PORT OF **WEIPA**

APPENDIX G

Comprehensive beneficial reuse assessment

Comprehensive Beneficial Reuse Assessment

Port of Weipa and Amrun Port – Sustainable Sediment Management Assessment for Navigational Maintenance

14 December 2018

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301001-02056-00-EN-REP-0004

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Synopsis

This study provides a comprehensive analysis of potential beneficial reuse options for the Port of Weipa and Amrun Port's maintenance dredge material. The Port of Weipa has a large volume annual maintenance dredging requirement of around 500,000m^3. Amrun Port's annual maintenance dredging requirement is about 19,000m^3.

Investigations were undertaken in two stages. Firstly, a fieldwork campaign was undertaken to determine the properties of sediments to be dredged. Secondly, potential beneficial reuse options for the sediments were identified and analysed.

At the Port of Weipa about 80% of the dredge material is fine grained (silt/clay) and 20% is coarse material (sand/gravel). Almost all the Amrun Port dredge material is fine grained. The coarse-grained sediments are typically more suitable for reuse in medium to high-load land reclamation, beach nourishment and use in concrete manufacture. The geotechnical properties of the fine-grained sediments (e.g. strength, plasticity, density, consolidation) are generally unsuitable for engineering applications and this material would require significant onshore processing and treatment to improve its suitability. As such, the fine-grained sediments are more suitable to habitat creation options and potentially for use in shoreline protection if placed in geotextile bags.

Fourteen opportunities to beneficially reuse dredge material were identified. These include options to reuse material for environmental enhancement or to recycle the material for engineering applications.

Comparative evaluation was applied to the identified beneficial reuse opportunities using 14 performance criteria. The highest ranked beneficial reuse opportunities for the Port of Weipa include land reclamation, beach nourishment, shoreline protection, concrete products and deep-water habitat creation. The top ranked reuse opportunity for the Amrun Port is deep water habitat creation.

The amount of dredge material required for each of the top ranked reuse opportunities is between about 5,000m^3/yr. (for concrete products) and 100,000m^3/yr. (for land reclamation) and represents a relatively small part of the total annual dredging requirement. No single beneficial reuse opportunity provides a long-term solution to utilise the large volume of dredge material produced year after year. Several potential hybrid options exist to target a small portion of the dredge material for specific reuse with the balance of material managed, as it has been historically, through offshore placement.

While maintenance dredge sediment derived from the ports may be suitable for a number of uses, the demand associated with reuse opportunities is very limited and the volume of material required for reuse opportunities (if any demand exists) is relatively small in comparison to the annual dredging requirement.

The analysis indicates that there is no clear preferred long-term beneficial reuse option for maintenance dredge material from the Port of Weipa or Amrun Port.

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Project No: 301001-02056-EN-REP-004 – Port of Weipa and Amrun Beneficial Reuse Assessment

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Cover Image: Port of Weipa Sunrise, March 2018

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Executive Summary

North Queensland Bulk Ports Corporation Limited (NQBP) has commenced work on a long-term strategic assessment for ongoing management of marine sediments at the Port of Weipa and Amrun Port. To support this work, NQBP commissioned Advisian to undertake a comprehensive investigation of options for the beneficial reuse of marine sediments that naturally accumulate in the navigational areas of the ports.

The beneficial reuse investigations were undertaken in two main stages:

1. Sediment properties investigations
2. Beneficial reuse options identification and analysis.

Performance criteria – The primary considerations of analysis are the properties of the sediment to be dredged, collectively known as sediment suitability. The fourteen performance criteria (and their abbreviations) considered in the comparative evaluation of the reuse opportunities are:

- Sediment suitability (Sed. Suit.)
- Demand for the opportunity (Opp.)
- Conceptual cost estimate (Cost)
- Confidence in beneficial reuse process (Process)
- Duration from construction to use (Duration)
- Greenhouse gas emissions (GHGs)
- Environmental implications (Enviro.)
- Socio-economic implications (Social)
- Indigenous community implications (Indig.)
- Economic implications (Econ.)
- Environmental approvals and permits (Approv.)
- Constraints (Constr.)
- Knowledge gaps requiring research (K. Gaps)
- Longevity and future considerations (Future).

A summary of the comparative analysis for each of the options identified is illustrated in Figure 1.

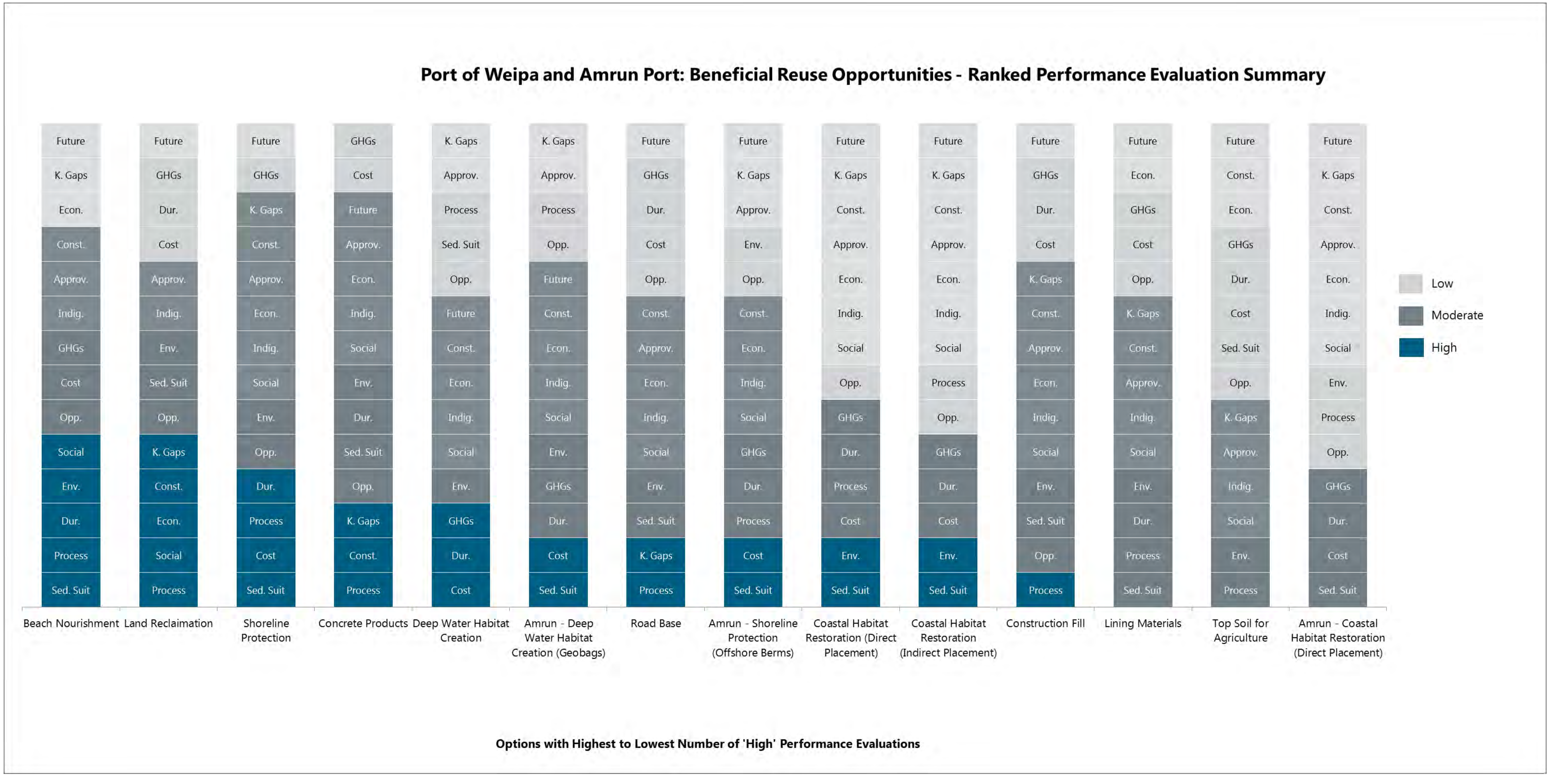

Figure 1: Beneficial reuse options performance summary

Port of Weipa

The analysis indicates that while several options for beneficial reuse may be feasible, with consideration of all the aspects relevant to the use, there is no clear preferred long-term beneficial reuse option solution for the port's maintenance dredge material.

Five reuse options ranked well based on the number of 'high' performance evaluation scores for the option. These options were land reclamation and beach nourishment, which ranked equal highest, followed by options for shoreline protection, concrete products and deep-water habitat creation. The 'process' performance criteria was the only common criteria that was rated high across these options (four of the five options – excluding deep-water habitat creation). No other individual performance criteria was assessed as 'high' for more than two of the five highest ranked options. This is an indication that there is diversity in the options assessed and that no option has emerged as superior.

All of options are considered to have a single or limited application. Only the concrete products and deep-water habitat creation uses may provide an option for ongoing use of the maintenance dredge material, albeit that these options use only a part of the annual dredge volume and the ongoing use would require regular assessment.

If a suitable land reclamation area is available, this option for reuse through direct placement potentially offers economic benefits in terms of construction jobs and increased Port capacity. Similarly, if an appropriate location is identified for beach nourishment, then direct placement of targeted sand dredge material may provide enhancement of the area's foreshore.

Reuse by recycling of the dredge material for engineering purposes relies on targeting the coarse (sand) component of the dredge sediment. Selective dredging of areas with high sand content may be possible, with placement to a designated onshore management area for screening and washing ready for use. Notwithstanding that this reuse option may technically be achievable, the quantity of sand that would be derived from annual maintenance dredging of the port far exceeds the current known demand for sand in the area.

Similarly, while the properties of the dredge sediment may mean it is suitable for reuse in environmental enhancement (e.g. coastal habitat creation and deep-water habitat creation), shoreline protection and beach nourishment options, their feasibility relies on demand and the final placement location being favourable, especially in relation to the local ecosystem including wave climate and currents.

A number of reuse options were identified where most of performance criteria were scored moderate, with only a few low performance criteria. These include options for material use as construction fill, road base and lining material. This finding may be interpreted as these options having few unknowns or constraints to their implementation. These options all involve the construction of an onshore management area and potential long-term treatment. If an onshore placement area were constructed this may create the potential for five of the beneficial reuse options to be realised (construction fill, road base, lining material, concrete products and topsoil for agriculture). Subject to user demand for an end product, a single reuse option or combination of reuse options is possible once the material is placed onshore, enabling portions of the material to be directed to different reuse as demand arises.

The main issue with beneficial reuse options for the port is the extremely large volume of material to be managed and the absence of clear demand for that material. Several potentially feasible beneficial reuse options have been identified that could use a small proportion of the available dredge material in the short term or for a single use project; however, there is no clear long-term option or combination of options that will cater for the sheer quantity of dredge material in any year, nor the cumulative volume of multiple years.

Dredging Task – There is approximately 500,000m^3/yr of material to be dredged from the Port for maintenance of depth in operational areas. Dredge material is transported to the Albatross Bay Dredge Material Placement Area, 20km offshore. Most of the material to be dredged is fine silt/clay material (71%), mixed with sand (25%) and small amounts of gravel material (4%). Most of the material to be dredged (about 90%) is in the Southern Channel and Extension with the balance of material from the berth areas (including Lorim Point, Humbug and Evans Landing) and the Approach Channel and Departure Channel.

Within each of the dredge areas, the sediments are typically dominated by fine material; however, there are several sites where sandy material constitutes more than 75% of the sediment. Based on the volume of coarse material in these locations it is likely to be practical to use selective dredging to target an estimated 100,000m^3/yr. of sandy material for possible reuse.

Analysis of the geotechnical properties of the sediment material to be dredged shows:

- Material varied considerably between and within areas with typically high fines (silt and clay) content
- Areas where coarse-grained sediments (sand) appear to prevail include most of the Approach Channel and Departure Channel and the inner portion of the Southern Channel
- Fine-grained sediments may be suitable for low to medium load applications following dewatering and compaction, noting that this material may take many months to many years to consolidate
- Coarser sediments may be suitable for medium to high loading applications following adequate compaction
- Sand material, following screening and washing, is suitable for use in premixed structural concrete manufacturing
- Fine sediment is likely to contain high plasticity clay with a medium to high potential for volume change
- Sediment to be dredged is likely to have very high moisture content, and therefore significant effort would be required to dry out the sediment, required for various reuse options.

Sediments to be dredged are likely to be Potential Acid Sulfate soils (PASS). However, they contain sufficient carbonate content acid neutralising capacity to buffer inherent acidity to negligible concentrations and as such are unlikely to require ASS treatment, albeit that this is dependent on the management measures required for reuse. The material to be dredged is free of contamination and therefore suitable for ocean placement.

Beneficial Reuse Analysis – Comparative analysis of the potential Port of Weipa reuse options shows that:

No Substantial Demand Identified – None of the options have a clear existing demand for the reuse of sediment material that would require minimal infrastructure. For several options, a potential demand exists that requires infrastructure construction, while for six options (road base, lining material, coastal habitat creation through direct or indirect placement, deep water habitat creation and top soil for agriculture) no substantive demand for the dredge material was identified.

Level of treatment required – Most of the options were assessed as having low to moderate sediment suitability performance, indicating the material would require some or significant treatment, processing and/or additives. For the reuse options of habitat creation (direct or indirect placement), beach nourishment and shoreline protection it is likely that the sediment material could be utilised without treatment or additives.

Estimated costs – Current annual dredging budget with placement at sea is approximately $2.5million including items such as: mobilisation, demobilisation and daily hire for the duration of the dredging program. Five of the beneficial reuse options involving onshore treatment and processing are estimated to cost significantly more (up to fifteen times more) than the current annual maintenance dredging program. Estimated costs in the first year are high due to the need to build infrastructure (e.g. onshore placement containment area, pump out mooring facilities and pipeline) to enable the beneficial reuse. All the options involving onshore temporary storage were of low performance with respect to cost (more than $20million/yr.) with the four environmental enhancement options being of moderate performance (between $10million/yr. and $20million/yr.). The four options involving geobags for shoreline protection or deep-water habitat creation have estimated costs that are similar to traditional offshore placement (less than $10million/yr.) and are considered to be high performance with respect cost. The options, except for deep water habitat, only provide a solution for a portion of the dredge material and are in effect additional costs 'on top of' normal dredging costs.

Greenhouse Gas Emissions – The options that did not require intermediate storage were of high performance (less than 2,000t CO_2 equivalent) with respect greenhouse gas emissions. The options that required onshore placement were of low performance (greater than 8,000t CO_2 equivalent) because of emissions associated with the construction of the onshore ponds and road transport.

Environmental Implications – Most of the options were rated as being of moderate performance with respect environmental implications, i.e. potential nuisance or harm issues identified, but for the most part considered manageable. Only the beach nourishment option for reuse of the dredge material as an environmental enhancement rated as high performance due to the net benefit opportunities that exist for positive environmental outcomes.

Social Implications – The land reclamation and beach nourishment options for reusing dredge material are rated as high performance due to the potential for positive social opportunities for local communities. The remaining options were rated as moderate performance, as they are likely to have minor social effects that are for the most part manageable.

Traditional Owner Implications – The coastal habitat creation options, either by both direct or indirect placement, were rated low performance due to potential negative impacts on Traditional Owners' lands and waters (impacts on the Albatross Bay foreshore mangrove and wetland areas) which are considered unlikely to be easily managed. Other options were rated as of moderate performance, as the implications for Traditional Owners are for the most part considered manageable.

Economic Opportunities – Only the option of land reclamation was rated as high performance due to positive economic opportunities for enhancing community capability and opportunities associated with development of upgraded port facilities. The reuses of liner material and topsoil for agricultural uses were all rated as low economic performance, due to the likely need for subsidisation for these uses to be acceptable. The remaining options were rated as moderate performance, as they may provide limited economic opportunities for enhancing port or community capability.

Approvals – The reuse of dredge material as an environmental enhancement in coastal habitat creation (direct and indirect placement) and deep-water habitat creation will require careful scientific investigation and specialist studies and significant effort to gain necessary regulatory approvals and consequently are assessed as low performance with respect approvals.

Knowledge Gaps – The land reclamation and concrete products options have few knowledge gaps and less than one year of further work would be required to progress the option. Conversely, each of the three options for reusing dredge material as an environmental enhancement, along with the shoreline protection and beach nourishment options would likely require greater than three years of further research to address knowledge gaps, particularly with respect confirmation of the demand for the use and suitability of the material and placement strategy. The remaining options would likely require one to three years of further research to address multiple knowledge gaps.

Amrun Port

The main issues that challenge the identification of potentially suitable beneficial reuse options for Amrun Port are the relatively small volume of material to be managed, the material type and the Port's location, including its remoteness. Due to the dredge material characteristics there are not likely to be any viable options to reuse dredge sediment as an engineering material or in an agricultural application. In any case, conveyance of the dredge material to an onshore placement area at Amrun (for processing and treatment required for an engineering use) would be extremely challenging due to many constraints including limited available storage area and the significant engineering, environmental and cultural heritage issues associated with traversing the shoreline's turtle nesting habitat and culturally significant coastal cliffs.

The dredge material from the port is most suited to reuse as an environmental enhancement; however, the remoteness of the port dictates that there is little demand in adjacent areas for environmental enhancement. The analysis indicates that while there some options for beneficial reuse of Amrun Port maintenance dredge material that may be possible, in consideration of all the aspects relevant to the use there is no clear long-term preferred beneficial reuse option that is well suited to meet the port's ongoing maintenance dredging needs. The potential option to build an artificial reef as a recreational fishing project emerged as a potentially feasible option among a scarcity of practical reuse options; however, this option would provide only a short-term option for beneficial reuse and further detailed scientific investigation would be required to assess its viability.

Dredging Task – Approximately 19,000m^3/yr. of sediment material is required to be dredged from Amrun Port for maintenance of depth in the Port's operational areas. The dredged material is currently placed at the Amrun Dredge Material Placement Area which is located approximately 14km offshore directly west of the Port.

Sediment Properties – Most of the material to be dredged is fine silt/clay material (86%), mixed with sand (13%) and very small amounts of gravel material (1%). The majority (approximately 90%) of sediment material to be dredged is in the berths, with the balance of material from the departure channel.

Analysis of the geotechnical properties of the sediment material to be dredged indicates:

- Sediment material is relatively homogeneous with typically very high fines (silt and clay) content
- Fine sediment is likely to contain high plasticity clay with high potential for volume change
- Fine sediment results suggest only relatively low dry densities and therefore low strengths could be achieved for low load application following adequate drying out and compaction
- Sediment to be dredged is likely to have very high moisture content, and therefore significant effort would be required to dry out the sediment as may be required for various reuse options
- Sediments have excessive fines and would not be easily used in concrete products.

Sediments to be dredged are likely to be PASS; however, they contain sufficient carbonate content acid neutralising capacity to buffer inherent acidity to negligible concentrations and as such are unlikely to require ASS treatment, albeit that this is dependent on the management measures required for reuse. The material to be dredged is free of contamination and therefore suitable for ocean placement.

A summary of the comparative analysis for the Amrun Port reuse options identified is illustrated in Figure 1.

Amrun Port's Three Reuse Options – Three potential beneficial reuse options were identified and analysed for Amrun Port, namely:

1. Shoreline Protection (offshore berms) – berms created by selective placement of geotubes filled with dredged material to modify the wave climate with the aim to reduce sedimentation at the berths

2. Coastal Habitat Creation (direct placement) – enhancement of intertidal habitat areas

3. Deep Water Habitat Creation – creation of an artificial reef by seabed placement of geotubes filled with dredged material.

Comparative analysis of the potential Amrun Port reuse options shows that:

No Substantive Demand Identified – None of the options have a clear existing demand for the reuse of sediment material that would not require significant further investigation, planning, design, negotiation and approvals. No substantive demand for the dredge material was identified.

Sediment Suitability – The option for coastal habitat creation by direct placement was assessed as having moderate performance with respect sediment suitability, indicating that the material would require some treatment or processing before placement in a coastal habitat. The reuse options for shoreline protection and deep-water habitat were assessed as moderate sediment suitability as the fine sediment material is suitable to be utilised if placed in geobags/tubes to avoid remobiltisation.

Estimated Costs – All the beneficial reuse options are estimated to cost significantly more (more than 10 times) than the traditional dredging approach, due to additional works associated with either direct placement via pipeline or using barges and double handling to fill geotubes.

Processes Unproved – For each of the three options, the proposed process is unproven and there are few examples of the reuse being applied to maintenance dredge material in environments similar to Amrun Port. Shoreline protection in the form of offshore berms may not ultimately reduce sedimentation in the berth. Given that the existing coastal environment is not degraded, direct placement to enhance or create habitat may be unnecessary and have negative impacts. Deep water habitat creation has some potential to provide recreational fisheries benefits; however, would require significant scientific investigation to assess the demand and viability of the potential use.

Local Recreational Fishing Economic Opportunity – Deep-water habitat creation was rated as medium performance given the potential for positive economic opportunities relating to recreational fishing and noting that an opportunity may exist for existing Amrun Port reference group assistance to support a local recreational fishing project.

1 Introduction

North Queensland Bulk Ports Corporation Limited (NQBP) is a port authority under the *Transport Infrastructure Act 1994*, for the seaport facilities at Hay Point, Mackay, Abbot Point, Weipa and Maryborough. Amrun Port is a facility owned and operated by RTA Weipa Pty Ltd (RTA). Amrun Port has been included in this study since the maintenance dredging operations at both Port of Weipa and Amrun are linked given that they are likely to occur at the same time with the mobilisation of a dredging vessel to Cape York. The management of the dredge material and potential beneficial reuse options for these ports are interrelated, with RTA and NQBP being the primary stakeholders.

1.1 Study purpose

NQBP has commenced work on a long-term strategic assessment for ongoing management of marine sediments at the Port of Weipa, known as the *Port of Weipa – Sustainable Sediment Management Assessment for Navigational Maintenance (SSM Project)*. To support this project, NQBP commissioned Advisian to undertake a comprehensive investigation of options for the beneficial reuse of marine sediments that naturally accumulate in the navigational areas of the Port of Weipa and Amrun Port.

The scope of this Beneficial Reuse Assessment is to evaluate, assess and document the engineering properties of maintenance dredging sediments within the navigational infrastructure of the Port of Weipa and Amrun Port. This study's purpose is to comprehensively compare the range of beneficial reuse (reuse, recycle, treat) options available, reuse methodologies and economics of each reuse option with respect to the sediment properties.

The beneficial reuse investigations were undertaken in two main stages:

1. Sediment properties investigations

2. Beneficial reuse options identification and assessment.

The first stage included the evaluation, assessment and documentation of the engineering properties of maintenance material sediments within the navigational infrastructure of the Port of Weipa and Amrun. These sediment investigations are described in detail in *Sediment Properties Report, Port of Weipa and Amrun, Advisian June 2018*, and are summarised in Section 2.1 below.

The beneficial reuse assessment's second stage identified potential reuse options (refer Section 3.2) and an analysis of each option involving a discussion of the individual features, processes or characteristics to enable a comparison evaluation, provided in Section 0.

Port of Weipa

Weipa is a coastal town of approximately 3,500 people, situated on the north-western side of Cape York Peninsula, around 200km from the tip of Australia, refer Figure 1-1 locality plan. The Port of Weipa is located within Albatross Bay and handles more than 30 Mtpa (million tonnes per annum), most of which is bauxite. RTA's operations at the port include major onshore bauxite handling, processing and stockpiling facilities. Its conveyors run to two wharves, Lorim Point East and Lorim Point West for ship loading. Two other wharves, Humbug Wharf and Evans Landing Wharf, handle a variety of commodities including general cargo, fuel and live cattle. The Port lies on the waters of the Gulf of Carpentaria and its proximity to South-east Asia makes it an export gateway to the region. Bauxite bulk carriers travel through the Gulf of Carpentaria to international export markets or the Australian market.

Currently the Port of Weipa's annual maintenance dredge management program manages the highest average estimated sedimentation rate volume of any Queensland port.[1] An average maintenance dredge volume of 500,000m^3/yr. has been assumed for the beneficial reuse assessment. Dredge material is transported to the Albatross Bay Dredge Material Placement Ground approximately 20km offshore.

[1] Estimated sedimentation rates from 2004 to 2014 at recognised Queensland Ports. Royal Haskoning DHV 2016.

Port of Weipa
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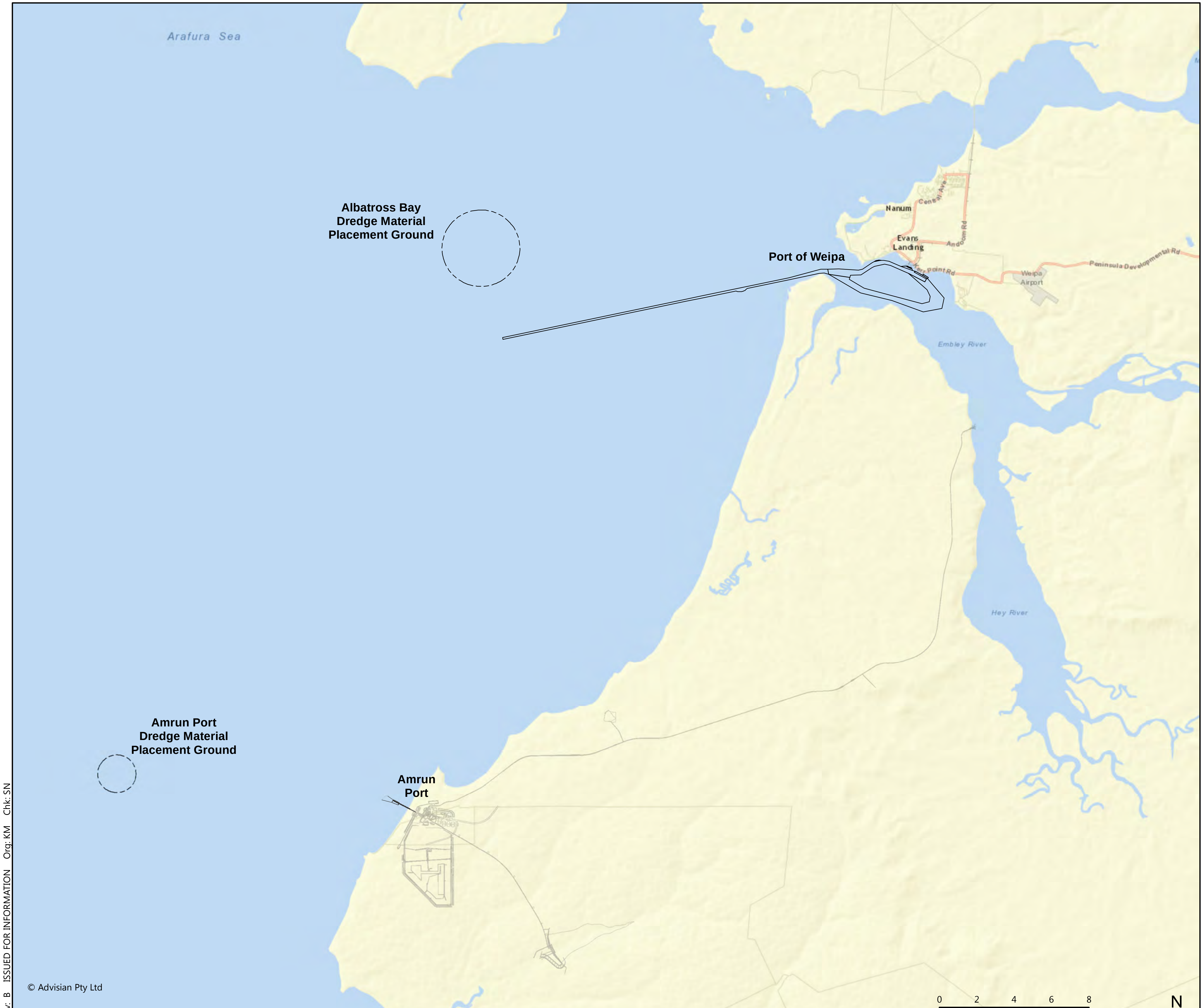
Figure 1-1: Project Locality



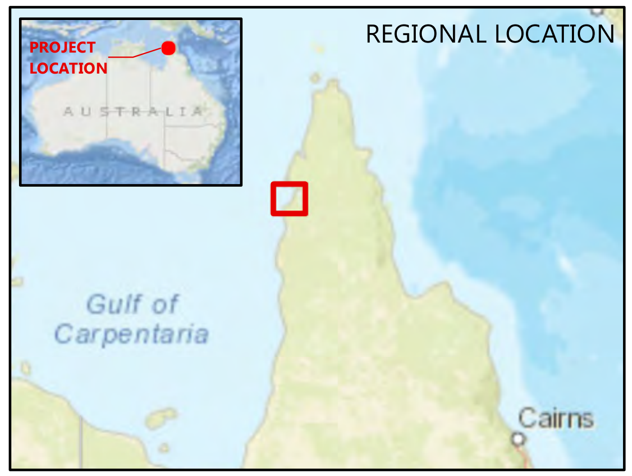


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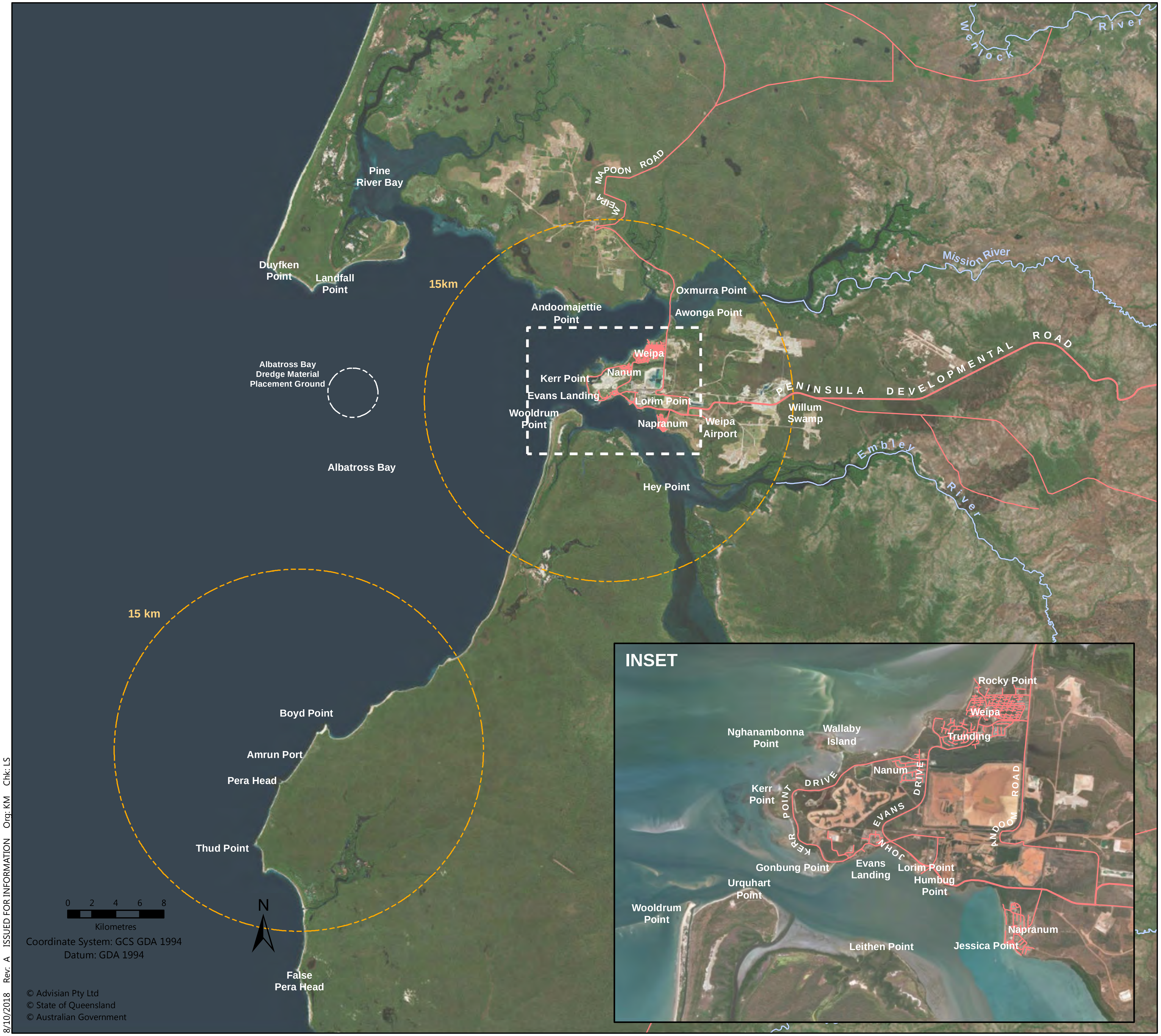
Figure 1-2: Regional Context and Proximity



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Source Information:
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Geoscience Australia
Baseline roads and tracks - Queensland
Qld Watercourse lines
Queensland Department of Natural Resources and Mines

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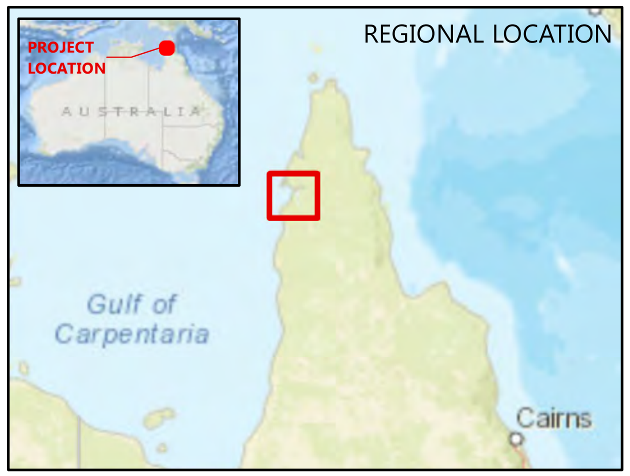

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Amrun Port

The Amrun Port has been recently developed to support RTA's Amrun Project. Amrun Port is located near Boyd Point on the western side of Cape York Peninsula approximately 40km South-west of Weipa and 40km north of Aurukun. The port development was completed in 2018, and incorporates ship loading facilities including a 650m long jetty, a bulk carrier vessel 350m long wharf and berthing structures, tug and line boat moorings. Berth pockets and departure areas were dredged as part of the port development, refer Figure 1-3, Figure 1-3 and Figure 1-4 aerial images. The Amrun Project includes a new bauxite mine and associated processing facilities, with first production scheduled for 2019.

A Native Title claim (Wik and Wik-Way People) covers the Amrun Project area.

Maintenance dredging for the Amrun Port utilises a placement area directly west and 14km offshore from the port. All dredging activities are conducted in coexistence with RTA commitments to Traditional Owners through the Western Cape Communities Coordinating Agreement (WCCCA) and under the Amrun Project's EPBC Act (Environment Protection and Biodiversity Conservation) approval and Queensland Environmental Authority. Capital dredging associated with construction was conducted in 2016 and the first maintenance dredging occurred in 2018, removing42,038m^3) of mostly fine (silt/clay) sediment material.

