic Conductivity, k	MaxArv[2]	ASTM D5887	40,000m^2	m/s	3.5×10^{-11}	2.8×10^{-11}	3×10^{-11}	2.4×10^{-11}
	Typical[3]				2.5×10^{-11}	1.9×10^{-11}	2.4×10^{-11}	1.7×10^{-11}
Bentonite Characteristics								
Bentonite Particle Size	Typical	Dry Screen	Weekly	% passing 75μm	≥ 75	≥ 75	≥ 75	≥ 75
		AS 1289-3.6.2		% ≤ 0.5μm	≥ 55	≥ 55	≥ 55	≥ 55
Swell Index	Typical	ASTM D5890	40,000m^2	mL/2g	≥ 24	≥ 24	≥ 24	≥ 24
Fluid Loss	Typical	ASTM D5891	40,000m^2	mL	≤ 15	≤ 15	≤ 15	≤ 15
GCL Components - Mass								
Cover Nonwoven Geotextile Mass per Unit Area	MARV[4]	AS 3706.1	10,000m^2	g/m^2	220	240	240	260
	Typical				250	270	270	300
Bentonite Mass per Unit Area @ 0% Moisture Content	MARV	ASTM D5993	2,500m^2	g/m^2	3,700	4,000	3,700	4,250
	Typical				4,100	4,500	4,250	4,700
Carrier / Composite Geotextile Mass per Unit Area	MARV	AS 3706.1	70,000m^2	g/m^2	110	110	350	350
	Typical				110	110	380	380
Geotextile Configuration (Carrier / Cover)					W / NW[5]	W / NW	W+NW / NW	W+NW / NW
GCL - Mass								
GCL Total Mass per Unit Area @ 0% Moisture Content	MARV	ASTM D5993	2,500m^2	g/m^2	3,930	4,350	4,290	4,860
	Typical				4,460	4,880	4,900	5,380
GCL - Strength Properties								
Strip Tensile Strength (MD)[6]	MARV	ASTM D6768	10,000m^2	kN/m	7	8	12	12
	Typical				10	11	15	16
CBR Strength	MARV	AS 3706.4	25,000m^2	N	1,400	1,600	3,900	4,100
	Typical				2,000	2,100	4,900	5,300
CBR Elongation	MARV	AS 3706.4	25,000m^2	%	10	15	30	30
	Typical				30	40	80	80
GCL - Shear Strength Properties								
Hydrated Peak Internal Shear Strength @ 10kPa Normal Stress	Typical[7]	ASTM D6243	Periodic	kPa	30	30	35	40
Hydrated Peak Internal Shear Strength @ 30kPa Normal Stress	Typical	ASTM D6243	Periodic	kPa	50	50	60	70
GCL Longitudinal Edge Treatment								
Bentonite Impregnation - Width ≥ 300mm - Typical				-	√	√	√	√
Edge Sealing Performance	Typical	ASTM STP 1308 (Mod.)[10,11]	Periodic	m/s	2.5×10^{-11}	1.9×10^{-11}	2.4×10^{-11}	1.7×10^{-11}
GCL Roll Dimensions								
Standard Roll Dimensions (Width x Length)				m	4.7 x 45	4.7 x 35	4.7 x 30	4.7 x 30
Typical Roll Mass (standard roll length). **Note:** Longer custom roll lengths are available to suit project requirements.			(Weighed every roll)	kg	1,395	1,050	960	950
GCL Spreader Bar Requirement				-	Heavy-Duty[8]	Heavy-Duty[8]	Standard[9]	Standard[9]

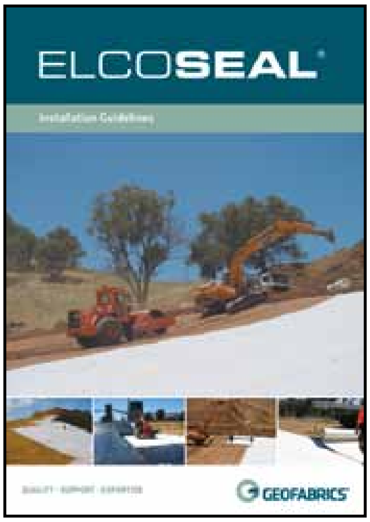
NOTES

1. **MQC** = Manufacturing Quality Control – an ongoing system that monitors and tests materials during manufacture to ensure compliance with certification documents and contract specifications.
2. **MaxARV** = Maximum Average Roll Value – a MaxARV is defined as the Mean or Typical values plus 2 standard deviations. Mathematically, it is implied that 97.5% of the results of the tested specimens will be less than the MaxARV. A MaxARV provides a confidence level of 97.5%. **NOTE** – in reference to GCL Permeability, **LOWER IS BETTER**.
3. **Typical** = A typical value is the arithmetic mean of a set of results. This implies that 50% of the tested specimens will typically exceed this value and 50% will typically not meet this value.
4. **MARV** = Minimum Average Roll Value – a MARV is defined as the Mean or Typical values less 2 standard deviations. Mathematically, it is implied that 97.5% of the results of the tested specimens will exceed the MARV. A MARV provides a confidence level of 97.5%.
5. **W**= Woven, **NW**= Nonwoven.
6. **MD** = Roll Machine Direction.
7. **Peak Value** reported at 10kPa or 30kPa normal stress. [The reported values are not intended to replace site specific internal shear or interface friction testing required for design].
8. **Heavy-Duty WLL** (Working Load Limit) = 1,400kg.
9. **Standard WLL** (Working Load Limit) = 1,000kg.
10. **Reference** - Daniel, D.E. Trautwein, S.J. and Goswami, P.K. 1997. Measurement of Hydraulic Properties of Geosynthetic Clay Liners Using a Flow Box, Testing and Acceptance Criteria for Geosynthetic Clay Liners, ASTM STP 1308, p. 196-207.
11. **Modification Reference** - Kendall, P.M., Austin, R. A. 2014. Investigation of GCL Overlap Techniques Using a Large Scale Flow Box, 7th International Congress on Environmental Geotechnics, 3B-3, p. 746-753.

OTHER LITERATURE AND TECHNICAL INFORMATION AVAILABLE

Literature can be sourced from the Geofabrics website or by contacting your nearest branch

General Information

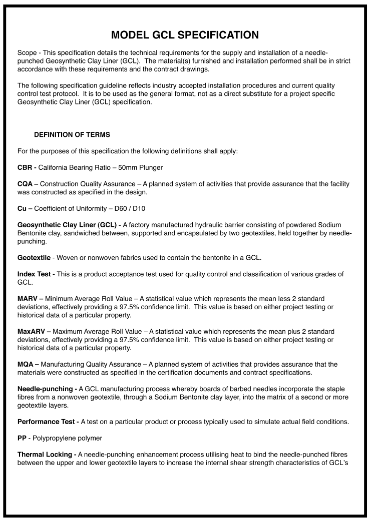


ELCOSEAL®
Installation Guidelines

Manufacturers Quality
Assurance & Control Manual

GCL Technical Notes

Bentonite Technical Notes



MODEL GCL SPECIFICATION

Scope - This specification details the technical requirements for the supply and installation of a needle-punched Geosynthetic Clay Liner (GCL). The material(s) furnished and installation performed shall be in strict accordance with these requirements and the contract drawings.

The following specification guideline reflects industry accepted installation procedures and current quality control test protocol. It is to be used as the general format, not as a direct substitute for a project specific Geosynthetic Clay Liner (GCL) specification.

DEFINITION OF TERMS

For the purposes of this specification the following definitions shall apply:

CBR - California Bearing Ratio – 50mm Plunger

CQA – Construction Quality Assurance – A planned system of activities that provide assurance that the facility was constructed as specified in the design.

Cu – Coefficient of Uniformity – D60 / D10

Geosynthetic Clay Liner (GCL) - A factory manufactured hydraulic barrier consisting of powdered Sodium Bentonite clay, sandwiched between, supported and encapsulated by two geotextiles, held together by needle-punching.

Geotextile - Woven or nonwoven fabrics used to contain the bentonite in a GCL.

Index Test - This is a product acceptance test used for quality control and classification of various grades of GCL.

MARV – Minimum Average Roll Value – A statistical value which represents the mean less 2 standard deviations, effectively providing a 97.5% confidence limit. This value is based on either project testing or historical data of a particular property.

MaxARV – Maximum Average Roll Value – A statistical value which represents the mean plus 2 standard deviations, effectively providing a 97.5% confidence limit. This value is based on either project testing or historical data of a particular property.

MQA – Manufacturing Quality Assurance – A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications.

Needle-punching - A GCL manufacturing process whereby boards of barbed needles incorporate the staple fibres from a nonwoven geotextile, through a Sodium Bentonite clay layer, into the matrix of a second or more geotextile layers.

Performance Test - A test on a particular product or process typically used to simulate actual field conditions.

PP - Polypropylene polymer

Thermal Locking - A needle-punching enhancement process utilising heat to bind the needle-punched fibres between the upper and lower geotextile layers to increase the internal shear strength characteristics of GCL's

GCL Model Specification

AUSTRALIA	**MELBOURNE** (03) 8586 9111	**SYDNEY** (02) 8785 8800	**NEWCASTLE** (02) 4951 2688	**COFFS HARBOUR** (02) 6653 5706	**PERTH** (08) 6305 0561	**ADELAIDE** (08) 8162 5855
	BRISBANE (07) 3279 1588	**TOWNSVILLE** (07) 4774 8222	**BUNDABERG** (07) 4155 9968	**GOLD COAST** (07) 5594 8600	**HOBART** (03) 6273 0511	**DARWIN** 0407 523 669
NEW ZEALAND	**AUCKLAND** (64 9) 634 6495	**HAMILTON** (021) 732 178	**NAPIER** (021) 916 736	**CHRISTCHURCH** (64 3) 349 5600		

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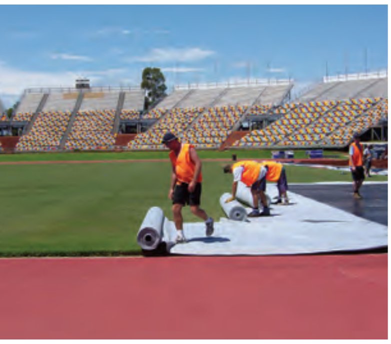
Nonwoven Geotextiles

Technical Data Sheet



QUALITY - SUPPORT - EXPERTISE

GEOFABRICS®

Issue Date: April 2016

Specifications

bidim® Nonwoven Geotextiles – MARV & Typical Values

All **bidim**® "A" range nonwoven, needle punched geotextiles are made in Australia.

bidim® geotextiles are manufactured in accordance to ISO 9001:2008, Cert No: QEC1773.

	Test	Standard	Units		A14	A24	A34	A44	A64	A74	A84
Mechanical Properties	**Wide Strip Tensile Strength** (MD/XMD)	AS 3706.2	kN/m	MARV Typical	9.0/9.0 11.0/11.0	14.0/14.0 16.0/16.0	18.5/18.5 21.5/21.0	26.5/26.5 30.0/30.0	37.5/37.5 42.0/42.0	43.5/43.5 46.5/46.5	52.0/52.0 58.0/58.0
	Wide Strip Toughness (MD/XMD)	AS 3706.2	kJ/m²	MARV Typical	1.6/2.0 2.5/3.1	2.7/3.1 4.1/4.5	3.5/3.8 5.2/5.7	4.8/5.5 7.6/8.1	8.2/8.2 12.3/12.6	8.6/8.7 14.6/15.8	14.2/13.1 20.2/19.8
	Grab Tensile Strength (MD/XMD)	AS 3706.2	N	MARV Typical	600/600 720/720	850/850 1,130/1,060	1,270/1,210 1,430/1,400	1,850/1,850 2,100/2,100	2,620/2,620 3,010/3,010	3,010/3,010 3,370/3,370	4,000/4,000 4,450/4,450
	Trapezoidal Tear Strength (MD/XMD)	AS 3706.3	N	MARV Typical	240/240 300/300	345/345 400/400	440/440 540/540	590/590 750/750	830/830 1,030/1,030	1,065/1,065 1,175/1,175	1,200/1,200 1,425/1,425
	CBR Burst Strength	AS 3706.4	N	MARV Typical	1,750 2,000	2,500 2,800	3,400 3,700	4,650 5,000	6,400 6,950	7,300 7,900	9,000 9,600
	G Rating	Austroads	-	MARV Typical	1,300 1,550	1,900 2,200	2,510 2,800	3,500 4,000	5,100 5,600	5,550 6,150	7,600 8,500
	(MD) = Machine Direction Strength (XMD) = Cross Machine Direction										
Hydraulic Properties	**Pore Size (O_{95})**	AS 3706.7	μm	Typical	110	80	75	75	75	75	75
	Permittivity	AS 3706.9	s^{-1}	Typical	3.20	1.80	1.65	1.2	0.90	0.60	0.55
	Coefficient of Permeability	AS 3706.9	m/s x 10^{-4}	Typical	43	43	43	43	43	43	43
	Flow Rate @ 100mm Head	AS 3706.9	l/m²/s	Typical	320	180	165	120	90	60	55

The data and specifications contained in this table are obtained from the manufacturer's laboratory testing. To ensure this information is current please contact your local branch of Geofabrics Australasia.
Please note: The Grab Tensile Strength test standard AS 3706.2 is equivalent to AS 2001.2.3b.

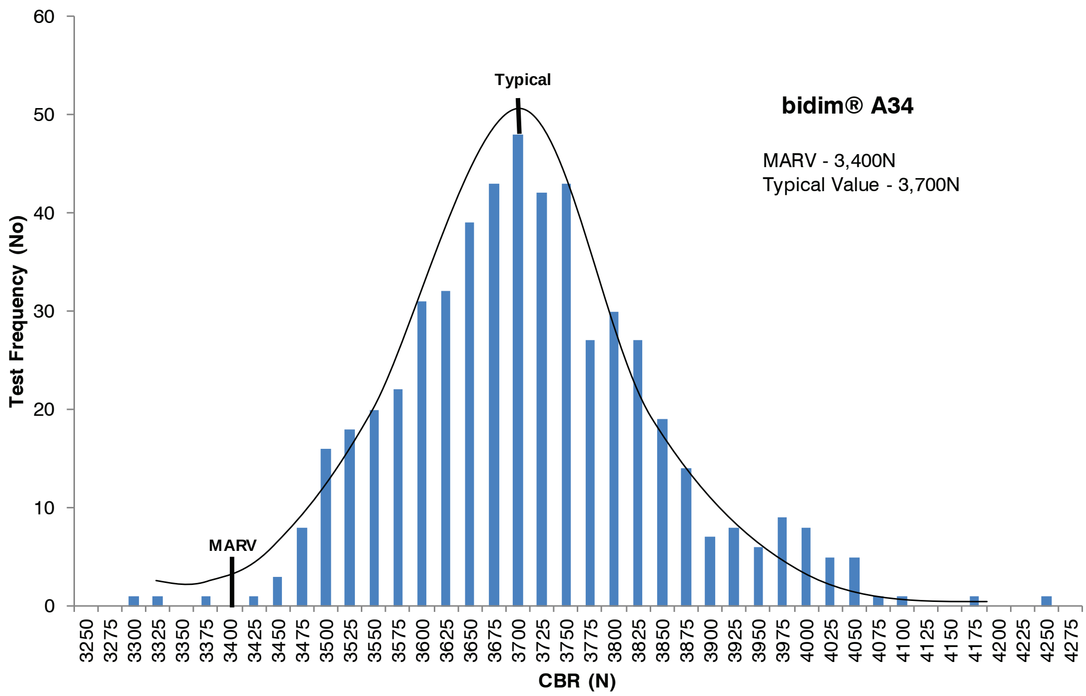
The product properties listed on this sheet include both Minimum Average Roll Values (MARV) and Typical for machine and cross machine directions (MD/XMD).
Definitions of these terms are included on the reverse side of this data sheet. All testing has been carried out by a NATA accredited laboratory and copies of test certificates are available on request.

Definition of Terms

ISO Accreditation	ISO9001 is a manufacturing quality assurance system under which **bidim**® is manufactured. Please refer to the **bidim**® Quality Assurance & Control Manual for testing frequencies. **Note:** not all manufacturers test to the same frequency.
Machine Direction (MD)	The direction in a machine-made fabric, parallel to the direction of motion of the material through the processing machine (i.e. along the length of the roll).
Cross Machine Direction (XMD)	The direction in a machine made fabric, perpendicular to the direction of motion of the material through the processing machine (i.e. across the width of the roll).
Typical Value	A typical value is the arithmetic mean of a set of results (refer to diagram below). This implies that 50% of the tested specimens will typically exceed this value and 50% will typically not meet this value.
Minimum Average Roll Value (MARV)	MARV is a statistical derivation for any distribution of data. It is defined as the mean or typical value less 2 standard deviations (refer to diagram below). Mathematically it is implied that 97.5% of the tested specimens will exceed the MARV.

Indicative Results Spread

(for a given test method for a given period of time)



AUSTRALIA	**MELBOURNE** (03) 8586 9111	**SYDNEY** (02) 8785 8800	**NEWCASTLE** (02) 4951 2688	**COFFS HARBOUR** (02) 6653 5706	**PERTH** (08) 6305 0561	**ADELAIDE** (08) 8162 5855
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Appendix D Cost Estimates

PORT OF HAY POINT 21 September 2016
ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross
COST ESTIMATE

SITE: DUDGEON POINT

ITEM	DESCRIPTION	UNIT	QTY	RATE		AMOUNT	
1	**Site Preparation**						
1.1	Clear bush and grub up roots	ha	50	$	2,000	$	100,000
2	**Earthworks & Bund Formation**						
2.1	Excavate to reduce levels and deposit, spread and level within 1km; including compaction to 90%	m^3	813,900	$	9.5	$	7,732,050
2.2	Bund formation using stockpiled material	m^2	200,000	$	12.5	$	2,500,000
2.3	Trench excavation (300mm x 300mm)	m	5,000	$	6	$	30,000
2.4	Install HDPE pipeline (200mm diam.)	m	5,000	$	60	$	300,000
2.5	Backfill with clean sand	cum	300	$	60	$	18,000
3	**Weir Boxes**						
3.1	Install weir boxes	LS	2	$	50,000	$	100,000
4	**Geotextiles**						
4.1	GCL (X800); delivered & install	m^2	200,000	$	9	$	1,800,000
4.2	GCL (X2000); delivered & install	m^2	100,000	$	13	$	1,300,000
4.3	BIDIM (A34); delivered & install	m^2	200,000	$	5	$	1,000,000
5	**Perimeter Drainage**						
5.1	Trench excavation (1000mm x 1000mm)	m	3,000	$	40	$	120,000
5.2	Install HDPE pipeline (800mm diam)	m	3,000	$	300	$	900,000
5.3	Backfill with clean sand	cum	3,000	$	60	$	180,000
5.4	Miscellaneous (Bends, junctions, manholes, etc.)	LS	0.2	$	900,000	$	180,000
6	**Miscellaneous**						
6.1	Concrete collars for drainage, etc.	LS	1	$	200,000	$	200,000
Sub-Total 1						$	16,460,050
	P&Gs			30%		$	4,938,015
	Contingencies			20%		$	4,279,613
TOTAL						**$**	**25,700,000**

PORT OF HAY POINT 21 September 2016
ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross
COST ESTIMATE

SITE: MACKAY ONSHORE

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**Site Preparation**				
1.1	Clear bush and grub up roots	ha	30	$ 2,000	$ 60,000
2	**Earthworks & Bund Formation**				
2.1	Excavate to reduce levels and deposit, spread and level within 1km; including compaction to 90%	m^3	221,000	$ 9.5	$ 2,099,500
2.2	Bund formation using stockpiled material	m^2	200,000	$ 12.5	$ 2,500,000
2.3	Trench excavation (300mm x 300mm)	m	5,000	$ 6	$ 30,000
2.4	Install HDPE pipeline (200mm diam.)	m	5,000	$ 60	$ 300,000
2.5	Backfill with clean sand	cum	300	$ 60	$ 18,000
3	**Weir Boxes**				
3.1	Install weir boxes	LS	2	$ 50,000	$ 100,000
4	**Geotextiles**				
4.1	GCL (X800); delivered to site	m^2	192,500	$ 9	$ 1,732,500
4.2	GCL (X2000); delivered to site	m^2	56,925	$ 13	$ 740,025
4.3	BIDIM (A34); delivered to site	m^2	192,500	$ 5	$ 962,500
5	**Perimeter Drainage**				
5.1	Trench excavation (1000mm x 1000mm)	m	2,000	$ 40	$ 80,000
5.2	Install HDPE pipeline (800mm diam)	m	2,000	$ 300	$ 600,000
5.3	Backfill with clean sand	cum	2,000	$ 60	$ 120,000
5.4	Miscellaneous (Bends, junctions, manholes, etc.)	LS	0.2	$ 600,000	$ 120,000
6	**Miscellaneous**				
6.1	Concrete collars for drainage, etc.	LS	1	$ 200,000	$ 200,000
Sub-Total 1					$ 9,662,525
	P&Gs			30%	$ 2,898,758
	Contingencies			20%	$ 2,512,257
TOTAL					**$ 15,100,000**

PORT OF HAY POINT 21 September 2016
ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross
COST ESTIMATE

SITE: HALF TIDE BAY
QUARRY: 80km AWAY

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**Breakwater Construction**				
1.1	Supply core rock	t	163,636	$ 45	$ 7,363,636
1.2	Deliver core rock and end tip	t	163,636	$ 35	$ 5,727,273
1.3	Profiling of core rock	t	163,636	$ 15	$ 2,454,545
1.4	Supply armour rock	t	90,000	$ 80	$ 7,200,000
1.5	Deliver armour rock and end tip	t	90,000	$ 35	$ 3,150,000
1.6	Profiling of armour rock	t	90,000	$ 15	$ 1,350,000
2	**Geotextiles**				
2.1	GCL (X800); deliver & install	m^2	16,125	$ 11	$ 177,375
Sub-Total 1					$ 27,422,830
	P&Gs			30%	$ 8,226,849
	Contingencies			20%	$ 7,129,936
TOTAL					**$ 42,800,000**

PORT OF HAY POINT 21 September 2016

ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross

COST ESTIMATE

SITE: HALF TIDE BAY

QUARRY: 50km AWAY

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**Breakwater Construction**				
1.1	Supply core rock	t	163,636	$ 45	$ 7,363,636
1.2	Deliver core rock and end tip	t	163,636	$ 30	$ 4,909,091
1.3	Profiling of core rock	t	163,636	$ 15	$ 2,454,545
1.4	Supply armour rock	t	90,000	$ 80	$ 7,200,000
1.5	Deliver armour rock and end tip	t	90,000	$ 30	$ 2,700,000
1.6	Profiling of armour rock	t	90,000	$ 15	$ 1,350,000
2	**Geotextiles**				
2.1	GCL (X800); deliver & install	m^2	16,125	$ 11	$ 177,375
Sub-Total 1					$ 26,154,648
	P&Gs			30%	$ 7,846,394
	Contingencies			20%	$ 6,800,208
TOTAL					**$ 40,800,000**