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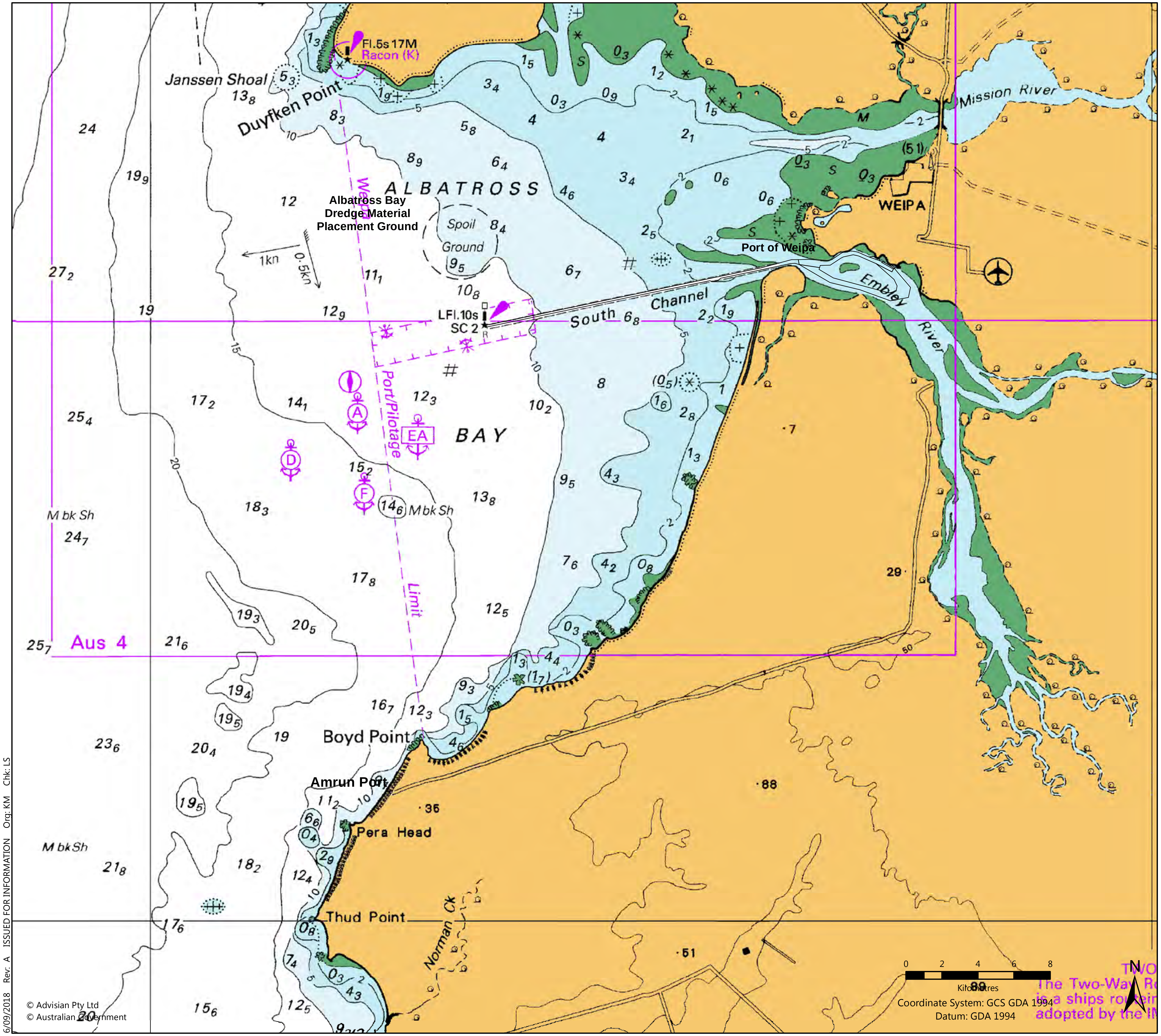
Figure 1-3: Project Locality (Bathymetry)



Source Information:
Seafarer GeoTiff - A0000301 Booby Island to Archer River
Hydrographic Office, Department of Defence

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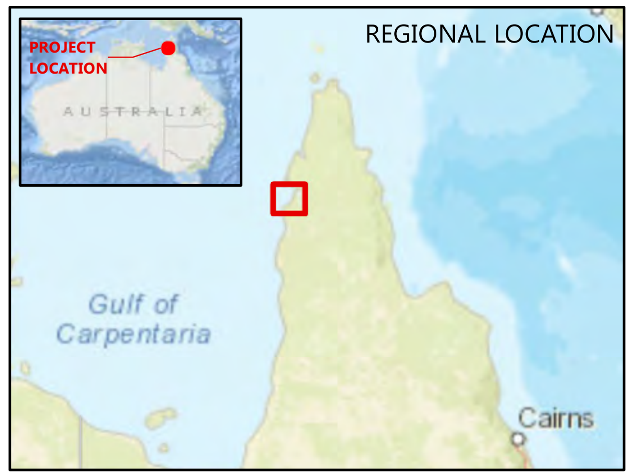

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Figure 1-4: Port of Weipa Lorim Point wharf

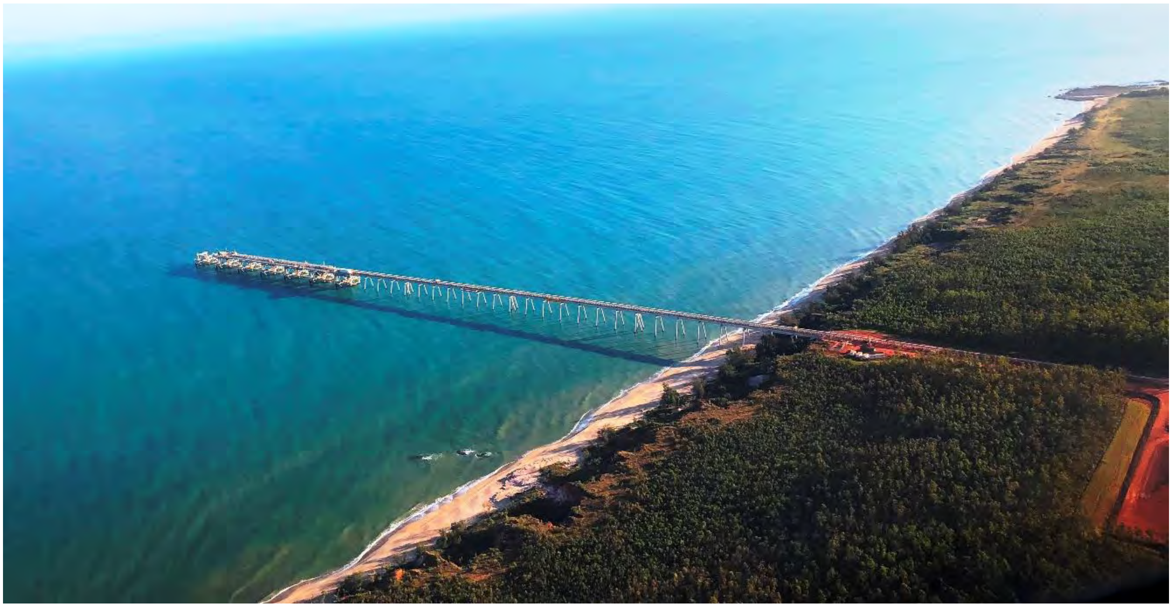


Figure 1-5: Amrun Port jetty and coastline, image courtesy of NQBP

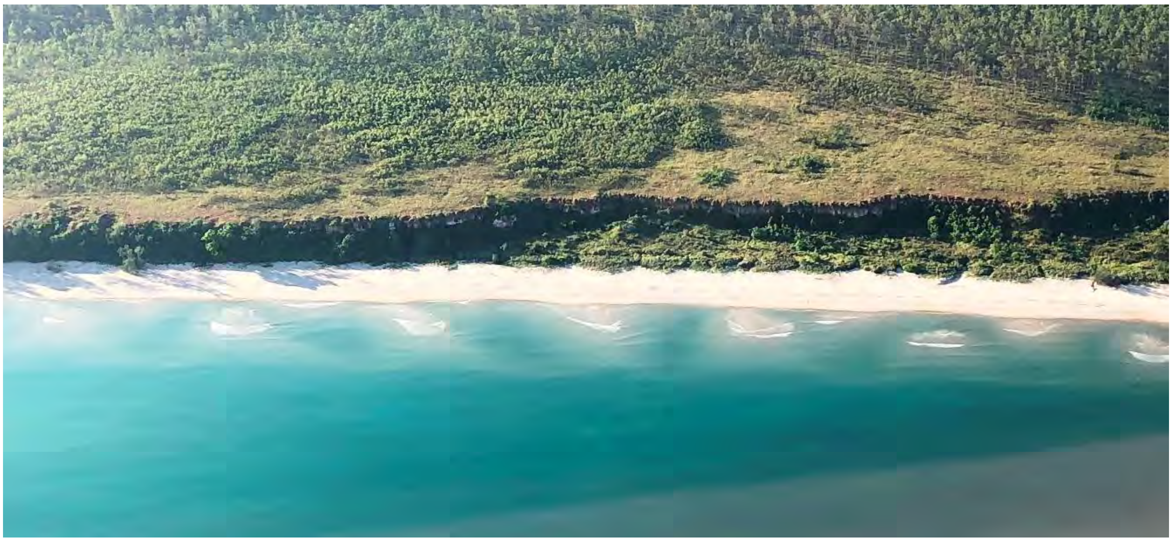


Figure 1-6: Amrun coastline illustrating wide sandy beach and costal cliff, image courtesy of NQBP

2 Sediment Properties

The sediment properties investigations provide the basis for identification of potential beneficial reuse options, along with subsequent analysis. Following identification of beneficial reuse options, the analysis compares the range of options at conceptual level, considering processes, potential constraints and implications, approvals, conceptual costs and greenhouse gas emissions, along with knowledge gaps and future considerations. The beneficial reuse investigations draw on other investigations undertaken for NQBP as part of the SSM Project, including bathymetric analysis and modelling undertaken to determine maintenance dredging requirements along with analysis of environmental values.

2.1 Sediment investigations

Targeted sediment properties field investigations were undertaken in February 2018. The purpose of the field investigations was to identify and classify marine sediment materials that require dredging within the navigational areas of the Port of Weipa and Amrun, and investigate their geotechnical properties and acid generating capacity for consideration of potential reuse options.

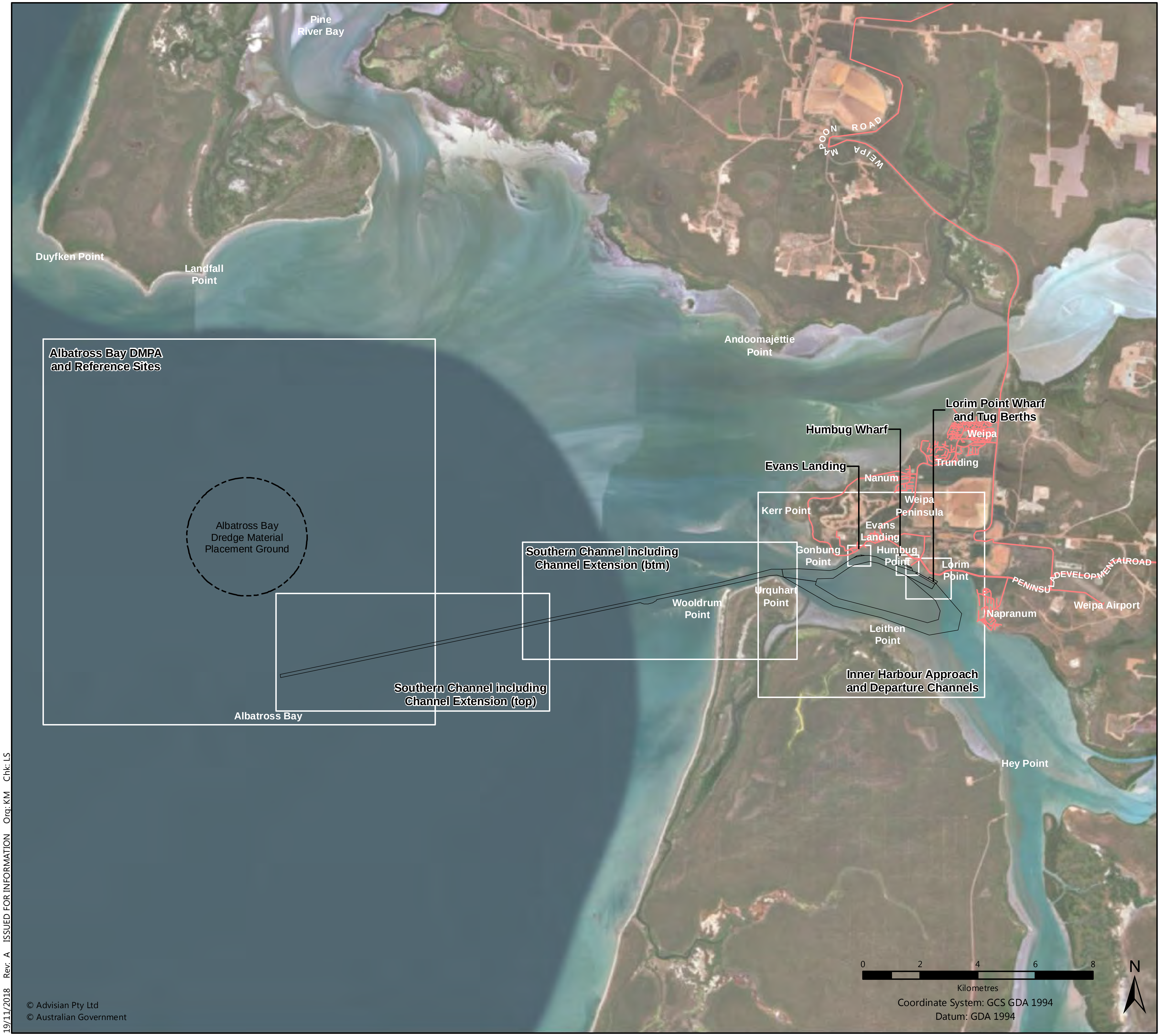
Sediments were sampled at 61 locations within Port of Weipa navigational areas, refer Figure 2-1 to Figure 2-7, including:

- Southern Channel (SC) including Channel Extension
- Inner Harbour Approach Channel (AC)
- Inner Harbour Departure Channel (DC)
- Lorim Point (LP)
- Humbug (H)
- Evans Landing (EL)
- Tug berths (TB)
- Reference Sites (REF)
- Dredge Management Placement Area (DMPA).

Sediments were sampled at 6 locations at Amrun Port, within the jetty mooring, berth pockets and departure areas refer Figure 2-8.

Port of Weipa Beneficial Reuse Report 2018

Figure 2-1: Map Key



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19/11/2018 Rev: A ISSUED FOR INFORMATION Orig: KM Chk: LS

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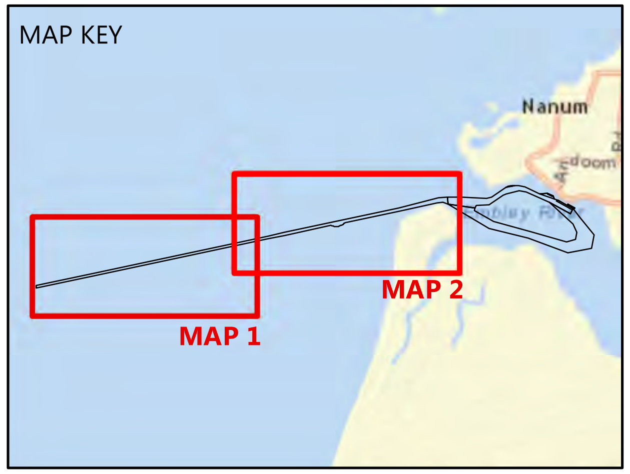
2018

Figure 2-2: Sampling Locations Southern Channel including Channel Extension

- Sediment sample location
- Acid Sulfate Soils (ASS) sample location
- Geotech sample location
- Dredge area



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24/04/2018 Rev: B ISSUED FOR INFORMATION Org: KM Chk: NB

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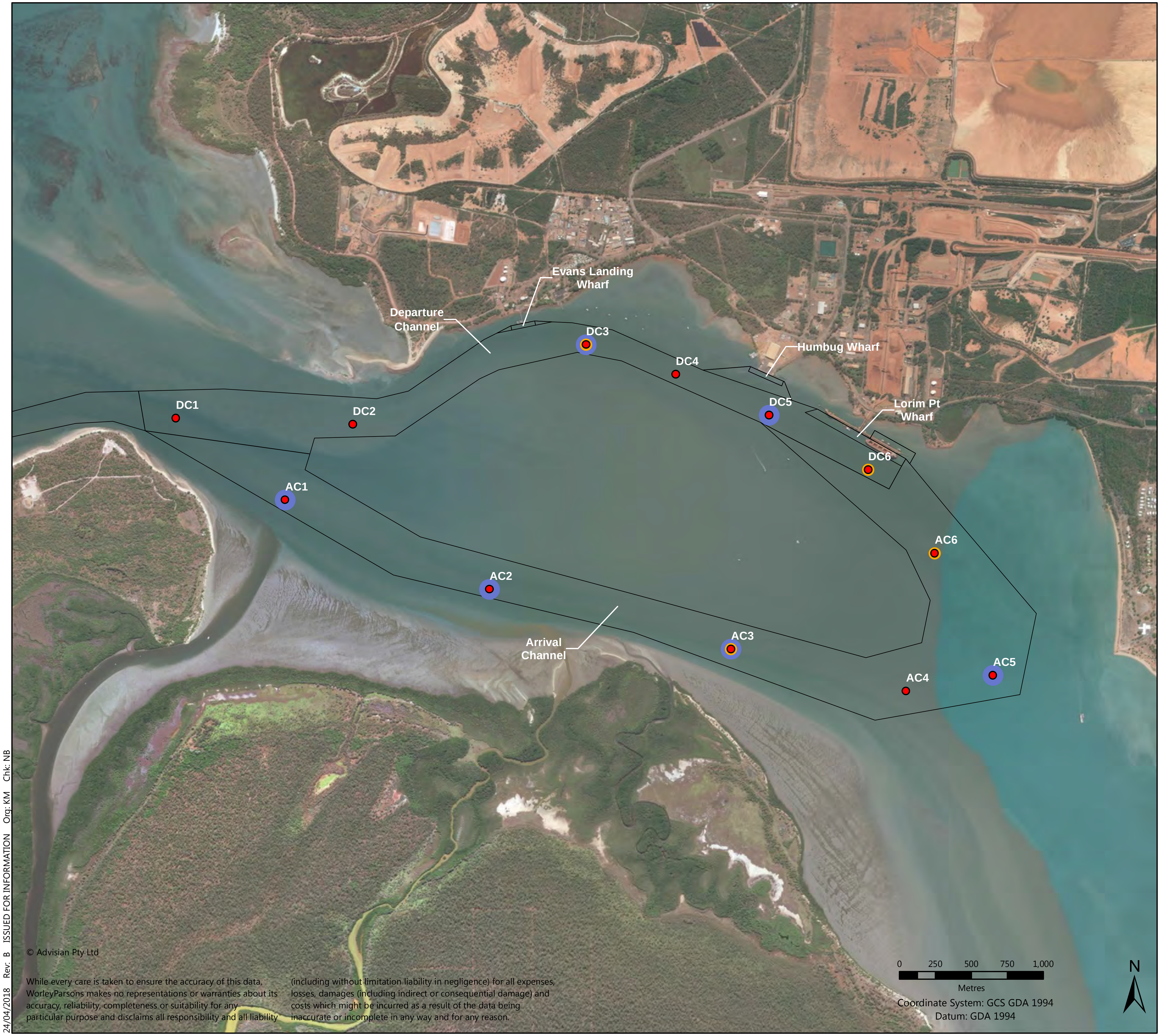
Figure 2-3: Sampling Locations Arrival and Departure Channels

- Sediment sample locations
- Acid Sulfate Soils (ASS) sample location
- Geotech sample location
- Dredge area



MAP KEY

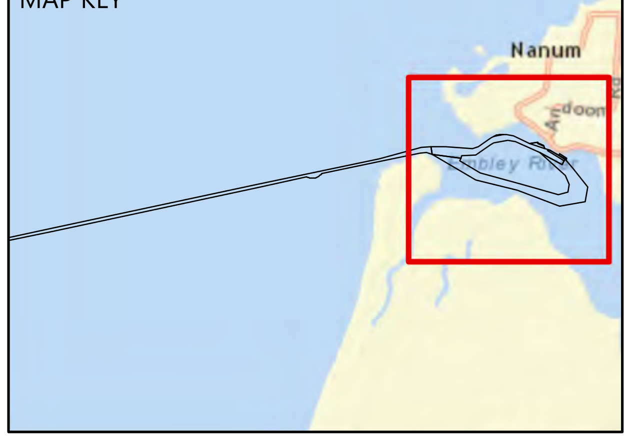


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Figure 2-4: Sampling Locations Lorim Point Wharf and Tug Berths

- Sediment sample locations
- Acid Sulfate Soils (ASS) sample location
- Geotech sample location
- Dredge area

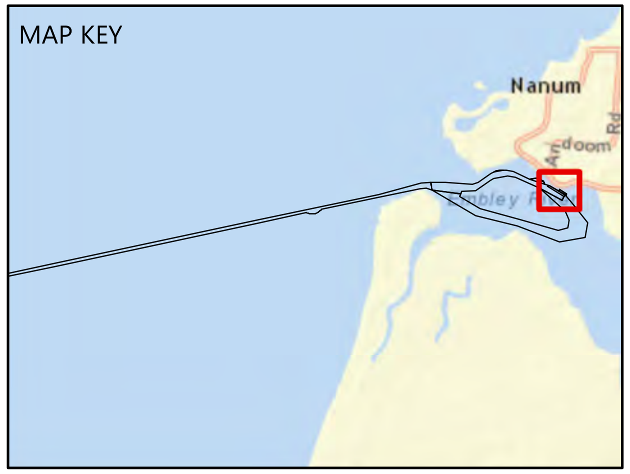

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Figure 2-5: Sampling Locations Humbug Wharf

Sediment sample locations

Acid Sulfate Soils (ASS) sample location

Geotech sample location

Dredge area

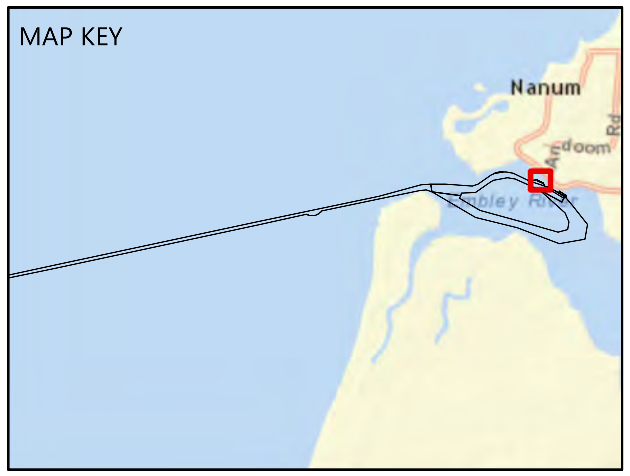

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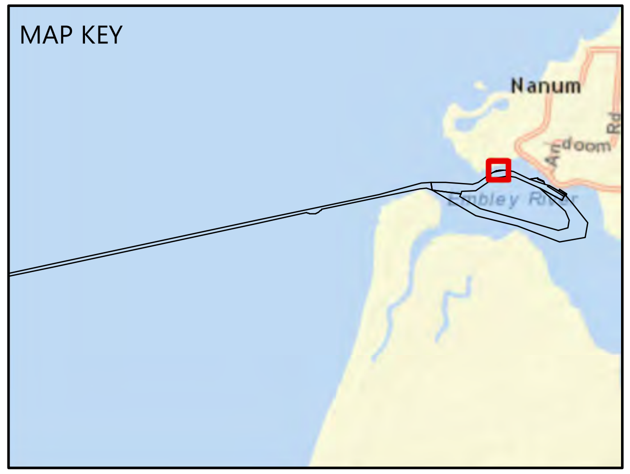
Figure 2-6: Sampling Locations Evans Landing

- Sediment sample locations
- Acid Sulfate Soils (ASS) sample location
- Geotech sample location
- Dredge area

MAP KEY



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Port of Weipa
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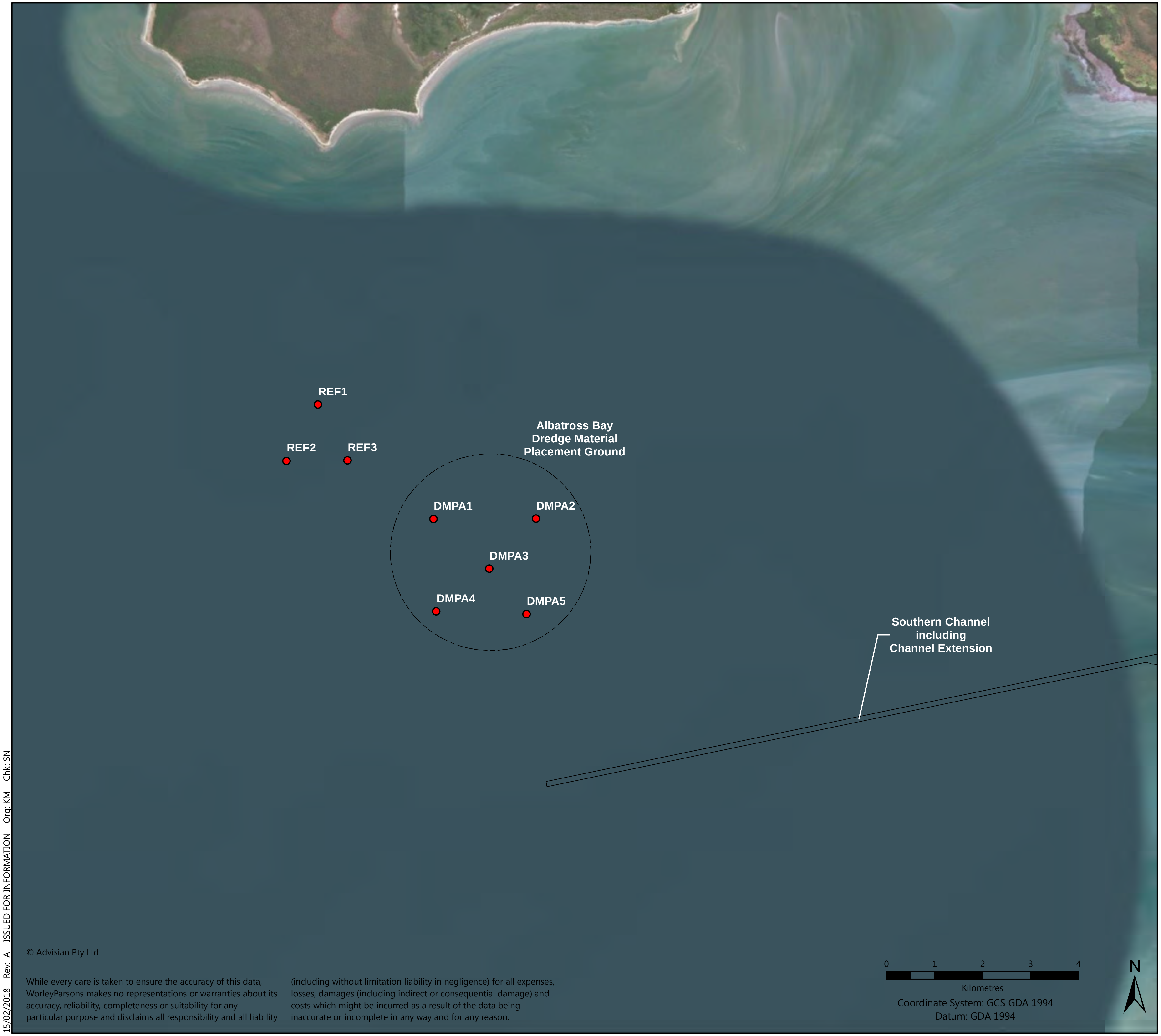
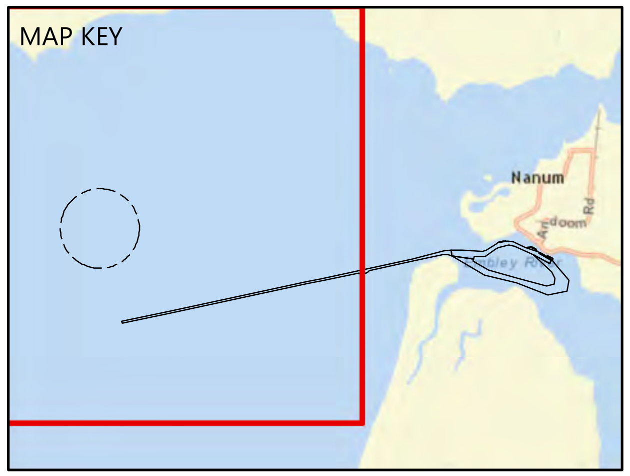
Figure 2-7: Sampling Locations Albatross Bay DMPA and Reference Sites



Sampling location
Dredge area



Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the

Coordinate System: GCS GDA 1994
Datum: GDA 1994

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Figure 2-8: Sampling Locations Amrun Port

- Sediment sample locations
- Acid Sulfate Soils (ASS) sample location
- Geotech sample location
- Mine and port infrastructure
- Dredge footprint

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The number of sampling locations selected was in general accordance with requirements for a pilot study outlined in the National Assessment Guidelines for Dredging (NAGD, 2009). A detailed description of the sediment properties investigations is provided in Appendix A, and a summary of the key findings is provided below.

2.1.1 Key findings

The sampling and laboratory testing found there is significant variation in the geotechnical properties, which determine the sediment characteristics of the dredge material within the Port of Weipa and at Amrun Port, which are outlined below.

Port of Weipa

- Naturally accumulating material encountered in the Port of Weipa navigational areas varied considerably between and within areas with typically high fines (clay and silt) content.
- Most of the dredging volume consists of fine sediment which accumulate in the middle section of the Southern Channel.
- The areas where coarse-grained sediments appear to prevail include most of the Approach and Departure Channel and the inner portion of the Southern Channel.
- The fine-grained sediments may be suitable for low to medium load applications following adequate drying out and compaction, noting that this material may take many months to many years to consolidate, dependent on drainage path length.
- The coarser sediments may be suitable for medium to high loading applications following adequate compaction.
- The sand material, following screening and washing, is suitable for use in premixed structural concrete manufacturing.
- Poor drainage characteristics were reported for the silt / clay samples and good drainage characteristics for the sand samples.

Amrun Port

- Naturally accumulating material encountered in Amrun Port were predominately silts and clays with relatively high fines contents of an estimated 86%.
- The Amrun sediments contain high plasticity silt and clay, and strength tests suggest that these fine-grained sediments may be suitable for low to medium load applications following adequate drying out and compaction, noting that this material may take many months to many years to consolidate, dependent on drainage path length.
- The Amrun sediments were very wet muds with excessive fines, and it is considered that these sediments would not easily be used in concrete products.
- Potential Acid Sulfate Soil (PASS) was detected in all Amrun samples; however, analysis of the Acid Neutralising Capacity (ANC) of these samples indicated that if bought ashore, the marine sediments are unlikely to require treatment via neutralisation with lime.
- All Amrun samples are considered highly saline and therefore if sediments are placed on land without treatment, salinity will degrade the quality of terrestrial soils and may impact the quality of receiving waters.

2.1.2 Geotechnical results

The geotechnical laboratory testing determined the properties and enabled characterisation of the sediment material. These properties and characteristics, detailed in Appendix A and outlined below, assist to define the suitability of material for various reuse options. The properties below are described in relation to the general results range for the test to indicate where the sediment characteristics lie in relation to other materials.

Port of Weipa

Material description

The sediments encountered in the Port of Weipa navigational areas varied considerably between and within areas with typically high fines (clay and silt) content. The areas where coarse-grained sediments appear to prevail include most of the Approach Channel and the inner portion of the Southern Channel. The Departure Channel contains both fine-grained and coarse-grained materials. Zones of coarse-grained sediment were present within the berth areas, particularly at Evan’s Landing and Lorim Point where clayey sand / gravel materials were identified.

Carbon content

The carbonate content testing indicated a range of results across all areas (between 8% and 57%); however, only one test result was greater than 50% carbonate content. Based on this, the sediments may be generally considered “calcareous soils” which potentially provides some PASS neutralising capacity.

Atterberg limits

Atterberg limits testing (liquid limit and plastic limit) is designed to reflect the influence of water content, grain size and mineral composition on the mechanical behaviour of clays and silts. The plasticity of the sediments is relatively variable across the sites. The fine-grained sediments range from low to high plasticity clay and low to high plasticity silt, with many samples falling close to the “A-Line”, meaning that these materials will exhibit engineering behaviour bordering between that of silt and clay.

Linear shrinkage

Linear shrinkage results indicate a generally low potential for volume change for most of the materials tested, with a medium / medium to high potential for volume change indicated by a sample in the Southern Channel and a combined sample from the Tug Berths. The Volume Change Classification (Look,1994) for the sediments ranges from “very low” to “low” in general, “moderate” in places and “high” for a combined sample from the Tug Berths.

Density

The sediment particle densities ranged between 2.51 t/m^3 and 2.63 t/m^3 across the Port of Weipa.

The results indicate that the dry densities of the coarse-grained dredge sediments will range between approximately 1.22 t/m^3 and 1.81 t/m^3, depending on the level of compaction or method of placement utilised onshore. As expected, as the fines content increases the density decreases.

Strength and consolidation

The CU triaxial testing was undertaken on four samples and the test results indicate that the coarse-grained sediments may achieve friction angles of 33° to 44° after compaction and loading. These values are within the range generally associated with medium dense to very dense sand deposits and suggest that the coarse-grained sediments may be suitable for medium to high loading applications following adequate compaction.

The test results for fine grained sediments (silt/clay) indicate that the average cohesion of the samples after compaction and loading ranges from 3 kPa to 13 kPa, and the average friction angle ranges from 33° to 36°. These strengths suggest that the fine-grained sediments may be suitable for low to medium load applications following adequate drying out and compaction.

The coefficient of consolidation values (c_v) (for the three samples with high fines content (Outer Southern Channel, Humbug and Tug Berth samples) are within the typical range expected for clays and silts, and the results for the remaining sample (Approach Channel) are within the range expected for a sandy silt. The c_v values for the samples with high fines content indicate that this material may take many months to many years to consolidate, dependent on drainage path length.

Permeability

The permeability test results are generally within the range expected for the types of sediments tested, with "poor" drainage characteristics being reported for the silt / clay samples and "good" drainage characteristics for the sand samples. The only exception to this was an Approach Channel sample (37% fines content, i.e. borderline sandy silt / silty sand), which behaved more like a sand with few fines rather than a sandy silt / silty sand material.

Cement laboratory testing

Cement laboratory testing was undertaken on four sediment samples from the Port of Weipa to assess their suitability as a binding agent in cement products. Summary results include:

- Most of the samples tested had a relatively high water and fines contents, which would limit their use in high quality concrete products.
- Humbug and Lorim Point sediments (coarse) may be suitable for use in flowable fill applications; however, additional testing on larger samples of the target material would be required to examine the effectiveness of stabilisation when mixed with Portland Cement.
- The Southern Channel sediments with relatively low fines, and high silica and sand content could be useful as an alternative source of normal fine sand in concrete and concrete products. To separate sand for general premixed concrete use, the fines and relatively high level of chlorides present would need to be washed, which would create a fine material and saline waste stream which would need to be managed. This fine sand could typically be used at a rate of 200kg per m^3 of concrete (or <10% by weight). For other concrete uses (blocks or flowable fill) where reinforcement is not present, it could be used at substantially higher levels, with less

pre-treatment. The Southern Channel sediments with excessive fines would not easily be used in concrete products.

Amrun Port

Material description

The sediments encountered in Amrun Port (Approaches and Berths) were predominately silts and clays with relatively high fines content. The carbonate content test results ranged between 33.2% and 35.3%, indicating that these sediments may be considered "calcareous soils" which potentially provides some PASS neutralising capacity.

Atterberg limits

Atterberg limits testing (liquid limit and plastic limit) indicated that the Amrun sediments contain high plasticity silt and clay.

Linear shrinkage

Linear shrinkage results indicate a low to medium potential for volume change for the materials tested. The Volume Change Classification for the Amrun sediments ranges from "low" to "moderate".

Density

The sediment particle densities ranged between 2.53 t/m^3 and 2.60 t/m^3 at Amrun Port. The results suggest that only relatively low dry densities (1.13 t/m^3 to 1.21 t/m^3) can be achieved for the Amrun dredge sediments; however, dry densities of 1.49 t/m^3 to 1.50 t/m^3 were able to be achieved during laboratory tests on remoulded samples. No minimum / maximum dry density testing or direct shear testing was carried out on the Amrun Port samples due to the fine-grained nature of the sediments.

Strength and consolidation

The CU triaxial testing was undertaken on a single sample from Amrun Port. The test results indicate that the cohesion (c') of the sediment after compaction and loading is approximately 10 kPa and the friction angle is approximately 29°. This strength suggests that the fine-grained sediments at Amrun Port may be suitable for low to medium load applications following adequate drying out and compaction.

The Amrun sample was also subjected to oedometer testing resulting in the coefficient of consolidation (c_v) values for the Amrun sample is within the typical range expected for clay / silt. The c_v value for the Amrun sediment sampled indicates that this material may take many months to many years to consolidate dependent on drainage path length.

Permeability

No permeability testing was carried out for the material from Amrun Port; however, the test results for similar materials from the Port of Weipa are considered likely applicable to the Amrun sediments i.e. "poor" drainage characteristics for the silt / clay samples at Amrun.

Cement laboratory

Cement laboratory testing was undertaken on two samples from the Amrun Port. The Amrun sediments were very wet muds with excessive fines, and it is considered that these sediments would not easily be used in concrete products.

2.1.3 Geochemical results

PASS

Potential Acid Sulfate Soils (PASS) was detected in all samples analysed for ASS parameters from the navigational areas of the Port of Weipa and Amrun. Samples with the highest chromium suite of analysis (S_{CR}) concentrations were samples where the predominant component was silt and/or clay (i.e. Southern Channel, Tug Berth and Amrun samples).

Acid Neutralising Capacity (ANC) was detected in all samples submitted for ASS analysis with concentrations sufficient to negate acidity. This buffering potential is expected to arise from the presence of carbonate within the sediments. These data indicate that the marine sediments from the Port of Weipa and Amrun may not require treatment through neutralisation using lime, dependent on the dredging and management methods applied to the sediments.

Contamination

Sediment samples tested from the Port of Weipa contained a small number of very low levels contamination, found to be below NAGD screening levels and hence are suitable for placement in the Albatross Bay DMPA.

Salinity

All samples are considered extremely saline (i.e. > 1210 μS/cm) according to Rayment and Lyons, 2011 salinity ratings. Higher salinity levels were reported for samples with finer textures (i.e. silts and clays), with the highest concentrations detected in Southern Channel, Tug Berth and Amrun samples. Sandy textured sediments generally located in Approach Channel, Departure Channel, Lorim Point, Humbug and Evan's Landing samples were reported with lower salinity. If sediments are placed on land without treatment, salinity will degrade the quality of terrestrial soils and may impact the quality of receiving waters (groundwater and surface water).

Organic material

Low Organic Material (OM) was reported for all samples analysed. The highest OM (i.e. >3%) was detected in finer textured samples. Samples with a gravel component had the lowest OM, <1%.

2.1.4 Interpretation

Interpretation of the general properties and range of the sediment material characteristics outlined above enables matching to a potentially corresponding beneficial reuse option or options. The appropriateness of sediment material characteristics to meet a particular reuse option's requirement ranges from suitable to potentially suitable (with treatment and processing) to entirely unsuitable. The suitability of specific sediment material properties is considered with reference to each individual potential reuse option and analysed in Sections 4.2, 4.3 and 4.4.

2.2 Maintenance dredging requirements

Port of Weipa

The South Channel has been regularly dredged for approximately 40 years to maintain safe access for shipping (WBM & LeProvost Dames and Moore, 1998). During the 1980s the channel was deepened and extended to a length of 14.5km and depth of 8.2m LWD (low water datum). It was further widened and deepened during 2006. Most recently, capital dredging in 2012 extended the entrance to the Southern Channel some 2,400m (PACE, 2013).

NQBP undertakes maintenance dredging to maintain declared depths within the Port of Weipa. Annual maintenance dredging is commonly undertaken by the Trailing Suction Hopper Dredge (TSHD) '*Brisbane*', under contract to NQBP, and placed at sea in the approved DMPA within Albatross Bay. A 10-year Sea Dumping Permit for the Port of Weipa allows for an average of 1,111,000m^3 to be dredged per annum[2]; however, as this amount includes contingency for effects such as cyclones, this volume is not typically realised on an annual basis (Table 2-1). Typical volumes dredged during maintenance dredging programs in the last five years range from 297,301m^3 in 2017 to 644,525m^3 in 2013.

Based upon data provided by NQBP the average volume of sediment removed for the past five years is 502,032m^3/yr. For the purposes of the beneficial reuse assessment a maintenance dredge volume of 500,000m^3/yr. has been assumed for the Port of Weipa.

Volumes of dredged material generated during past dredging programs (2002 – 2017) are shown in Table 2-1. Note that the 2002 program was conducted after a two-year gap in maintenance dredging. Given that the previous dredging occurred in 2000 this resulted in a larger than average dredge volume in 2002.

Table 2-1: Volume of Dredge Material removed every year since 2002

Year of Dredging	Type of Dredging	Volume of *in situ* Material removed (m^3)
2002	Maintenance	976,585
2003	Maintenance	463,513

[2] NQBP Port of Weipa – Long Term Environmental Management Plan (LTDMP) Sep. 2013.

Year of Dredging	Type of Dredging	Volume of *in situ* Material removed (m^3)
2004	Maintenance	621,650
2005	Maintenance	803,098
2006	Capital and Maintenance	2,976,868
2007	Maintenance	711,000
2008	Maintenance	774,100
2009	Maintenance	553,457
2010	Maintenance	832,779
2011	Maintenance	470,820
2012	Capital and Maintenance	927,057
2013	Maintenance	644,525
2014	Maintenance	394,523
2015	Maintenance	368,384
2016	Maintenance	504,071
2017	Maintenance	297,301
2018	Maintenance	591,875

Amrun Port

Capital dredging at Amrun Port was undertaken in March/April 2016 with 202,416m^3 (in-situ volume) removed for the berth pocket and departure area (RTA, 2017). The dredged material was placed at the Amrun DMPA.

Maintenance dredging of 42,038m^3 (with the majority of this being within the berth pocket) and bed levelling was undertaken in May 2018 to return the depths to the original design depths in anticipation of the Port being operational towards the end of 2018.

Maintenance dredging is required at Amrun Port due to sedimentation (which occurs principally in the berth pocket) mainly due to the resuspension of existing fine-grained sediment within the port area due to wave action. The suspended sediment is then transported backwards and forwards repeatedly past the channel with 2-3% of the total (gross) suspended sediment transported becoming trapped. The sedimentation occurs predominantly during the wet season due to increased suspended sediment concentrations resulting a combination of runoff and coastal wave action.

It is currently interpreted that Amrun Port maintenance dredging of 11,000m^3/yr. of material may be required and 26,000m^3/yr. of material every second year with additional sediment accumulation due to a cyclonic event. As such, for the purposes of this assessment it is proposed to use 19,000m^3/yr. as the average annual Amrun Port dredge volume, and it is assumed that 90% (17,000m^3) of the material will be dredged from the berth pocket and 2,000m^3 from the departure channel.

2.2.1 Determining dredge volumes

Port of Weipa

Maintenance dredging volumes have been defined for each of the nominated dredge areas based on historical dredging information provided by NQBP (refer to Table 2-2 below). The total 500,000m^3/yr. volume estimate are based on the average of the volumes dredged since 2012, excluding the 2012 capital dredging volume and excluding 2017[3].

Table 2-2: Estimated volumes for each identified dredge area

Dredge Area	Volume estimate (m^3)	Design depth(-mLAT)	Footprint (ha)
Southern Channel (and Extension)	462,000	11.1 (12)	256
Evans Landing	500	9.4	0.5
Humbug	500	9.5	0.86
Lorim Point	500	12.3	2.45
Approach Channel	24,000	7.3	272.5
Departure Channel	12,000	11.1	138.3
Tug Berth	500	5.0	2.12

[3] The 2017 dredge volume was excluded as an unusually small dredge volume.

It is considered that most of the maintenance dredging (estimated at 90%) will be required in the Southern Channel (and Extension), with a notable amount of dredging in the Approach and Departure Channels and very little dredging required in the berth areas.

Amrun Port

Table 2-3: Estimated volumes for identified dredge area

Dredge Area	Volume estimate (m^3)	Design depth(-mLAT)	Footprint (ha)
Amrun Port	19,000	13.8 (16.2 berth)	16

NQBP considers it reasonable to assume that maintenance dredging will be required to remove approximately 19,000m^3/yr., based upon average of normal year 11,000m^3/yr. and cyclonic every second year 26,000m^3/yr. from the navigational areas (90% berth and 10% departure channel) of Amrun Port.

2.2.2 Dredging methods

A TSHD has been used for the Port of Weipa's maintenance dredging program since 2002. The TSHD Brisbane was contracted to service dredging needs at the Port of Weipa and Amrun Port by NQBP, (on behalf of RTA for Amrun Port) in 2018 and is expected to be engaged to conduct maintenance dredging during 2019. This type of dredge is well-suited to the maintenance dredging requirements of the Port of Weipa and Port Amrun.

2.3 Implications for potential beneficial reuse

The properties of the sediment to be dredged along with the current and predicted future maintenance dredging requirements are key considerations for identification and analysis of potential beneficial reuse options for the sediment. An approximation of the amount of each sediment type (fines, sand and gravel) that currently require dredging from each of the Weipa and Amrun port areas is represented in Tables 2-4 and 2.6 respectively. These representations have been derived in consideration of the PSD results from sediment properties analysis and the current maintenance dredging requirements described above, rather than the historical annual totals which do not quantify individual areas.

Given the average volume of sediment removed for the past five years from the port of Weipa is 502,032m^3/yr. a maintenance dredge volume of 500,000m^3/yr. has been assumed for the purposes of this beneficial reuse assessment. 100,000m^3/yr. of the total volume is assumed to be sand/gravel and the balance 400,000m^3/yr. fine material. Refer Table 2-5. It is currently interpreted that Amrun Port maintenance dredging of 11,000m^3/ yr. of material may be required and 26,000m^3/yr. of material every second year with additional sediment accumulation due to a cyclonic event. As such, for the purposes of this assessment it is proposed to use 19,000m^3/yr. as the average annual Amrun Port dredge volume, and it is assumed that 90% (17,000m^3) of the material will be dredged from the berth pocket and 2,000m^3 from the departure channel.

Table 2-4: Approximation by PSD of Weipa dredge volumes (m^3) and sediment type in each dredge area

Area	Approximate Dredge Volumes by Particle Size (m^3)			
	Approximate Total Dredge Volume Estimate (m^3)	Fines	Sand	Gravel
Southern Channel & Extension (SC-1 to Sc-5))	106,000	8,500	86,900	10,600
Southern Channel & Extension (SC-6 to SC18)	426,000	391,000	29,800	4,300
Evans Landing	10,000	2,300	4,000	3,700
Humbug	10,000	5,400,	4,300	300
Lorim Point	10,000	3,300	4,800	1,900
Approach Channel	11,000	2,400	8,000	600
Departure Channel	11,000	2,400	6,800	1,800
Tug Berth	10,000	7,900	800	1,300
Totals	**594,000**	**417,800 (72%)**	**145,400 (24%)**	**24,800 (4%)**

Table 2-5: Assumed Weipa total dredge volumes (m^3) and sediment types by historical data

Area	Assumed Dredge Volumes by Historical Data (m^3)			
	Assumed Total Dredge Volume (m^3)	Fines	Sand	Gravel
Totals	**500,000**	**400,000 (80%)**	**100,000 (20%)**	

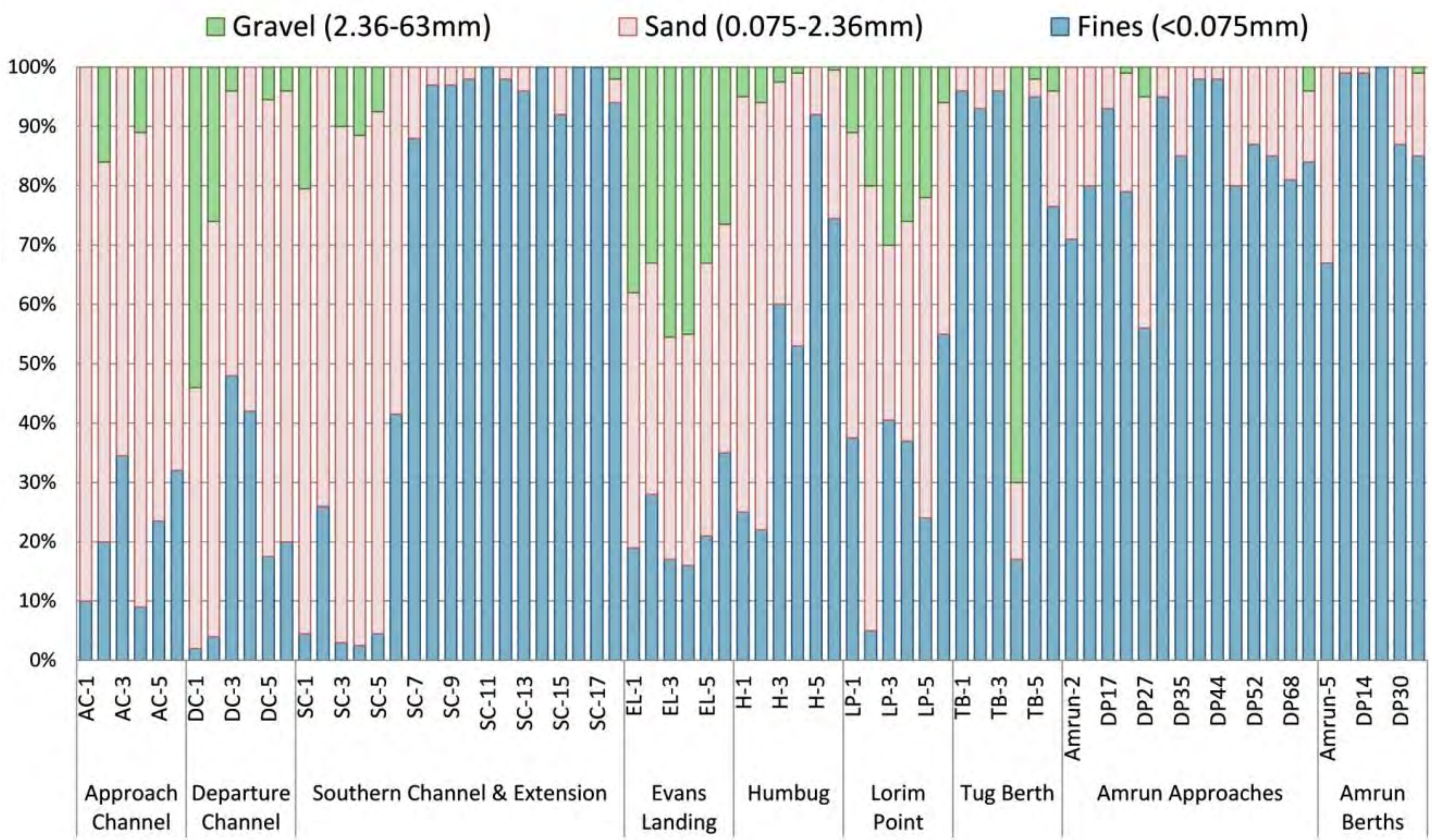
Table 2-6: Approximation by PSD of Amrun dredge volumes (m^3) and sediment type in each dredge area

Area	Approximate Dredge Volumes by Particle Size (m^3)			
	Approximate Total Dredge Volume Estimate (m^3)	Fines	Sand	Gravel
Amrun Approaches	25,000	21,000	3,800	300
Amrun Berths	17,000	15,300	1,700	0
Totals	**42,000**	**36,300 (86%)**	**5,500 (13%)**	**300 (1%)**

Table 2-7: Assumed Amrun total dredge volumes (m^3) and sediment type in each dredge area by historical data

Area	Assumed Dredge Volumes by Historical Data (m^3)			
	Assumed Total Dredge Volume (m^3)	Fines	Sand	Gravel
Amrun Approaches	**2,000**	**2,000**	-	-
Amrun Berths	**17,000**	**17,000**	-	-
Totals	**19,000**	**19,000 (100%)**	-	-

Table 2-8: Particle Size Distribution (gravel / sand / fines proportions) by sample location



hese estimated dredging volumes from Table 2-2 (based upon particle size distribution for each of the main Port of Weipa and Amrun Port areas) have been used for the beneficial reuse assessment options identification and analysis described in Section 0.

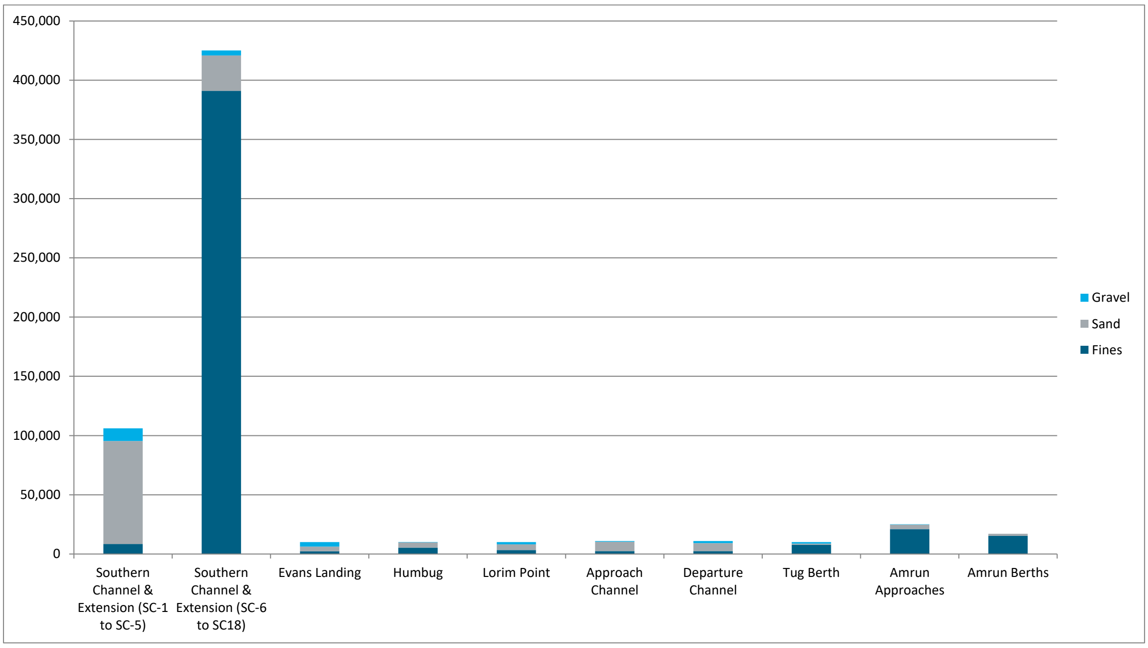


Figure 2-9: Dredge volumes (m^3) and proportion of sediment type in each dredge area based on average particle size distribution

As illustrated in Figure 2-9, the sediment is dominated by the fine clay/silt and sand portions with coarse material (gravel) almost absent. This unbalanced distribution of fine particle size means the sediment material is considered poorly graded.

Given the predictions of future maintenance dredging requirements described above, it is considered likely that the volumetric split of material per dredge area and sediment type will be similar for future maintenance dredging i.e. the vast majority of material to be dredged from the Southern Channel and Extension area, the majority of which will be fine material (SC-6 to SC-18) with some potential to target sand material in the nearshore (SC-1 to SC-5), Approach Channel and Departure Channel areas.

The predominantly sandy material in the Southern Channel nearshore (SC-1 to SC-5), Approach Channel and Departure Channel areas may be of sufficient quantity (estimated at 100,000m^3/yr. based upon PSD approximation.) to warrant targeted dredging to support a beneficial use separate from that of the remaining material from other areas. Otherwise most of material to be dredged is a mixture of sediment type, dominated by fine material, which has accumulated in relatively confined areas, within which it would likely be impractical to separate sediment types during dredging. As such, it is considered likely that selective dredging of material for alternate beneficial reuse options (e.g. managing sand material for one use, separate from fine material for another use) may be feasible. In addition, there may be some opportunity within a reuse option, to maximise the proportion of sand versus fine material dredged and placed or vice versa through dredge operations ‘overflow technique’ and dredge material handling activities.

3 Analysis Method

The second stage of investigations comprised two phases, being:

- Identification of potential beneficial reuse options
- Analysis of the opportunity, potential feasibility and achievability of the options in the context of the Port of Weipa and Amrun Port.

A description of the considerations for analysis is provided below, followed by description of the methods of analysis.

3.1 Relevant considerations

3.1.1 Primary considerations

The primary considerations of the analysis were the properties of the sediment to be dredged and the current and likely future maintenance dredging requirements.

While the basis of the analysis is that the maintenance dredge material is delivered in a wet state to a reuse area which is not defined in a geographical space, it is considered reasonable for the analysis to provide some consideration of regional context i.e. potential beneficial reuse options may be limited by the location of the potential downstream beneficial use relative to the maintenance dredge areas. Figure 1-2 shows the port areas in the regional context which was considered in the beneficial reuse analysis.

3.1.2 Other considerations

3.1.2.1 Dredge and dredge material placement method

One of the key assumptions identified by NQBP to apply to the beneficial reuse analysis was the assumption that dredged material is delivered to a reuse placement area (not defined in geographical space) in a wet state. Nonetheless it is notable that the potential feasibility of beneficial reuse options depends heavily on the cycle from dredging to end use. Dredging and placement methods affect the ability to successfully reuse the material. Some options may be enabled directly by the dredge used (e.g. they may be delivered directly to their final location by the dredge).

To provide context to the potential beneficial reuse options analysis, this section outlines the main dredging and placement methods that were considered, firstly through discussion of the overall 'route' to beneficial reuse, and secondly through discussion of specific dredge and placement methods. This is largely drawn from the Permanent International Association of Navigational Congresses (PIANC) publication *Dredged material as a resource: Options and Constraints* (PIANC, 2009).

3.1.2.2 Implications of beneficial reuse route

There are several potential approaches which may be used in conveying dredged material towards a beneficial reuse, including direct use, treatment and intermediate storage.

Direct use

Direct use options involve the direct use of dredge material without the need for treatment and/or storage. The dredged material may be utilised directly for uses such as embankment construction, land reclamation, beach nourishment, off shore berms or habitat restoration or creation.

Capital dredging with cutter suction dredgers, backhoes, grab or bucket ladder dredgers often produces dredged material consisting of rock, gravel, sand and consolidated clay. The material can be pumped through a pipeline to the place of use, or into barges for transport direct to the required location.

Maintenance dredging with suction dredgers (predominantly trailer suction hopper dredgers) typically produces material consisting of loose gravel, sand and mud. The material is transported in the vessel's hopper to the area of use. The material is either deposited through hatches at the bottom of the ship, dumped by method of split hopper dumping, pumped through a floating pipe or rainbowed[4].

Hydraulic dredging (i.e. using cutter suction or trailer suction hopper dredgers) typically results in the dredged material containing a large proportion of water, which may not be desirable in certain applications of reuse. Use of a bucket dredger typically sees less water entrainment than hydraulic dredging, with the dredged material loaded by the bucket dredge into a barge which then transports the material to the place of reuse.

Treatment prior to use

For dredged material not directly meeting the potential reuse criteria, many treatment techniques may be applied, depending on the sediment properties and desired reuse.

Treatment techniques designed to meet geotechnical requirements include physical techniques such as dewatering, separation (e.g. screening plant) or blending with other materials. Treatment techniques designed to meet environmental requirements may include chemical, biological or thermal treatment (e.g. bioremediation, immobilisation and thermal oxidation), which are most commonly applied to contaminated sediments. The high salinity levels in the dredged material may be reduced by leaching or washing techniques. A combination of several techniques might be necessary to meet reuse requirements in a treatment chain; which typically commences with material dewatering.

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[4] Discharge from the dredge by propelling the material in a high arc 'rainbowing' to a particular location, typically depositing the dredge material on the water's surface or onshore.

Intermediate storage

Intermediate storage between dredging and use might be necessary due to logistical reasons such as:

- Different timing between dredging and use due to planning or environmental reasons
- Difference in production rate of the dredging activity and the capacity and rate of demand for the use
- Difference in capacity of dredging and treatment, as the rate of treatment is generally an order of magnitude lower than the production rate of the dredging plant
- To create homogeneity of the input of dredged material, as certain treatment processes such as mechanical separation need homogenous inflows for proper operation.

Intermediate storage may also be useful as it may allow more detailed characterisation of the dredged material before use.

3.1.2.3 Implications of dredge and placement method

Dredging method

The dredge method chosen may enable some treatment of sediments during dredging, and as such has implications for the potential feasibility of reuse options available.

A trailer suction hopper dredger may allow for some separation of dredge material during the dredging operation based on grain size. If a mixture of coarser material (sand and gravel) and fines is dredged, a large proportion of the fines can be washed out with the overflow while dredging. The coarser material settles in the hopper while the fines, together with the process water leave the hopper through funnels or weirs in the hopper. This may enable the separation of sands from finer material, of which the sands may have greater reuse potential (e.g. for beach nourishment); however, this type of dredging (overflow dredging) creates greater levels of turbidity in the dredge areas, which may be less desirable.

Placement method

Specific placement methods are sometimes specified for certain types of reuse such as:

- **Diffusers**: Diffusers may be required for certain uses to reduce the velocity of the dredged material discharge stream. Diffusers limit the suspension of material and may enable coverage of an area with a homogeneous layer of sediments.
- **Rainbowing**: For reuse situation where access for direct unloading might be difficult, the placement may be executed using a front discharge from the dredge propelling material in an arc through the air, depositing the dredge material on the water surface or onshore. This may be useful for beneficial reuse options in shallow areas where the placement of a floating pipeline is problematic.
- **Seabed placement**: Direct placement of material on the seabed from a pipeline or via a diffuser may be undertaken to reduce turbidity through the water column.

Dredge, placement and reuse logistics

The matching of dredging, placement and reuse logistics is a significant consideration in the successful development of a beneficial reuse project. Several logistical issues warrant consideration:

- **Timing**: Ideally the schedule for dredging and reuse are matched, such that they may be planned and organised concurrently. If direct matching is not possible, intermediate storage may be necessary.
- **Operational aspects**: To match dredging and reuse, operational aspects of both activities need consideration, such as production rate and duration of delivery. Treatment and direct use routes may impose limits on the dredging operation, e.g. due to limited capacity for treatment or settling/consolidation times in reuse areas.

3.1.2.4 Environmental approval requirements

Environmental approval requirements are considered in the analysis of each of the beneficial reuse options. As there are likely to be common environmental approval requirements across each of the options, a summary of key approvals is provided in Table 3-1. For each approval identified in Table 3-1, an indication is given as to whether it is likely to apply to the 'dredging and placement', 'onshore reuse' or 'offshore reuse' components of beneficial reuse options (discussed in Section 4). Offshore reuse includes works in the tidal zone.

Approval for unconfined ocean disposal has previously been granted to NQBP for the Port of Weipa maintenance dredging, pursuant to the issue of a Sea Dumping Permit under Section 19 of the *Environment Protection (Sea Dumping) Act 1981*.

Rio Tinto has received a Commonwealth Sea Dumping Permit (SD2017/3722) to facilitate maintenance dredging at Amrun Port from 2018 to 2020.

The approvals required for the beneficial reuse of dredged material will ultimately depend on the detailed project scope of works, timing and strategy for approval obtainment and the position of the Australian and Queensland Governments with respect the works while taking into consideration feedback from the Traditional Owners.

Table 3-1: Potential environmental approvals required

Approval	Legislation and administering authority	Potential trigger / activity covered	Potentially applicable reuse component
Approval for a controlled action	*Environment Protection and Biodiversity Conservation Act 1999* Australian Government Department of the Environment and Energy	Potential for significant impact on: ▪ Listed threatened species and communities ▪ Listed migratory species ▪ Commonwealth marine areas	Dredging and Placement Onshore reuse Offshore reuse
Land owner's consent for works on State-owned land	*Planning Act 2016* (Planning Act) *Coastal Protection and Management Act 1995* (CP&M Act) Queensland Department of Natural Resources and Mines (DNRM)	Material Change of Use proposed on State land Works on lots owned by the State below the high-water mark and outside a canal as defined under the CP&M Act	Dredging and placement Onshore reuse Offshore reuse
Allocation of quarry material	CP&M Act Queensland Department of Environment and Science (DES)	Works on lots owned by the State that involve interference with quarry material (seabed or earthworks)	Dredging and placement Onshore reuse Offshore reuse
Quarry material sales permit	*Forestry Act 1959* Queensland Department of Agriculture, Forestry and Fisheries (DAFF)	Disturb soil or other material in lots for which quarry material is reserved to the Crown (Crown land, freeholding leases and properties subject to a deed of grant)	Placement

Approval	Legislation and administering authority	Potential trigger / activity covered	Potentially applicable reuse component
Port Development Approval and Material Change of Use where a use is inconsistent with the Land Use Plan	Planning Act 2016 *Transport Infrastructure Act 1994* (TI Act) and relevant code: Port of Weipa Land Use Plan NQBP Minister under the TI Act	Works in strategic port land (onshore and offshore lots) for the beneficial reuse project	Dredging and placement Onshore reuse Offshore reuse
Material Change of Use and/or reconfiguration of a lot under the Local Government planning scheme	Planning Act and Weipa Town Authority Interim Development Control Regulation Advisory Development Plan for Weipa Local Government Area Weipa Town Authority	Works in the local government area that are inconsistent with the designation of the planning scheme and / or require approval under the scheme	Placement Onshore reuse
Operational Work - Tidal works	Planning Act Planning Regulation 2017 CP&M Act Referral agency: Queensland State Assessment and Referral Agency (SARA) Technical advice: DES, Maritime Safety Queensland (MSQ)	Works in tidal waters for the beneficial reuse project	Dredging and placement Offshore reuse
Operational work – removal, damage or destruction of marine plants	Planning Act, Planning Regulation *Fisheries Act 1994* Referral agency: SARA Technical advice: DAFF	Works in tidal waters potentially involving the removal, damage or destruction of marine plants	Dredging and placement Offshore reuse
Amendment of existing Material Change of Use (MCU) for Environmentally	Planning Act Planning Regulation *Environmental Protection Act 1994* (EP	Dredging in offshore lots	Dredging

Approval	Legislation and administering authority	Potential trigger / activity covered	Potentially applicable reuse component
Relevant Activity (ERA) 16 – extractive and screening activities - dredging	Act 1994) Referral agency: SARA Technical advice: DES		
Amendment of current Environmental Authority for ERA 16 - extractive and screening activities - dredging	EP Act 1994 DES	Dredging in areas previously approved, with subsequent beneficial reuse	Dredging
Amendment of current Environmental Authority for ERA - Mining Activities	EP Act 1994 DES	Onshore reuse on the RTA Mining Lease	Dredging, onshore dredge material treatment areas, Regulated Dams, Beach Nourishment, Shoreline protection
Operational work - Clearing native vegetation	Planning Act Planning Regulation *Vegetation Management Act 1999* Referral agency: SARA Technical advice: DNRM	Clearing of native vegetation.	Placement Onshore reuse
Permit to tamper with animal breeding places	*Nature Conservation Act 1994* (NC Act 1994) Nature Conservation (Wildlife Management) Regulation 2006 DES	Tampering with native animal breeding places during clearing and grubbing activities.	Placement Onshore reuse
Protected Plants Clearing Permit	*NC Act 1994* *Nature Conservation (Administration Wildlife Management) Regulation 2006* DES	Required if clearing flora species protected under the NC Act	Placement Onshore reuse

3.2 Options identification

Following completion of the sediment properties investigations, the sediment properties assessment report (Appendix A), was provided to a multi-disciplinary team to identify potential reuse options for the material. The team was also provided with basic details of the current and likely future dredging requirements.

The team consisted of a combination of local, international and specific dredging and materials use experience including:

- **Jaap van Thiel de Vries** (Boskalis Ecoshape management team Senior Engineer) of global maritime service company Royal Boskalis Westminister N.V., which has extensive experience in dredging and dredged material management. Jaap is involved in coordination of Boskalis' 'Building with Nature' program, which seeks to enable sustainable marine infrastructure development, while at the same time creating opportunities for nature and society.
- **Russell Genrich** (Wagner Earth Friendly Concrete Research and Development Laboratory Manager) of building materials company Wagners, which has wide experience with varied applications of most types of construction material including stabilised soils, production of cements, processing of fly ash and ground granulated blast furnace slag.
- **Greg Holz** (Advisian Principal Soil Scientist) with over 40 years of experience in soil science, including numerous soil suitability assessments for agriculture in Queensland.
- **Andrew Keep** (Advisian Lead Geotechnical Engineer) with around 15 years of experience in geotechnical engineering and engineering geology for civil infrastructure and development schemes.
- **Walter Cambruzzi** (Advisian, Principal Consultant Dredging Services) with 35 years of experience in dredging and marine construction and has been involved in some of Australia's largest port developments.
- **Luke Stalley** (Advisian Principal Consultant) with over 20 years of experience as a civil/environmental engineer in planning, design and construction of major infrastructure projects.
- **Bill Boylson** (Advisian Senior Consultant) with more than 15 years of experience as an environmental engineer particularly in the planning, development, environmental impact assessment, approvals and management of Queensland ports and marine projects.

The team reviewed the sediment properties report, considered the maintenance dredging requirements and associated implications for beneficial reuse, drew on international literature (such as publications of PIANC relevant to beneficial reuse of dredged material) and considered global and local examples of reuse of dredge material. Based on this information and in consultation with NQBP staff and RTA Environment team representatives the team developed a list of reuse and recycling options that warranted further analysis.

3.3 Options analysis

The primary and other considerations described above informed the analysis undertaken for each of the options identified. The analysis of each option includes a discussion of the individual features, processes or characteristics to enable comparison. The description of each option is organised to include:

- Description of the beneficial reuse activity that may be applicable
- Description of the specific opportunity that may be applicable, including the core assumptions of the analysis (e.g. demand and location of the beneficial reuse)
- Discussion of the suitability of the sediments to the beneficial reuse opportunity
- Description of the process required to realise the opportunity, typically with delineation between dredging and placement, and infrastructure and management requirements
- Identification of the potential constraints to successful delivery of the opportunity
- Identification of the potential implications (environmental, commercial, socio-economic) of execution of the opportunity
- Summary of the environmental approvals likely to be required to enable the opportunity
- Quantification at a conceptual level of estimated costs and greenhouse gas emissions that may be associated with the execution of the opportunity
- Identification of existing key knowledge gaps with respect to execution of the beneficial reuse opportunity
- Identification of future considerations for the opportunity (e.g. does it provide a long-term reuse option).

As each opportunity may have numerous alternative configurations (including alternative dredging and/or processing method and location), for each option the analysis focuses on what is considered to be a reasonable and practicable configuration to achieve the beneficial reuse outcomes of that option.

3.3.1 Sediment suitability

As part of the assessment for each of the proposed reuse opportunities an analysis of the sediment suitability was undertaken, based upon properties determined from results of the laboratory testing of the samples. The sediment was subsequently categorised as:

- Likely suitable
- Potentially suitable with treatment/processing
- Not likely to be suitable
- Not applicable (irrelevant or no negative or positive impact upon the reuse).

The suitability categories have been considered for each of the of the properties including: material colour, particle size distribution, moisture content, plasticity index, linear shrinkage, density test, strength and consolidation, permeability, cement laboratory testing, PASS, salinity and organic material. The consideration of relevant material properties and sediment suitability for each individual reuse option is discussed in the respective analysis sections and this work has informed option comparison described in Sections 4.2, 4.3 and 4.4. The suitability of the properties and characteristics of the sediment material for the ultimately selected beneficial reuse option will require confirmation as part of the detailed planning and design.

3.3.2 Cost and greenhouse gas emissions estimates

Cost and greenhouse gas emissions estimations have been developed based on conceptual reuse option information for comparison between options. The estimate information provided in Appendix B and C are not an indication of any option's feasibility but are a preliminary cost and greenhouse gas emissions estimate of the key activities required for each.

It is notable that quantification of conceptual cost and greenhouse gas emissions associated with each option is based on assessment of dredge material use from a single maintenance dredging program. For several options, infrastructure that is developed for the initial program may be used for subsequent programs, and therefore this initial cost of infrastructure, may provide long-term use. This is identified for each option where relevant in the description of future considerations.

Identification of a conceptual cost and estimation of potential greenhouse gas emissions for each of the options requires the delineation of boundaries of the assessment, effectively to identify what and where the final beneficial reuse product is for the purposes of assessment. There are numerous alternatives and sub-options associated with each of the potential beneficial reuse options identified, both in terms of downstream processing applications and geographical location of the ultimate beneficial reuse. As such, it is considered reasonable for the purposes of comparative analysis to use the delivery of the dredged material (following processing if relevant) to the beneficial reuse placement location (detailed in the relevant process description) as the boundary of the assessment, e.g. for road base this includes delivery to the assumed point of use.

Cost estimate

The basis of the conceptual cost estimate is pricing of the key activities associated with the offshore and onshore tasks for all 14 beneficial reuse options. The conceptual cost estimate is indicative and enables a high-level comparison of various beneficial use options. Assumptions for vessel mobilisation and operation, plant and equipment, sailing distance, production rates, local condition and unit rates have been considered in the development of the estimate. It is noteworthy that some pump-ashore, treatment, processing, monitoring and transport to end user options are more complex and have a longer duration than others, and this has been considered where relevant. The vessel mobilisation, demobilisation and production rate costs were estimated with the assistance of historical cost information (2013 to 2018) for Port of Weipa dredging provided by NQBP and reviewed by the Tender Manager, Boskalis Australia Pty Ltd. A detailed breakdown of the cost estimate, and assumptions is provided in Appendix A.

No allowance has been made in the cost estimate for items including: project management, administration, design, approvals, specialist engineering or scientific studies, access road to intermediate storage location or any contingency. These items are not considered necessary to include in an estimate for comparative options analysis. The preliminary cost estimate does not consider any cost recovery should opportunistic uses be identified where the end user may pay for the reuse material providing an income stream.

Greenhouse gas emissions estimate

The basis of the greenhouse gas emissions calculation is estimation of the emissions associated with all 14 beneficial reuse options, expressed as tonnes of CO_2 equivalent. Assumptions for the vessels, plant and equipment, fuel type, fuel consumption, installed power, utilisation and total hours of operation have been considered in the development of the emission calculations. The emission factors have been referenced from the National Greenhouse and Energy Reporting (NGER) Scope 1 - National Green House Account Factors 2018. A detailed list of assumptions, activity data and emission calculations are provided in Appendix C.