PORT OF HAY POINT 21 September 2016

ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross

COST ESTIMATE

SITE: MACKAY RECLAMATION

QUARRY: 5km AWAY

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**Breakwater Construction**				
1.1	Supply core rock	t	122,727	$ 45	$ 5,522,727
1.2	Deliver core rock and end tip	t	122,727	$ 20	$ 2,454,545
1.3	Profiling of core rock	t	122,727	$ 15	$ 1,840,909
1.4	Supply armour rock	t	67,500	$ 80	$ 5,400,000
1.5	Deliver armour rock and end tip	t	67,500	$ 20	$ 1,350,000
1.6	Profiling of armour rock	t	67,500	$ 15	$ 1,012,500
2	**Geotextiles**				
2.1	GCL (X800); delivered & install	m^2	16,125	$ 11	$ 177,375
Sub-Total 1					$ 17,758,057
	P&Gs			30%	$ 5,327,417
	Contingencies			20%	$ 4,617,095
TOTAL					**$ 27,700,000**

PORT OF HAY POINT 21 September 2016

ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross

COST ESTIMATE

SITE: MACKAY RECLAMATION

QUARRY: 20km AWAY

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**Breakwater Construction**				
1.1	Supply core rock	t	122,727	$ 45	$ 5,522,727
1.2	Deliver core rock and end tip	t	122,727	$ 25	$ 3,068,182
1.3	Profiling of core rock	t	122,727	$ 15	$ 1,840,909
1.4	Supply armour rock	t	67,500	$ 80	$ 5,400,000
1.5	Deliver armour rock and end tip	t	67,500	$ 25	$ 1,687,500
1.6	Profiling of armour rock	t	67,500	$ 15	$ 1,012,500
2	**Geotextiles**				
2.1	GCL (X800); delivered & install	m^2	16,125	$ 11	$ 177,375
Sub-Total 1					$ 18,709,193
	P&Gs			30%	$ 5,612,758
	Contingencies			20%	$ 4,864,390
TOTAL					**$ 29,200,000**

PORT OF HAY POINT 21 September 2016
ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross
COST ESTIMATE

SITE: MACKAY ONSHORE
FUTURE USE: REMOVE DREDGE MATERIAL

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**Site Preparation**				
1.1	Clear bush and grub up roots	ha	0	$ 2,000	$ -
2	**Earthworks & Bund Formation**				
2.1	Excavate to reduce levels and deposit, spread and level within 1km; including compaction to 90%	m^3	300,000	$ 9.5	$ 2,850,000
2.2	Bund formation using stockpiled material	m^2	0	$ 12.5	$ -
2.3	Trench excavation (300mm x 300mm)	m	0	$ 6	$ -
2.4	Install HDPE pipeline (200mm diam.)	m	0	$ 60	$ -
2.5	Backfill with clean sand	cum	0	$ 60	$ -
3	**Weir Boxes**				
3.1	Install weir boxes	LS	0	$ 50,000	$ -
4	**Geotextiles**				
4.1	GCL (X800); delivered to site	m^2	0	$ 9	$ -
4.2	GCL (X2000); delivered to site	m^2	0	$ 13	$ -
4.3	BIDIM (A34); delivered to site	m^2	0	$ 5	$ -
5	**Perimeter Drainage**				
5.1	Trench excavation (1000mm x 1000mm)	m	0	$ 40	$ -
5.2	Install HDPE pipeline (800mm diam)	m	0	$ 300	$ -
5.3	Backfill with clean sand	cum	0	$ 60	$ -
5.4	Miscellaneous (Bends, junctions, manholes, etc.)	LS	0.0	$ -	$ -
6	**Miscellaneous**				
6.1	Concrete collars for drainage, etc.	LS	0	$ 200,000	$ -
Sub-Total 1					$ 2,850,000
	P&Gs			30%	$ 855,000
	Contingencies			20%	$ 741,000
TOTAL					**$ 4,400,000**

PORT OF HAY POINT 21 September 2016
ONSHORE POND AND RECLAMATION ENGINEERING DESIGN J. Cross
COST ESTIMATE

SITE: MACKAY ONSHORE
FUTURE USE: RAISE BUND HEIGHTS USING DREDGE MATERIAL

ITEM	DESCRIPTION	UNIT	QTY	RATE		AMOUNT	
1	**Site Preparation**						
1.1	Clear bush and grub up roots	ha	0	$	2,000	$	-
2	**Earthworks & Bund Formation**						
2.1	Excavate to reduce levels and deposit, spread and level within 1km; including compaction to 90%	m^3	150,000	$	9.5	$	1,425,000
2.2	Bund formation using stockpiled material	m^2	150,000	$	12.5	$	1,875,000
2.3	Trench excavation (300mm x 300mm)	m	0	$	6	$	-
2.4	Install HDPE pipeline (200mm diam.)	m	0	$	60	$	-
2.5	Backfill with clean sand	cum	0	$	60	$	-
3	**Weir Boxes**						
3.1	Install weir boxes	LS	1	$	50,000	$	25,000
4	**Geotextiles**						
4.1	GCL (X800); delivered to site	m^2	0	$	9	$	-
4.2	GCL (X2000); delivered to site	m^2	40,000	$	13	$	520,000
4.3	BIDIM (A34); delivered to site	m^2	0	$	5	$	-
5	**Perimeter Drainage**						
5.1	Trench excavation (1000mm x 1000mm)	m	0	$	40	$	-
5.2	Install HDPE pipeline (800mm diam)	m	0	$	300	$	-
5.3	Backfill with clean sand	cum	0	$	60	$	-
5.4	Miscellaneous (Bends, junctions, manholes, etc.)	LS	0.0	$	-	$	-
6	**Miscellaneous**						
6.1	Concrete collars for drainage, etc.	LS	0	$	200,000	$	-
Sub-Total 1						$	3,845,000
	P&Gs			30%		$	1,153,500
	Contingencies			20%		$	999,700
TOTAL						**$**	**6,000,000**

PORT OF HAY POINT 23-Sep-16
ONSHORE POND AND RECLAMATION ENGINEERING DESIGN
DREDGING COST ESTIMATE

			OPTION: HTTH RECLAMATION					
Area	Volume m^3 (as at 2015)	Min No. hopper fills	Total time filling hopper (hrs)	Total time steaming to RA (hrs)	Total time disposing (hrs)	Total time steaming back to dredge area (hrs)	Total time (days)	Estimated Cost
DBCT Berths	139,800	93	117	23	186	19	16	$1,680,081
HPCT Berths	6,700	4	6	1	9	1	1	$80,519
Northern Apron	19,800	13	17	3	26	3	2	$237,951
Apron	28,900	19	24	5	39	4	3	$347,313
Departure Path	10,600	7	9	2	14	1	1	$127,388
	205,800	**137**	**172**	**34**	**274**	**29**	**24**	**$2,623,252**
								**includes mobilsation cost*

			OPTION: PORT OF MACKAY RECLAMATION					
Area	Volume m^3 (as at 2015)	Min No. hopper fills	Total time filling hopper (hrs)	Total time steaming to RA (hrs)	Total time disposing (hrs)	Total time steaming back to dredge area (hrs)	Total time (days)	Estimated Cost
DBCT Berths	139,800	93	117	93	186	78	22	$2,303,032
HPCT Berths	6,700	4	6	4	9	4	1	$110,374
Northern Apron	19,800	13	17	13	26	11	3	$326,181
Apron	28,900	19	24	19	39	16	5	$476,092
Departure Path	10,600	7	9	7	14	6	2	$174,622
	205,800	**137**	**172**	**137**	**274**	**114**	**32**	**$3,540,301**
								**includes mobilsation cost*

			OPTION: DUDGEON POINT ONSHORE					
Area	Volume m^3 (as at 2015)	Min No. hopper fills	Total time filling hopper (hrs)	Total time steaming to RA (hrs)	Total time disposing (hrs)	Total time steaming back to dredge area (hrs)	Total time (days)	Estimated Cost
DBCT Berths	139,800	93	117	23	186	19	16	$1,680,081
HPCT Berths	6,700	4	6	1	9	1	1	$80,519
Northern Apron	19,800	13	17	3	26	3	2	$237,951
Apron	28,900	19	24	5	39	4	3	$347,313
Departure Path	10,600	7	9	2	14	1	1	$127,388
	205,800	**137**	**172**	**34**	**274**	**29**	**24**	**$2,623,252**
								**includes mobilsation cost*

			OPTION: MACKAY ONSHORE					
Area	Volume m^3 (as at 2015)	Min No. hopper fills	Total time filling hopper (hrs)	Total time steaming to RA (hrs)	Total time disposing (hrs)	Total time steaming back to dredge area (hrs)	Total time (days)	Estimated Cost
DBCT Berths	139,800	93	117	93	186	78	22	$2,303,032
HPCT Berths	6,700	4	6	4	9	4	1	$110,374
Northern Apron	19,800	13	17	13	26	11	3	$326,181
Apron	28,900	19	24	19	39	16	5	$476,092
Departure Path	10,600	7	9	7	14	6	2	$174,622
	205,800	**137**	**172**	**137**	**274**	**114**	**32**	**$3,540,301**
								**includes mobilsation cost*

PORT OF HAY POINT 23-Sep-16

ONSHORE POND AND RECLAMATION ENGINEERING DESIGN

DREDGING COST ESTIMATE: page 2

Assumptions	
Hopper Capacity (m^3)	2900
Hay Point assumed hopper volume (m^3)	1500
Time to fill hopper (hrs)	1.25
Steaming speed to disposal area (kts)	10
Steaming speed to dredge area (kts)	12
Distance to disposal area (nm)	
HTTH Reclamation	2.5
Mackay Harbour Reclamation	10
Dudgeon Point Onshore	2.5
Mackay Onshore	10
Time to empty hopper - bottom dumping (hrs)	0.25
(de)mooring and pipeline (de)connection time (hrs)	1
Pumping ashore (hrs)	1
Total Time to empty hopper - bow pumping (hrs)	2
No. of hours per week	168
Operational downtime	10%
Dredge hours per week (hrs)	151.2
Dredge hours per day (hrs)	21.6
Dredge Cost Mobilisation	$150,000
Dredge Cost Daily Rate	$105,000

Appendix E GHG Emission Assessment

Note / Memo

HaskoningDHV UK Ltd.
Industry & Buildings

To: Andrew Symonds (Royal HaskoningDHV)
From: Joe Parsons & Matthew Hunt (Royal HaskoningDHV)

Date: 26 September 2016
Our reference: I&BN001D01_PB5694/002

Subject: **Pond Reclamation Options, Port of Hay Point: Greenhouse Gas Emissions Assessment**

1 Introduction

North Queensland Bulk Ports Corporation (NQBP) is undertaking a long-term strategic assessment for the ongoing management of marine sediments at the Port of Hay Point. The Port of Hay Point is located on the central east coast of Queensland, approximately 15 kilometres to the south of Mackay. The port comprises of two operational export terminals: the Dalrymple Bay Coal Terminal (DBCT) and the Hay Point Coal Terminal (HPCT).

Methods to reduce siltation at the Port of Hay Point, and an associated Greenhouse Gas (GHG) assessment, were investigated in a previous study by Royal HaskoningDHV[1]. This identified that maintenance dredging is the only feasible option to manage the existing requirement and was also determined to be the lowest GHG emission solution to manage the ongoing siltation at the port.

NQBP have commissioned Royal HaskoningDHV to develop concept designs for reclamation options and onshore ponds to store the existing (approximately 200,000m^3 of in-situ volume) and future marine sediment (estimated to be in the order of 200,000m^3 of in-situ volume every five years) from maintenance dredging at the Port of Hay Point. There are two reclamations and two onshore ponds considered in the study, which are:

- Land reclamations to the north of Mackay Harbour and to the north of Half Tide Tug Harbour (HTTH); and
- Onshore sediment ponds at the Port of Mackay and Dudgeon Point.

As part of the concept designs for the reclamation and onshore pond options, a comparative assessment of GHG emissions emitted from the maintenance dredging (e.g. movement of marine vessels) and associated activities (e.g. consumption of fuel from construction plant and vehicles) for each option was undertaken. In addition, embodied cradle to gate GHGs associated with the construction materials for each marine sediment management option were also included as part of the GHG assessment. These GHG emissions are associated with the production of the construction materials, but do not include transport of the final materials from the factory (gate), to the point of use.

The Port of Hay Point, Port of Mackay and HTTH are displayed in **Figure 1**.

[1] Royal HaskoningDHV (2016); Port of Hay Point: Assessment for Navigational Maintenance. Prepared for North Queensland Bulk Ports Corporation, August 2016.

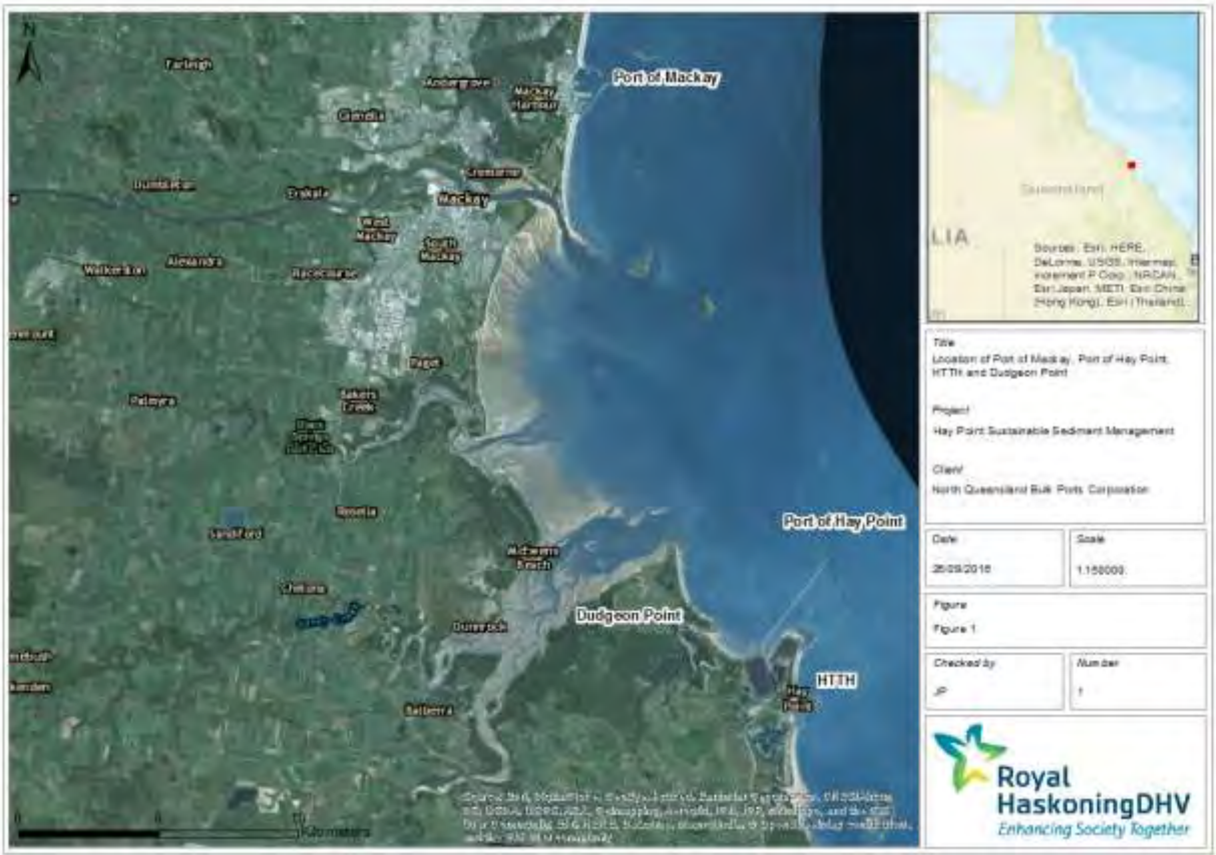

Figure 1: Location of the Port of Hay Point, Port of Mackay and HTTH

2 Legislation

The United Nations Framework Convention on Climate Change (UNFCCC) was ratified by Australia in 1992, and adopted in March 1994. Australia ratified the Kyoto Protocol in March 2008 which commits State Parties to reduce GHGs through a series of emissions targets.

The Australian Government Department of the Environment publishes Australia's National Greenhouse Accounts to meet Australia's commitments adopted under the UNFCCC and tracks progress against their Kyoto Protocol targets. The National Greenhouse Account emissions are estimated using methods provided by the Intergovernmental Panel on Climate Change (IPCC). The Department of the Environment provides country-specific methodologies and emissions factors, which are consistent with the IPCC guidelines.

Australia's total GHG emissions, excluding the land use, land use change and forestry (LULUCF) sector were estimated to be 541.9 million tonnes (Mt) of carbon dioxide equivalent[2] (CO_2e) in 2013. This was a

[2] Expressed by parts per mission by volume (ppmv), the terms carbon dioxide equivalent (CDE) and equivalent carbon dioxide (CO_2e and CO_2eq) are two measures for describing how much global warming a given type and amount of GHG (e.g. methane, nitrous oxide) may cause. A calculation uses the functionally equivalent amount or concentration of CO_2 as the 'reference' and is considered to be more accurate than using only CO_2. These additional GHG emissions have a different global warming potential (GWP) to CO_2, i.e., CH_4 emissions are 25 times the GWP of CO_2 and N_2O emissions 298.

decrease of 7.8Mt, or 1.4% on net emissions from 2012, and an increase of 26.5% (113.6 Mt CO_2e) from 1990 (i.e. base year) levels[3].

3 GHG Assessment Methodology

3.1 Project Boundaries

The boundary for the GHG emissions assessment for the marine sediment management options was determined to include the:

- Mobilisation and demobilisation of the dredger. It was assumed that the dredger would be travelling from Gladstone Port and then onto the Port of Townsville;
- The berths, apron and departure channel of the Port of Hay Point (as defined by the blue outline in **Figure 2**) where maintenance dredging would occur and the locations where the dredger would be pumping material from;
- The areas considered for the reclamation and pond storage areas for each option, including the Mackay, Half Tide Tug Harbour and Dudgeon Point; and
- The assumed network where construction materials would be sourced from as part of the cradle to gate GHG emissions.

The activities considered within the defined geographical boundary are detailed in **Section 3.2**.

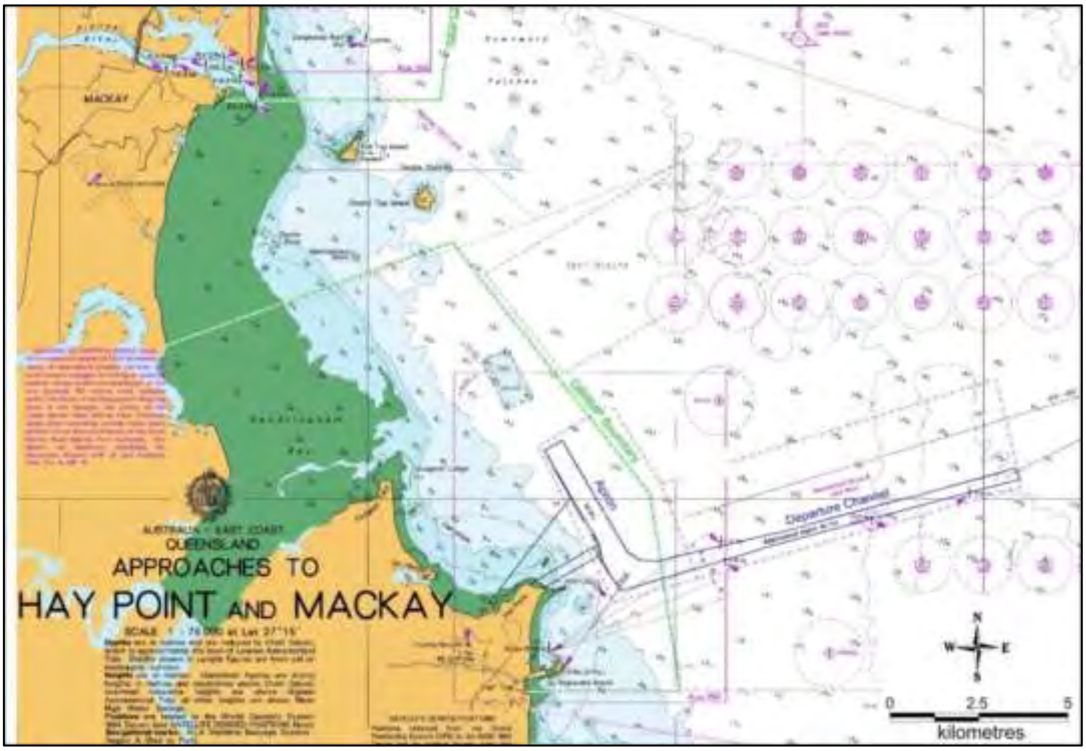

Figure 2: Location of the DBCT and HPCT Berths, Departure Channel and Material Placement Site at the Port of Hay Point. The Dredged Areas are Represented by the Blue Outline.

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[3] Australian Government (2015); Department of the Environment, National Inventory Report, Volume 1, The Australian Government Submission to the United National Framework Convention on Climate Change, Australian National Greenhouse Accounts, May 2015

3.2 The Three Scopes in GHG Emissions Assessment/Footprinting

The GHG emissions assessment was undertaken in accordance with the internationally recognised methodology outlined in the GHG Protocol[4]. The GHG Protocol defines three groups of GHG emissions that arise from an organisation's operational entity:

- **Scope 1 emissions**: "direct" GHG emissions arising from each of the options, such as those associated with fossil fuel consumption by marine vessels and road vehicles;
- **Scope 2 emissions**: account for "indirect" GHG emissions from the production of purchase electricity used by plant and equipment associated with each option; and
- **Scope 3 emissions**: are indirect emissions arising from supporting activities (e.g. business travel by employees, GHG emissions upstream and/or downstream, the activities of sub-contractors and ancillary travel associated with a project) associated with the project options. Scope 3 emissions are voluntary and an organisation can take a decision on the materiality of such activities before deciding to spend effort on calculating them for inclusion in a GHG footprint, or excluding them.

This assessment considered Scope 1 GHG emissions (from fuel combustion associated with the dredger and construction plant) and Scope 3 GHG emissions (embodied cradle-gate emissions from the use of construction materials) from each of the options. The embodied cradle-gate emissions consider GHGs associated with the extraction of raw materials and production of materials.

It has been assumed that Scope 2 emissions associated with the consumption of purchased electricity would be minimal and there would be no material variation in emissions from the base case in each marine sediment management option. Therefore, Scope 2 emissions were not considered in this comparative GHG assessment.