3.3.3 Performance summary

In consideration of each of the aspects of analysis described above, and to facilitate presentation of the qualitative comparison of the options (using a consistent basis), a performance evaluation key was developed in consultation with NQBP, as shown in Table 3-2. Fourteen performance criteria have been developed to enable comparative evaluation between each of the individual reuse options.

This key was utilised to develop a summary of performance for each option. This summary is included in the analysis for each option in Sections 4.2, 4.3 and 4.4. The summary analysis is aggregated to enable easy comparison between the options at Section 5, Conclusions.

Table 3-2: Performance evaluation key

Performance Criteria	High Performance	Moderate Performance	Low Performance
Opportunity	**HIGH:** The is an existing demand in a location accessible to the Port, requiring minimal infrastructure needs	**MODERATE:** Potentially a demand reasonably accessible to the Port, requiring infrastructure construction	**LOW:** No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	**HIGH:** Reuse option well suited to the dredge material. Requires no additives or treatment (other than dewatering if necessary)	**MODERATE:** Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable	**LOW:** Reuse option poorly suited to the dredge material. Requires substantial treatment, processing and/or additives to make material suitable; or treatment to a suitable level is considered unachievable
Cost	**HIGH:** Less than $10M annually	**MODERATE:** $10M to $20M annually	**LOW:** More than $20M annually
Process	**HIGH:** The proposed process is well understood and clearly demonstrated in similar environments to the Port	**MODERATE:** The proposed process is sound but there are few examples of it being applied in environments	**LOW:** The proposed process is mostly unproven

Performance Criteria	High Performance	Moderate Performance	Low Performance
	using maintenance dredge material	similar to the Port using maintenance dredge material	
Duration	**HIGH:** Less than 1 year to construct and function as the proposed final use	**MODERATE:** 1 to 3 years to construct and function as the proposed final use	**LOW:** Greater than 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	**HIGH:** < 2000t CO_2 equivalent in 1 year period	**MODERATE:** >2000t and <8000t CO_2 equivalent	**LOW:** >8000t CO_2 equivalent
Environmental Implications	**HIGH:** Net benefit opportunities exist for positive environmental outcomes, with very minor nuisance or harm issues	**MODERATE:** Nuisance or harm issues identified, but for the most part are considered manageable	**LOW:** Nuisance or harm issues unlikely to be easily managed
Social Implications	**HIGH:** Positive social opportunities e.g. jobs exist for local communities and other key user groups	**And MODERATE:** Social effects for the most part are considered manageable	**LOW:** Negative social impacts are unlikely to be easily managed
Indigenous Implications	**HIGH:** Positive outcomes and opportunities exist for Traditional Owners' lands/waters and the local indigenous community	**MODERATE:** Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable	**LOW:** Negative impacts upon Traditional Owners' lands/waters and the indigenous community are unlikely to be easily managed
Economic Implications	**HIGH:** Positive economic opportunities exist enhancing port or community capability	**MODERATE:** Limited economic opportunities exist enhancing port or community capability	**LOW:** Lost or negative economic opportunities to enhance port or community capability
Approvals	**HIGH:** Recognised approvals pathway, with few management issues identified	**MODERATE:** Recognised approvals pathway, with significant management issues identified	**LOW:** Not supported but current legislation or policy would require high level offset considerations
Constraints	**HIGH:** There are few constraints which are for the most part considered manageable	**MODERATE:** Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them	**LOW:** Multiple constraints are present that would limit realistic implementation
Knowledge Gaps	**HIGH:** There are few knowledge gaps and less than 1 year of further research work would be required to progress the	**MODERATE:** There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the	**LOW:** There are multiple and/or complex knowledge gaps and greater than 3 years of further research work

Performance Criteria	High Performance	Moderate Performance	Low Performance
	reuse option	reuse option	would be required to progress the reuse option
Future considerations	**HIGH:** The reuse option provides a long term solution for the Port for a period greater than 10 years	**MODERATE:** The reuse option would cater for immediate needs and has some scope in the short term (several years), although options would need to be regularly reassessed	**LOW:** The reuse option has only a single or limited application.

4 Beneficial Reuse Analysis

4.1 Options identified

As identified in Section 3.2, the beneficial reuse analysis team developed a list of reuse and recycling options that warranted further analysis. The potential beneficial reuse options were categorised as 'recycle as an engineering material', 'reuse as an environmental enhancement' or 'reuse in agricultural applications'. The options identified are outlined below:

Recycle of dredge material as an engineering material:

- Land Reclamation
- Construction Fill (low strength)
- Road Base
- Lining Material
- Concrete Products
- Shoreline Protection
- Beach Nourishment

Reuse of dredge material as an environmental enhancement:

- Coastal (Tidal) Habitat Creation Including
  - Direct Placement
  - Indirect Placement
- Deep Water Habitat Creation

Reuse of dredge material as an agricultural application:

- Topsoil for Agricultural Use

Each of these potential beneficial reuse options were analysed by the multidisciplinary team for the Port of Weipa and Amrun Port. In total 14 beneficial reuse options (11 Port of Weipa options and 3 Amrun Port options) have been analysed and these are as described in Sections 4.2, 4.3 and 4.4.

Any onshore placement and treatment reuse option at Amrun would be limited to a location within the Mine Infrastructure Area (MIA) which is constrained for available space with only the 'borrow pit' facility identified as a potential onshore placement area; however, onshore placement and treatment relates only to beneficial reuse as an engineering material option (e.g. construction fill or road base). As Amrun sediment is predominantly fines (silt and clay) it is not suitable for engineering reuse applications and because of the relatively small annual dredging volumes any Amrun options that utilise onshore placement are not considered further.

Amrun Port is approximately 40km south of the Port of Weipa, which is a sufficiently long distance to make it inefficient for a dredge vessel to steam between dredging and pump out locations refer Figure 1-2. If the Ports were located closer to one another it may have enabled dredge material to be managed though a single beneficial reuse option. The small volume of Amrun Port dredge material along with the sediment characteristics makes any potential benefits of aggregation with Port of Weipa volumes negligible in relation to the analysis. Hence the following analysis of the reuse options considers the two Ports' dredging areas and requirement separately.

4.2 Reuse dredge material as engineering material

The following beneficial reuse options for recycling maintenance dredge material as an engineering material are considered:

Port of Weipa

- Land Reclamation
- Construction Fill
- Road Base
- Lining Material
- Concrete Products – low strength, construction material., artificial reef
- Shoreline Protection – offshore berms
- Beach Nourishment

Amrun Port

- Shoreline Protection (offshore berms)

4.2.1 Land reclamation

4.2.1.1 Activity description

Land reclamation using dredged materials involves filling, raising and protecting an area that is otherwise periodically or permanently submerged. Reclamation usually involves construction of a perimeter enclosure around the reclamation area, which, depending on dredged material types and location, incorporates protection against erosion by waves and currents. In sheltered locations (e.g. estuarine waters with small tidal range), erosion protection may be unnecessary if the dredged material is coarse enough to form a stable slope which will adequately resist erosion.

The most common method of perimeter enclosure involves the construction of an embankment with the seaward face typically incorporating some form of erosion protection e.g. graded rock or concrete revetment. For some uses, (e.g. development of adjacent wharf facilities), the enclosure may require a vertical face, which may be achieved through use of steel sheet piling or caisson construction.

It is possible to use coarse or fine material for land reclamation; however, fine material typically requires a long time to adequately drain and consolidate, and the load bearing strength achieved for land reclaimed with fine material is likely to be low. As such, the use of fine grained material in reclamation is usually restricted to uses where the imposed loads are small, e.g. recreational uses, such as parks, while land required for industrial development usually requires sand or coarser material (PIANC, 1992).

The Port of Brisbane has successfully undertaken land reclamation works over many years using both capital and maintenance dredging material, where suitable dredged material is pumped into containment paddocks within the reclamation area and consolidation aided by wick drains. This reclamation process has created land suitable for high loads (e.g. container terminals) and work is ongoing for the development of a further 230 hectares of port land at Fisherman Island at the mouth of the Brisbane River.

4.2.1.2 Opportunity

The three existing wharfs at Port of Weipa, namely Lorim Point, Humbug and Evans Landing, cater for a variety of operations and different sized vessels. Rio Tinto Alcan's operations, nearby mine administration, warehouse, laboratory and ship loading conveyors and two wharves are located at Lorim Point. Humbug wharf and Evans Landing wharf handle a variety of commodities including general cargo, fuel and live cattle.

The Evans Landing wharf berthing length is 63.80m, capable of berthing a vessel of up to 191.11m LOA. The depth of water alongside the berth is 9.4m. The wharf structure is rated to 40,000 displacement tonnes. The berth consists of two berthing dolphins with conical buckling fendering and two mooring dolphins and a timber decked, steel piled structure between the berthing dolphins supporting a light roadway (refer Figure 2-5). Distillate, jet fuel and unleaded grade fuels are all discharged via Evans Landing wharf through a 200mm diameter pipeline.

Humbug wharf's total berthing length is 114.3m, capable of berthing a vessel up to 195m LOA. The depth of water alongside the berth is 9.5m. The berth consists of six interconnected cellular sand filled steel caissons and reclaimed land to the foreshore (refer Figure 2-4) The wharf is connected to the RTA's Weipa mine railway system and is also used for the discharging/loading of general cargo, stores and equipment for Weipa township.

Currently there is no NQBP master plan for the Port of Weipa; however, to provide greater capacity to increase the throughput capacity of the Port, the smallest of the existing wharfs at Evans Landing may potentially be upgraded. There has been some preliminary planning for a potential upgrade the Evans Landing wharf to provide a Roll on Roll Off (RORO) facility or a tourism wharf with ship lift facility, and thereby cater for increased port services demand. A foreshore tourism and entertainment precinct may also be incorporated into a redevelopment. This upgrade could occur through extending the quay line and reclaiming the area between an upgraded wharf and the shore line to create a new terminal operation/storage area. The potential land reclamation area, approximately 20ha, would ideally accommodate heavy lift of materials, including break bulk cargo, to support future port operations.

It is not presently known if other opportunities or needs for future reclamation at or near the Port of Weipa exist. It is considered that reclamation at Evans Landing wharf (or in this area) is a realistic opportunity for the purposes of this assessment, and as such the analysis below assumes of reclamation occurring at Evans Landing wharf. Given that an adequate portion of the dredged material is coarse grained (sand), the end use of the reclamation area is assumed to be one where the imposed loads are high load-bearing with port operations capability, this is the basis of the analysis below.

It is important to note that as a limited quantity of the dredge material is suitable for reclamation (approximately 100,000m^3 sand) that the majority balance of dredged material, approximately 400,000m^3 silt/clay, would need to be managed elsewhere (e.g. offshore dredge placement area). Hence the reclamation beneficial reuse option is a partial solution option for annual dredging needs as part of a hybrid solution to manage the total annual volume of dredged material.

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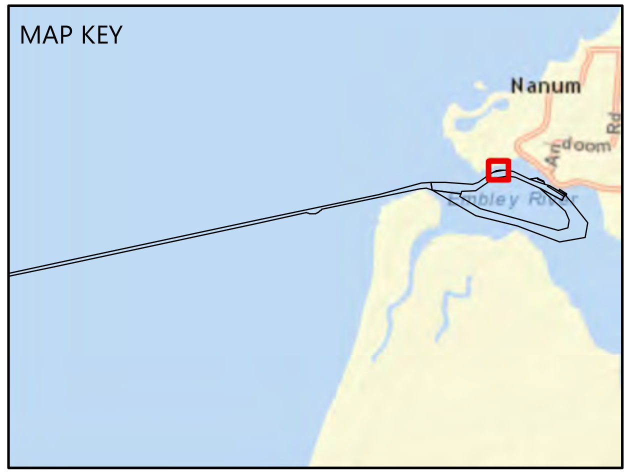
Figure 4-1: Sampling Locations Evans Landing

Sediment sample locations
Acid Sulfate Soils (ASS) sample location
Geotech sample location
Dredge area



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WorleyParsons Group

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4.2.1.3 Suitability of Port of Weipa sediments

Sandy or coarse material is preferred for reclamation where the created land must have sufficient strength for construction purposes. Fine material typically requires a long time to consolidate, which may be accelerated by surcharging or 'wick drains'; however; the final strength achieved may still be low. As such, land created with fine material may be limited to recreational purposes such as parks or uses where imposed loads will be small. As described in Section 2.3, it is considered that there is limited opportunity for the selective dredging of fine and coarse materials within the outer Southern Channel and extension, berth and apron areas. However, within the Southern Channel (SC-1 and SC-5) and Approach Channel and Departure Channel most of the dredge material (assumed volume 100,000m^3) is sand which may be targeted for its higher strength properties. In this analysis it is assumed to target an adequate volume of the sand dredged material for its high load bearing characteristics for reuse in land reclamation.

As part of the assessment of the proposed land reclamation (high load-bearing) reuse opportunity described above, the sediment suitability, based upon properties determined from results of laboratory testing of the samples, is outlined in Table 4-1 (suitability categories as per Section 3.3.1).

Table 4-1: Suitability of dredge sediment (sand) for proposed high load-bearing land reclamation reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment/processing
Moisture content	Potentially suitable with treatment/processing
Plasticity Index	Likely suitable
Linear Shrinkage	Likely suitable
Density test	Potentially suitable with treatment/processing
Strength and Consolidation	Potentially suitable with treatment/processing (targeting sand)
Permeability	Potentially suitable with treatment/processing
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable

Sediment Material Property	Suitability
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

Most of the sediments are fine grained and only suitable for low to medium load applications following adequate drying out and compaction. The coarse-grained sediments within the Southern Channel (SC1 to SC 5), Approach Channel and Departure Channel suggest the sand deposits may be suitable for medium to high loading applications following adequate compaction., however this would involve targeted dredging of estimated at 100,000m^3 in these specific locations. There are no identified low medium loading potential reclamation areas (e.g. recreation areas or car parks) to utilise the majority volume of the Port of Weipa's annual dredge material, it assumed this material is disposed by traditional methods.

4.2.1.4 Process description

Dredging and placement

Dredge material would be dredged and transported to the Evans Landing reclamation site. Various types of dredging equipment may be used to develop land reclamation, including a Trailing Suction Hopper Dredge, Backhoe or Cutter Suction Dredge. Trailing Suction Hopper Dredges typically have significant draft, meaning that dredged material may need to be pumped to the reclamation area through a pipeline. Depending on vessel, material and reclamation location, booster stations may be required to deliver material to the reclamation area. A Backhoe dredge can excavate in-situ material and place it on barges that transport the material towards the reclamation area. A Cutter Suction Dredge may also be used to dredge and pipe the dredge material to the reclamation area; albeit that use of this type of dredge would require a very long pipeline. Use of both the Cutter Suction Dredge and Backhoe Dredge options would be likely to cause interference with port navigation, due to limited manoeuvrability and time taken to dredge. As such, it is considered likely that a Trailing Suction Hopper Dredge would be the most appropriate dredge type for this beneficial reuse option, and this forms part of the basis of the analysis below.

Given that the dredge 'TSHD Brisbane' is based in Queensland and has historically been used for maintenance dredging at the Port of Weipa, it is considered reasonable to assume that the 'TSHD Brisbane', or a similar dredge may be used for future dredging, and as such, this forms the basis for analysis below. The 'TSHD Brisbane' has the facility to pump out its hoppers through a nozzle mounted on the bow into a pipeline; however, there are many operational considerations for pump out to a reclamation area, including:

- The distance which the dredged material can be pumped and how close the dredge can get to the discharge point (pipeline) into the reclamation area
- Provision of the infrastructure for the pump-out and clear access for the dredge to pick up the pump-out point.

Infrastructure required to facilitate the pump-out could be permanent or temporary and would include a pipeline (potentially a combination of floating and submerged pipeline, along with a pump out coupling), and a mooring system for the dredge during pump-out.

Trailing Suction Hopper Dredges have significant draft, which affects how closely they may approach shore, and consequently the pumping distance required to a potential reclamation area at Evans Landing wharf (or general vicinity). The design depth of the berth at Evans Landing Wharf is 9.4m below Lowest Astronomical Tide (LAT). A dredge such as the 'TSHD Brisbane' has a draft of 6.25m, and with allowance of under keel clearance of 0.9m, the fully-laden dredge would be limited to water depths of 7.15m. It is understood that the 'Brisbane' has a maximum guaranteed pumping distance of 1.5km, noting that the distance from the Southern Channel (SC1 to SC5) to Evans Landing wharf is some 9km, this will involve the TSHD steaming to a pump out point.

For the purposes of the analysis it has been assumed that the TSHD will travel approximately 9km from the dredge area (SC1 to SC5) to access the pump-out point near the Evans Landing reclamation location, with a pipeline installed to transfer approximately 100,000m^3 sand material into the reclamation area. Mooring and pump-out facilities will be required; however, it is assumed that no booster pumping station is required for pump-out to the reclamation area.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last an estimated 32 days based on pump out for sand and traditional disposal for balance of the material

Infrastructure and management requirements

The volume of a reclamation area required to accommodate the dredged material needs to account for the in-situ volume of the dredged material, bulking of the dredge material (which may increase the volume of material to be managed initially by around three times) and retention of water in the reclamation area, sufficient that discharge from the reclamation area of that water is of acceptable water quality. While the extent of demand for land at the Evans Landing wharf area is unclear, based on an assumption of a reclamation area within or adjacent to Evans Landing of approximately 20,000m^2 would require. an area of 2ha, 75m wide and 350m long at shoreline, 200m long at quayline, depth between 0m to 10m (average 5m)). The calculated compacted volume of this theoretical reclamation area is approximately 103.000m^3. A perimeter sheet pile wall ranging between 0m to 10m high is anticipated to be required at the sides and alongside the berth.

As the material to be dredged is predominately sand, and Evans Landing is subject to waves and currents, enclosure of the reclamation area would be required to be developed to provide protection against erosion. Depending on the proposed use of the reclamation area, this enclosure would likely incorporate graded rock or concrete revetment, steel sheet piling or caisson construction, or a combination of these. Given that use of the reclaimed land would be high loads, it is considered likely that sheet piling wall would be suitable protection for the area. Based upon the assumed dimensions (75m wide and 200m long) it is estimated that an outer sheet piled wall of approximately 3,925m^2 face area will be required.

Construction of the reclamation area will require the use of sheet pile driver and a barge. For the purposes of analysis, it is assumed that construction of the perimeter sheet pile wall will take approximately 20 weeks.

The dredged material is disposed and trapped in the enclosed reclamation area and would dewater to the sea. Dewatering would need to be managed such that impacts to water quality near the reclamation area are kept within acceptable limits. This may require management of the location of the dredge spoil placement inlet point relative to the dewatering discharge location.

Monitoring and management effort would be required during construction of the reclamation area and placement of the dredge material until it is effectively dewatered. As described previously, the sand is likely to take a long time (potentially greater than three years) to drain and consolidate, such that it is available for subsequent use.

4.2.1.5 Potential constraints

Potential constraints associated with this option include:

- Only land created with coarse material (i.e. sand from the Southern Channel areas SC-1 to SC-5, Approach Channel and Departure Channel) is likely to have suitable strength for industrial heavy load-bearing port operations applications
- Demand for reclaimed land of low strength within or adjacent to Port of Weipa, or elsewhere in the region is considered likely to be substantially less than 400,000m^3 (in situ) potentially being created through reclamation using fine maintenance dredge material, hence offshore disposal requirement likely for silt/clay majority of dredge material
- Dewatering needs to be managed to avoid potential impacts of discharge water quality (entrained fined material), near the reclamation area, especially any seagrass areas, refer Figure 4-11
- Evans Landing Area has a significant sea grass meadow, which can be offset, but may be costly (estimated $60k for 2ha)
- Rock sea wall will need geofabric or HDPE internal liner (or similar) installed to retain fines material and avoid fine sediment being 'leached' through voids between sheet piles to adjacent marine environment
- The reclamation area of the theoretically upgraded Evans Landing wharf (estimated sand compacted volume required 103,000m^3) or otherwise in the vicinity of the port requiring reclamation is significantly less than the 500,000m^3/yr, and as such the reuse in unlikely to meet long term maintenance dredging needs
- Dredging and placement will cause some constraints to navigation, as dredge will be required to traverse multiple navigation areas (departure and Southern channels) to reach discharge pipeline/pump out point
- Potential acid Sulfate soils, while unlikely to be a significant issue, will require consideration and potentially management during reclamation
- Location of a reclamation area and determination of the placement approach (e.g. pipeline route) will be constrained by existing uses (port users and community users)
- Land access including Traditional Owner concerns or issues may be an issue depending on the reclamation location.

4.2.1.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Creation of reclaimed land within the port area that may be suitable for future port activity uses, e.g. RORO, loading/unloading, storage facilities, which may facilitate increased port capacity and a positive socio-economic outcome
- Reclamation may cause some impacts to Traditional Owners' lands or waters and exiting partnerships or agreements
- Sea grass meadows in the vicinity of Evans Landing may be impacted by reclamation option and require offset.

4.2.1.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option. Depending on how material is sourced to construct the project (e.g. the perimeter embankment), approvals associated with onshore reuse may also be required.

It is considered that the beneficial use of maintenance dredge material in land reclamation is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.1.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the land reclamation options is provided in Table 4-2. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $37/m^3$ measured in situ.

Table 4-2: Land reclamation summary cost estimate table

Key Activity	Land Reclamation
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$500,000

Key Activity	Land Reclamation
TSHD dredging and pump ashore	$5,000,000
Onshore	
Processing material including dewatering/desalination/ripening	$1,000,000
Sheet piling for reclamation area	$4,000,000
Monitoring and management	$250,000
Total	**$18,250,000**

4.2.1.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the land reclamation option is 2,130 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in B.

4.2.1.10 Knowledge gaps

If a reclamation option was to be further pursued, key areas where additional information would be required include:

- Demand and suitable locations for reclaimed land for port and/or community uses
- Coastal dynamics and processes specific to the proposed location of the reclamation and dredge pump-out areas to enable design of fit-for-purpose structures, including consideration of siting, erosion protection requirements and dewatering discharge location
- Availability of suitable construction materials for the reclaimed area revetment wall
- Detailed design including consideration of dredging, placement, construction and ultimate use of the reclamation area.

4.2.1.11 Future considerations

As described above, the dredged material (targeted sand) may enable reclamation of an area of approximately 20ha, in the Evans Landing wharf area or elsewhere within the Port, albeit that the immediate need for such an area for high load-bearing purposes is unclear. It may be that this area can be expanded over time; however, without there being a sufficient existing or likely future need for high load-bearing lands within the immediate area of the port, it is considered unlikely that this option would provide beyond one or two annual dredge programs for the use of the targeted sand portion of the dredge material.

4.2.1.12 Performance summary

A summary of the performance of the land reclamation option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-3.

Table 4-3: Land reclamation performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	MODERATE: $10M to $20M annually
Process	HIGH: The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material
Duration	LOW: Greater than 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	MODERATE: >2000t and <8000t CO_2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	HIGH: Positive social opportunities e.g. jobs exist for local communities and other key user groups
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	HIGH: Positive economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	HIGH: There are few constraints which are for the most part considered manageable
Knowledge Gaps	HIGH: There are few knowledge gaps and less than 1 year of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.2.2 Construction fill

4.2.2.1 Activity description

In some circumstances, dredged material may be used as a construction fill for various purposes. This is most likely to be a beneficial use where the dredged material has superior physical qualities compared to soils at the construction site (e.g. the replacement of weak soils with sand that may be derived from dredging). Fine-grained soils do not have the necessary physical properties for industrial fill in most civil works projects, though they may be suitable for other applications such as parks (PIANC, 1992).

Typically, dredged material consists of a mixture of sand and clay fractions, which requires separation through dredging or screening treatment prior to use as fill at the placement site. Dredged material, such as sand or gravel, may be used as construction fill for higher strength applications (e.g. beneath pavement, foundations or embankments), although screening and the addition of imported materials is typically necessary to achieve the desired grading. Dewatering is typically required, given high water content of dredged material, and desalination may also be required depending on the construction use.

4.2.2.2 Opportunity

The potential opportunity identified is that dredged material from the Port of Weipa may be used as low to medium strength construction fill material. This may include use as a low to medium performance general construction fill, embankments including land improvement where the quality of existing land is not adequate for anticipated use or where the land elevation is subject to flooding. Currently there is no identified need or end user for the low to medium strength dredge sediment construction fill material in the Port of Weipa region. A future use may exist associated with the development of Humbug Wharf for a future potential port user, that may require construction of a laydown area /pavement of 6 to 8ha in size.

As described in Section 2.1.2, sandy material is more likely to be suitable for load bearing purposes, while fine (silt and clay) material will require a long time to consolidate and the final compaction and strength achieved will still be low. As noted previously, there is some opportunity for the selective dredging of sand materials to target the PSD approximated 100,000m^3 of sand material in the Southern Channel (SC-1 to SC-5) Approach Channel and Departure Channels. Given this, and the need to process material by screening and the addition of imported materials for it to meet the required grading and plasticity specifications as a construction fill, the opportunity requires onshore placement of the dredged material. The treated and dried sand material may be suitable as a general fill material. Onshore placement and processing for use as a general low to medium strength construction fill is the focus of the analysis below.

The analysis assumes that an onshore placement and treatment area may be constructed at the inactive Tailings Storage Facility (TSF) location in East Weipa, approximately 1km north of Evans Landing wharf (as shown on Figure 2-2). This land is on the RTA Mining Lease, is reasonably proximate to the dredging area, and is of sufficient size to accommodate onshore placement. The approximate area of the inactive TSF is 153.7 hectares or 1,537,000m^2 and prior to any reuse proposal environmental impacts, especially groundwater issues, need to be fully considered. The dredged material, once processed at the onshore placement site, may then be transported to sites at the Port of Weipa or to construction sites in the Weipa region for use as low strength construction fill.

4.2.2.3 Suitability of Port of Weipa sediments

Well graded (particle size distribution), sandy or coarse material is preferred for construction fill to have sufficient strength for construction purposes. The fine sediment material with higher clay content is subject to swelling (high plasticity index) and cracking (high linear shrinkage) and a low final strength. The sediment material will require dewatering to achieve moisture content to enable optimum compaction (density, strength and consolidation) to be achieved. The use of fine material for construction fill purposes is likely to be limited to bulk fill and uses where imposed loads will be small. As described in Section 2.3, it is considered that the majority of sediments, estimated at 71% in the Southern Channel and extension and berth areas are fine (silt/clay) materials; however, it may be possible to undertake selective dredging of higher strength sand materials to target the PSD approximated 100,000m^3 of sand material in the Southern Channel (SC-1 to SC-5) and 8000m^3 and 6,800m^3 sand in the Approach Channel and Departure Channels, respectively.

The high fines (silt and clay) content and accompanying low strength characteristics of the material indicates that it is only able to be used for low strength and low load bearing construction fill uses or alternatively as a low proportion (<20% approximately) component of a manufactured construction fill. The dredge sediment material's construction fill performance characteristics can be enhanced with the addition of imported materials to improve the particle size distribution, material grading and swell/shrinkage characteristics by adding particle shapes and sizes with superior properties. Utilising the sediment material as a minor component potentially enables the manufacture of a construction fill material that will achieve better compaction, higher strength to be used in different layers of an engineered pavement. Typically, construction fill is derived from spoil material that can be reused in is current state. The need to treat and potentially process dredge sediment to enhance its characteristics to make it suitable for construction fill for uses other than low strength/low load bearing decreases this option's cost competitiveness.

Utilisation of the treated dredge sediment materials following reclamation from an onshore management area, with processing involving screening and blending all the dredge materials (silt/clay/sand/gravel) to produce a low to medium strength fill was considered the most likely to be feasible of the construction fill options, and as such, is the subject of analysis below.

As part of the assessment of the proposed low to medium strength, low to medium load bearing construction fill reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-4 (suitability categories as per Section 3.3.1).

Table 4-4: Suitability of dredge sediment for proposed construction fill (low strength) reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment
Moisture content	Potentially suitable with treatment
Plasticity Index	Potentially suitable with treatment
Linear Shrinkage	Potentially suitable with treatment
Density test	Potentially suitable with treatment
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	Potentially suitable with treatment
Geochemical	
PASS	Likely suitable
Salinity	Potentially suitable with treatment
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The volumes to be dredged are large and the sediment material requires onshore placement, treatment and potentially some processing including the blending of imported materials with superior geotechnical characteristics to improve its suitability for use as construction fill. This reuse option may be suitable for a construction fill project, particularly an area having low to medium load requirements such as a laydown area or certain types of engineered embankments.

4.2.2.4 Process description

Dredging and placement

Dredge material would be dredged and transported to the onshore placement site. As described for the land reclamation option, various types of dredging equipment may be used to dredge and place sediment material onshore, including a Trailing Suction Hopper Dredge, Backhoe and Cutter Suction Dredge; however, due to the superior manoeuvrability of the Trailing Suction Hopper

Dredge this is considered the most appropriate dredge type for this beneficial reuse option, and this forms part of the basis of the analysis below.

Also, and as described for the land reclamation option above, it is considered reasonable to assume dredging and onshore placement using the dredge 'TSHD Brisbane' or similar as the basis for analysis. Operational considerations for pump out to an onshore placement area are like those for the land reclamation option, and need to contemplate:

- The distance which the dredged material can be pumped and how close the dredge can get to the discharge point (pipeline) into the bunded onshore placement area
- Provision of the infrastructure for the pump-out and clear access of dredge to pick up the pump-out point.

Infrastructure required to facilitate the pump-out could be permanent or temporary and would include a pipeline (potentially a combination of floating and submerged pipeline, along with a pump out coupling) and a mooring system for the dredge during pump-out. It is considered that pump-out infrastructure would be more likely to be permanent for onshore placement than reclamation, as onshore placement is more likely to provide a longer term beneficial reuse opportunity than reclamation.

Like the operational limitations associated with the land reclamation option, a dredge such as the 'Brisbane' would be draft-limited in terms of how close it could approach the shore adjacent to the Inactive TSF at either Gonbung Point (refer Figure 4-12) shore during low tide when fully-laden with dredged material. It is likely that it could approach to within 100m of shore utilising the Departure Channel, which would then require the maximum pumping distance of such a dredge, understood to be 1.5km, to transport dredged material to the assumed storage area. Draft limitation constraints can be dealt with to some degree through dredging management techniques such as programming of dredging, such that pump-out does not occur on low tides and short loading of the dredge so that it doesn't achieve maximum draft; however, use of these techniques affect the efficiency of the dredging operation. Alternatively, 'TSHD Brisbane' could moor at Evans Landing Wharf for pump out operations.

For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will travel up to 20km from the farthest dredging area (SC-18). to access the Evans Landing pump-out point, potentially at one of the older dolphins at Evans Landing wharf, Evans Landing is approximately 1.5km from the onshore placement location at the inactive TFS, and a pipeline could be installed to transfer material from the pump out point into the dredge material storage and treatment area. Mooring and pump-out facilities will be required to convey dredged material in a pipeline up a 10m elevation gradient to the Inactive TSF area; however, a booster pumping station is likely to be required for pump-out to the onshore placement area.

The dredge is assumed to operate almost continuously, i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last approximately 32 days.

Infrastructure and management requirements

Dredge material would be transported to the onshore placement location for intermediate storage and processing. The configuration of an onshore placement facility at the inactive TSF is constrained by:

- Extent of available and suitable land, including topographical, environmental, vegetation, groundwater and potentially Traditional Owner constraints
- Capacity of the placement area required for handling and treatment of material, including whether the placement area can be used for a single or multiple maintenance dredging programs. Assuming all 500,000m^3 dredge material annually is brought onshore for placement and treatment an area of approximately 50ha is required. The estimated total area of the Inactive TSF is 153.7ha including areas that may not be available or suitable for dredge material placement.
- Distance of the onshore placement facility intake to a dredge pump-out point, with a shorter distance being more desirable
- Need for a suitable marine discharge outlet point for dewatering release.

Like the description of dredged material volume needing consideration for the land reclamation option, sizing of the onshore placement area needs to consider the in-situ volume of dredged material, bulking of that material (potentially by three times) and sufficient retention of water, such that water discharged from the area to the marine environment is of acceptable quality.

In order that the onshore placement area may be reused for multiple dredging programs (i.e. to accept approximately 500,000m^3 of dredged material every year) it has been assumed that the depth of placement of the dredged material (bulk factor 3x) would be 3m to assist processing (i.e. dewatering) of the material. As such, the area of land required to support any given year's onshore placement would be approximately 50ha. The placement area may be divided into multiple adjacent and cascading (two or three) ponds to enable multiple entry points and / or sufficient flow path so that discharge water is of acceptable quality.

Embankment bund walls will need to be constructed around the area of the ponds using clay material (if available) or a liner, depending on site conditions. For the purposes of analysis, it has been assumed that an estimated 97,000m^3 of material will be required to construct the ponds, using some material sourced from on-site, but with the majority assumed to be imported from off-site sources (delivered by truck). It is estimated that construction would be undertaken over a period of estimated 52 weeks using earthworks machinery including excavators, loaders and trucks.

Placement of the dredge material in thin layers minimises to some extent the ongoing dewatering management requirements to enable construction fill development in the placement area. Nonetheless it is assumed for the purposes of analysis that some management is required to enhance dewatering, which includes the use of earthworks machinery (dozer and excavator) for enhancement of ambient drying through improvement of surface drainage. Weipa's annual monsoon wet season high rainfall pattern would limit the dredge material drying period to low rainfall months between May to September. Following placement, machinery use would be intermittent over a period of approximately three years, to meet dewatering and construction fill development requirements. It is assumed that screening, blending and mixing will be required, given the general low-to medium strength construction fill use proposed. It is assumed that no desalination is required for the use as general construction. For the purposes of analysis, it is assumed that construction fill (low to medium strength) would be delivered to Weipa or nearby mining areas requiring an approximately 50km round trip from the inactive TSF, with excavators, loaders and trucks used for loadout.

The marine discharge point, which is assumed to be to the west of the inactive TSF into Albatross Bay, would require ongoing monitoring and management during the dredging, placement and dewatering activities.

4.2.2.5 Potential constraints

Potential constraints associated with this option include:

- Most of the material (fines) has limited usefulness in construction applications, and the demand for low strength construction fill within the region is not clear
- Dredge material as source of construction fill will be opportunistic only, i.e. not a continuous option for reuse of dredge material
- Construction of the embankment bunds for the onshore placement area requires an estimated 97,000m^3 of material, much of which may require importation, and access to this material may be difficult
- Weipa's monsoonal wet season and high rainfall levels will influence the speed of dewatering and limit when it may occur
- Infrastructure development would need to consider potential impact of extreme events (i.e. cyclones), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, groundwater aquifers, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Potential acid Sulfate soils, while unlikely to be an issue, will require consideration and potentially management during placement, particularly if separation of potentially acid forming material from acid neutralising capacity material occurs during processing
- Construction and operation of the placement area may require improvement of road access to the inactive TSF and will increase traffic on local roads.

4.2.2.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Development of a potential source of construction fill (low to medium strength) in the region, however there is no known demand from discussion with NQBP and RTA
- Onshore placement may cause temporary sterilisation of land at the inactive TSF
- Onshore placement storage ponds have potential significant implications for local surface and groundwater impacts
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas

- Onshore placement may cause some impacts to Traditional Owners' lands or existing partnerships or agreements
- Construction and operation of the onshore placement area will cause temporary and intermittent loss of amenity to the local community, through increases in local traffic, particularly along Kerr Point Road and haul routes for imported fill to construct the bund embankments.

4.2.2.7 Approvals

Approvals associated with dredging and placement and onshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material as construction fill is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.2.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the construction fill (low strength) options is provided in Table 4-5. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $76/m^3$ measured in situ.

Table 4-5: Construction fill (low strength) summary cost estimate table

Key Activity	Construction Fill
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$320,000
TSHD dredging and pump ashore	$5,000,000
Onshore	
Dredge Management ponds construction	$14,500,000
Processing material including dewatering/desalination/ripening	$500,000

Key Activity	Construction Fill
Processing material including screening/bending/mixing	$4,000,000
Monitoring and management	$250,000
Transport – road transport form site to end user	$6,000,000
Total	**$38,070,000**

4.2.2.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the land reclamation option is 9,981 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.2.10 Knowledge gaps

If the construction fill option (low to medium strength) was to be further pursued, key areas where additional information would be required include:

- Demand for low to medium load bearing construction fill
- Availability of suitable construction materials for the embankment bunds, and conditions on-site suitable for the construction of ponds
- Site access requirements including potential road upgrades
- Coastal dynamics and processes specific to the dewatering discharge location
- Groundwater conditions beneath the potential onshore placement area and potential for groundwater contamination, particularly through salinity impacts, given that groundwater is used as a primary water source for the Weipa town and the groundwater aquifers are known to be shallow (pers. conv. RTA)
- Detailed design including consideration of dredging, placement, construction, pond lining system and ongoing use of the onshore storage area.