3.3 Four Options for the Proposed Reclamation Areas and Onshore Ponds

Four marine sediment management options to store 200,000m^3 of marine sediments from the required maintenance dredging programme at the Port of Hay Point have been developed. These include two land reclamation areas, at the Port of Mackay and at the HTTH, and two onshore pond sites, on land at the Mackay and at Dudgeon Point.

The maintenance dredging for each option has been assumed to be undertaken by the Trailing Suction Hopper Dredger (TSHD) Brisbane, which currently undertakes the maintenance dredging at ports within Queensland and historically has undertaken dredging at the Port of Hay Point. The TSHD would remove accreted sediment from the berths at the DBCT and HPCT, and the North Apron, then transport to a mooring point where the vessel would connect to a pipeline and the vessel would pump the material to the reclamation or onshore pond.

The following construction plant would be required for the options:

- Bulldozers (D10 - D12);
- Dump Trucks (40 tonnes);
- Excavators (40 – 60 tonnes);
- Trenchers;
- Scrapers;

[4] World Resources Institute and World Business Council on Sustainable Development (2015), Greenhouse Gas Protocol, available at URL: http://www.ghgprotocol.org/

- Graders;
- Roller Compactors;
- Water Trucks; and
- Mobile Cranes.

More detail for each option is provided below.

3.3.1 Option 1: Mackay Reclamation

NQBP oversees operations at the Port of Mackay, which is located approximately 20km to the north-west of the Port of Hay Point. There is a 20 hectare area adjacent to the north harbour wall which is designated as proposed future strategic port land. The proposed reclamation area for Option 1 would be located in this area, directly to the north of the existing Mackay Harbour. It is estimated that 200,000 tonnes of rock would be required for the 860m rock wall as part of the Mackay reclamation option, as defined in Appendix D of the Engineering Design report[5]. It has been assumed that this would be sourced in equal quantities from the Mount Basset and Farleigh quarries, located approximately 5km and 20km from the Port of Mackay respectively. The Port of Mackay reclamation area is shown in **Figure 3**, as the area adjacent to the northern breakwater of Mackay Harbour marked as future strategic port land.

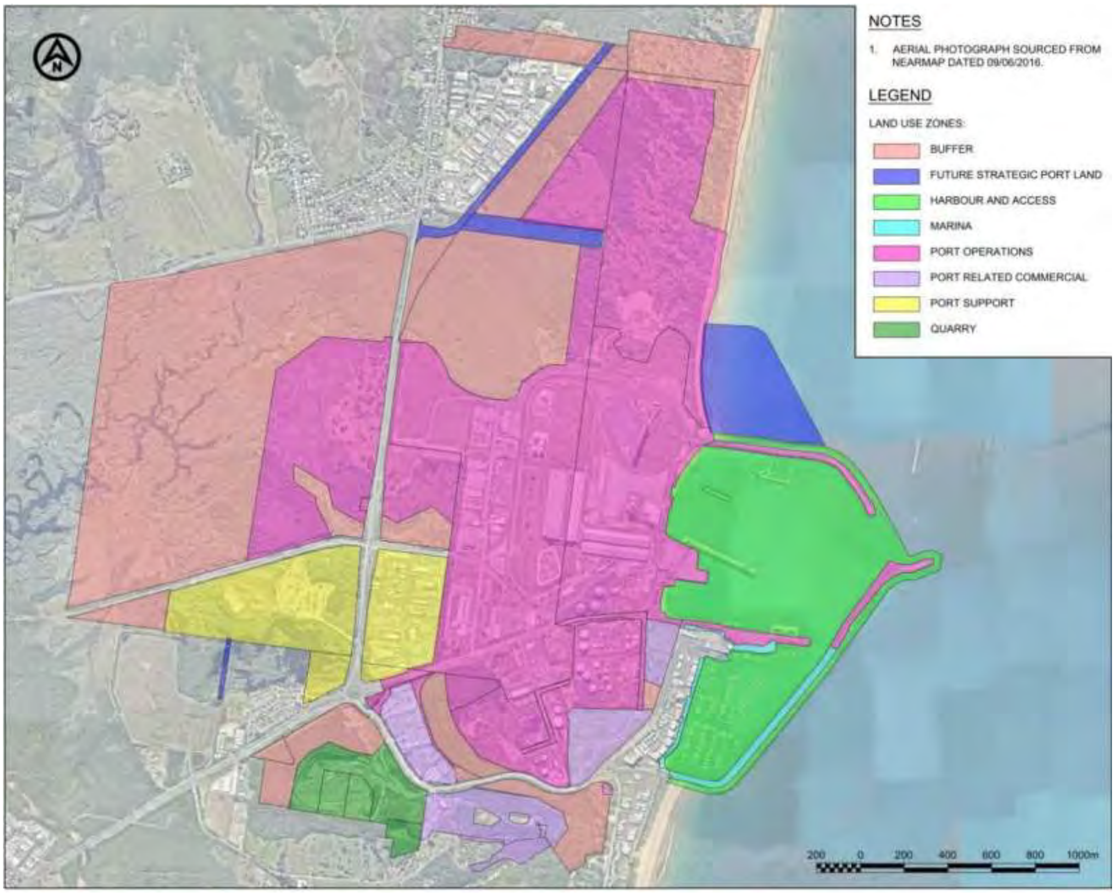

Figure 3: Location of the Port of Mackay Reclamation Area

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[5] Royal HaskoningDHV (2016); Port of Hay Point – Onshore Pond and Reclamation Engineering Design, Reference M&PA1163-105R001D01, September 2016

3.3.2 Option 2: Half Tide Tug Harbour Reclamation

The HTTH is located approximately 3km to the south-west of the Port of Hay Point, and currently provides services for the Port of Hay Point tug boats. The Port of Hay Point 10 year development masterplan[6] identifies three potential reclamation areas which would create laydown areas within the port. The most suitable reclamation area for dredged marine sediment has been identified to the north-west of the existing harbour wall.

It was estimated that 250,000 tonnes of rock are required for the 1,250m rock wall as part of Option 2, as defined in Appendix D of the Engineering Design report[6]. It has been assumed that this rock would be sourced in equal quantities from the Mount Basset and Nebo quarries, located approximately 50km and 80km from the HTTH respectively. The HTTH reclamation area is shown in **Figure 4**.

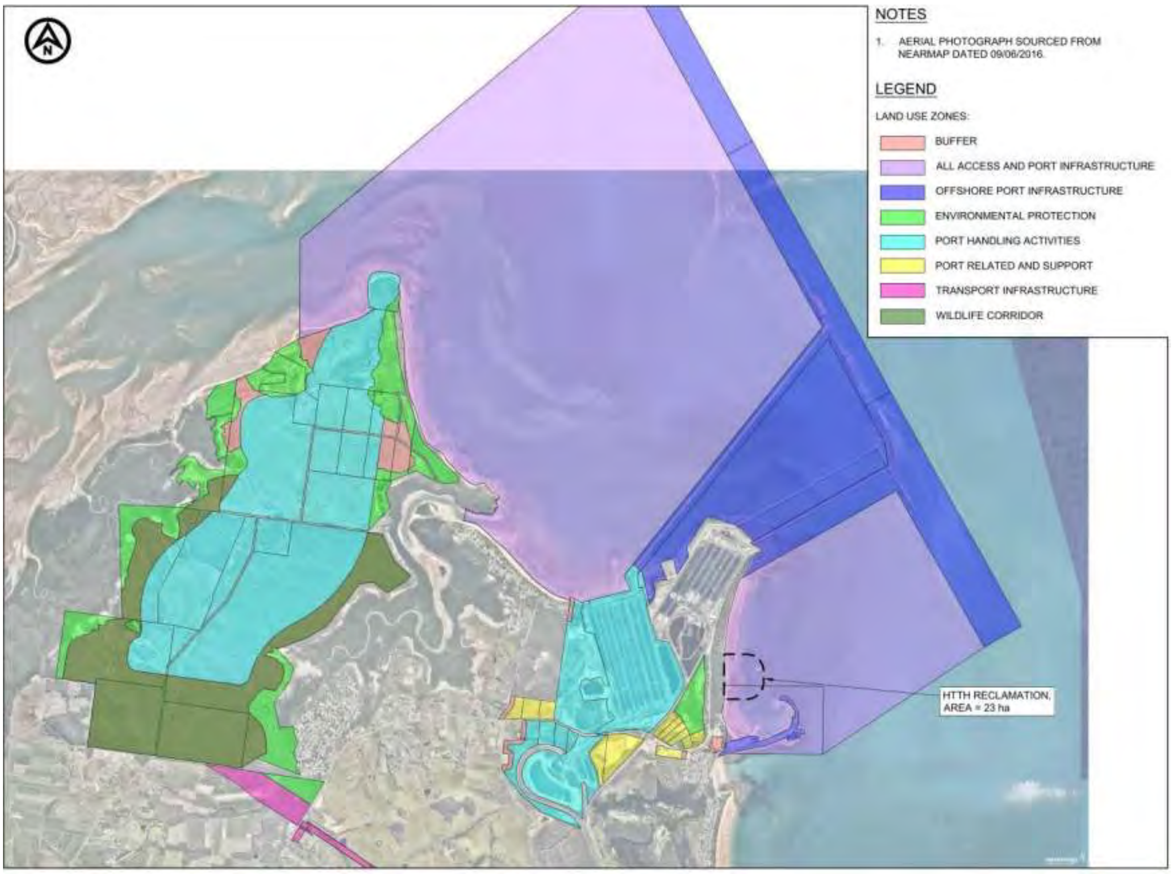

Figure 4: Location of the HTTH Reclamation Area

3.3.3 Option 3: Mackay Onshore Pond

A constraints analysis was undertaken in 2011 of the Strategic Port Land owned by NQBP and the Australian Maritime Safety Association at the Port of Mackay. The assessment identified four potential growth opportunity areas. A site to the west of Slade Road was identified as the preferred location for siting the onshore ponds, as this area is relatively flat and is the furthest from the existing port (i.e. it is less likely to be required for other future port infrastructure). There are 31.5 hectares of land available at

[6] Aurecon (2012); Port of Hay Point Ten Year Development Master Plan, September 2012

this site which can accommodate the required volumes of sediment from the maintenance dredging. A minimum bund height of four metres is required as part of the design for the pond. The main construction materials required for the Mackay onshore pond would be high-density polyethylene (HDPE) pipelines, and geotextiles. The Mackay onshore pond location is shown in **Figure 5**.