4.2.2.11 Future considerations

The dredged material is unlikely to be able to be dewatered and processed within the annual period between dredging programs. The dewatering process is likely to take a minimum of three years and assuming there is insufficient demand for the material so that it may be removed from the onshore placement ponds, the storage capacity of the area is likely to be consumed within two years. It is unclear whether there would be demand for the construction fill material, and particularly any ongoing demand to provide a long-term solution for receipt of dredged material.

The material may provide a form of cost-recovery should opportunistic uses (e.g. Humbug Wharf laydown area for new users) be identified for it.

4.2.2.12 Performance summary

A summary of the performance of the construction fill option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-6.

Table 4-6: Construction fill (low strength) performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	LOW: More than $20M annually
Process	HIGH: The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material
Duration	LOW: Greater than 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	LOW: >8000t CO2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	MODERATE: There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.2.3 Road base

4.2.3.1 Activity description

Road construction requires large quantities of aggregate, sand and fine (slit and clay) material to make road base material. The specific characteristics of these constituent materials are combined, placed in layers and compacted to create road pavements. In some circumstances dredged material may be used to supply some or all the component materials required for road base.

4.2.3.2 Opportunity

The dredge material potentially provides a source of sand, fine and some gravel (aggregate) materials for road sub-base construction in the Weipa region. This opportunity relies on onshore placement of the dredge material (as described for construction fill above), followed by processing.

Market demand for the dredge sediment as road base material is likely to be low because of the time and cost needed to blend the mostly fine dredge material with other sources of aggregate and fine material to meet pavement specifications. Established commercial quarry operations in the Weipa region supply road base materials in accordance with Queensland Department of Transport and Main Roads (TMR) specifications for an estimated $50/m^3, which is likely to be significantly less expensive than producing road base materials from the dredge sediment material. To use dredge material as a component for road base material it will require several years of storage followed by treatment, processing and screening, along with the addition of other imported materials which will add to the cost of production. There may exist opportunities for private road construction applications if the end user is willing to accept dredge sediment as a low performance road base material and NQBP are willing to provide it at a substantially subsidised cost rate.

4.2.3.3 Suitability of Port of Weipa sediments

The performance characteristics of a road pavement are directly related to the different strength and properties of the base course materials. The potential opportunity of reusing dredge material in road base relies upon the material properties meeting the requirements of road pavement specifications. The Transport and Main Roads (TMR) technical specifications for pavements are adopted as the road industry standard. To be acceptable for road construction in accordance with the TMR specification, material properties must meet stringent requirements verified by compliance testing. The sediment material properties suitability as pavement material have assessed, for all the samples (silts/clay/sand/gravel) tested across the dredge areas, against the TMR Specification (MRTSO5) unbound pavement requirements for typical mid-range base course gravel Type 2 and Type 3 sub base[5], along with other essential properties described in Table 4-7.

[5] TMR Specification MRTS05 Unbound Pavements July 2017, Fines component properties – Table 7.2.3 - Type 2 (2.5) and Table 7.3.3 - Type 3 (3.5) and grading Envelopes Table 7.2.4.A - Type 2 - and Table 7.3.4 - Type 3.

Table 4-7: Comparison of Type 2.5/3,.5 road base/pavement requirements and sediment material properties

Material Property	Requirement	Sediment Material Results
MRTSO5 Specification Properties		
Plasticity Index (PI)	maximum 14%	ranges between 3% and 34%
Liquid Limit (LL)	maximum 40%	ranges between 27% and 67%
Linear Shrinkage (LS)	maximum 7.5%	ranges between 1.0% and 18.5%
Other Properties		
Moisture Content	typically, between 5% and 20%	Sand 28% to 41% Silt/Clay 40.6% to 218%
Salinity	>0.250% TSS high risk[6]	Ranges between 0.772% to 2.32%

[6] Salinity Risk Management Flowchart, Main Roads Western Australia, Document No. 6706/02/133, 2013.

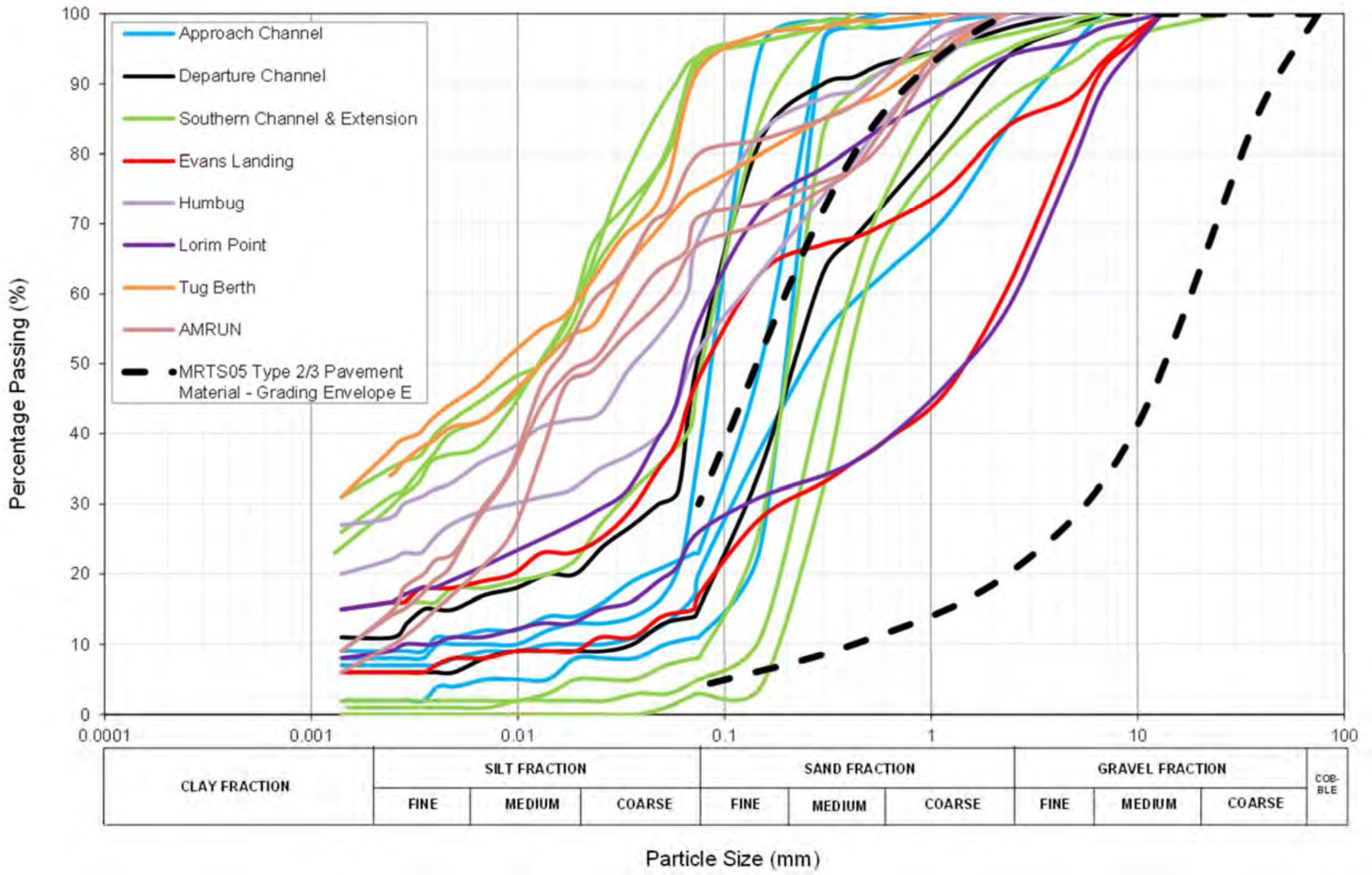

Figure 4-2: Type 2 and 3 Grading E Envelope (MRTS05) comparison with Sediment Sample Particle Size Gradings

The dredge sediment material tested does not meet the Transport and Main Roads Type 2/3 pavement material properties criteria in Table 4-7or the Grading Envelope E (Figure 4-2) for road base specification. The sediment materials' range of moisture content, salinity and the material properties (i.e. Plasticity Index, Liquid Limit and Linear Shrinkage) for road base are outside the specification requirements.

The dredge material particle size distribution is dominated by the fine clay/silt and sand portions with coarse material (gravel) almost absent. This unbalanced distribution of fine particle size means that the sediment material is considered poorly graded and unsuitable for road base/pavement.

The liquid limit and plastic limit tests are designed to reflect the influence of water content, grain size and mineral composition on mechanical behaviour of clays and silts. These tests found that fine grained material (Southern Channel and Extension (outer), Tug Berth and Amrun Approaches and Amrun berth) is indicative of high plasticity clay. Linear shrinkage results (ranging from 10.0% to 18.5%) indicate a potential for swelling in fine grained materials, most of which were above the critical potential for expansion limit of 8%. The fine sediment material with high plasticity has potential for swelling and makes the material unsuitable for road base/pavement material.

The moisture content is important to determine the amount of effort required to dry out sediment material for various reuse options. The optimum moisture content is the quantity of moisture within the material to achieve the maximum dry density, which would be targeted in the preparation of the sediment material to be used in road base application. Typical optimum moisture content for road base or pavement material ranges between 5% and 15%, and general earthworks up to 20%. The sediment moisture content between 28% and 218% can be characterised as extremely wet and unsuitable for road base/pavement material.

Salinity can shorten the expected lifespan of a road pavement by accelerating the rate of deterioration[7]. If evaporation occurs, salts are further concentrated in the remaining water and/or the salts may become solids in the form of crystals. The type of salt and the conditions under which they crystallise will determine the size and shape of the crystal formed. This in turn determines the amount of pressure exerted on the surrounding material, as the salt makes space for itself within the road pavement. The sediment sample results are extremely saline and places the material in the high-risk range if used for road base/pavements.

Only with a significant amount of treatment, processing and blending with other superior materials to improve its properties would the sediment material be potentially suitable for use in a road base/pavement. The sediment will require dewatering to achieve moisture content to enable optimum compaction (density, strength and consolidation) to be achieved. Treatment to achieve desalination though leaching by a repeated process of rainfall and 'turning over' the material over a period of years will reduce the salinity levels. After dewatering and desalination, the sediment material can be processed by screening, blending and mixing with other imported material to manufacture a base material to meet specified properties requirements. It is likely that even with treatment and processing the sediment material will be a constituent part of a low specification road base/pavement material, unless it blended in small proportions (<10% to 20%) with large quantities of high grade materials to achieve a higher specification road base material.

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[7] Salinity Risk Management Flowchart, Main Roads Western Australia, Document No. 6706/02/133, 2013.

As part of the assessment of the proposed road base/pavement reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-8 (suitability categories as per Section 3.3.1).

Table 4-8: Suitability of dredge sediment for proposed road base/pavement reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment/processing
Moisture content	Potentially suitable with treatment/processing
Plasticity Index	Potentially suitable with treatment/processing
Linear Shrinkage	Potentially suitable with treatment/processing
Density test	Potentially suitable with treatment/processing
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	N/A
Geochemical	
PASS	Likely suitable
Salinity	Potentially suitable with treatment/processing
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The sediment material generally has poor properties for the construction of road base/pavement. Only four of the 21 samples (located at Lorim Point, Evans Landing, Approach Channel and Departure Channel) comply with the grading specification and could potentially be used as a least stringent Grading E material for lower sub base layers (i.e. not in base or upper base layer) road pavement material, refer Figure 4.2. This better dredge material would have to be targeted in selective dredging and separated through treatment. The sediment material generally has poor properties for the construction of road base/pavement. It requires extensive treatment (dewatering and desalination) and processing (screening, blending, mixing) with other materials to manufacture a material where the sediment material is a minor constituent to meet the road pavement specification. Notwithstanding this, if the treated and process material is blended with suitable material it may be acceptable for a private road construction when the owner is willing to accept the lower performance material and it would be suitable for light traffic volumes and light vehicle situations such as an access track not used by heavy vehicles (dual axel trucks).

4.2.3.4 Process description

Dredging and placement

The dredging and placement requirements for this option are as identified for construction fill at Section 4.2.2.4.

Infrastructure and management requirements

In addition to the onshore infrastructure and management requirements identified for construction fill at Section 4.2.2.4, material to be used for road base requires more intensive treatment to desalinate the material, and more extensive processing to separate and / or mix material suitable for road base.

The high salt level will be reduced by a combination of exposure to rainfall to assist leaching of the salts plus periodic 'mixing and turning over' of the stored material by an excavator over an extended period (up to three years).

The material will need to be extracted from the storage pond and sorted into various particle sizes be a screening plant. The resulting material stockpiles can then be batched, and blended with imported material, to create a material suitable for road base...

For the purposes of analysis, it is assumed that road base would be delivered to Weipa or adjacent mining areas area requiring an approximately 50km round trip.

Relevant standards

The industry standard for road construction materials in Queensland is the Queensland TMR Specification Category 5: Pavements, Sub grade and Surfacing. These specifications are universally used by State Government, Local Government and private sector for road and pavement construction. The specifications relevant to beneficial reuse and a road base or pavement material include:

- MRTS05 Unbound Pavements (July 2017)
- MRTS35 Recycled Materials for Pavements (July 2018)
- MRTS39 Lean Mix Concrete Sub Base for Pavements (July 2017).

4.2.3.5 Potential constraints

Potential constraints associated with this option include:

- Complex process of mixing, treatment, extraction, processing by screening, stockpiling and then blending and batching with imported material to manufacture road base material

- Stringent TMR road pavement specifications and compliance testing likely required by end user
- Production of road base from the dredge material is more process intensive than other methods of road base production, and as such the cost of supply will likely need to be subsidised by NQBP to create demand
- Dredge material as a source of road base will be opportunistic only i.e. not a continuous reuse opportunity for dredge material
- Construction of the embankment bunds for the onshore placement area requires 97,000m^3 of material, much of which may require importation, and access to this material may be difficult
- Weipa's monsoonal wet season and high rainfall levels will influence the speed of dewatering and limit when it may occur
- Infrastructure development would need to consider potential impact of extreme events (cyclones), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, groundwater aquifers, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Potential acid Sulfate soils, while unlikely to be an issue, will require consideration and potentially management during placement, particularly if separation of potentially acid forming material from acid neutralising capacity material occurs during processing
- Construction and operation of the placement area will require improvement of road access to the inactive TSF and will increase traffic on local roads.

4.2.3.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Development of a potential alternative source of road base material in the region, albeit that it would be extremely unlikely to be cost competitive to produce from dredge material and would require subsidisation if it were to be sold
- Onshore placement may cause temporary sterilisation of land at the inactive TSF
- Onshore placement storage ponds have potential significant implications for local surface and groundwater impacts
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas
- Onshore placement may cause some impacts to Traditional Owners' lands or exiting partnerships or agreements
- Construction and operation of the onshore placement area will cause temporary and intermittent loss of amenity to the local community, through increases in local traffic, particularly Kerr Point Road and haul routes for imported fill to construct the bund embankments.

4.2.3.7 Approvals

Approvals associated with dredging and placement and onshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material as road base is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.3.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the road base option is provided in Table 4-9. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that dredging and processing costs will be approximately $81/m^3$ measured in situ. An additional estimated $50.00/m^3$ cost for higher quality material to add to dredge material through blending to create a suitable material for road base would bring the total estimated cost to $131/m^3$.

Table 4-9: Road base summary cost estimate table

Key Activity	Road Base
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$320,000
TSHD dredging and pump ashore	$5,000,000
Onshore	
Dredge Management ponds construction	$14,500,000
Processing material including dewatering/desalination/ripening	$1,000,000
Processing material including screening/bending/mixing	$5,500,000
Monitoring and management	$500,000
Transport – road transport form site to end user	$6,000,000
Total	**$40,320,00**

4.2.3.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the road base / pavement materials option is 10,294 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.3.10 Knowledge gaps

If the road base option was to be further pursued, key areas where additional information would be required include:

- Demand for road base material and improved understanding of comparative cost of production
- Availability of suitable construction materials for the embankment bunds, and conditions on-site suitable for the construction of ponds
- Site access requirements including potential road upgrades
- Coastal dynamics and processes specific to the proposed location of the dewatering discharge location
- Groundwater conditions beneath the dredge spoil placement area and potential of groundwater contamination, especially salinity, since Weipa region in known to have shallow groundwater aquifers
- Detailed design including consideration of dredging, placement, construction, pond lining system and ongoing use of the onshore storage area.

4.2.3.11 Future considerations

The dredged material is unlikely to be able to be dewatered and processed within the annual period between dredging programs. The dewatering process is likely to take a minimum of three years and assuming there is insufficient demand for the material so that it may be removed from the onshore placement ponds, the storage capacity of the area is likely to be consumed within two years.

The availability of a local project willing to use the dredge material as road base and availability of significantly less expensive local Weipa quarry suppliers makes road base material from dredged sediment establishment and operation likely to be cost prohibitive.

4.2.3.12 Performance summary

A summary of the performance of the road base option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-10.

Table 4-10: Road base performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	LOW: More than $20M annually
Process	HIGH: The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material
Duration	LOW: Greater than 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	LOW: >8000t CO_2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	HIGH: There are few knowledge gaps and less than 1 year of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.2.4 Lining material

4.2.4.1 Activity description

Dredged material, once processed may be used as a liner in Confined Disposal Facilities (CDFs). Liners are often used to reduce the release of leachate from CDFs containing contaminated materials. Leachate may be produced by several potential sources including gravity drainage of the original pore water and ponded water, inflow of groundwater, and infiltration of rainwater. Leachate generation and transport in a CDF thus depend on many site-specific and sediment-specific factors.

Liner systems function to minimize contaminant release into the environment by controlling leachate pathways. Liners not only serve to physically isolate the sediments from lateral dikes and foundation materials, but they also function to reduce contaminant migration by employing low-permeability materials to retard the passage of water that may contain contaminants. Figure 4-3 and Figure 4-4 shows CDFs without and with a typical liner system respectively.

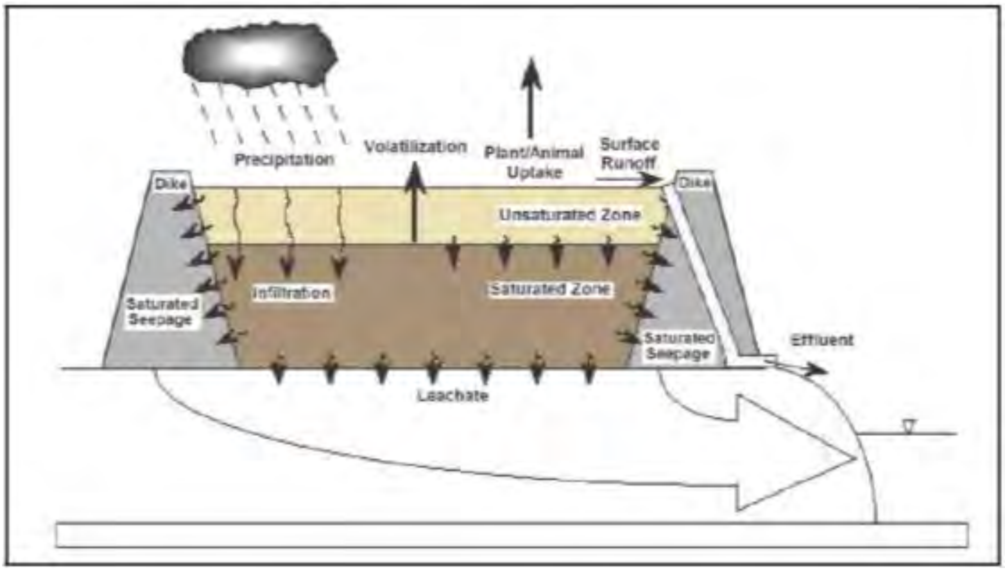

Figure 4-3: Potential contaminant loss pathways for CDFs without a leachate control system

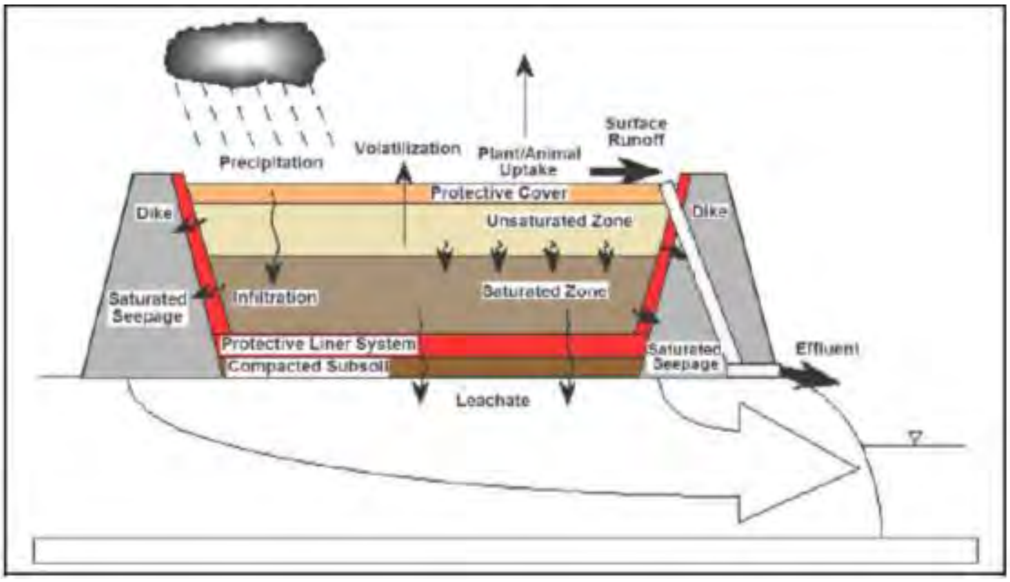

Figure 4-4: Potential contaminant loss pathways for CDFs with a leachate control system

4.2.4.2 Opportunity

The fine component of the dredge material is considered likely to have appropriate characteristics to be used as lining material for a CDF, such as the Weipa Landfill Facility Weipa landfill, Tailings Disposal Facility or RTA landfill located at Kerr Point Road. This opportunity relies on onshore placement of the dredge material (as described for construction fill above), followed by processing.

4.2.4.3 Suitability of Port of Weipa sediments

The USACE Dredging Operations and Environmental Research (DOER) Technical Note ERDC TN-DOER-R6 (USACE, 2004) provides detailed guidance for liner design for CDF Leachate Control.

Detailed consideration would need to be given to the flux retardation properties of the dredge material if were to be used as a liner. Attention would also need to be given to chemical compatibility of the liner materials with the leachate. Chemical degradation of liner systems can result from interactions of the contaminants and/or the water in the leachate with the liner system, potentially leading to defects in the liner and increased leakage rates for leachate transport.

One of the most important design parameters influencing liner material selection is hydraulic conductivity. Soil and dredged material liners should provide a field hydraulic conductivity of $1x10^{-10}$ to $1x10^{-12}$m/s or less when compacted. According to the NSW EPA Draft Guidelines for Solid Waste Landfills (2015) permeability for leachate barrier should be less than $1x10^{-9}$m/s. Clean dredged fine-grained material when allowed to settle and condense, dredged from rivers and harbors can reach permeabilities as low as 10^{-9} to 10^{-12}m/s (Giroud et al. 1997, Schroeder et al. 1994). By most standards, this range of liner permeability is acceptable for service as hydraulic barriers. Additional reductions in hydraulic conductivity may be realized through modification of clean dredged material with additives, use of clay layers, or employment of geosynthetic materials and composite liner systems. Liners and their underlying soils must also possess sufficient strength after compaction to support themselves and the overlying materials without failure.

Of the clay samples tested, the samples with the highest fines contents (H-3, TB-6 and SC-12,13 and14) achieved permeability values of $1.9x10^{-10}$ to $2.8x10^{-10}$ m/s, which indicate that a proportion of the fine-grained materials may be suitable for use as a hydraulic barrier in a lining material, depending on other requirements such as geochemical test results.

As part of the assessment of the proposed lining material reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-11 (suitability categories as per Section 3.3.1).

Table 4-11: Suitability of dredge sediment for proposed lining material reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment/processing
Moisture content	Potentially suitable with treatment/processing
Plasticity Index	Potentially suitable with treatment/processing
Linear Shrinkage	Potentially suitable with treatment/processing
Density test	Potentially suitable with treatment/processing
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	Likely suitable (selected samples)
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

Based on the sediment tested a proportion of the fine-grained material may be suitable for use in liners. Targeted dredging of samples with the highest fines contents (H-3, TB-6 and SC-12, 13 and

14), especially the Southern Channel could produce significant estimated volumes, greater than 100,000m^3, of potentially suitable fine material. Weipa's landfill facility is located at Kerr Point Drive and is owned by RTA and operated by third party contractor Remondis. The demand for liner material or requirements for any particular CDF in the Weipa region are unknown. The majority of dredge sediment material would require treatment and processing to improve its suitability as a lining material.

4.2.4.4 Process description

Dredging and placement

A hydraulically placed clean fine dredge material liner may be an economical solution; however, given that the dredge sediments have various proportion of fines, sand and clay and very high moisture contents the material will require treatment and processing prior to use as a lining material. A potential solution would be for material to be first pumped on land to an intermediate storage location, dewatered and then trucked to the CDF. As such, the dredging and placement requirements for this option are as for those identified for construction fill at Section 4.2.2.4.

Infrastructure and management requirements

In addition to the onshore infrastructure and management requirements identified for construction fill at Section 4.2.2.4, material to be used for CDF liner material is likely to require more extensive processing to separate and / or mix material suitable for a liner.

The dewatered sediment material will need to be extracted from the storage pond and sorted into various particle sizes be a screening plant. The resulting material stockpiles can be batched, and if necessary blended with imported material, to create a liner material to achieve the required properties. The processing to separate the fine material for use as a lining material would produce a waste steam of unsuitable larger particle material that would need to be managed separately.

For the purposes of analysis, it is assumed that liner material would be delivered to the Weipa landfill on Kerr Point Road adjacent to the inactive TSF requiring an approximately 2km round trip.

Relevant standards

Several standards may be relevant to the evaluation of the suitability of the dredged material as a liner for a CDF:

- ASTM D6141-18 (ASTM 2018) Standard Guide for Screening Clay Portion and Index Flux of Geosynthetic Clay Liner (GCL) for Chemical Compatibility to Liquids provides guidance for evaluation of clay portions of geosynthetic clay liners.
- ASTM D2487-17 (ASTM 2017) Standard Practice for Classification of Soils for Engineering Purposes (unified Soil Classification System) is used to classify engineering properties of soils based on particle size and organic matter content.
- ASTM D4318-17e1 (ASTM 2017) Standard Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils and EM 1110-2-1906 Laboratory Soils Testing (USACE 1970) provides water contents at which a fine-grained soil or sediment changes from a semisolid to a plastic solid and from a plastic solid to a semiliquid.

4.2.4.5 Potential constraints

Potential constraints associated with this option include:

- The demand for lining material for use in CDFs in the region is not clear
- Complex process of mixing, treatment, extraction, processing by screening, stockpiling and then potential blending and batching with imported material to manufacture liner material
- Production of liner from the dredge material may be more process intensive than other methods of liner production, and as such the cost of supply will likely need to be subsidised by NQBP to create demand
- Likely to be a limited requirement for liner material in the region, and as such, dredged material as source of liner material will be opportunistic only i.e. not a continuous source reuse for the dredged material
- Construction of the embankment bunds for the onshore placement area requires an estimated 97,000m^3 of material, much of which may require importation, and access to this material may be difficult
- Weipa's monsoonal wet season and high rainfall levels will influence the speed of dewatering and limit when it may occur
- Infrastructure development would need to consider potential impact of extreme events, (cyclones) including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, groundwater aquifers, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Potential acid Sulfate soils, while unlikely to be an issue, will require consideration and potentially management during placement, particularly if separation of potentially acid forming material from acid neutralising capacity material occurs during processing
- Construction and operation of the placement area will require improvement of access to inactive TSF and will increase traffic on local roads.

4.2.4.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Development of a potential source of liner material in the region, albeit that it would be unlikely to be cost competitive without subsidisation
- Onshore placement may cause temporary sterilisation of land at the inactive TSF
- Onshore placement storage ponds have potential significant implications for local surface and groundwater impacts
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging marine discharge areas
- Onshore placement may cause some impacts to Traditional Owners' lands or exiting partnerships or agreements

- Construction and operation of the onshore placement area will cause temporary and intermittent loss of amenity to the local community, through increases in local traffic, particularly along Kerr Point Road and haul routes for imported fill to construct the bund embankments.

4.2.4.7 Approvals

Approvals associated with dredging and placement and onshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material as lining material is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.4.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the liner material option is provided in Table 4-12. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $75/m^3$ measured in situ.

Table 4-12: Liner material summary cost estimate table

Key Activity	Lining Material
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$320,000
TSHD dredging and pump ashore	$5,000,000
Onshore	
Dredge Management ponds construction	$14,500,000
Processing material including dewatering/desalination/ripening	$1,000,000
Processing material including screening/bending/mixing	$5,500,000
Monitoring and management	$500,000

Key Activity	Lining Material
Transport – road transport form site to end user	$3,000,000
Total	**$37,320,000`**

4.2.4.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the lining material option is 8,253 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.4.10 Knowledge gaps

If the liner material option was to be further pursued, key areas where additional information would be required include:

- Requirements for liner material of CDFs in the region, and the potential for dredged material to be suitable for the specific use
- Demand for liner and improved understanding of comparative cost of production
- Coastal dynamics and processes specific to the proposal location of the dewatering discharge location
- Groundwater conditions beneath the dredge spoil placement area and potential of groundwater contamination, especially salinity, since Weipa region in known to have shallow groundwater aquifers
- Availability of suitable construction materials for the bunds, and conditions on site suitable for the construction of ponds
- Detailed design including consideration of dredging, placement, construction and ongoing use of the reclamation area
- Site access requirements including potential road upgrades.

4.2.4.11 Future considerations

The dredged material is unlikely to be able to be dewatered and processed within the annual period between dredging programs. The dewatering process is likely to take a minimum of three years and assuming there is insufficient demand for the material so that it may be removed from the onshore placement ponds, the storage capacity of the area is likely to be consumed within two years. The availability of a local project able to use the dredge material as lining material and availability of significantly less expensive existing local clay sources (pers. conv. RTA June 2018) makes lining material from dredged material reuse likely to be cost prohibitive.

It is considered that the volume of fine grained sediment that may be derived from the dredging area (SC1-12,13,14) would be sufficient for the creation of a liner system for a CDF, depending on the specifications and ongoing requirements e.g. a CDF of 200mx200mx10m deep with a 1m thick liner, would require an estimated 8,000m^3 of liner material.

It is unclear whether there would be demand for the material, and particularly ongoing demand to provide a long-term solution for reuse of dredged material and lining material.

4.2.4.12 Performance summary

A summary of the performance of the liner material option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-13.

Table 4-13: Liner material performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	LOW: More than $20M annually
Process	MODERATE: The proposed process is sound but there are few examples of it being applied in environments similar to the Port using maintenance dredge material
Duration	MODERATE: 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	LOW: >8000t CO2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	LOW: Lost or negative economic opportunities to enhance port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them

Performance Criteria	Performance Rating
Knowledge Gaps	MODERATE: There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.2.5 Concrete products

4.2.5.1 Activity description

Dredged sediment material may potentially be reused in the manufacture of a range of concrete products including:

- Bricks, blocks and pavers for domestic/commercial and industrial construction
- Low strength concrete (<5MPa) in flowable fill type concrete applications such as a sub-base for construction pads and pavements, or as back fill for trenches. This low strength sub-base layer may be used beneath an engineered pavement with higher strength such as quarry supplied well-graded and highly specified base course material (tested/verified) or a rigid pavement concrete slab and engineered foundations
- Artificial reef created from multiple pre-cast concrete units, refer figures 4-5 and 4-6, placed on the seabed to form an artificial reef structure that may provide recreational fishing opportunities
- Coastal engineering interlocking structural precast units generically known as tetrapods, refer Figure 4-7, to prevent erosion or to dissipate the force of incoming waves, typically used in breakwaters or seawalls

Figure 4-5: Example pre cast concrete unit for the creation of artificial reef

Figure 4-6: Concrete artificial reef, colonised by marine flora and fauna

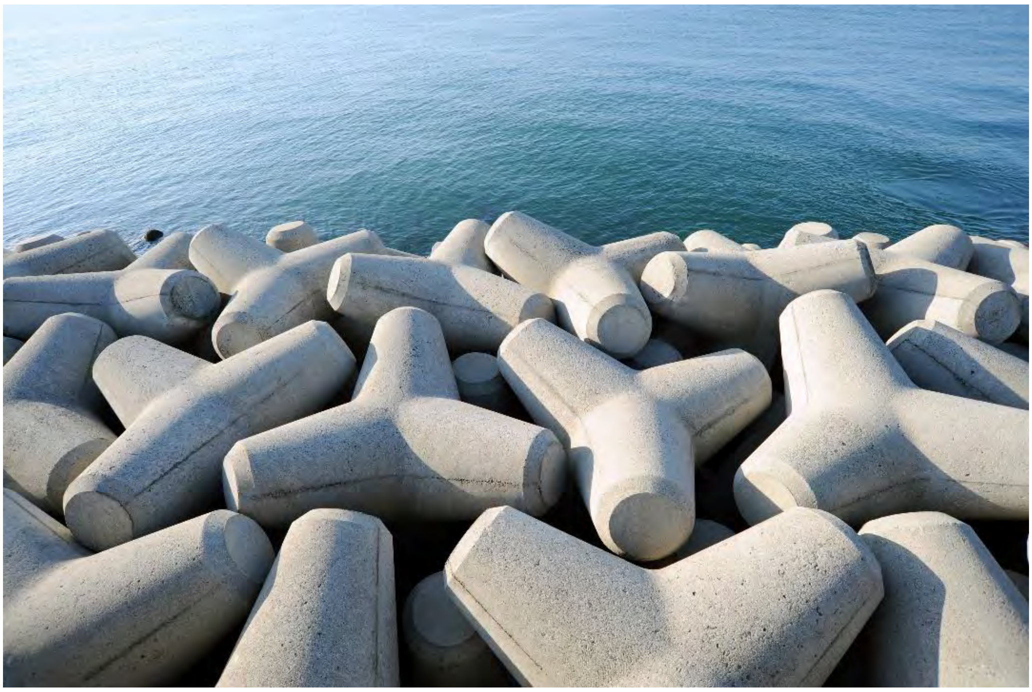

Figure 4-7: Concrete tetrapod units for use in breakwaters and coastal erosion protection

4.2.5.2 Opportunity

Two different concrete product process courses were considered for utilising the dredge material in combination with a binder for reuse as a component of concrete products as follows:

- Portland cement binder based treatment
- Geopolymer binder based treatment.

Either process course relies on onshore placement and treatment of the dredge material (as described for construction fill refer Section 4.2.2 followed by processing.

High end use of the sand material in concrete products (bricks, blocks and pavers) would require significant processing, producing waste from unsuitable material and be expensive relative to the Weipa local sand supply sources. To meet the stringent material specifications for manufacturing concrete construction products the dredge material would require:

- Selective dredging to target estimated 100,000m^3 sand material in the Southern Channel (SC-1 to SC-5) and in the Approach Channel and Departure Channels. Treatment of sand to remove the chlorides (salt) would be required as this will otherwise affect mix strength properties.
- Treatment to remove internally held salt as this will otherwise migrate and become a cause of efflorescence (crystalline surface salt deposit, whitish in appearance) on the finished masonry surface which is visually unacceptable in architectural applications.
- Processing to avoid clay particles that will swell and shrink with wetting and drying. This characteristic affects the workability of the mix when manufacturing bricks, blocks or pavers and requires more water to be added which will reduce the strength of the mix and the final product.
- Avoidance of coloured fines, as colour is important in concrete products, as the dark grey colour of sediment material will be reflected in the final product and may leach out or concentrate in areas blemishing appearance which will be unacceptable for end users.

The reuse of dredge material sediment in manufacture of concrete products (bricks, blocks, pavers) is considered unsuitable due to the material's properties and is unable to be cost competitive in this market sector due to remoteness from major population centres, and as such, is not considered further in this analysis.

Utilisation of dredge sand as an alternative source of normal fine sand in premixed structural concrete is considered the most feasible of the concrete products options. Premixed structural concrete, incorporating dredge sand with other concrete constituents, may be used in structural concrete in construction or pre cast concrete applications such as artificial reefs or tetrapods.

There are two main concrete manufactures and suppliers in the region: Boral Weipa and Weipa Concrete. Subject to the sediment sand material suitability (screening, washing and testing) both suppliers indicated potential interest in the dredge material as a source of sand material. These organisations would typically use between 5,000m^3 and 10,000m^3 of similar sand material annually in manufacture of premixed concrete for structural applications (NQBP pers. conv. Aug. 2018).

4.2.5.3 Suitability of Port of Weipa and Amrun sediments

Analyses of the six sediment samples (sample location described in Section 2.1) showed marked differences in properties for concrete product suitability between the samples:

- Sediment from the Southern Channel (SC-5) has low fines and a high silicas and sand content and has good potential for use as an alternative source of normal fine sand in structural premixed concrete and concrete products. The silt and relatively high level of chlorides present would need to be dewatered and washed before general use in concrete may be permitted. This fine sand would typically be used at a rate of 200kg/m^3 of concrete (or less than 10% by weight). This dredged sediment sand could be used in concrete for construction or precast unit such as artificial reef or shoreline protection 'tetrapods'.
- Sediment samples from the Humbug Wharf (H-6) and Lorim Point (LP-6) berth areas have some sand, but relatively high clay content. This would interfere with its use in concrete; however, these clays can undergo stabilisation through an ion exchange mechanism with a calcium bearing material (e.g. lime or Portland cement). By altering the level of Portland cement added (approximately between 2% and 5%) the final product could be used for the low strength trench flowable backfill, up to the low-performance sub-base fill material described above.
- Sediment samples for the outer Southern Channel (SC-16,17 and 18) and Amrun (Amrun-1 and 6) are characterised as wet mud with excessive fines and cannot be easily used in concrete products.

The Portland cement approach would be the simplest treatment of the fine sediment material; however, Portland cement is an expensive additive (bulk cement costs approximately $225/t in major regional Queensland centres, including Weipa) and its manufacture is a large source of carbon emissions. The geopolymer process would generate lower carbon emissions (the binder generates more than 80% lower carbon emissions during manufacture); however, the high water content in the fine sediments is likely to be problematic for this process. The material would need to be dewatered and dried before use. To achieve maximum benefit in a geopolymeric product, the fine sediment material would need to be heated to approximately 750°C to improve reactivity, which is an expensive and impractical alternative to Portland cement additive option.

Sediment materials with any salt content are unsuitable for manufacturing concrete used in structural applications, as the steel reinforcing is susceptible to physical and chemical attack by salt which may cause concrete spalling, cracking and crumbling, reducing its load bearing strength for the purpose it was designed. Substitution of composite fibre reinforcement for normal steel reinforcement in structural concrete would avoid the chlorides corrosion of reinforcement but is a more expensive product.

The clay particles in the sediment will swell and shrink with wetting and drying. This characteristic affects the workability of the mix when manufacturing concrete and requires more water to be added, which will reduce the strength of the mix and the final concrete, and also makes the sediment unsuitable for structural concrete. Utilisation of targeted sediments with high sand content as an alternative source of normal fine sand in premixed structural concrete is considered the most likely to be feasible of the concrete products options, and as such, is the subject of analysis below. Premixed structural concrete, utilising treated and processed dredge sand, could be used in structural concrete in construction project or even pre cast concrete applications such as an artificial reef or tetrapods.

As part of the assessment of the proposed concrete products (dredge sand replacing normal fine sand) reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-14 (suitability categories as per Section 2.1.3).

Table 4-14: Suitability of dredge sediment for proposed concrete products as an alternative source of normal fine sand in structural concrete

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment/processing
Moisture content	Potentially suitable with treatment/processing
Plasticity Index	Potentially suitable with treatment/processing
Linear Shrinkage	Potentially suitable with treatment/processing
Density test	Potentially suitable with treatment/processing
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	Potentially suitable with treatment/processing
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable (non-structural concrete only with, sand washing required for structural concrete)
Organic Material	Likely suitable
Other	
Cement laboratory testing	Potentially suitable with treatment/processing

The sand component of the sediment material requires targeted dredging, followed by treatment and processing to improve its suitability for potential use as a fine sand replacement concrete product. An estimated 100,000m^3 of sand material could be targeted from three dredge areas ((SC1-SC-5, Approach Channel and Departure Channel). The dredge sands have relatively high levels of chlorides which would need to be washed out the sediment sand material for use in general structural premixed concrete.

4.2.5.4 Process description

Dredging and placement

The dredging and placement requirements for this option are as identified for construction fill at Section 4.2.2.4.

Infrastructure and management requirements

Material to be used as fine sand replacement in general structural premixed concrete use will require placement onshore in a sediment material treatment area and undergo similar treatment (dewatering) as that identified for construction fill at Section 4.2.2.4. A screening and washing plant operation would be required to separate and then wash the target sand component. The screening and washing plant would need a clean water supply and a conveyor system all operated by a diesel engine. Washed sand would be moved by a loader and stockpiled in designated areas for sampling and laboratory testing before being trucked as an input raw material to a concrete batching plant at either Boral Weipa, Weipa Concrete or to a construction site mobile concrete bathing plant.

For the purposes of analysis, it is assumed that fine sand replacement would be delivered to the Weipa and adjacent mining region requiring an approximately 50km round trip.

Relevant standards

Australian Standards relevant to the concrete products under consideration include:

- AS3700 “Masonry Structures”
- AS 1379 “Specification and Supply of Concrete”
- Queensland Department of Transport and Main Roads Specification Category 5: Pavements, Sub Grade and Surfacing: MRTS39 “Lean Mix Concrete Sub Base for Pavements”, July 2017.

4.2.5.5 Potential constraints

Potential constraints associated with this option include:

- Production of concrete products from the dredge material may be more process intensive than other methods of production and may not be supported by demand
- The sediment sand characteristics and the quantities potentially available (100,000m^3 annually) are suitable as fine sand replacement in general structural premixes concrete use. Boral Weipa and Weipa Concrete have potential demand of 5,000m^3 to 10,000m^3 per annum unless there was a large construction or specific project such as a concrete artificial reef
- Sand sourced from dredging sediments would be more expensive than current sand supplies. NQBP would likely need to subsidise this materials production cost to incentivise concrete manufactures to use sediment material as a raw material input to their products

- Construction of the embankment bunds for the onshore placement area requires 97,000m^3 of material, much of which may require importation, and access to this material may be difficult
- High Rainfall levels in the region will impact the speed at which dewatering may occur
- Infrastructure development would need to consider potential impact of extreme events, (cyclones) including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, groundwater aquifers, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Potential acid Sulfate soils, while unlikely to be an issue, will require consideration and potentially management during placement, particularly if separation of potentially acid forming material from acid neutralising capacity material occurs during processing
- Construction and operation of the placement area will require improvement of access to Inactive TSF, and will increase traffic on local roads

4.2.5.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Sand sourced from dredging sediments may be suitable for concrete suppliers to use as a raw material in product manufacture; however, the onshore placement and processing would likely need to be subsidised by NQBP
- Onshore placement may cause temporary sterilisation of land at the inactive TSF
- Onshore placement storage ponds have potential significant implications for local surface and groundwater impacts
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas
- Onshore placement may cause some impacts to Traditional Owners' lands, waters or exiting partnerships or agreements
- Construction and operation of the onshore placement area will cause temporary and intermittent loss of amenity to the local community, through increases in local traffic, particularly along Kerr Point Road and haul routes for imported fill to construct the bund embankments
- Any proposal to create an artificial reef, using dredge sand material in pre cast concrete, would require consultation in the planning, design and development with the Weipa Reference Group including representatives of charter boat operators and the Weipa Sportsfishing Club.

4.2.5.7 Approvals

Approvals associated with dredging and placement and onshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material in concrete products is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.5.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the concrete products (low strength) option is provided in Table 4-15. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and material processing and transport), it is estimated that costs will be approximately $\$78/m^3$ measured in situ. An additional estimated $\$50.00/m^3$ cost for cement and gravel material to add to dredge material to manufacture concrete would bring the total estimated cost to $\$128/m^3$.

Table 4-15: Concrete products (low strength) summary cost estimate table

Key Activity	Concrete Products
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$320,000
TSHD dredging and pump ashore	$5,000,000
Onshore	
Dredge Management ponds construction	$14,500,000
Processing material including dewatering/desalination/ripening	$1,000,000
Processing material including screening/bending/mixing	$4,000,000
Monitoring and management	$500,000
Transport – road transport form site to end user	$6,000,000
Total	**$38,820,000**

4.2.5.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the concrete products option is 10,294 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.5.10 Knowledge gaps

If the concrete products option was to be further pursued, key areas where additional information would be required include:

- Demand for sediment sand as fine sand replacement in concrete for general premixed structural concrete uses and improved understanding of comparative cost of sand production
- Obtain samples of the dredge sediment material to prepare trial mixes to see how specific mixes react. Test blends of various proportions of Portland cement, flyash and lime to determine optimum mix design for performance characteristics and cost
- Coastal dynamics and processes specific to the proposed location of the dewatering discharge location
- Availability of suitable construction materials for the bunds, and conditions on site suitable for the construction of ponds
- Detailed design including consideration of dredging, placement, construction, material processing / segregation / storage and ongoing use of the reclamation area
- Site access requirements including potential road upgrades.

4.2.5.11 Future considerations

The total 500,000m^3 dredged material is unlikely to be able to be dewatered and processed within the annual period between dredging programs. The dewatering process is likely to take a minimum of three years and assuming there is insufficient demand for the material so that it may be removed from the onshore placement ponds, the storage capacity of the area is likely to be consumed within two years. Production of low performance flowable concrete material from the dredged material is unlikely to support a new business given high relative costs. It is unclear whether there would be demand for the material in concrete products, and particularly sufficient ongoing demand to provide a long-term solution for receipt of dredged material.

Selective dredging and processing to target dredged sand material is likely to be suitable as fine sand replacement in general premixed structural concrete products uses. The annual quantity of dredge sand material (estimated 100,000m^3) outstrips normal commercial demand by more than factor of 10, However it may be used opportunistically in structural concrete manufacture for port construction projects, major regional construction projects or other special projects application (e.g. artificial reef) in the vicinity of the Weipa.

4.2.5.12 Performance summary

A summary of the performance of the concrete products (low strength) option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-16.

Table 4-16: Concrete products (low strength) performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	LOW: More than $20M annually
Process	HIGH: The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material
Duration	MODERATE: 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	LOW: >8000t CO2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	HIGH: There are few constraints which are for the most part considered manageable
Knowledge Gaps	HIGH: There are few knowledge gaps and less than 1 year of further research work would be required to progress the reuse option
Future considerations	MODERATE: The reuse option would cater for immediate needs and has some scope in the short term (several years), although options would need to be regularly reassessed

4.2.6 Shoreline protection

4.2.6.1 Activity description

Dredged material (including silt, clay, sand, gravels and rock) may be used to provide shoreline protection to compensate for erosion. This may include the placement of material to protect low lying areas from erosion, or the use of offshore berms to modify the local wave climate.

4.2.6.2 Opportunity

Coastal erosion may occur in the estuaries around Port of Weipa including in areas where mangrove dieback may have occurred, as mangroves can provide a natural protection against erosion from wave action, tidal and (partially) high flow currents in the estuaries. No specific demand for shoreline protection has been identified; however, it is noted that wave action from an easterly direction at the Evans Landing Boat Ramp hampers trailer vessel launching and retrieval and at Gonbung Point sand accumulation is occurring enhancing the shoreline. Both these locations may benefit from shoreline protection in the form of installation of offshore berms to modify the nearshore wave climate.

For the purposes of analysis, it has been assumed that shoreline protection may be applied offshore in the Embley River estuary east of the Evans Landing Boat Ramp. Several shoreline protection options may be utilised, including:

- Direct placement on the beds and banks of waterways to protect low lying land against wave action, where coarser material will remain where placed on the bank
- Placement in geotextile bags / tubes, above and/or underwater to prevent erosion.

Placement in geobags / geotubes

Geotubes and bags exist in different shapes and forms and can be used in different design applications to prevent erosion. Figure 4-8 and Figure 4-9 shows various applications for geobags and geotubes respectively:

- Revetments
- Groynes
- Artificial reefs
- Slope buttressing
- Temporary protection dykes
- Offshore breakwaters
- Containment dykes.

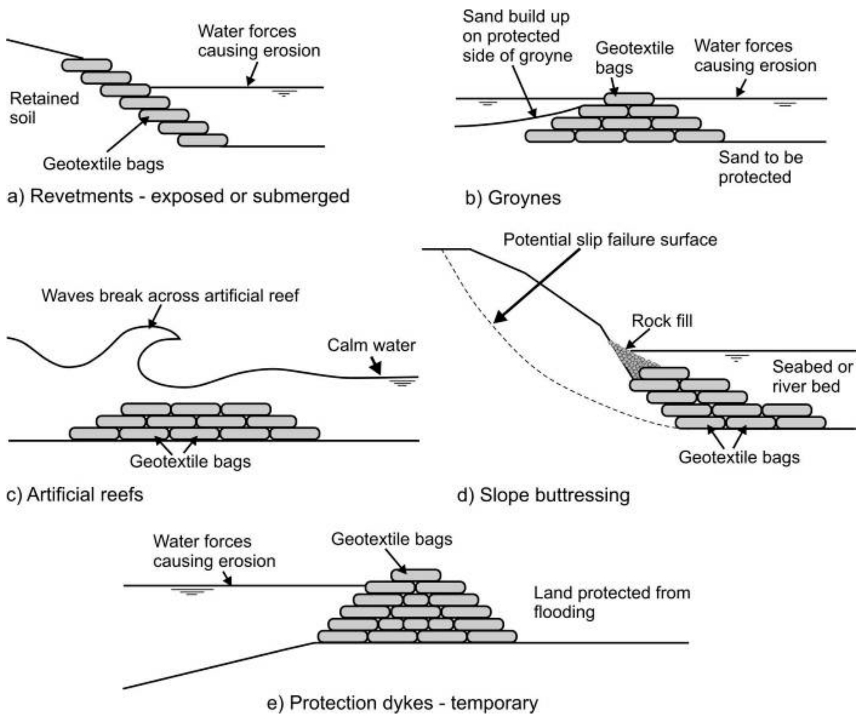

Figure 4-8: Geobag applications, source: Pilarczyk (2000)

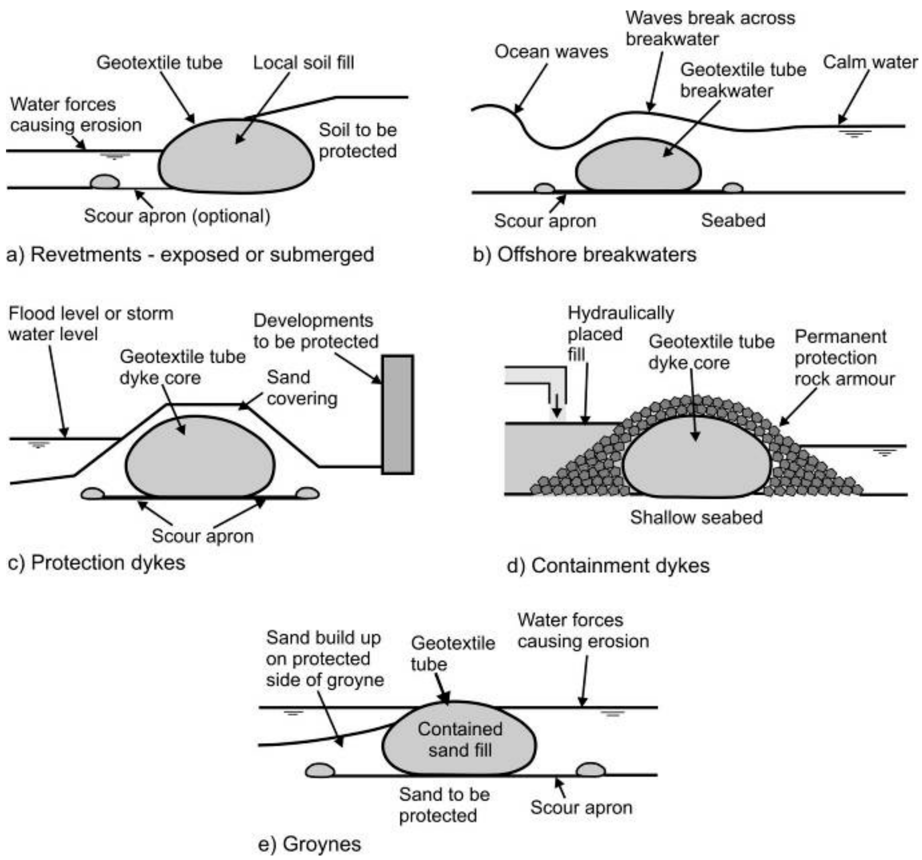

Figure 4-9: Geotube applications, source: Pilarczyk, (2000)

In all of the above cases, the bags and tubes can be filled hydraulically. Bags can be filled hydraulically on a pontoon and placed by crane, and tubes can be filled hydraulically at the placement site from a hopper barge with a pump which liquefies the dredge material in the hopper. This means that the material needs to be handled twice i.e. dredged and transported and then pumped again to place it in the geobags or geotubes.

Due to the large amount of Port of Weipa fine material to be dredged, it is considered that the dredge material is unsuitable for shoreline protection through direct placement; however, is suitable for use in geobags or geotubes. The geotextile allows for gradual dewatering of the dredge material and the fines are maintained within the structure of the bag or tube.

The geotubes may be hydraulically filled in a split hopper barge at the dredging site, therefore eliminating the need of transport of the dredge material to the placement site prior to filling and eliminating any plumes resulting from the filling of the bags at the placement site. The tubes are sewn shut once filled and reinforced with rope ties. Subject to water levels (at high tide) the split hopper barge can place and/or stack the tubes in the placement area (under water). Figure 4-10 illustrates the placement of geotube / geocontainer with a split hopper barge.

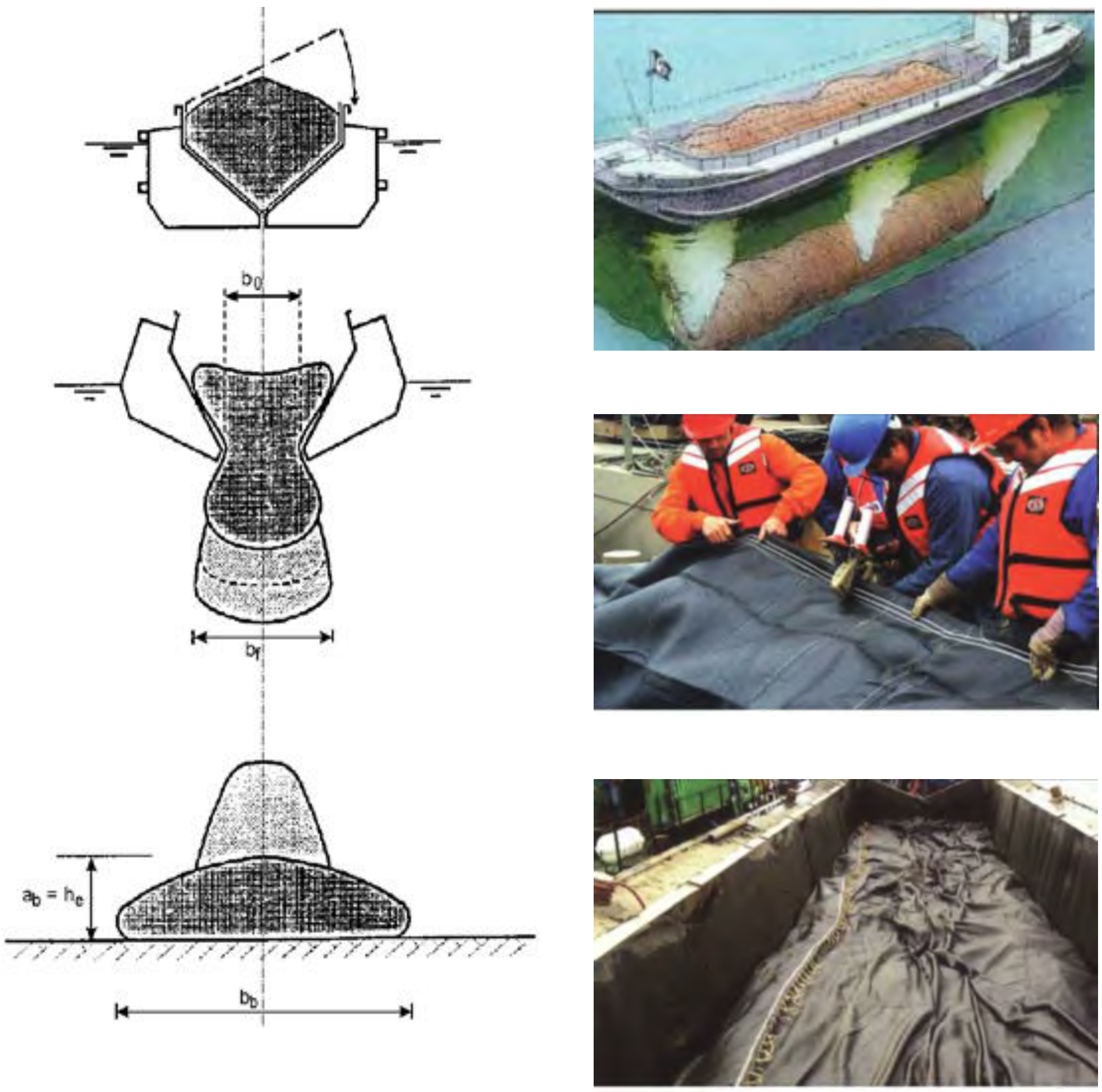

Figure 4-10: Geotube / geocontainer placement, source: TenCate (2016)

4.2.6.3 Suitability of Port of Weipa sediments

The majority of material is fine-grained direct placement is unlikely to effectively address wave attenuation or any coastal erosion issues, as the material would not remain in place. As such only the option of placement in geotextile tubes underwater is considered further.

As part of the assessment of the proposed shoreline protection reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-17 (suitability categories as per Section 3.3.1).

Table 4-17: Suitability of dredge sediment for proposed shoreline protection (geobags) reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Likely suitable
Moisture content	Likely suitable
Plasticity Index	Likely suitable
Linear Shrinkage	Likely suitable
Density test	Likely suitable
Strength and Consolidation	Likely suitable
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The proposed sediment material reuse option of placing sediment into geobags to create shoreline protection requires very little if any treatment or processing of the material. Dewatering will assist reduce the volumes of sediment material to be handled and placed directly into geobags.

4.2.6.4 Process description

Dredging and placement

Sediment material would be dredged and transported to the site of shoreline protection works. Given the depth limitations around Evans Landing Boat Ramp or alternative areas such as Gonbung Point, and the restriction of dredge manoeuvrability to within navigational areas, it is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a Trailing Suction Hopper Dredge (such as the 'Brisbane') with multiple split hopper barges, which would be hydraulically filled at the dredging area, and would transport the dredged material to the placement site.

For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will load the split hopper barges at the dredging area and the barges will travel up to 20km to a placement site. Mooring and transfer facilities would be required to enable secure transfer between the Trailing Suction Hopper Dredge and the barges.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last approximately 37 days. The dredge program would be slightly longer duration than options involving onshore treatment as operations to transfer dredged material to barges are less efficient.

4.2.6.5 Potential constraints

Potential constraints associated with this option include:

- Demand for shoreline protection for which the dredge material usage would be suitable is unclear
- Availability of equipment (e.g. appropriate split hopper barges) to execute the works may be limited
- Tidal range may present significant operational constraints, dependent on the shoreline protection option
- Sea and weather conditions may affect operability of the configuration, particularly transfer of material from dredge to barge, and placement of geotubes
- Potential acid Sulfate soils, may require consideration in development of the shoreline protection concept
- Turtles nesting season generally occurs between October and February and dredging activities, especially involving any foreshore areas, should be planned to avoid impacting protected species and their habitat
- Placement on or near seagrass habitat, refer Figure 4.11 for seagrass locations
- Agreement for access to the marine areas and adjacent land for the proposed works
- Suitable geofabric material able to contain the fine clay/silt material, yet permeable to allow the filled geobag to 'sink' into position.

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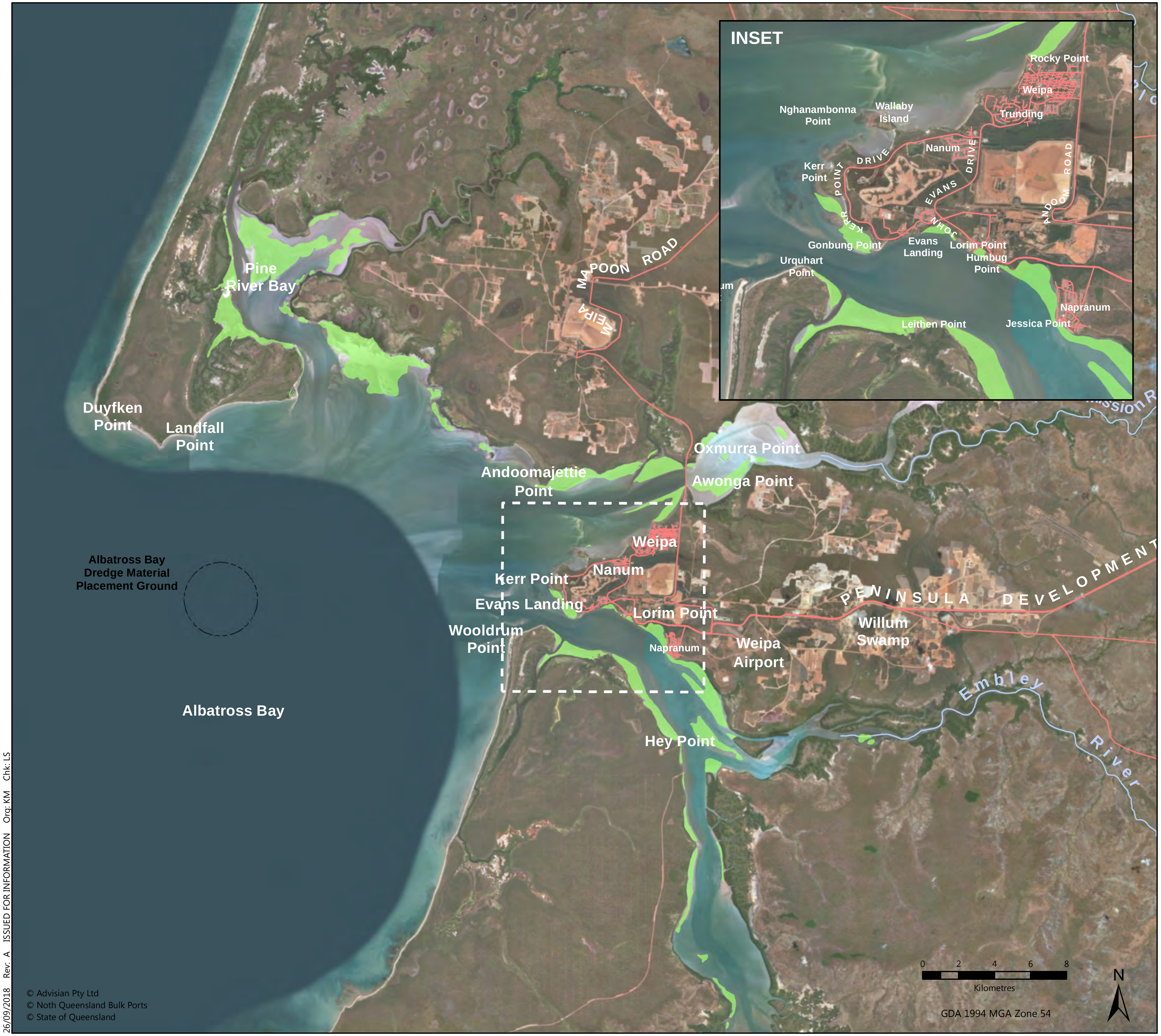
Figure 4-11: Location of Seagrass Meadows in the Port of Weipa

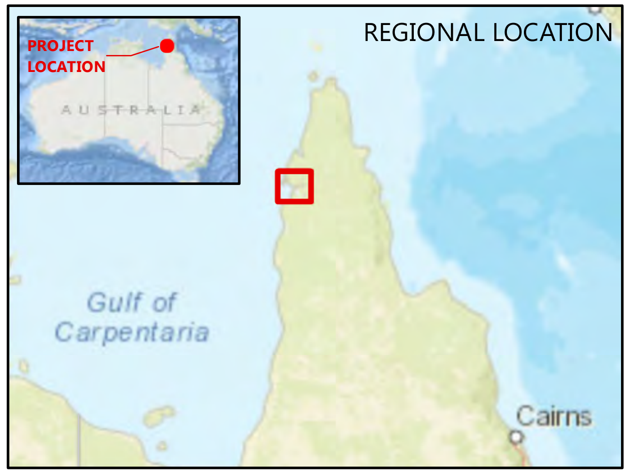


LEGEND

- Major Road
- Minor Road
- Major watercourse
- Seagrass meadows - Aug 2017

Source Information:
Place name Gazeteer
Geoscience Australia
Baseline roads and tracks - Queensland
Qld Watercourse lines
Queensland Department of Natural Resources and Mines
2017 Seagrass meadow locations
Supplied by North Queensland Bulk Ports - Sep 2018

While every care is taken to ensure the accuracy of this data, WorleyParsons makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaims all responsibility and all liability (including without limitation liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which might be incurred as a result of the data being inaccurate or incomplete in any way and for any reason.



Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China

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26/09/2018 Rev: A ISSUED FOR INFORMATION Org: KM Chk: LS

4.2.6.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to provide potentially cost-effective shoreline protection (should demand exist) which may have positive socio-economic, commercial and environmental outcomes
- Placement of structures in the coastal environment may have implications for coastal processes, including sediment dynamics and transport in the local area
- Placement of structures will cause some (manageable) impacts to water quality in areas adjacent to the dredging and placement areas
- Placement on or near seagrass habitat, refer Figure 4.11 for seagrass locations
- Shoreline protection measure placement may cause some impacts to Traditional Owners' lands, waters or exiting partnerships or agreements
- Any proposal to create shoreline protection, using dredge material, would require extensive consultation in the planning, design and development with the local Weipa community groups.

4.2.6.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material in shoreline protection is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.6.8 Costs

A summary breakdown of the estimated costs associated with execution of the shoreline protection option is provided in Table 4-18. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $\$12/m^3$ measured in situ.

Table 4-18: Shoreline protection (geotubes) summary cost estimate table

Key Activity	Shoreline Protection
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Workboat	$500,000
Tug and barge mobilisation and demobilisation	$2,000,000
Place nearshore with tug, barge and geobags	$800,000
Onshore	
Monitoring and management	$250,000
Total	**$6,050,000**

4.2.6.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the shoreline protection option is1,363 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.6.10 Knowledge gaps

If the shoreline protection option was to be further pursued, key areas where additional information would be required include:

- Demand for shoreline protection in the vicinity of the Port of Weipa
- Coastal dynamics, wave climate, current regimes and processes specific to the proposed location of the shoreline protection areas to enable effective design and implementation
- Availability of suitable equipment to execute the works
- Detailed design including consideration of dredging, dredge material transfer and placement.

4.2.6.11 Future considerations

This shoreline protection option for beneficial reuse of dredged material is heavily constrained by demand. While the quantity of material to be dredged per program may be suitable for this option (i.e. typically dredge material quantities of 100,000-300,000m^3 are required to make this option feasible) dependent on the need for shoreline protection, it is considered likely that reuse would only have a single or limited application utilising only a small portion of the total annual available dredged material.

4.2.6.12 Performance summary

A summary of the performance of the shoreline protection option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-19.

Table 4-19: Shoreline protection (geobags) performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	HIGH: Less than $10M annually
Process	HIGH: The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material
Duration	HIGH: Less than 1 year to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	HIGH: < 2000t CO_2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	MODERATE: There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.2.7 Beach nourishment

4.2.7.1 Activity description

Beach nourishment or sand replenishment is a process by which sediment (usually sand) lost through longshore drift or erosion is replaced from sources outside of the eroding beach. A wider beach can reduce storm damage to shoreline by dissipating wave energy and protecting from storm surges and unusually high tides. Beach nourishment is typically a repetitive process, since it does not remove the physical forces that cause erosion, but simply mitigates their effects.

4.2.7.2 Opportunity

The dredge material potentially provides a source of sand and fine materials for beach nourishment in the vicinity of the Port of Weipa. No locations with significant demand for beach nourishment have been identified; however potential minor areas of erosion that may benefit from beach nourishment have been identified at Gonbung Point., refer Figure 4-12. Anecdotally sand accumulation in recent years at Gonbung Point is re-establishing a 'beach,' and encouraging mangrove regrowth in an area where disused tyres, placed as shoreline protection, have been recently removed. The Gonbung Point area is at the mouth of the Embley River and is crossed by unformed vehicle and walking tracks. The area is used for fishing and recreation. Beach nourishment to increase the sand area and encourage stabilisation by vegetation is considered a potential enhancement to the area's amenity and an opportunity to rehabilitate the environment at Gonbung Point.

Beaches are typically made up of materials including sand, gravel, pebbles, cobbles, rock or shells. Material on the beaches within the vicinity of the Port of Weipa that may require management, may benefit from application of the sand component of the maintenance dredge material. The dredge spoil sand from areas such as the Approach Channel, Departure Channel and Southern Channel (SC-1 to SC-5) would need to be targeted and placed onshore for beach nourishment beneficial reuse.

Figure 4-12: Gonbung Point at the mouth of the Embley River, image courtesy of NQBP

For the purposes of analysis, it has been assumed that beach nourishment may be applied within approximately 10km of the Port of Weipa dredge area i.e. the approximate distance to the closest areas where some beach nourishment demand may exist. Beach nourishment of exposed beaches on the coastline north and south of Weipa has not been further considered as these beaches are well established, any modification of beach profile in these more remote locations may interfere with known turtle nesting habitat and Traditional Owner land. Analysis focuses on the use of dredge material sand for beach nourishment, rather than potential mudflat nourishment, which is described in Sections 3.1.2.2.

4.2.7.3 Suitability of Port of Weipa sediments

Beach nourishment generally requires selective dredging of pure sand. The dredge sediment has a high proportion of fine silt and clay (dark colour) that may not be suitable for placement on beaches in the vicinity of the port. The properties of the fine (clay and silt) mean that this material is more readily susceptible to remobilisation by the tidal range and currents.

It is considered reasonable to assume that the sand material dredged from areas at the mouth of the Embley River will be colour compatible with shoreline sand at potential beach nourishment areas also at the mouth of the Embley River as the sand is likely to have migrated to the area from similar sources. The sediment suitability to facilitate the beach nourishment option considers targeting the sand component of the dredged material and this is what the analysis below is based.

As part of the assessment of the proposed beach nourishment reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-20 (suitability categories as per Section 3.3.1).

Table 4-20: Suitability of dredge sediment for proposed beach nourishment reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	Sand colour likely to be suitable
Particle Size Distribution	Potentially suitable with treatment/processing (i.e. selective dredging to target sand)
Moisture content	N/A
Plasticity Index	N/A
Linear Shrinkage	N/A
Density test	N/A
Strength and Consolidation	N/A

Sediment Material Property	Suitability
Permeability	N/A
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The fine (clay/silt) material (approximately 71% of all material) is unlikely to be suitable for beach nourishment reuse; however, the sandy material may be specifically targeted for use in beach nourishment. If there is a suitable foreshore location in the Weipa area that may benefit and has favourable water current patterns, then direct placement of sandy material as beach nourishment is a potentially suitable reuse option.

4.2.7.4 Process description

Dredging and placement

Dredge material would be dredged and transported to the site of the beach nourishment works. Given the depth limitations around Gonbung Point and other river estuary beaches around Albatross Bay, and the limitation of dredge manoeuvrability to within navigational areas, it is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a Trailing Suction Hopper Dredge (such as the 'TSHD Brisbane') with pump out to the beach requiring nourishment.

Infrastructure required to facilitate the pump-out would likely be temporary, and would include a pipeline (potentially floating, along with a pump out coupling) and a mooring system for the dredge during pump-out. For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will travel approximately 9km from the selected sand dredging areas to access the pump-out point. If Gonbung Point was selected for beach nourishment the dredge is likely to be able to moor at Evans Landing wharf for pump out since it is the closest existing mooring facility to the placement location. It is likely that a booster pump would be required for the pump-out, given that the dredge is unable to moor less than 1.5km from the beach to be nourished.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last approximately 32 days.

4.2.7.5 Potential constraints

Potential constraints associated with this option include:

- Demand for beach nourishment for which the dredge material usage would be suitable is not established
- The dark grey colour of the fine sediment material (silt/clay) is unlikely to be visually acceptable for reuse on any lighter coloured sandy beach hence it is foreseen that the coarser (sand) sediment will be selectively dredged for beach nourishment reuse
- As the dredge mooring point for pump out is more than 1.5km from the beach to be nourished it is likely that a booster pump would be required
- Tidal range in the region may present operational constraints, dependent on the beach nourishment option
- Dredge material placed onshore as beach nourishment is typically eroded by the forces that caused the eroding beach in the first instance. Material is potentially transported elsewhere following placement and may only provide a wider beach temporarily. The fine dredge material is likely to be highly susceptible to erosion
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the beach nourishment area
- Potential acid Sulfate soils, may require consideration in development of the beach nourishment concept
- Turtles nesting season generally occurs between October and February and dredging and dredge material placement activities, especially involving any foreshore areas, should be planned to avoid impacting protected species and their habitat
- Placement on or near seagrass habitat, refer Figure 4.11 for seagrass locations
- Agreement for access to the land, potentially from Traditional Owners, for the proposed works.