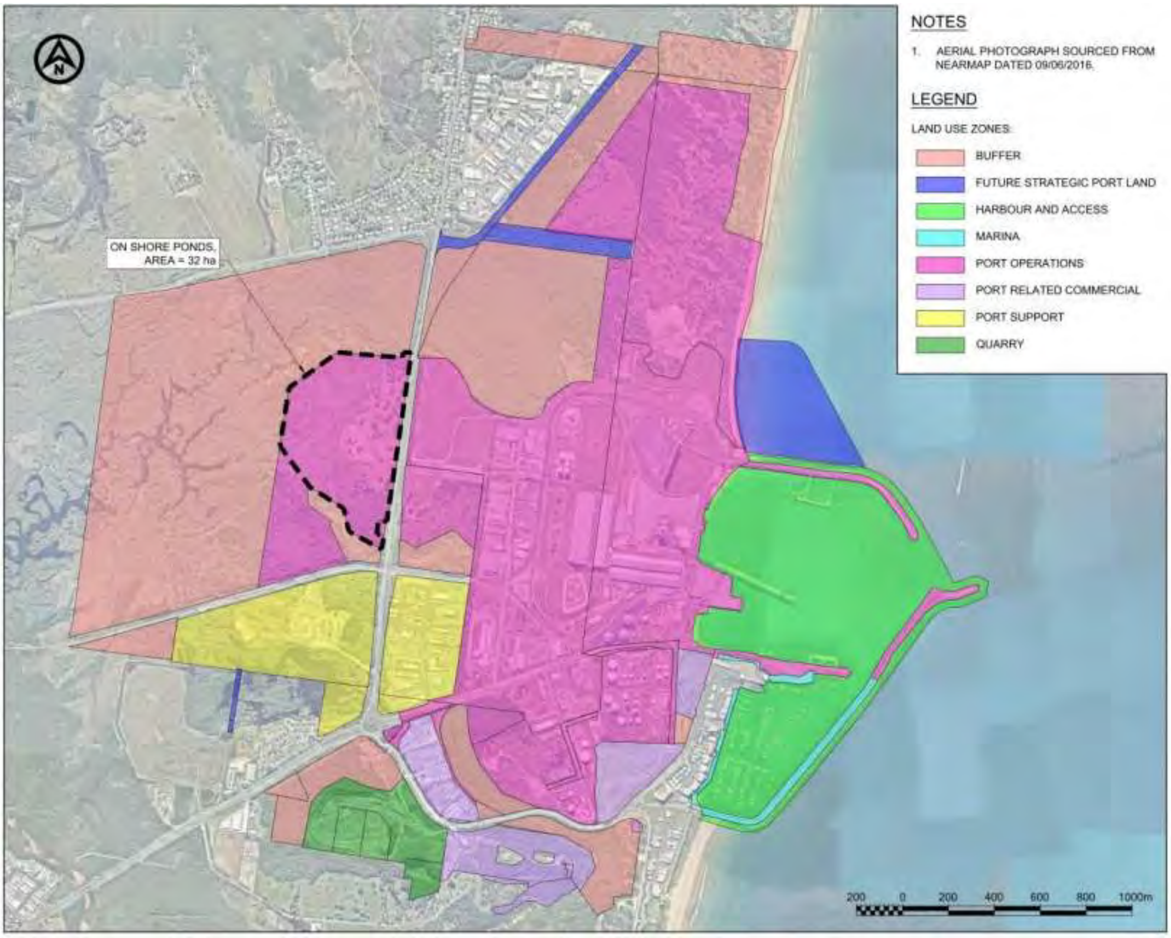

Figure 5: Location of the Mackay Onshore Pond

3.3.4 Option 4: Dudgeon Point Onshore Pond

The area of potentially available land for the onshore ponds at Dudgeon Point is approximately 180 hectare, situated approximately 6km to the west of the Port of Hay Point. Due to the large area of land available at the site the onshore ponds at Dudgeon Point have been designed to be of a larger area of 50 hectares (including bund and buffer areas) to help improve the potential for the material in the pond to dry over time. To accommodate the existing maintenance dredging requirement, the bund walls would be three (3) metres high. The main construction materials required for the Dudgeon Point onshore pond would be high-density polyethylene (HDPE) pipelines, and geotextiles. The Dudgeon Point onshore pond location is shown in **Figure 6**.

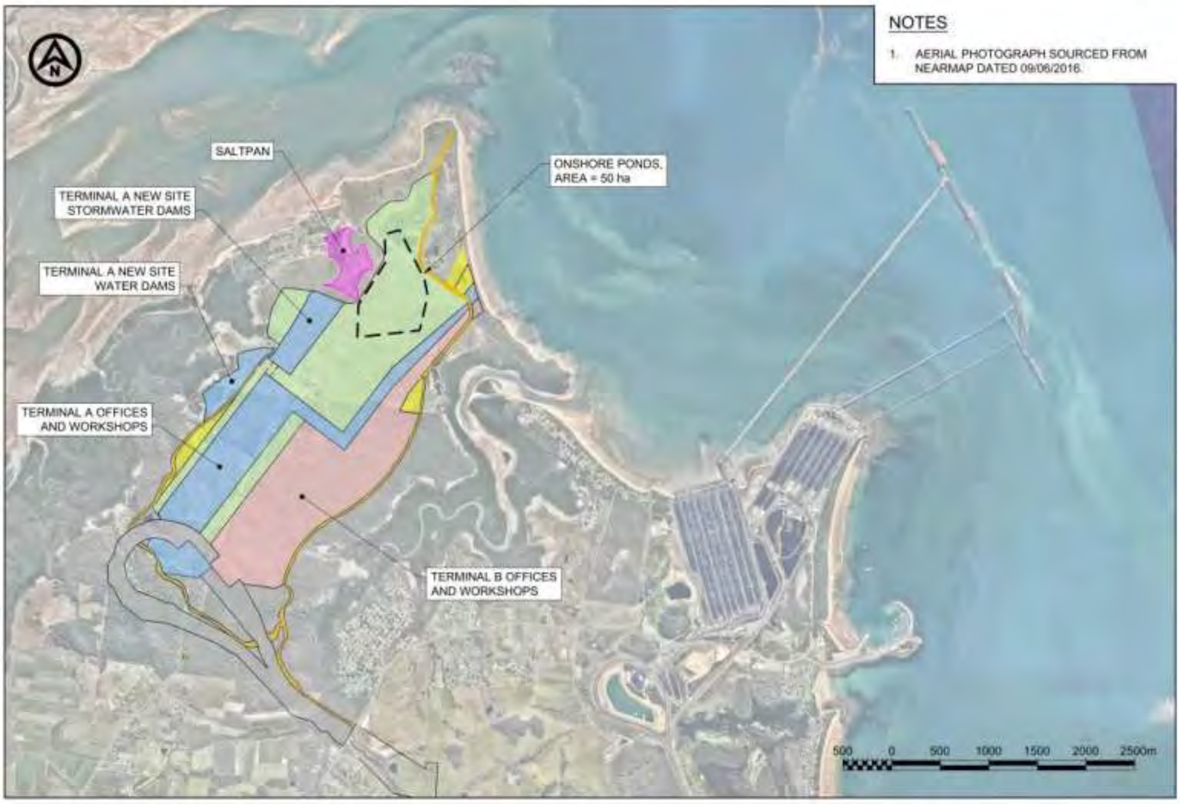

Figure 6: Location of the Dudgeon Point Onshore Pond

3.4 Emission Factors and Calculations

3.4.1 Scope 1 GHG Emissions Calculations and Factors for each Option for Fuel Consumption from Dredging Activities

Scope 1 GHG emissions from the consumption of bunker fuel during the operation of the TSHD Brisbane in each option were calculated using guidance from the Environmental Protection Agency (USEPA) methodology '*Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*'.[7] The emission parameters and emission rates used in the assessment were derived using the USEPA methodology, and the TSHD Brisbane specification, and are detailed in

Table 1. Emissions from fuel consumption by the THSD Brisbane were determined from equation 1:

[1] $$E=P \times LF \times A \times EF$$

where:

E = Emissions (grams [g])
P = Engine Power (kilowatts [kW])
LF = Load Factor (percent of vessel's total power)
A = Activity (hours [h])
EF = Emission Factor (grams per kilowatt-hour [g/kWh]).

[7] USEPA (2009); Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report, April 2009

Table 1: Parameters for the THSD Brisbane & Emissions Factors Utilised in the GHG Assessment for Dredging Activities

Marine Vessel Used	Engine Power (kW)	Load Factor*	CO_2 Emission Factor* (g/kWh)	CH_4 Emission Factor* (g/kWh)	N_2O Emission Factor* (g/kWh)
THSD Brisbane	3,700	0.69	690	0.09	0.02

* Obtained from (USEPA) methodology '*Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*'.

GHG emissions were calculated from fuel consumption associated with the transport of the TSHD Brisbane to, and from the site, throughout the duration of the forecast dredging activities including pumping, and transport to the mooring areas for each option and the dredge area. The mooring area is defined as the location where the TSHD Brisbane would pump the sediment ashore, and would be located up to 2km from the reclamation/pond location. It was anticipated that the TSHD Brisbane would travel to the site from the Port of Gladstone, and then onwards from the site to the Port of Townsville, based on this a GHG emission contribution relative to 800km of steaming was included for the mobilisation and demobilisation of the vessel. Emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were determined for each marine sediment management option, and converted to figures of CO_2e using the calculation provided in **Footnote 2**.

The TSHD Brisbane also consumes diesel fuel when operating two dredge pumps of 1500kW, two jet water pumps of 620kW, and an 800kW diesel generator which is used to provide power to the vessel. The dredge and steaming rates for the four options are provided in **Table 2**.

Table 2: Dredging and Steaming Rates for the Four Options Considered in the GHG Assessment

Activity	Activity Hours			
	Option 1 – Mackay Reclamation	Option 2 – HTTH Reclamation	Option 3 – Mackay Onshore	Option 4 – Dudgeon Point Onshore
Steaming to Port of Hay Point from Port of Gladstone	36	36	36	36
Dredging at Port of Hay Point	167	167	167	167
Steaming to Mooring Area	133	33	133	33
Pumping	267	267	267	267
Steaming to Dredge Area	111	28	111	28

The following assumptions were used:

- When the TSHD Brisbane travels from the Port of Gladstone the vessel engines would operate at 65% of capacity;
- During dredging activities the vessel engines operate at 31% of full power, and the dredge and jet water pumps would be run at full capacity;
- For the time steaming to the mooring and dredge areas the vessel engines would operate at 80% of capacity;
- During pumping activities the dredge and water pumps operate at full capacity, and the vessel engines operate at 10% of full power; and
- The diesel generator would be in operation throughout all activities detailed in **Table 2**.

3.4.2 Scope 1 GHG Emissions Calculations and Factors for Fuel Consumption from Construction Plant

Scope 1 GHG emissions associated with diesel fuel consumption from construction plant for each option were calculated as part of the assessment. The assessment used emission factors from the Australian National Greenhouse Accounts from the Australia Department of the Environment[8]. Hourly diesel fuel consumption for each construction plant was derived from equation 2[9]:

[2] $$FC = ((CSF \times P \times LF) / FD) / 1000$$

where:

FC= Fuel Consumption (kL hr^{-1})
CSF = Engine fuel consumption at full power (0.268 kg kWh^{-1})
P = Engine Power (kW)
LF = Engine Load Factor
FD = Fuel Density (0.85 kg l^{-1} for diesel)

Fuel consumption figures were then used to calculate GHG emissions per hour of operation for each construction plant. Equation 3 was obtained from the Australian National Greenhouse Accounts to determine GHG emissions from the combustion of diesel fuel by construction vehicles:

[3] $$E = (FC \times EC \times EF) / 1000$$

where:

E= GHG emissions (CO_2e per hour of operation)
EC = Energy content factor of fuel type (for diesel oil - 38.6 GJ/kL)
EF = Emission Factor (kg CO_2-e/GJ)

The construction plant details and emission factors used to determine GHGs are provided in **Table 3**. Engine power figures were obtained from the specification based on the model used for each construction vehicle. Load factors for each vehicle were obtained from the USEPA[10]. The CO_2e figures for each construction plant were then multiplied by the predicted operating hours, derived from the information provided in **Table 9** of the Engineering Design report[5] associated with each option, as provided in **Table 3**.

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[8] Australia Government, Department of the Environment, Australian National Greenhouse Accounts, 2015

[9] Kecojevic and Komljenovic, 2011; Impact of Engine Load Factor on Fuel Consumption, CO_2 Emission and Cost, American Journal of Environmental Sciences, 7 (2): 125 – 131, 2011.

[10] United States Environmental Protection Agency (2010); Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modelling, EPA -420-R-10-016, July 2010.

Table 3: Activity Hours and Emission Parameters used to Determine GHG Emissions from Construction Vehicles.

Construction Vehicle	Model	Engine Power – P (kW)	Load Factor	Activity Hours			
				Option 1 – Mackay Reclamation	Option 2 – HTTH Reclamation	Option 3 – Mackay Onshore	Option 4 – Dudgeon Point Onshore
Bulldozers (D10 - D12)	Caterpillar D11	698	0.50	2,900	2,700	1,100	2,600
Dump Trucks (40t)	Volvo A 40D Dump Truck	318	0.21	6,800	16,300	1,700	4,000
Excavators (40 - 60 t)	Volvo EW160E	115	0.59	4,200	4,000	1,400	3,000
Trenchers	Vermeer T955111 Trencher	310	0.59	0	0	700	700
Scrapers	Caterpillar 657G	447	0.59	0	0	400	1,800
Graders	Caterpillar M Series M24	397	0.59	0	0	200	900
Roller Compactors	Volvo Single Drum Compactor SD1620, SD200	151	0.59	0	0	900	2,200
Water Trucks	Cat C15 ACERT Engine (25,000 litre)	350	0.59	0	0	400	1,100
Mobile Cranes	Liebherr LR 1100	230	0.43	500	700	0	0

The emission factors for CO_2, CH_4 and N_2O used in the assessment, as obtained from the Department of the Environment[8], are provided in **Table 4**. Emissions of CO_2, CH_4 and nitrous oxide N_2O were determined for each marine sediment management option, and converted to figures of CO_2e using the calculation provided in **Footnote 2**.

Table 4: Diesel Combustion Emission Factors used in the GHG Assessment

Fuel Combusted	Emission factor (kgCO_2-e/GJ)		
	CO_2	CH_4	N_2O
Diesel	69.9	0.1	0.5

3.4.3 Embodied Scope 3 GHG Emissions Calculations and Factors from Construction Materials

Embodied Scope 3 GHG emissions were calculated from the volume of construction materials used for each marine sediment management option, and derived from Appendix D of the Engineering Design Report. Embodied GHGs within construction materials are the resultant emissions from all activities associated with the cradle – gate production of the construction materials. Emission factors were

Royal HaskoningDHV

obtained from the Inventory for Carbon & Energy (ICE)[11]. The volumes of construction materials used, and emission factors for each material are detailed in **Table 5**.

The volumes of each construction material were converted to weight in kilograms, using best estimate assumptions, as provided below the table.

Table 5: Volumes of Construction Materials and Emission Factor to Determine Scope 3 GHG Emissions from Use of Construction Materials for Each Sediment Management Option

Construction Material	Volumes of Construction Materials				Emission Factor (kg CO_2e/kg)
	Option 1 – Mackay Reclamation	Option 2 – HTTH Reclamation	Option 3 – Mackay Onshore	Option 4 – Dudgeon Point Onshore	
HDPE Pipeline (200mm diameter)	0	0	5000m	5000m	1.930
HDPE Pipeline (800mm diameter)	0	0	2000m	3000m	1.930
Concrete	0	0	80m^3	100m^3	0.107
Steel	0	0	0.9t	0.9t	2.030
Rock	200,000t	250,000t	0	0	0.079
Geotextile (Heavy)	0	0	250,000m^2	300,000m^2	3.430
Geotextile (Light)	20,000m^3	20,000m^3	200,000m^2	200,000m^2	3.430

The following assumptions were used:

- The HDPE Pipeline was converted to kilograms from data provided in the Engineering Toolbox[12] It was assumed that the Pressure Rating for the 200mm and 800mm diameters was PN6, which indicates the maximum pressure the pipe can support with water a would be 6 bar;
- The volume of concrete was converted to weight using the general purpose concrete formula, where 0.42m^3 equates to 1 metric tonne of concrete; and
- The Geotextiles were converted to weight assuming a mass per unit area of 100g/m^3.[13]

There is a wide range of factors that determine the embodied cradle to gate GHG emissions within construction materials, and therefore there may be a wide margin of uncertainty in the Scope 3 GHG calculations in this assessment. This is particularly pertinent as there is a lack of applicable emission factors for construction materials within Australia. Therefore, the assessment only provides a high level estimate of Scope 3 GHG emissions, but was provided for comparative purposes.

[11] Inventory of Carbon and Energy (2011); Version 2.0, Prof Geoff Hammond and Craig Jones, Sustainable Energy Research Team, Department of Mechanical Engineering, University of Bath, 2011.

[12] Engineering Toolbox (2016); available at URL: http://www.engineeringtoolbox.com/pe-pipe-weights-d_324.html, accessed on 21/09/2016.

[13] Jones, D.R.V., Shercliff, D.A. & Dixon, N. 2000. Difficulties associated with the specification of protection geotextiles using only unit weight, Proceedings 2nd European Conference on Geosynthetics, Bologna (2): 551-555.

4 Results of GHG Calculations

Based on the approach outlined in Section 3, the predicted GHG emissions associated with each marine sediment management option are detailed in **Table 6**. The results were separated for Scope 1 and Scope 3 emissions for each option.

Table 6: Predicted GHG Emissions from each Marine Sediment Management Option.

Option	Scope 1 CO_2e Emissions (Tonnes)			Scope 3 Emissions (CO_2e Tonnes)	Total Scope 1 + Scope 3 Emissions (CO_2e Tonnes)
	Fuel Consumption from THSD Dredger	Fuel Consumption from Construction Plant	Total Scope 1 Emissions	Embodied Emissions from Construction Materials	
Option 1 - Port of Mackay Reclamation	1,183	2,433	**3,616**	15,869	**19,485**
Option 2 - Half Tide Reclamation	795	4,160	**4,955**	19,819	**24,774**
Option 3 - Mackay Onshore	1,183	1,663	**2,846**	2,040	**4,886**
Option 4 - Dudgeon Point	795	4,200	**4,995**	2,426	**7,421**

The results show that the Mackay onshore pond (Option 3) is predicted to have the lowest Scope 1 and Scope 3 GHG emissions of the options considered. This is due to the relatively flat nature of the site in comparison to the Dudgeon Point site (Option 4), which requires a significant cut and fill programme to prepare the site for the onshore pond. Therefore, there is more diesel fuel consumption associated with construction plant such as bulldozers, dump trucks, excavators and roller compactors for the Dudgeon Point onshore pond (Option 4), in comparison to the Mackay onshore pond (Option 3).

The reclamation options, Option 1 and Option 2 result in much higher embodied Scope 3 GHG emissions due to the large quantities of rock material to be used in the construction of the reclamation areas. There is potential for reducing the embodied Scope 3 GHG emissions associated in Options 1 and 2, by using low carbon replacement materials such as low carbon concrete.

5 Conclusions

A GHG emissions assessment was undertaken of four potential reclamation and onshore pond options for storage of sediment from maintenance dredging at the Port of Hay Point. The assessment was undertaken in line with the global standard methodology provided by the GHG Protocol. Scope 1 GHG emissions were calculated from diesel and bunker fuel consumption associated with the operation of the TSHD Brisbane undertaking the maintenance dredging, and construction plant required for each reclamation and onshore pond option. Embodied Scope 3 cradle-gate GHG emissions within construction materials were also calculated for each option.

Option 3, the Mackay onshore pond was predicted to have the lowest Scope 1 and Scope 3 GHG emissions. Due to the large quantities of rock required for the reclamation options, Scope 3 GHG emissions in Option 1 and 2 were much higher than the onshore pond options.

Appendix F Numerical Modelling

Note / Memo

Haskoning Australia PTY Ltd.
Maritime & Aviation

To:	NQBP
From:	Mitchell Havenaar and Heiko Loehr
Date:	22 September 2016
Copy:	
Our reference:	PA1163-105
Classification:	Project related

Subject: **Hydrodynamic Model**

Introduction

This technical memo provides details of the development of a Delft3D depth-averaged hydrodynamic model for the Mackay/ Hay Point region. This includes the calibration process undertaken as part of the numerical modelling for the engineering design of the proposed reclamations and onshore pond options.

Model Setup

The extent of the model grid developed for this assessment along with the interpolated model bathymetry is shown in **Figure 1**. The figure also shows the extent of the four different resolution grids, details of these are provided in **Table 1** and **Table 2**.

Table 1: Model grid configuration Hay Point region.

Description	Extent (X by Y cells)	Spatial resolution (m)
Grid 1 – Outer Grid	192 by 162	535
Grid 2 – Mid Grid	200 by 218	180
Grid 3 – Inner Grid	409 by 211	60

Table 2: Model grid configuration Mackay region.

Description	Extent (X by Y cells)	Spatial resolution (m)
Grid 1 – Outer Grid	192 by 162	535
Grid 2 – Mid Grid	200 by 218	180
Grid 3 – Inner Grid	524 by 212	60

Bathymetry

High resolution hydrographic survey data for the area surrounding the Port was provided by North Queensland Bulk Ports Corporation. The bathymetry for the remaining areas of the model domain was from digitised navigation charts provided through MIKE C-MAP and the 250m gridded Geoscience Australia bathymetry.

The different bathymetric data utilised were corrected to Australian Height Datum (AHD) and then interpolated onto the model grid.

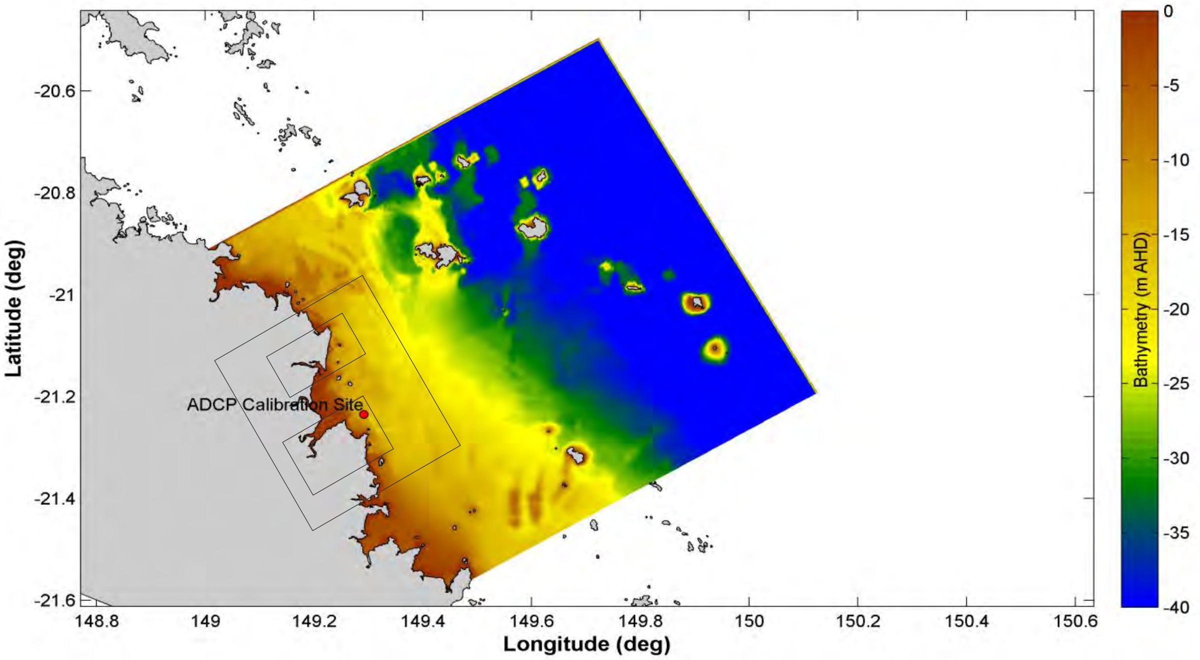

Figure 1: Model extent, bathymetry, location of calibration site (D1S1) and extent of the nested higher-resolution grids.