4.2.7.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to provide potentially cost-effective beach nourishment (should demand exist) which may have positive social, recreational and environmental outcomes
- Placement of the coarse (sand) dredge material on any foreshore area need to be similar colour to the existing beach material to avoid negative community response
- Placement of dredge material in the nearshore coastal environment may have implications for coastal processes, including sediment dynamics and transport in the local area
- Beach nourishment activities particularly pipeline management (including booster pump operation) and placement in some beaches in the Weipa region may cause impacts to turtle nesting zones or seagrass
- Utilisation of fine materials for beach nourishment is likely to cause impacts to marine water quality at the placement location, which may cause nuisance that is unlikely to be easily managed

- Beach nourishment may cause some impacts to Traditional Owners' lands, waters or exiting partnerships or agreements.

Any proposal for beach nourishment, using dredge material, would require extensive consultation in the planning, design and development with the local Weipa Community Groups.

4.2.7.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material as beach nourishment is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.7.8 Costs

A summary breakdown of the estimated costs associated with execution of the beach nourishment option is provided in Table 4-21. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $32/m^3$ measured in situ.

Table 4-21: Beach nourishment summary cost estimate table

Key Activity	Beach Nourishment
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$500,000
TSHD dredging and pump ashore	$7,500,000
Onshore	
Monitoring and management	$500,000
Total	**$16,000,000**

4.2.7.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the beach nourishment option is 1,728 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.7.10 Knowledge gaps

If the beach nourishment option was to be further pursued, key areas where additional information would be required include:

- Demand for beach nourishment using maintenance dredge material in the vicinity of the Port of Weipa
- Coastal dynamics and processes specific to the proposed location of the beach nourishment to enable effective targeting of dredged sand material, placement, beach accretion, vegetation and benthic habitat and design of sand discharge facilities
- Detailed design including consideration of dredging and pump out facilities.

4.2.7.11 Future considerations

This beach nourishment option for beneficial reuse of dredged material is heavily constrained by demand. It may have a single or limited application for only the suitable sand component of targeted dredged material. It is considered that targeted sand dredging volumes (estimated 100,000m^3 annually) could provide a long-term suitable source of material for beach nourishment that significantly exceeds demand in the region.

4.2.7.12 Performance summary

A summary of the performance of the beach nourishment option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-22.

Table 4-22: Beach nourishment performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	MODERATE: $10M to $20M annually
Process	HIGH: The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material
Duration	HIGH: Less than 1 year to construct and function as the proposed final use

Performance Criteria	Performance Rating
Greenhouse Gas Emissions (GHGs)	HIGH: < 2000t CO2 equivalent in a one year period
Environmental Implications	HIGH: Net benefit opportunities exist for positive environmental outcomes, with very minor nuisance or harm issues
Social Implications	HIGH: Positive social opportunities e.g. jobs exist for local communities and other key user groups
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	LOW: Lost or negative economic opportunities to enhance port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.2.8 Amrun – shoreline protection (offshore berms)

4.2.8.1 Activity description

Dredged material (including silt, clay, sand, gravels and rock) may be used to provide shoreline protection to compensate for erosion. This may include the placement of material to protect low lying areas from erosion, or the use of offshore berms to modify the local wave climate.

4.2.8.2 Opportunity

The Amrun project area is an elevated bauxite plateau that is fringed on much of the coastline by low cliffs and continuous sandy beaches (refer figures 1.3 and 1.4). No specific demand for shoreline protection in the vicinity of the Amrun Port has been identified. Fine material (silt/clay) is 86.4% of the total sediment volume that requires annual dredging maintenance at Amrun Port. This fine sediment is highly mobile compared to sand or gravel. As part of a strategy to minimise dredging activities and reduce the frequency and volume or maintenance dredging at Amrun Port the location may benefit from the selective placement of shoreline protection near the port facilities in the form of offshore berms to modify the nearshore wave climate and reduce fines transport and deposition into the Amrun Port areas.

The Amrun jetty is effectively perpendicular to a straight stretch of exposed coastline, and the local wave pattern is not influenced by the river estuary. Hydrodynamic modelling of sediment transport and wave climate and current patterns may be required to assess the feasibility of offshore berms to influence and reduce sediment deposition at the port.

For the purposes of analysis, it has been assumed that shoreline protection may be installed offshore from the end of the Amrun Jetty and berths and parallel to the coastline. Various shoreline protection options may be utilised:

- Direct placement on the seabed to protect berth and jetty areas against wave action and accompanying sediment deposition
- Placement in geotextile bags / tubes, above and/or underwater to prevent or minimise sediment deposition in the berths and port area.

Placement in geobags / geotubes

As described in Section 4.2.6, geotubes and bags exist in different shapes and forms and can be used in different design applications to prevent erosion. Figure 4-8 and Figure 4-9 shows various applications for geobags and geotubes respectively.

4.2.8.3 Suitability of Amrun Port sediments

Given that most of material (estimated 19,000m^3 annually) is fine-grained it is considered unlikely that direct placement would effectively address wave attenuation or any coastal erosion issues, as the material would be unlikely to remain in place. As such only the option of placement in geotextile tubes underwater is considered further.

As part of the assessment of the proposed shoreline protection reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-17 (suitability categories as per Section 3.3.1).

Table 4-23: Suitability of dredge sediment for proposed shoreline protection (geobags) reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Likely suitable
Moisture content	Likely suitable
Plasticity Index	Likely suitable
Linear Shrinkage	Likely suitable
Density test	Likely suitable

Sediment Material Property	Suitability
Strength and Consolidation	Likely suitable
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The proposed sediment material reuse option of placing into geotubes to create shoreline protection in the form of offshore berms to modify the nearshore wave climate requires very little if any treatment or processing of the material. Dewatering in the dredging operation will assist reduce the volume of sediment material to be handled and placed directly into geotubes.

4.2.8.4 Process description

Dredging and placement

Sediment material would be dredged and transported to the site of shoreline protection works. Given the depth limitations around Amrun Port, and the restriction of dredge manoeuvrability to within navigational areas, it is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a Trailing Suction Hopper Dredge (such as the 'Brisbane') with multiple split hopper barges, which would be hydraulically filled at the dredging area, and would transport the dredged material to the placement site.

For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will load the split hopper barges at the dredging area and the barges will travel up to 1km to a placement site. Mooring and transfer facilities alongside the Amrun Port jetty would be required to enable secure transfer between the Trailing Suction Hopper Dredge and the barges.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last approximately 6 days. Potential constraints

4.2.8.5 Potential constraints

Potential constraints associated with this option include:

- Demand for shoreline protection (offshore berms) to modify the wave climate for which the dredge material usage would be suitable is unclear. It is possible that the options described above will not be effective in reducing sediment deposition in the Amrun berths (NQBP Pers. Conv Ports & Coastal Sep. 18)
- Availability of equipment (e.g. appropriate split hopper barges) to execute the works may be limited
- Sea and weather conditions may affect operability of the configuration, particularly transfer of material from dredge to barge, and placement of geotubes
- Suitable geofabric material able to contain the fine clay/silt material, yet permeable to allow the filled geobag to 'sink' into position.

4.2.8.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to provide cost effective shoreline protection (should demand exist) which may have positive socio-economic, commercial and environmental outcomes
- Placement of structures in the coastal environment may have implications for coastal processes, including sediment dynamics and transport in the local area
- Placement of structures will cause some (manageable) impacts to water quality in areas adjacent to the dredging and placement areas
- Shoreline protection measures placement may cause some impacts to Traditional Owners' lands, waters or exiting partnerships or agreements.

4.2.8.7 Approvals

Any proposal to create shoreline protection, using dredge material, would require consultation in the planning, design and development and approvals with under Western Cape Communities Coexistence Agreement (WCCCA) between RTA and Traditional Owners Approvals.

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

Amrun Port maintenance dredging can only be approved and conducted under the WCCCA agreement with Traditional Owners and the EPBC Act conditions of approval.

It is considered that the beneficial use of maintenance dredge material in shoreline protection is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.2.8.8 Costs

A summary breakdown of the estimated costs associated with execution of the shoreline protection option is provided in Table 4-18. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $208/m^3$ measured in situ.

Table 4-24: Amrun Shoreline protection (geobags) summary cost estimate table

Key Activity	Amrun – Shoreline Protection (Offshore Berms)
Offshore	
TSHD mobilisation and demobilisation and daily hire	$400,000
Workboat	$500,000
Tug and barge mobilisation and demobilisation	$2,000,000
Place nearshore with tug barge and geobags	$800,000
Onshore	
Monitoring and management	$250,000
Total	**$3,950,000**

4.2.8.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the shoreline protection option is 542 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description describe above, with further detailed assumptions provided in Appendix B.

4.2.8.10 Knowledge gaps

If the shoreline protection option, in the form of offshore berms to modify the nearshore wave climate was to be further pursued, key areas where additional information would be required include:

- Demand for shoreline protection in the vicinity of the Amrun Port

- Coastal dynamics, wave climate, current regime and processes specific to the proposed location of the shoreline protection areas are a very significant issue to enable effective design and implementation to reduce sediment accumulation at the berths
- Availability of suitable equipment to execute the works
- Detailed design including consideration of hydrodynamics, dredging and dredge material transfer and placement.

4.2.8.11 Future considerations

This shoreline protection option for beneficial reuse of dredged material is heavily constrained by demand. While the quantity of material to be dredged per program may be suitable for this option (i.e. typically dredge material quantities of 19,000m^3/yr. are required to make this option feasible) dependent on the need for shoreline protection, it is considered likely that reuse would only have a single or limited application.

4.2.8.12 Performance summary

A summary of the performance of the shoreline protection option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-19.

Table 4-25: Amrun Shoreline protection (geotubes) performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	HIGH: Less than $10M annually
Process	MODERATE: The proposed process is sound but there are few examples of it being applied in environments similar to the Port using maintenance dredge material
Duration	MODERATE: 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	HIGH: < 2000t CO2 equivalent in a one year period
Environmental Implications	LOW: Nuisance or harm issues unlikely to be easily managed
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable

Performance Criteria	Performance Rating
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	LOW: Not supported but current legislation or policy would require high level offset considerations
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.3 Reuse dredge material and environmental enhancement

The following beneficial reuse options are considered below where the dredge material reuse option may provide environmental enhancement:

Port of Weipa

- Coastal Habitat Creation – (Direct Placement)
- Coastal Habitat Creation – (Indirect Placement)
- Deep Water Habitat Creation

Amrun Port

- Coastal Habitat Creation – (Direct Placement)
- Deep Water Habitat Creation (Geobags)

4.3.1 Coastal habitat creation (direct placement)

4.3.1.1 Activity description

Direct placement

Maintenance dredge material may be used in the creation of environmental bunds to support the restoration or creation of coastal habitat areas. Coarser material (either dredged or imported to site) can be used to create the bund, and fine dredge material can be deposited behind the bund. The fine material is retained behind the bund and may form new mudflats in which mangrove habitat can be restored or created. There are two potential alternative methods for the use of environmental bunds, being underwater or circular closed offshore bunds.

A bund retains the fine silts and clays behind it to create a new mud flat and associated habitat with the silt-mud sediment as shown on Figure 4-16.

Figure 4-13: Mud flat habitat creation with bund at Salhouse Broad, UK, source PIANC Report No 176, 2018

Similarly, in an offshore shallow water area, coarser material can be used to create a circular closed bund, and fines can be deposited behind the bund to form a mudflat. An example is the 'creation of nature' development in the Bird Island, Siene Estuary France. This demonstrates how an offshore bunded are may contain silts and clays that can be colonised by vegetation and animal species and become an environmental area refer Figure 4-17.

Figure 4-14: Bird island, Seine Estuary France constructed using offshore bund and dredged sediment, source PIANC Report No 176, 2018

4.3.1.2 Opportunity

The coastline in a 30km radius from Weipa from Boyd Point over Albatross Bay to Duyfken Point consist of a series of headlands with exposed sandy beaches, mudflat and mangrove lined estuaries around the rivers (Mission R., Pine R. and Embley R.) and creeks feeding this system with a very shallow coastline.

The Weipa local government wetland area by habitat type is 68% estuarine and 19% coastal and sub coastal floodplain tree swamp (Melaleuca and Eucalyptus species)[8]. Mudflats provide habitat for worms, small crustaceans such as crabs and burrowing shrimp, and a variety of snails and other molluscs, many of which use broken down organic debris washed into these areas for food. Mudflats also provide feeding areas for birds and fish. There are no known areas of mangrove dieback in the immediate vicinity of the Port of Weipa, or of mudflats that are similarly impacted resulting in loss of habitat. Loss of mangroves typically destabilises the shoreline and may cause erosion and subsequent decline in coastal water quality with increased turbidity and nutrient levels.

The region's estuaries support and contribute significantly to recreational fisheries which are a very popular leisure pursuit for residents, tourists and Traditional Owners. The recreation fishing industry supports two retail outlets in town and attracts visitors to the region for the annual Weipa Fishing Classic. The 2017 Weipa Fishing Classic which drew over 2,200 participants and an estimated $1 million in increased business opportunities for Weipa (DSDMIP, 2018). Estuaries within the region are highly valued by communities, particularly for recreational fishing and crabbing opportunities. In addition to their economic and social values, mangroves provide ecosystem benefits, including nursery grounds for prawns and fish, and coastal protection functions through which the effects of storm surges and cyclones are reduced.

There are no known activities currently targeted at the rehabilitation of mangroves in Albatross Bay, nor is there an established demand for rehabilitation. However, for the purposes of the analysis below, it has been assumed that any demand for mangrove habitat rehabilitation for which direct or indirect placement of dredge material may be suitable exists in Albatross Bay between Mission River and Pine River in local areas of existing mud flats and mangrove habitat that are potentially favourable to habitat creation.

The maintenance dredge material may be directly placed through the development of environmental bunds to restore habitat. Intertidal mudflat could be created to effectively rehabilitate and cap a mangrove habitat loss area and create a new mangrove habitat area for replanting. This is the focus of the direct placement analysis below.

Alternatively, dredge material may be placed indirectly, through use of natural currents to transport sediment from the discharge point to areas of habitat requiring restoration or creation. This is the focus of the indirect placement analysis Section 4.3.2 below.

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8 *www.wetaldninfo.ehp.qld.go.au/wetland/facts-maps/lga-weipa/*

4.3.1.3 Suitability of Port of Weipa sediments

Sandy or coarse material is preferred for environmental bunds to have sufficient strength for construction purposes. The fine sediment material is suitable to backfill behind the main bund. Both types of material are necessary for the reuse option analysed below.

As part of the assessment of the proposed direct placement habitat creation opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in suitability categories as per Section 3.3.1).

Table 4-26: Suitability of dredge sediment for proposed direct placement habitat creation reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment/processing
Moisture content	Likely suitable
Plasticity Index	Likely suitable
Linear Shrinkage	Likely suitable
Density test	Likely suitable
Strength and Consolidation	Likely suitable
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The sediment material requires little or no processing to improve its suitability for direct placement reuse. Targeted dredging to obtain coarse sand material from the approach channel, departure channel and Southern Channel (SC-1 to SC-5) to build the outer bund first would be desirable followed by dredging fine material (other dredge areas) to backfill behind the established bund.

The characteristics of the sediment material and the potential impacts (positive and negative) on the foreshore ecosystems would need to be the subject of detailed scientific investigations.

4.3.1.4 Process description

Dredge material would be dredged and transported to the site of the direct placement. Construction of the bunds may be undertaken hydraulically through either discharging through the bow coupling to a floating pipeline and spreader pontoon in shallow water for the underwater bund, or by 'rainbowing'. Given the depth limitations around Albatross Bay (i.e. extensive tidal flats exposed during low tides as illustrated by figures), and the dredge manoeuvrability restricted to within navigational areas, it is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a Trailing Suction Hopper Dredge (such as the 'Brisbane') with pump out to the area of the habitat creation.

Infrastructure required to facilitate the pump-out would likely be temporary, and would include a pipeline (potentially floating, along with a pump out coupling) and a mooring system for the dredge during pump-out. For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will travel up to 20km from the farthest dredging area (SC-18) to access the pump-out point. It is likely that a booster pump would be required for the pump-out, given that the dredge is unlikely to be able to moor less than 1.5km from the direct placement area.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last approximately 32 days.

Material for the environmental bund may be dredged from the Approach Channel, Departure Channel and South Channel (SC-1 to SC-5) areas first and / or to some extent dredged selectively by using overflow to separate the fines in the other areas (apron and berth areas). If insufficient coarse material is available for use, the environmental bunds may be constructed using imported material, with the dredge material placed behind the bunds subsequently. For the purposes of analysis, it has been assumed that the coarse dredge material (estimated 100,000m^3 sand) is available and sufficient for use in development of the environmental bunds.

4.3.1.5 Potential constraints

Potential constraints associated with this option include:

- Specific demand for mudflat and mangrove habitat creation is unclear
- Placement on or near seagrass habitat, refer Figure 4.11 for potentially sensitive seagrass locations
- Tidal range in the region may present significant operational constraints, dependent on the habitat rehabilitation option
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the habitat rehabilitation area
- Potential acid Sulfate soils, may require consideration in development of the concept
- Agreement for access to the land and marine areas for the any habitat creation works likely to be contentious with the local community and Traditional Owners.

- Approvals for habit creation works in marine vegetation areas (mangrove) anticipated to be difficult to obtain due to risk of potential harm to existing environment

4.3.1.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to address habitat degradation or enhance habitat in the area (should sufficient demand in the vicinity of the Port of Weipa exist) which may have positive socio-economic, commercial and environmental outcomes
- Placement of dredge material in the nearshore coastal environment may have implications for coastal processes, including sediment dynamics and transport in the local area
- Habitat creation activities, particularly pipeline management (including booster pump operation) and placement in Albatross Bay may cause temporary impacts to turtle nesting habitat
- Placement of dredge material to create environmental bunds may impact existing benthic community, which will take time to recover.

4.3.1.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of both the direct placement habitat creation option.

It is considered that the beneficial use of maintenance dredge material in coastal habitat creation (direct placement) is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.3.1.8 Costs

A summary breakdown of the estimated costs associated with execution of the direct placement habitat creation option is provided in Table 4-27. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $36/m^3$ measured in situ.

Table 4-27: Direct placement habitat creation summary cost estimate table

Key Activity	Coastal Habitat Creation (Direct Placement)
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$7,000,000
Workboat	$500,000
TSHD dredging and pump ashore	$7,500,000
Onshore	
Monitoring and management	$500,000
Total	**$18,000,000**

4.3.1.9 Greenhouse gas emissions

Direct placement

The estimated Green House Gas emissions associated with the direct placement habitat creation option is 2,162 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description described above, with further detailed assumptions provided in Appendix B.

4.3.1.10 Knowledge gaps

If the direct placement habitat creation option was to be further pursued, key areas where additional information would be required include:

- Demand for coastal mangrove and/or mudflat habitat rehabilitation or habitat enhancement in the vicinity of the Port of Weipa
- Coastal dynamics and processes specific to the proposed location of the habitat rehabilitation to enable effective targeting of placement, and design of pump-out facilities
- Detailed design including consideration of dredging and pump out facilities.

4.3.1.11 Future considerations

The annual dredge volumes (estimated 500,000m^3 annually) could provide a long-term suitable source of material for coastal habitat creation or enhancement by direct placement to mangrove habitat that significantly exceeds demand in the region. This reuse option may have a single or limited application due to unknown demand. Ideally a small test direct placement habitat creation project in shallow water could occur to assess the viability of the reuse option. The rehabilitation areas may be expanded when more material needs to be stored, if further demand for rehabilitation exists. A test case start-up has the advantage that some monitoring is possible and adjustments can be made in the design if needed during subsequent dredging.

4.3.1.12 Performance summary

Direct placement

A summary of the performance of the direct placement habitat creation option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-28.

Table 4-28: Direct placement habitat creation performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	MODERATE: $10M to $20M annually
Process	MODERATE: The proposed process is sound but there are few examples of it being applied in environments similar to the Port using maintenance dredge material
Duration	MODERATE: 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	MODERATE: >2000t and <8000t CO2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	LOW: Negative social impacts are unlikely to be easily managed
Indigenous Implications	LOW: Negative impacts upon Traditional Owners' lands/waters and the indigenous community are unlikely to be easily managed
Economic Implications	LOW: Lost or negative economic opportunities to enhance port or community capability
Approvals	LOW: Not supported but current legislation or policy would require high level offset considerations
Constraints	LOW: Multiple constraints are present that would limit realistic implementation
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to

Performance Criteria	Performance Rating
	progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.3.2 Coastal habitat creation (indirect placement)

4.3.2.1 Activity description

Direct placement of sediment on top of mudflats may alter the benthic community that may take years to recover; however indirect nourishment schemes may provide a lower impact habitat creation option. The concept of a 'mud motor' is considered, in which (fine) sediment availability in the system is locally increased and natural currents are utilised to transport the sediment to the mudflats and mangroves systems, where natural siltation rates will take place, with which the benthic community can tolerate. The basic principle of the 'mud motor' concept is that dredged material that is supplied to a tidal current can be picked up by that current so that it achieves its maximum transporting capacity. Higher mud concentrations in the currents that feed a mudflat will likely speed up mudflat development processes, while maintaining the desired gradients that are associated with natural mudflat development.

An advantage of indirect nourishment is that soil properties at the anticipated nourishment location will develop from natural siltation processes. Given that the nourished sediment is from the same coastal system, this increases the likelihood of successful habitat creation.

An example of this method being used is a pilot project in the Port of Harlingen in the Netherlands refer Figure 4-19 In this case dredged material is placed and transported by natural processes as a semi-continuous source of sediment (the mud-motor) to nearby salt marshes. The extra input of sediment is expected to lead to the formation and extension of salt marshes, and will yield the following favourable effects for the Port of Harlingen:

- Less recirculation towards the port, hence less maintenance dredging
- Promotion of the growth and stability of salt marshes, improving the regional marine ecosystem
- Stabilizing the foreshore of the dykes, and therefore less maintenance of the dyke.

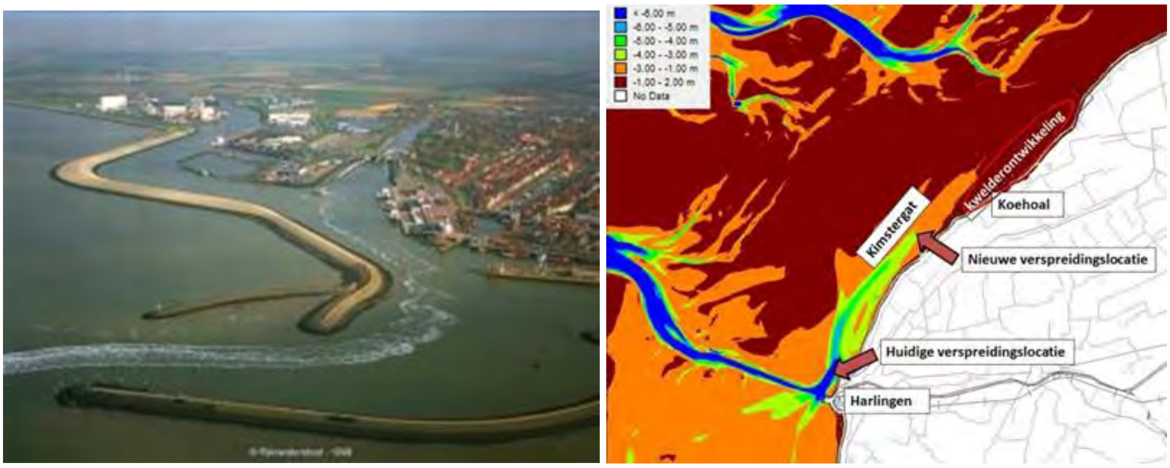

Figure 4-15: Mud motor pilot in Port of Harlingen (The Netherlands), source PIANC Report No 176, 2018

4.3.2.2 Opportunity

The opportunity for coastal habitat creation of mangrove habitat by indirect placement is the same as described for the direct placement in Section 4.3.1.2.

4.3.2.3 Suitability of Port of Weipa sediments

Indirect placement

Habitat creation through indirect nourishment will require dredging and placement in a suitable nearshore area of material able to be remobilised by currents to transport the sediment material to the target location. This reuse analysis relies on the fine material (silt/clay) characteristics that make them suitable for transport to a designated placement area by the local currents.

As part of the assessment of the proposed indirect placement habitat creation reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in suitability categories as per Section 3.3.1.

Table 4-29: Suitability of dredge sediment for proposed indirect placement habitat creation reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Likely to be suitable
Moisture content	N/A
Plasticity Index	N/A

Sediment Material Property	Suitability
Linear Shrinkage	N/A
Density test	Likely to be suitable
Strength and Consolidation	N/A
Permeability	N/A
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

Given that an estimated 40000m^3/yr. of the sediment material is fine (clay/silt), it is likely to be suitable for remobilisation for habitat creation by indirect placement. A suitable foreshore location in the Port of Weipa area would need to be identified and favourable wave climate and water current patterns utilised, such that indirect placement of sediment material may function appropriately.

4.3.2.4 Process description

Dredge material would be dredged and transported to a discharge location, where material may be transported through natural processes to the location of the rehabilitation area.

Given the depth limitations around Albatross Bay (i.e. extensive tidal flats exposed during low tides as illustrated by Figure 1-2, and the dredge manoeuvrability restricted to within navigational areas, it is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a Trailing Suction Hopper Dredge (such as the 'Brisbane') with pump out to the area of the habitat creation.

Infrastructure required to facilitate the pump-out would likely be temporary, and would include a pipeline (potentially floating, along with a pump out coupling) and a mooring system for the dredge during pump-out. For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will travel up to 19km from the dredging area to access the discharge point. It is likely that a booster pump would be required for the pump-out, given that the dredge is unlikely to be able to moor less than 1.5km from the indirect placement area.

The dredge is assumed to operate with some tidal and current constraints and the dredge program is assumed to last approximately 32 days.

Material for the mangrove habitat creation by indirect placement will likely need to be dredged selectively to target the fines (silt and clays) material suitable for wave and current transport to the final destination. For the purposes of analysis, it has been assumed that the fine dredge material (estimated 423,200m^3/yr. silt and clay is available and sufficient for use in mangrove habitat creation by indirect placement.

4.3.2.5 Potential constraints

Indirect placement

Potential constraints associated with this option include:

- Specific demand for mangrove and/or mudflat habitat rehabilitation is unclear
- Placement on or near seagrass habitat, refer Figure 4.11 for potentially sensitive seagrass locations
- Determination of suitable discharge location/s to enable mudflat rehabilitation in a target area may require extensive investigation including consideration of environmental conditions over a long period of time
- Tidal range and sea conditions may dictate when discharge may occur, potentially reducing the efficiency of dredging operations
- Tidal range in the region may present operational constraints, dependent on the habitat rehabilitation option location
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the discharge point
- Potential acid Sulfate soils, may require consideration in development of the concept
- Coarse dredge material namely sand and gravel, 29% of estimated total annual volume, may be unable to be transport by wave and current in the indirect placement method plus likely unsuitable in the mudflat environment of the mangroves. Consequently, traditional disposal will likely be required for sand and gravel portion
- Agreement for access to the land and marine areas for the any habitat creation works likely to be contentious with the local community and Traditional Owners.
- Approvals for habit creation works in marine vegetation areas (seagrass and mangrove) anticipated to be difficult to obtain due to risk of potential harm to existing environment.

4.3.2.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to address mangrove habitat degradation or habitat enhancement in the area (should sufficient demand in the vicinity of the Port of Weipa exist) which may have positive socio-economic, commercial and environmental outcomes
- Placement of dredge material in the nearshore coastal environment may have implications for coastal processes, including sediment dynamics and transport in the local area

- Dredging and placement activities near Albatross Bay may cause temporary impacts to turtle nesting and other potentially sensitive habitat
- Discharge of the dredge material, reliant on transport by natural currents is likely to cause temporary impacts to water quality in the areas of discharge.

4.3.2.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of indirect placement habitat creation option.

It is considered that the beneficial use of maintenance dredge material in coastal habitat creation (indirect placement) is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.3.2.8 Costs

A summary breakdown of the estimated costs associated with execution of the indirect placement habitat creation option is provided in Table 4-30. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately \$36/m^3 measured in situ.

Table 4-30: Indirect placement habitat creation summary cost estimate table

Key Activity	Coastal Habitat Creation (Indirect Placement)
Offshore	
TSHD mobilisation and demobilisation and daily hire	\$2,500,000
Pipeline mobilisation and demobilisation	\$7,000,000
Workboat	\$500,000
TSHD dredging and pump ashore	\$7,500,000
Onshore	
Monitoring and management	\$500,000
Total	**\$18,000,000**

4.3.2.9 Greenhouse gas emissions

Indirect placement

The estimated Green House Gas emissions associated with the indirect placement habitat creation option is 2,162 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description described above, with further detailed assumptions provided in Appendix B.

4.3.2.10 Knowledge gaps

If the indirect placement habitat creation option was to be further pursued, key areas where additional information would be required include:

- Demand for coastal mangrove and/or mudflat habitat rehabilitation or enhancement in the vicinity of the Port of Weipa
- Coastal dynamics and processes specific to the proposed location of the dredge material discharge point and of the habitat creation location (likely including extensive hydrodynamic modelling over a range of conditions) to enable effective targeting of placement, and design of pump-out facilities
- Detailed design including consideration of dredging and pump out facilities.

4.3.2.11 Future considerations

As for the direct placement option the estimated dredge volumes (approximately 400,000m^3/yr.) could provide a long-term suitable source of material for coastal habitat creation or enhancement by indirect placement that significantly exceeds demand in the region. This reuse option may have a single or limited application due to unknown demand; however, detailed investigation would be required of the long-term sediment requirements within the target rehabilitation area/s, to determine whether a long term requirement for the dredge material is likely to exist to support this option as an ongoing beneficial reuse.

4.3.2.12 Performance summary

Indirect placement

A summary of the performance of the indirect placement habitat creation option based on the use of the performance criteria described in Section 3.3.3 is provided in Figure 4-31.

Table 4-31: Indirect placement habitat creation performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	MODERATE: $10M to $20M annually
Process	LOW: The proposed process is mostly unproven
Duration	MODERATE: 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	MODERATE: >2000t and <8000t CO_2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	LOW: Negative social impacts are unlikely to be easily managed
Indigenous Implications	LOW: Negative impacts upon Traditional Owners' lands/waters and the indigenous community are unlikely to be easily managed
Economic Implications	LOW: Lost or negative economic opportunities to enhance port or community capability
Approvals	LOW: Not supported but current legislation or policy would require high level offset considerations
Constraints	LOW: Multiple constraints are present that would limit realistic implementation
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.3.3 Deep Water Habitat Creation

4.3.3.1 Activity description

Various habitats may be environmentally enhanced through the use of dredge material including inter-tidal areas (Section 3.1.2.2). The potential for habitat creation in deeper water is described below.

One of the benefits of deep water habitat creation is ease of access for dredging equipment. An Ecoshape pilot project has been undertaken in the Netherlands (De Jong et al., 2016) in which depth and texture of sand mining locations have been optimized from an ecological perspective (Figure 4-16). The local ecosystem may be enhanced by optimizing water depth and by adding specific bedform features that introduce variations in hydraulic load and consequently biodiversity.

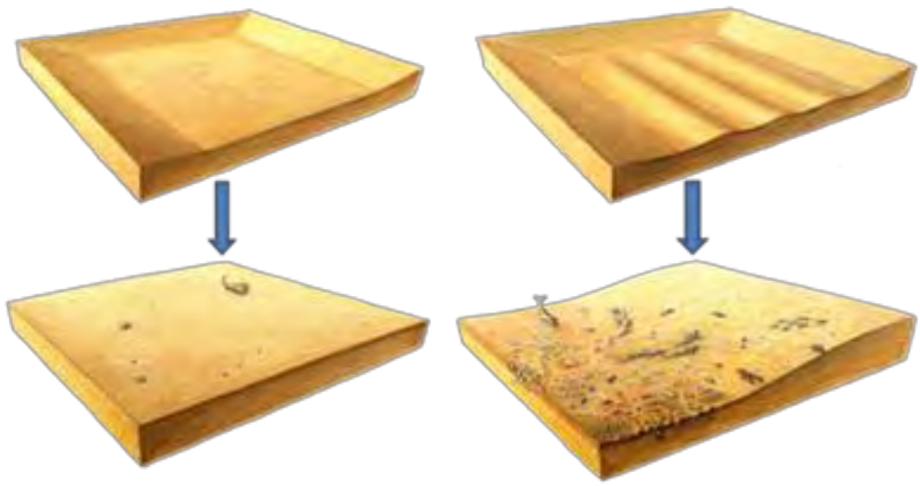

Figure 4-16: Concept of deep water habitat improvement for sand mine areas (De Jong et al., 2016)

In the case study described by De Jong et al. (2016) it was noted that dredging operations for the extraction of sand, typically leave the floor of the extraction area flat, and that the flat seabed did not encourage biodiversity. The pilot project sought to encourage the recolonization and promote productivity and biodiversity of these deep (up to 20m below the seabed) extraction pits by implementing local seabed landscaping. The pilot project involved selective dredging, leaving behind sand ridges in the designated borrow area. These artificial bedforms are about 700m long and 100m wide with crests 10m high, similar to natural sand waves observed on the North Sea bed. The recolonization of the borrow area has been monitored since 2010. Four to five times more fish have been found inside the pit than outside it, along with greater species richness.

4.3.3.2 Opportunity

Dredge material from Port of Weipa may be placed in the offshore environment in such a way as to develop features / bedforms that enhance the local habitat. The local ecosystem may be enhanced by optimising water depth and by adding specific bedform features that introduce variations in hydraulic load and consequently biodiversity.

4.3.3.3 Suitability of Port of Weipa sediments

In the example described above, habitat was created through selective dredging of sand to create bedform features to encourage local habitat. The dredge sediment has a high proportion of fine silt and clay that may not be suitable for habitat creation through placement on the seabed in the vicinity of the port. The properties of the fine (clay and silt) material make the sediment placed on a seabed potentially more readily susceptible to remobilisation. The analysis below considers utilising all the dredge material types for deep water habitat creation

As part of the assessment of the deep-water habitat creation reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Section 2.1 (suitability categories as per Section 3.3.1).

Table 4-32: Suitability of dredge sediment for proposed deep water habitat creation reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	Likely to be suitable
Particle Size Distribution	Not likely to be suitable
Moisture content	N/A
Plasticity Index	N/A
Linear Shrinkage	N/A
Density test	N/A
Strength and Consolidation	N/A
Permeability	N/A
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable

Sediment Material Property	Suitability
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

Given that 400,000m^3 of the dredge material is fine (clay / silt) it is not likely to be suitable for a deep water habitat creation reuse. However, if a suitable offshore fisheries habitat location was identified, with sediment characteristics similar to those of the 100,000m^3 sand material to be dredged, along with favourable water current patterns, direct placement of sand sediment material for deep water habitat creation may provide an opportunity for beneficial reuse. Sand dredge material is more likely to be suitable as it would form a more stable seabed 'structure'. Further consideration would be required of the characteristics of the sediment material to be dredged and of the potential placement location, along with the potential impacts (positive and negative) on offshore ecosystems and potential for fisheries development.

4.3.3.4 Process description and key activities

Dredging and placement

Dredge material would be loaded and transported to a deep-water habitat creation site where sediments would be placed selectively according to design. Depending on design, dredge material placement can be heterogeneous i.e. spatial spreading of fine and coarse material with height or capping of finer material when desired.

For the purposes of analysis, it is assumed that the Trailing Suction Hopper Dredge (such as the 'Brisbane') would undertake the works, with no other infrastructure required.

For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will travel at the most approximately 20km from the outer dredging area (SC18) to the habitat creation site. The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last 32 days.

4.3.3.5 Potential constraints

Potential constraints associated with this option include:

- Demand for seabed fisheries habitat creation or rehabilitation is unclear
- Significant research effort may be required to demonstrate potential for enhancement of existing habitat through placement of dredge material, to achieve regulatory agency acceptance of the option as a beneficial reuse
- Dredge material, namely fines, may not be retained on the seabed floor in the placement location, and as such long-term habitat creation may not be possible.

4.3.3.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to develop fisheries habitat in the area which may have positive socio-economic, commercial and environmental outcomes
- Placement of the material on the seafloor will impact existing benthic habitat
- Impacts to water quality similar to offshore placement previously undertaken at the port would be expected.

4.3.3.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material in deep water habitat creation is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.3.3.8 Costs

A summary breakdown of the estimated costs associated with execution of the deep-water habitat creation option is provided in Table 4-33. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $12/m^3$ measured in situ.