Boundary Conditions

The astronomical tidal boundaries for the model were derived using RHDHV's Queensland tidal model. RHDHV's tidal model represents measured water levels well throughout all of Queensland, including sites within the GBR Lagoon and in the area with tidal amplification around the Hay Point region.

A uniform bed roughness was applied in the model, with a Manning's n roughness coefficient of 0.02 adopted. This value represents a medium to smooth bed and was found to result in the best model calibration at the nearshore calibration site.

The currents within the GBR Lagoon can be significantly affected by wind forcing (SMEC, 2012). To ensure wind forcing was included in the model, wind data was purchased from the Bureau of Meteorology (BoM) from the automatic weather station at Hay Point which was used as spatially uniform forcing over the model domain.

Model Calibration

Model calibration is the process of setting physically realistic values for model parameters so that the model reproduces observed values to the desired level of accuracy. In this case the model calibration was achieved by defining realistic boundary conditions derived from RHDHV's Queensland tidal model and by setting a bed roughness value of 0.02 which represents a medium to smooth bed.

The hydrodynamic model has been calibrated against measured water level and current data over a spring neap tidal cycle at a site just north of the existing apron at Hay Point (**Figure 1**). The data was collected in 2011 by an ADCP as part of investigations for previous projects.

An assessment of the differences in phase and amplitude between the modelled and measured water level and current data was undertaken to assess the level of calibration achieved. It is important to note that unlike a tide gauge it is not possible to accurately survey the level of an ADCP and as a result it is not possible to relate the water level to a specific datum such as Australian Height Datum (AHD). The water level measured by the ADCPs can be calculated relative to approximate mean sea level (MSL), but as the bathymetry in the model is relative to AHD it is expected that inherently there would be minor differences between the two.

For coastal waters such as at Hay Point and Mackay, the following performance criteria can be adopted:

- Modelled peak current speeds within 10% of measured speeds over a spring neap cycle;
- Modelled water levels within 10% of the tidal range over a spring neap cycle; and
- Timing of high water and low water should be within 15 minutes.

These standards provide a good basis for assessing model performance, but experience has shown that sometimes they can be too prescriptive and it is also necessary for visual checks to be undertaken. Under certain conditions, models can meet statistical calibration standards but appear to perform poorly. Conversely, seemingly accurate models can fall short of the guidelines. Consequently a combination of both statistical calibration standards and visual checks has been used to ensure that the model is representative.

Water Levels

A time-series plot of the modelled and measured water levels at the calibration site is shown in **Figure 2**. The measured water levels include non-tidal variations in water levels due to variations in atmospheric conditions causing residual water levels. Nevertheless, the modelled water levels agree well with the measured data throughout the period.

In order to further assess the level of calibration achieved, statistical analysis was undertaken to quantify the difference in elevation and phase between the modelled and measured high and low water values. The results of the analysis for the difference in water level at high water and low water are presented as absolute values in **Table 3**. The results demonstrate that the model is well calibrated relative to the measured water level both in terms of magnitude and phase.

Table 3: Summary of calibration statistics for the difference between modelled and measured water levels.

Statistical Description	ADCP (Sep, 2011)
Mean HW Difference (m)	-0.05
Mean HW Difference relative to Tidal Range (%)	-1.3
Mean LW Difference (m)	0.09
Mean LW Difference relative to Tidal Range (%)	2.2
RMSE for HW (m)	0.12
RMSE for LW (m)	0.10
Mean HW Phase Lag (mins)	-11
Mean LW Phase Lag (mins)	-12

Note: The differences in phase of the high and low waters were derived by subtracting the time of the measured value from the time of the model value. A negative value therefore indicates that the model is early compared to the measured data.

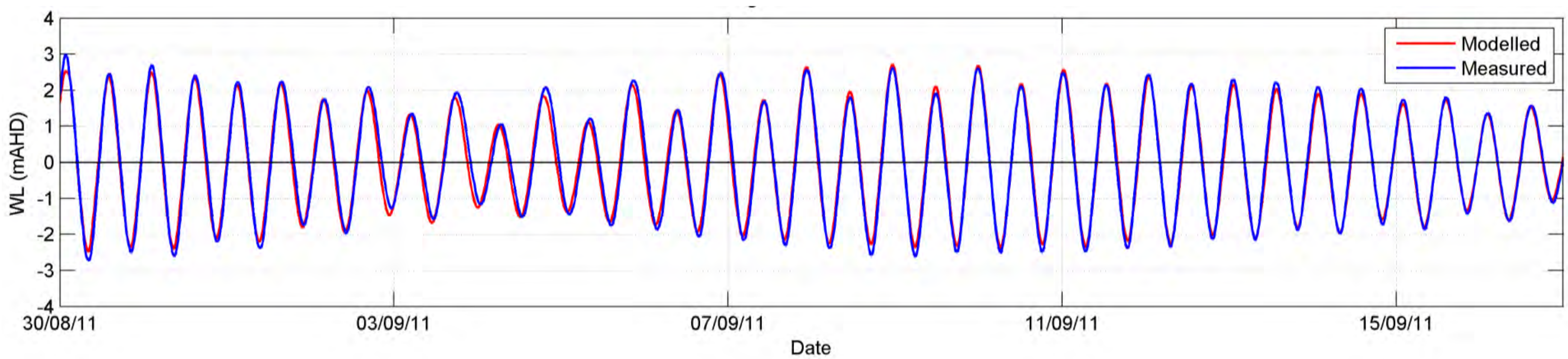

Figure 2: Comparison of modelled and measured water levels at the ADCP calibration site.

Current Speed and Direction

The current speeds and directions offshore of Hay Point are influenced by forcing from astronomical tides, local winds and regional circulation, with the astronomical tide providing the strongest and most regular forcing. As such, this is considered to be a highly complex hydrodynamic environment which requires understanding of all the processes to be able to accurately replicate the current speeds and directions.

Time series plots for the calibration of current speed and direction are shown in **Figure 3**. A statistical summary of the calibration is provided in **Table 4**. The table shows that the model is capable of providing a good representation of the peak flood and ebb current speeds, demonstrating that the hydrodynamic model is able to accurately reproduce the observed processes. Given the high degree of variability in the measurements, indicating a complex interaction between the astronomical tide and the local wind processes, the overall model calibration achieved for current speed and direction is considered to be good.

Table 4: Current speed and direction calibration statistics for the difference between modelled and measured data.

Statistical Description	ADCP (Sep, 2011)
Mean Difference in Speed of Flood (m/s)	-0.01
Mean Difference in Flood Speed Relative to Maximum Observed Speed (%)	-2.63
Mean Difference in Speed of Ebb (m/s)	0.04
Mean Difference in Ebb Speed Relative to Maximum Observed Speed (%)	10.6
RMSE for Flood Speed (m/s)	0.03
RMSE for Ebb Speed (m/s)	0.05
Mean Difference in Direction of Flood (°)	-12.35
Mean Difference in Direction of Ebb (°)	-11.82

Note: The differences were derived by subtracting measured values from model values. A negative value therefore indicates that the model is under-predicting measured values.

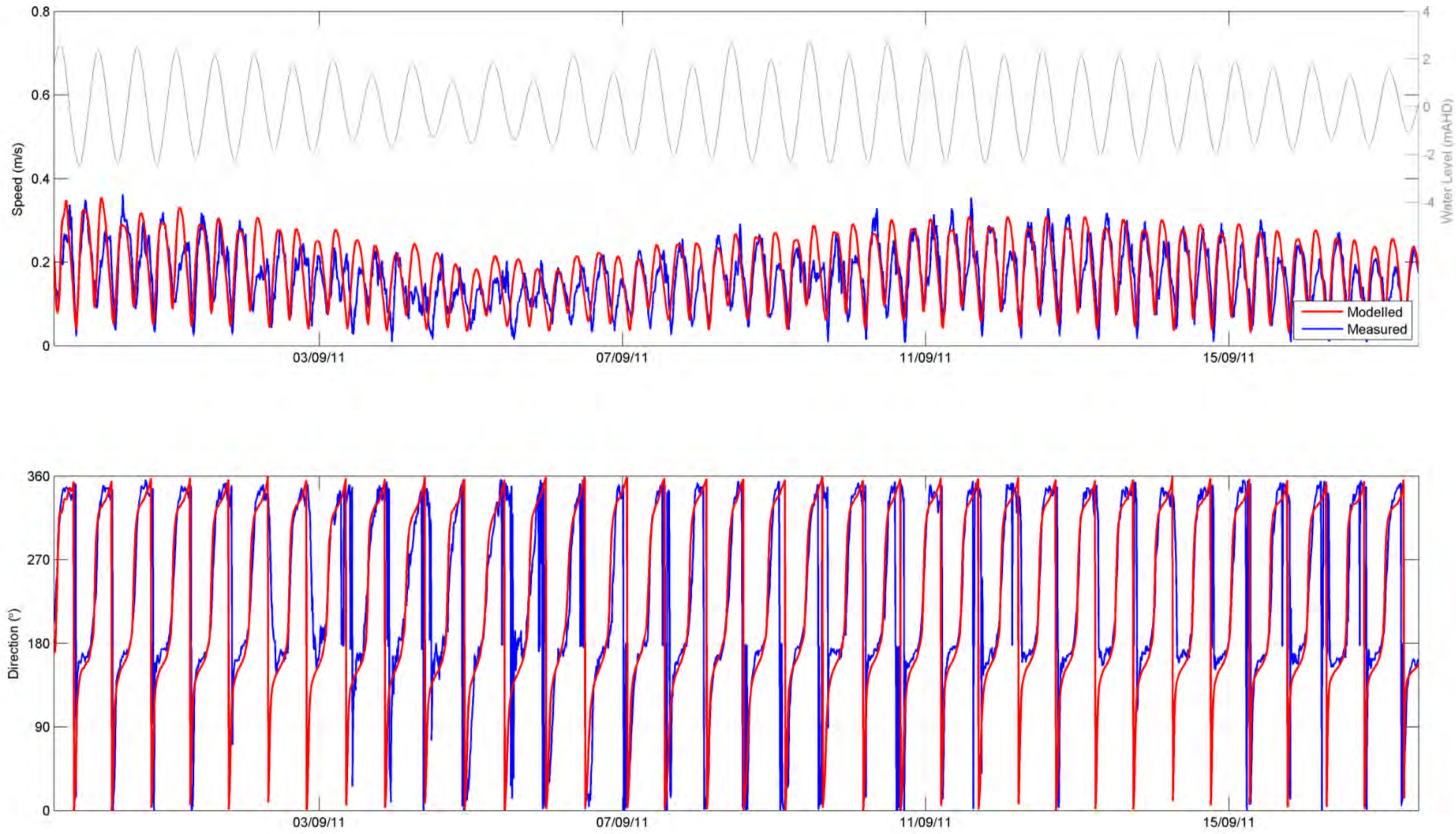

Figure 3: Comparison of modelled and measured current speed (top) and direction (bottom) at the ADCP calibration site

Summary

The model configuration and calibration process presented in this memo has demonstrated that:

- The hydrodynamic model provides a good representation of water levels at the ADCP location to the north of the existing Hay Point Apron; and
- The hydrodynamic model can accurately represent the resultant currents due to forcing from astronomical tides and local wind.

The good hydrodynamic model calibration achieved provides confidence in the modelling of the driving processes for the plume dispersion modelling.