Table 4-33: Deep water habitat creation summary cost estimate table

Key Activity	Deep Water Habitat Creation
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Workboat	$500,000
TSHD dredging and seabed placement	$2,500,000
Onshore	
Monitoring and management	$250,000
Total	**$5,750,000**

4.3.3.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the deep water habitat creation materials option is 1,181 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description described above, with further detailed assumptions provided in Appendix B.

4.3.3.10 Knowledge gaps

If the deep water habitat creation option was to be further pursued, key areas where additional information would be required include:

- Demand for fisheries habitat creation in the vicinity of the Port of Weipa, and the value of existing seabed habitat within the area
- Coastal dynamics and processes specific to the proposed location of the habitat creation area (likely including hydrodynamic modelling over a range of conditions) to enable effective determination of likelihood of success of habitat creation.

4.3.3.11 Future considerations

This quantity of material to be dredged are sufficiently large for a pilot project; however, the suitability of the options for acceptance of maintenance dredging material on a long term basis would depend on the success of the pilot project, and whether that could be expanded, or replicated across other areas of the sea floor.

4.3.3.12 Performance summary

A summary of the performance of the deep-water habitat creation option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-34.

Table 4-34 Deep water habitat creation performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	HIGH: Less than $10M annually
Process	LOW: The proposed process is mostly unproven
Duration	HIGH: Less than 1 year to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	HIGH: < 2000t CO2 equivalent in a one year period

Performance Criteria	Performance Rating
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	MODERATE: The reuse option would cater for immediate needs and has some scope in the short term (several years), although options would need to be regularly reassessed

4.3.4 Amrun – coastal habitat creation (direct placement)

4.3.4.1 Activity description

Maintenance dredge material may be used in the creation of environmental bunds through direct placement methods to support the restoration or creation of habitat areas, as previously described in Section 4.3.1.

4.3.4.2 Opportunity

The coastline within a 20km radius of Amrun consists of low cliffs, exposed sandy beaches, a series of headlands and is a known turtle nesting area. The area of the Amrun project and the coastline cliffs, refer figures 1-3 and 1-4, has especially high value for the Traditional Owners. The Wik and Wik-Way People have numerous sacred sites and locations with shell middens, stone axes and a number of the woomera scarred trees with high archaeological significance. There is a major creek, Norman Creek, with four major tributaries, located approximately 13km south of Amrun. The Norman Creek system includes perennial stream reaches and aquatic refugia and supports a host of aquatic habitat types including streams, tree swamps, sedge swamps, lagoons and lakes[9]. Norman Creek is characterised by a diverse mangrove forest community of 18 species and submerged aquatic plant communities including seagrass. The ecosystem supports habitat for 32

[9] Environmental Impact Statement for South of Embley Project, Section 8 Aquatic Ecology, RTA 2011.

species of fish, both estuary and freshwater. Norman Creek has known records of threated and migratory fauna records including Black- Necked Stork, Little Tern and Radjah Shelduck. The estuary areas of Norman Creek are classified as 'Near Pristine', the highest category in the National Land and Water Resources Audit, 2002.

There are currently no known areas in the Norman Creek catchment that would benefit from rehabilitation of mangrove and /or other intertidal habitat. For the purposes of the analysis below, it has been assumed that any demand for mangrove habitat rehabilitation for which direct dredge material may be suitable exists in Norman Creek. Within a 20km radius of Amrun Port the coastline does not have any mangrove habitat that may potentially benefit from placement of the fine silt and clay sediment, except for that estuary of Norman Creek.

Triluck Creek wetlands area is located approximately 25km north east of Amrun just inland from the coast, with its downstream section paralleling the coastline until the estuary enters the Embley River near Weipa approximately 40km away. It is understood that some of the wetland areas have been damaged by feral pig activity (pers. conv. RTA September 2018) and may benefit from habitat restoration. Due to the distance from Amrun Port, workboat access via Weipa, and need to construct a pipeline across the beach and coastal dunes to access any potential placement location it was considered potential impacts would outweigh the potential benefits this coastal habitat creation location was not progressed.

The maintenance dredge material may be directly placed, through the development of environmental bunds to restore habitat. Intertidal mudflat could be created to effectively rehabilitate a mangrove habitat loss area or enhance the habitat by the creation of a new area for mangrove colonisation nearest to Amrun most easily in Norman Creek. This is the focus of the direct placement analysis below.

4.3.4.3 Suitability of Amrun Port sediments

Sandy or coarse material is preferred for environmental bunds to have sufficient strength for construction purposes. The fine sediment material is suitable to backfill behind the main bund. An estimated 86% of the 19,000m^3 of dredge sediment material at Amrun is fines (silt or clay). The reuse analysis below considers utilising all the dredge sediment types (silt/clay/sand/gravel) potentially available at Amrun Port.

As part of the assessment of the proposed direct placement habitat creation opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-35 (suitability categories as per Section 3.3.1.

Table 4-35: Suitability of dredge sediment for proposed Amrun direct placement habitat creation reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Potentially suitable with treatment/processing
Moisture content	Likely suitable
Plasticity Index	Likely suitable
Linear Shrinkage	Likely suitable
Density test	Likely suitable
Strength and Consolidation	Likely suitable
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The sediment material requires little or no processing to improve its suitability for direct placement reuse. Selective placement of the coarse sand material to build the outer bund first would be desirable followed by dredging fine material to backfill behind the established bund. The 'TSHD Brisbane' dredge vessel has an ability to overflow fines to target the coarser material. Prior to proceeding the characteristics of the sediment material and the potential environmental impacts (positive and negative) on the creek estuary ecosystems would need to be the subject of detailed scientific investigations.

4.3.4.4 Process description

Dredge material would be dredged and transported to the site of the direct placement. Construction of the bunds may be undertaken hydraulically through either discharging through the bow coupling to a floating pipeline and spreader pontoon in shallow water for the underwater bund. Given the depth limitations of the Norman Creek estuary, it is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a 'TSHD Brisbane' with pump out to the area of the habitat creation.

Infrastructure required to facilitate the pump-out would likely be temporary, and would include a pipeline (potentially floating, along with a pump out coupling) and a mooring system for the dredge during pump-out. For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will travel approximately 15km from the dredging area to access the pump-out point. It is likely that a booster pump would be required for the pump-out, given that the dredge is unlikely to be able to moor less than 1.5km from the direct placement area.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime and the dredge program would last approximately 4 days.

If insufficient coarse material is available for use, the environmental bunds may be constructed using imported material, with the dredge material placed behind the bunds subsequently. For the purposes of analysis, it has been assumed that the coarse dredge material (estimated 2,700m^3 sand and gravel) is available and sufficient for use in development of the environmental bunds.

4.3.4.5 Potential constraints

Potential constraints associated with this option include:

- There is no demand for mangrove habitat creation or rehabilitation in the Amrun Port region
- Environmental impacts of direct placement at Norman Creek may be unacceptable due to inability to manage adverse effects upon the area's pristine environmental values and hence implementation is unrealistic
- Agreement for access to the land, estuary and marine areas for the proposed direct placement activities are highly unlikely to be acceptable under any circumstances to Traditional Owners
- Tidal range in the region may present significant operational constraints, dependent on the habitat rehabilitation option
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the habitat rehabilitation area
- Rate of delivery of dredge material from the vessel pump out likely to exceed the rate of material supply required for sensitive placement in a final location, and no area available for temporary storage of the material at Norman Creek
- Potential acid Sulfate soils, may require consideration in development of the concept.

4.3.4.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to address habitat degradation or enhance habitat in the area (should sufficient demand in the vicinity of the Amrun Port exist) which may have positive environmental outcomes

- Placement of dredge material in the nearshore coastal environment may have implications for coastal processes, including sediment dynamics and transport in the local area
- Habitat creation activities, particularly dredge mooring and pipeline management (including booster pump operation) and placement in Norman Creek coastal estuary may cause temporary impacts sensitive environmental values
- Placement of dredge material to create environmental bunds may impact existing benthic community, which will take time to recover
- Quantity of dredge material annually (estimated 19,000m^3) is relatively small and any local Amrun area benefits may not justify the time and expense or potential impact upon high environmental, social and heritage values.

4.3.4.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of both the direct placement habitat creation option.

Regulatory approvals to undertake direct placement of dredge material in the pristine Norman Creek location, regardless of the intention to create or enhance mangrove habitat, are extremely unlikely to be granted

It is considered that the beneficial use of maintenance dredge material in coastal habitat creation (direct placement) is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.3.4.8 Costs

A summary breakdown of the estimated costs associated with execution of the direct placement habitat creation option is provided in Table 4-36. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately \$837/m^3 measured in situ.

Table 4-36: Amrun direct placement habitat creation summary cost estimate table

Key Activity	Amrun – Coastal Habitat Creation (Direct Placement)
Offshore	
TSHD mobilisation and demobilisation and daily hire	\$400,000
Pipeline mobilisation and demobilisation	\$7,000,000

Key Activity	Amrun – Coastal Habitat Creation (Direct Placement)
Workboat	$500,000
TSHD dredging and pump ashore	$7,500,000
Onshore	
Monitoring and management	$500,000
Total	**$15,900,000**

4.3.4.9 Greenhouse gas emissions

Direct placement

The estimated Green House Gas emissions associated with the direct placement habitat creation option is 793 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description described above, with further detailed assumptions provided in Appendix B.

4.3.4.10 Knowledge gaps

If the direct placement habitat creation option was to be further pursued, key areas where additional information would be required include:

- Coastal dynamics and Norman Creek Estuary processes specific to the proposed location of the habitat rehabilitation to enable effective targeting of placement, and design of pump-out facilities
- Detailed scientific investigation of the Norman Creek terrestrial and aquatic ecology and an impact assessment to determine if potential impacts could be successfully mitigated
- Detailed design including consideration of dredging and pump out facilities.

4.3.4.11 Future considerations

The Amrun annual estimated dredge volumes (19,000m^3) could provide a long-term suitable source of material for coastal habitat creation or enhancement by direct placement to mangroves habitat that significantly exceeds demand in the region. This reuse option may have a single or limited application due to unknown demand.

This direct placement of dredge material for coastal habitat rehabilitation in the vicinity of the Amrun Port area is extremely unlikely to be acceptable due to the highly pristine environment. Gaining Traditional Owners agreement or obtaining the necessary regulatory approvals is likely to be very challenging.

4.3.4.12 Performance summary

Direct placement

A summary of the performance of the direct placement habitat creation option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-37.

Table 4-37: Amrun direct placement habitat creation performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	HIGH: Less than $10M annually
Process	LOW: The proposed process is mostly unproven
Duration	MODERATE: 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	HIGH: < 2000t CO_2 equivalent in a one year period
Environmental Implications	LOW: Nuisance or harm issues unlikely to be easily managed
Social Implications	LOW: Negative social impacts are unlikely to be easily managed
Indigenous Implications	LOW: Negative impacts upon Traditional Owners' lands/waters and the indigenous community are unlikely to be easily managed
Economic Implications	LOW: Lost or negative economic opportunities to enhance port or community capability
Approvals	LOW: Not supported but current legislation or policy would require high level offset considerations
Constraints	LOW: Multiple constraints are present that would limit realistic implementation
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

4.3.5 Amrun – deep water habitat creation (geobags)

4.3.5.1 Activity description

The potential for habitat creation in deeper water is previously described in Section 4.3.3.

One of the benefits of deep water habitat creation is ease of access for dredging equipment. An aim of deep water habitat creation is to encourage the recolonisation and promote productivity and marine biodiversity of these areas by implementing local seabed landscaping. A real life pilot project, refer Section 4.3.3, involved selective dredging, leaving behind sand ridges in the designated borrow area. These artificial bedforms have been created with crests and troughs, similar to natural sand waves.

4.3.5.2 Opportunity

Dredge material from Amrun Port may be placed in the offshore environment in such a way as to develop features / bedforms that enhance the local habitat, while fitting in with the local environment. The local ecosystem may be enhanced by optimising water depth and by adding specific bedform features that introduce variations in hydraulic load and consequently biodiversity.

The predominantly fine silt material for Amrun maintenance dredging would need to be placed inside geobags or geotubes and then positioned on the seabed to create features or an artificial reef.

Established reference group processes may potentially be utilised to progress this opportunity for deep water habitat creation (artificial reef) to benefit recreational fishing.

4.3.5.3 Suitability of Amrun Port sediments

The Amrun dredge sediment has a high proportion of fine silt and clay that may not be suitable for habitat creation through direct placement on the seabed in the vicinity of the port. The properties of the fine (clay and silt) material make the sediment placed on a seabed potentially more readily susceptible to remobilisation. Hence the Amrun sediments will need to be placed into geobags or geotubes to construct seabed features or an artificial reef. As such only the option of placement in geotextile tubes underwater is considered further.

As part of the assessment of the deep-water habitat creation reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in section 2.1 (suitability categories as per Section 3.3.1).

Table 4-38: Suitability of dredge sediment for proposed deep water habitat creation reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	Likely suitable
Particle Size Distribution	Potentially suitable with processing (geotubes)
Moisture content	Likely suitable
Plasticity Index	Likely suitable
Linear Shrinkage	Likely suitable
Density test	Likely suitable
Strength and Consolidation	Likely suitable
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

Further consideration would be required of the characteristics of the sediment material to be dredged and of the potential placement location, along with the potential impacts (positive and negative) on offshore deep-water habitat ecosystems and potential for fisheries development.

4.3.5.4 Process description and key activities

Dredging and placement

Due to the largely fine material to be dredged, it is considered that the Amrun dredge material is unsuitable for deep water habitat creation through direct placement; however, is suitable for use in geobags or geotubes. The geotextile allows for gradual dewatering of the dredge material and the fines are maintained within the structure of the bag or tube, as previously discussed in Section 4.2.8.

It is considered that a reasonable dredge configuration for the purposes of analysis is a combination of a 'TSHD Brisbane' with multiple split hopper barges, which would be hydraulically filled at the dredging area, and would transport the dredged material to the offshore habitat creation placement site.

For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will load the split hopper barges at the dredging area and the barges will travel up to 10km to an offshore deep-water placement site. Mooring and transfer facilities alongside the Amrun Port jetty would be required to enable secure transfer between the Trailing Suction Hopper Dredge and the barges.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, with minimal downtime and the dredge program would last approximately 5 days. The dredge program would be longer duration than options involving offshore placement as operations to transfer dredged material to barges and into geotubes and placement before accepting next load is less efficient.

4.3.5.5 Potential constraints

Potential constraints associated with this option include:

- Demand for deep water seabed habitat (fisheries) creation or an artificial reef is likely to exist but is currently unclear
- Significant research effort may be required to demonstrate potential for enhancement of existing habitat through placement of dredge material, to achieve regulatory agency acceptance of the option as a beneficial reuse
- Availability of equipment (e.g. appropriate split hopper barges) to execute the works may be limited
- Sea and weather conditions may affect operability of the configuration, particularly transfer of material from dredge to barge, and placement of geotubes
- Potential acid Sulfate soils, may require consideration in development of the deep-water habitat concept
- Agreement for access to the marine areas from Traditional Owners for the proposed work
- Suitable geofabric material able to contain the fine clay/silt material, yet permeable to allow the filled geotube to 'sink' into position.

4.3.5.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Provides a potential option to develop fisheries habitat in the area which may have positive socio-economic, commercial and environmental outcomes
- Placement of the material on the seafloor will impact existing benthic habitat
- Recreation fishing vessel and activity likely to increase around 'artificial reef' location which may have potential for overfishing

- Should the creation of an artificial reef and creation of a recreational fishery be successful there may be community demand for extension of the reuse option
- Any proposal to create deep-water habitat or an artificial reef, using dredge material, would require consultation in the planning, design and development with the Amrun Reference Group and Traditional Owners.

4.3.5.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material in deep water habitat creation (geobags) is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.3.5.8 Costs

A summary breakdown of the estimated costs associated with execution of the Amrun deep water habitat creation option is provided in Table 4-39. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $208/m^3 measured in situ.

Table 4-39: Amrun Deep water habitat creation summary cost estimate table

Key Activity	Amrun – Deep Water Habitat Creation (Geobags)
Offshore	
TSHD mobilisation and demobilisation and daily hire	$400,000
Workboat	$500,000
Tug and barge mobilisation and demobilisation	$2,000,000
Place with tug, barge and geobags	$800,000
Onshore	
Monitoring and management	$200,000
Total	**$3,950,000**

4.3.5.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the deep-water habitat creation materials option is 542 tonnes of CO_2 equivalent. The estimated emissions are based on the assumed process description described above, with further detailed assumptions provided in Appendix B.

4.3.5.10 Knowledge gaps

If the deep-water habitat creation option was to be further pursued, key areas where additional information would be required include:

- Demand for fisheries habitat creation in the vicinity of the Amrun Port, and the value of existing seabed habitat within the area
- Coastal dynamics and processes specific to the proposed location of the habitat creation area (likely including hydrodynamic modelling over a range of conditions) to enable effective determination of likelihood of success of habitat creation.

4.3.5.11 Future considerations

This quantity of material to be dredged are sufficiently large for a deep-water habitat (geotubes) creation pilot project; however, the suitability of the options for acceptance of maintenance dredging material on a long term basis would depend on the success of the pilot project, and whether that could be expanded, or replicated across other areas of the sea floor.

It is considered that Amrun dredging volumes (estimated 19,000m^3 annually) could provide a long-term suitable source of material for deep water habitat that significantly exceeds demand in the region and may only provide a single or 'one off' beneficial reuse option.

4.3.5.12 Performance summary

A summary of the performance of the deep-water habitat creation option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-40.

Table 4-40: Deep water habitat creation performance summary

Performance Criteria	Performance Rating
Opportunity	MODERATE: Potentially a demand reasonably accessible to the Port, requiring infrastructure construction
Sediment suitability	MODERATE: Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable
Cost	HIGH: Less than $10M annually
Process	LOW: The proposed process is mostly unproven
Duration	HIGH: Less than 1 year to construct and function as the proposed final

Performance Criteria	Performance Rating
	use
Greenhouse Gas Emissions (GHGs)	HIGH: < 2000t CO_2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	MODERATE: Limited economic opportunities exist enhancing port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	MODERATE: Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them
Knowledge Gaps	LOW: There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	MODERATE: The reuse option would cater for immediate needs and has some scope in the short term (several years), although options would need to be regularly reassessed

4.4 Reuse dredge material in an agricultural application

A single agricultural reuse application was identified as part of the assessment. The use of dredge material as topsoil was considered in the analysis for Port of Weipa material but not considered for Amrun. The dredge material at Amrun Port is considered to contain excessive fine material (silt/clay) for reuse as topsoil material.

Port of Weipa

4.4.1 Topsoil for agriculture

4.4.1.1 Activity description

Dredged material may be used to improve soil structure for agricultural use. Maintenance dredging in harbors, access channels, and rivers produces mixtures of sand, silt, clay, and organic matter, while the best topsoil is a mixture of sand, silt, clay, and organic matter. As the dredged material comes from coastal areas, attention must be given to salinity, as practically no agricultural species can grow in salty soils and few in brackish soils. Salinity may be reduced naturally by rain or by the dewatering process (PIANC, 1992).

4.4.1.2 Opportunity

An estimated 71% of total dredge material is silt and clay, mostly silt (2.3 parts silt to 1-part clay). This means the material is heavily weathered and contains low reactivity material and accordingly has a low potential for ripening. It may be possible to use the Port of Weipa dredge material for agricultural use after significant treatment and processing including dewatering, oxidising, leaching to remove salt, structure development and bioturbation (reworking of soils and sediments by animals or plants).

There is no identified demand for soil produced from dredge material in mining rehabilitation activities near the Port of Weipa.

There are two options that may be considered for the reuse of the dredge material for agricultural purposes:

- Option 1: The dredge material could be deposited in a bunded and drainage controlled area, allowed to ripen[10] and then used in-situ for growing vegetation – horticulture
- Option 2: The dredge material that has been deposited in a bunded and drainage controlled area is allowed to ripen and is then excavated and used as a soil additive applied to existing crops or possibly pastures – broad scale cultivation.

It is considered that of these options, the most likely feasible as a long-term beneficial reuse, is Option 1, i.e. onshore placement of material, followed by processing, transport and use in horticultural crops as there is no large scale agricultural cropping in the region. This option is the focus of analysis below.

The Weipa region climate is tropical characterised by high mean temperatures across the year mean maximum 31.3°C and mean minimum temperatures 21.8°C with highly seasonal rainfall, typically 2200mm-2400mm/yr. between October and May and a net evaporation of 1925mm/yr.[11].

This climate creates a difficult moisture regime for crop production, with a water surplus for four months (water logging) then six months of severe dry. Irrigation would be required to carry a crop through the dry period. Some crops' production, such as mangos, will tolerate the dry months, however would produce a lower yield in these conditions.

Horticultural crops generally prefer freely draining substrate soils and fine silty materials exhibit poor drainage and low infiltration. This results in fine silty soils material being difficult to manage and with a narrow range of moisture when soils can be cultivated and typically being too wet through water logging or too dry.

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[10] Soil ripening is defined as a pedogenetical process that converts soft, waterlogged and reduced materials into soils (Pons and Zonneveld, 1965). It is comprised of chemical, biological and physical processes. The chemical processes include oxidation of reduced materials in the dredge material and leaching of salts. Biological processes include bioturbation and plant growth while the physical processes mainly include dewatering and changes in bulk density, permeability and structure.
[11] Bureau of Meteorology, www.bom.gov.au temperature, mean annual rainfall (1914 – current), average pan evaporation data.

The climate in combination with the poor soils characteristics of the dredge material means there is very limited opportunity for reuse as soil for agriculture because an economically viable crop is unlikely even with irrigation.

4.4.1.3 Suitability of Port of Weipa sediments

As part of the assessment of the proposed agricultural horticultural soils reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-41 (suitability categories as per Section 3.3.1).

Table 4-41: Suitability of dredge sediment for proposed agricultural topsoil reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	N/A
Particle Size Distribution	Not likely to be suitable
Moisture content	Potentially suitable with treatment/processing
Plasticity Index	Not likely to be suitable
Linear Shrinkage	Not likely to be suitable
Density test	N/A
Strength and Consolidation	N/A
Permeability	Not likely to be suitable
Geochemical	
PASS	Likely suitable
Salinity	Potentially suitable with treatment/processing
Organic Material	Potentially suitable with treatment/processing
Other	
Cement laboratory testing	N/A

The sediment material requires significant treatment (dewatering and desalination) and processing (soil ripening, blending, structure development and mixing) to improve its suitability for reuse as agricultural topsoil.

4.4.1.4 Process description

Dredging and placement

The dredging and placement requirements for this option are as identified for construction fill at Section 4.2.2.4.

Infrastructure and management requirements

A review of literature suggests that given the fine textured materials, the depth of the deposited dredge material should be a maximum of 1m to allow dewatering, leaching and oxidising i.e., ripening (van Driel and Nijssen, 1988). A depth of 500mm would promote more rapid ripening. Given the volume of sediment is 500,000m^3 the area needed for ripening would be 100ha if deposited 500mm thick, which is approximately two thirds of the potentially available Inactive TSF. As such the onshore infrastructure requirements described for the construction fill option, in Section 4.2.1 would be double in area for this option. In addition to these requirements, material to be used for an agricultural purpose requires further treatment to desalinate the material, and more extensive processing to separate and / or mix material.

The high salt level will be reduced by a combination of exposure to rainfall to assist leaching of the salts plus periodic 'mixing and turning over' of the stored material by an excavator over an extended period (up to three years).

Halophytes could be planted to increase the rate of ripening when salinity levels in the surface 100-200mm of the dredge material has been reduced to acceptable levels, e.g. 2.5 dSm^{-1} (Koropchak et al 2015). Soil amendments such as compost may be beneficial at this stage.

The material will need to be extracted from the storage pond and sorted into various particle sizes by a screening plant. The resulting material stockpiles can then be batched, and if necessary blended with imported material, to create agricultural soil material to achieve the required particle properties.

For the purposes of analysis, it is assumed that top soil would be delivered to a horticultural facility in the region requiring an approximately 50km round trip.

The chemical characteristics of the samples analysed to date as described in the sediment properties report suggest that acidification of the sediments following dredging is unlikely.

4.4.1.5 Potential constraints

Potential constraints associated with this option include:

- Complex process of mixing, treatment, extraction, processing by screening, stockpiling and then blending and batching with imported material to manufacture soil material suitable for agriculture
- Production of agricultural materials from the dredge material is more process intensive than other methods, and as such the cost of supply will likely need to be subsidised by NQBP to create demand

- Dredge material as source of agricultural soil material will be opportunistic only i.e. not a continuous reuse option for material produced from annual dredging
- Construction of the bunds for the onshore placement ponds requires an estimated 97,000m^3 of material, much of which may require importation, and access to this material may be difficult
- Weipa's monsoonal wet season and high rainfall levels will influence the speed of dewatering and limit when it may occur
- Infrastructure development would need to consider potential impact of extreme events (i.e. cyclones), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, groundwater aquifers, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Construction and operation of the placement area will require improvement of access to inactive TSF and will increase traffic on local roads.

4.4.1.6 Potential implications

Potential implications of this option, considering environmental, commercial and socio-economic outcomes include:

- Development of a potential source of agricultural material in the region, albeit that it would be unlikely cost competitive without subsidisation
- The Weipa climate is difficult for crop production, with a water surplus for four months then six months of severe dry and irrigation would be required
- Onshore placement may cause temporary sterilisation of land at inactive TSF
- Onshore placement storage ponds have potential significant implications for local surface and groundwater impacts
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas
- Onshore placement may cause some impacts to Traditional Owners' lands or exiting partnerships or agreements
- Construction and operation of the onshore placement area will cause temporary and intermittent loss of amenity to the local community, through increases in local traffic, particularly Kerr Point Road and haul routes for imported fill to construct the bund embankments.

4.4.1.7 Approvals

Approvals associated with dredging and placement and onshore reuse (as identified in Table 3-1) will be required for the construction and operation of this option.

It is considered that the beneficial use of maintenance dredge material topsoil for agriculture is consistent with the intent of existing Queensland legislation and policy, which is to limit marine impacts from dredge material disposal.

4.4.1.8 Costs

A summary breakdown of the estimated costs associated with execution of the agricultural topsoil materials option is provided in Table 4-42. The costs are based on the assumed process description described above, with further detailed assumptions provided in Appendix A.

Depending on the location of the concept (dredge method, distance from dredging zone and water depth for accessibility), it is estimated that costs will be approximately $\$80/m^3$ measured in situ.

Table 4-42: Agricultural topsoil material summary cost estimate table

Key activity	Topsoil for Agriculture
Offshore	
TSHD mobilisation and demobilisation and daily hire	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$320,000
TSHD dredging and pump ashore	$5,000,000
Onshore	
Dredge Management ponds construction	$14,500,000
Processing material including dewatering/desalination/ripening	$1,000,000
Processing material including screening/bending/mixing	$5,500,000
Monitoring and management	$250,000
Transport – road transport to end user	$6,000,000
Total	**$40,070,000**

4.4.1.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the agricultural materials option is 10,294 tonnes of CO2-equivalent. The estimated emissions are based on the assumed process description described above, with further detailed assumptions provided in Appendix B.

4.4.1.10 Knowledge gaps

If the top soil for agricultural option was to be further pursued, key areas where additional information would be required include:

- Demand for agricultural soil materials and improved understanding of comparative cost of soil production
- Comparative cost of horticultural production as a beneficial reuse in Weipa region against existing commercial horticultural production in Far North Queensland
- Further investigations related to the rate of soil ripening in an onshore placement facility
- Coastal dynamics and processes specific to the proposed location of the dewatering discharge location
- Availability of suitable construction materials for the bunds, and conditions on site suitable for the construction of ponds
- Detailed design including consideration of dredging, placement, construction and ongoing use of the reclamation area
- Site access requirements including potential road upgrades.

4.4.1.11 Future considerations

While further work is required to more accurately estimate the rate of ripening, the current estimate is that dredge material deposited 500mm thick could not be ripened and removed off-site before the subsequent dredging operation (assuming annual programs) i.e., one site of 100 ha would be required and reused for each dredging operation. As such, assuming there is a demand for the material so that it may be removed from the onshore placement ponds, the inactive TSF area is unlikely to be available for ongoing use for onshore placement.

4.4.1.12 Performance summary

A summary of the performance of the agricultural materials option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-43.

Table 4-43: Agricultural topsoil material performance summary

Performance Criteria	Performance Rating
Opportunity	LOW: No demand identified, poor access to the Port, requiring extensive infrastructure construction
Sediment suitability	LOW: Reuse option poorly suited to the dredge material. Requires substantial treatment, processing and/or additives to make material suitable; or treatment to a suitable level is considered unachievable
Cost	LOW: More than $20M annually

Performance Criteria	Performance Rating
Process	MODERATE: The proposed process is sound but there are few examples of it being applied in environments similar to the Port using maintenance dredge material
Duration	LOW: Greater than 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	LOW: >8000t CO_2 equivalent in a one year period
Environmental Implications	MODERATE: Nuisance or harm issues identified, but for the most part are considered manageable
Social Implications	MODERATE: Social effects for the most part are considered manageable
Indigenous Implications	MODERATE: Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable
Economic Implications	LOW: Lost or negative economic opportunities to enhance port or community capability
Approvals	MODERATE: Recognised approvals pathway, with significant management issues identified
Constraints	LOW: Multiple constraints are present that would limit realistic implementation
Knowledge Gaps	MODERATE: There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the reuse option
Future considerations	LOW: The reuse option has only a single or limited application.

5 Conclusions

The sediment properties investigations provide the basis for identification of potential beneficial reuse options, along with subsequent analysis. Following identification of beneficial reuse options, the analysis compared the range of options and opportunities at conceptual level, considering processes, potential constraints and implications, approvals, conceptual costs and greenhouse gas emissions, along with knowledge gaps and future considerations.

Fourteen potential beneficial reuse options were developed and then evaluated against fourteen performances criteria. Only two reuse options had five out of fourteen criteria rated as 'high' performance with the remaining reuse options only having four or less 'high' ratings. This may be interpreted overall as the dredge material and local opportunities not being especially well suited to beneficial reuse solutions. The performance ratings and a comparison of the beneficial reuse options analysed is provided in Figure 5-1 and Figure 5-2.

The analysis indicates that, while there are several options for beneficial reuse that may be feasible, in consideration of all the aspects relevant to the use, there is no clear long term beneficial reuse option solution for Port of Weipa or Amrun Port maintenance dredge material. The analysis conclusions for the beneficial reuse options for both ports are summarised below.

Port of Weipa

There is approximately 500,000m^3/yr of material to be dredged from the Port for maintenance of depth in operational areas. At the Port of Weipa about 400,000m^3 of the annual dredge material is fine grained (silt/clay) and about 100,000m^3 is coarse material (sand/gravel).

Most of the material to be dredged is fine silt/clay material (71%), mixed with sand (25%) and small amounts of gravel material (4%). Most of sediment material to be dredged (approximately 90%) is in the Southern Channel and Extension with the balance of material from the three berth areas (Lorim Point, Humbug and Evans Landing) and the Approach Channel and Departure Channel.

Within each of the dredge areas, the sediments are typically dominated by fine material; however, there are several sites where sandy material constitutes more than 75% of the sediment. Based on the volume of coarse material in these locations it is considered likely to be practical to use selective dredging to target sandy material for some potential beneficial reuse options.

Sediments to be dredged are likely to be Potential Acid Sulfate soils (PASS); however, they contain sufficient carbonate content acid neutralising capacity to buffer inherent acidity to negligible concentrations and as such are unlikely to require ASS treatment, albeit that this is dependent on the management measures required for reuse. The material to be dredged is free of contamination and therefore suitable for ocean placement.

Comparative analysis of the potential Port of Weipa reuse options shows that:

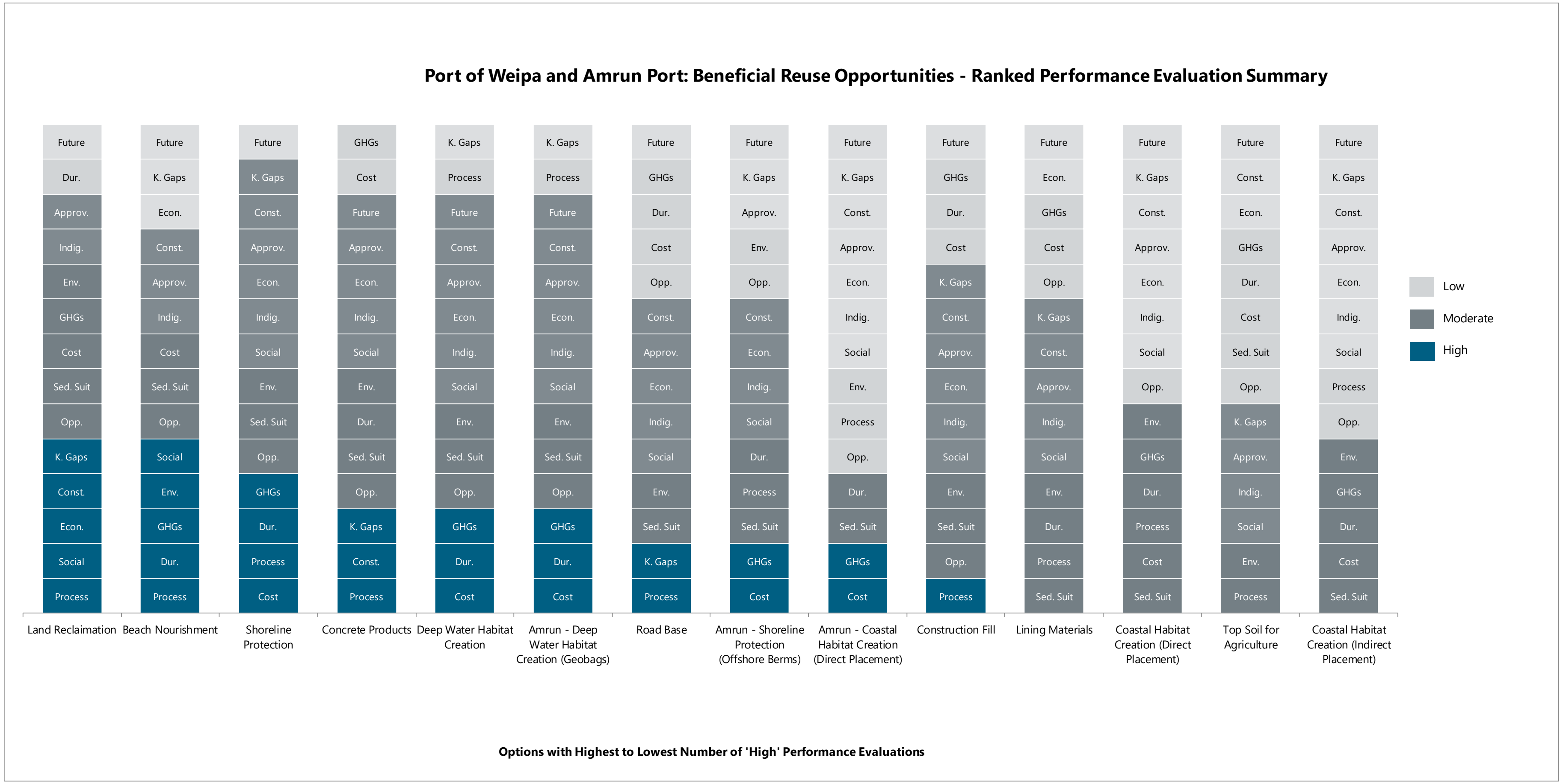
- **Opportunity**: None of the options have a clear existing demand for the reuse of sediment material that would require minimal infrastructure. For several options, a potential demand exists that requires infrastructure construction, while for six options (road base, lining material, coastal habitat creation through direct or indirect placement, deep water habitat creation and top soil for agriculture) no substantive demand for the dredge material was identified.

- **Sediment Suitability**: Most of the options were assessed as having low to moderate sediment suitability performance, indicating the material would require some or significant treatment, processing and/or additives. For the reuse options of habitat creation (direct or indirect placement), beach nourishment and shoreline protection it is likely that the sediment material could be utilised without treatment or additives.
- **Cost**: Annual dredging budget is approximately $2.5M including mobilisation, demobilisation and daily hire for a 24 dredge program. All the beneficial reuse options are estimated to cost significantly more (up to 15 times more expensive) than the current annual maintenance dredging program. Estimated costs in the first year are high due to the need to build infrastructure (e.g. onshore placement containment area, pump out mooring facilities and pipeline) to enable the beneficial reuse. All the options involving onshore temporary storage were of low performance with respect to cost (more than $20million/yr.) with the four environmental enhancement options being of moderate performance (between $10million/yr. and $20million/yr.). The four options involving geobags for shoreline protection or deep-water habitat creation have estimated costs that are similar to traditional offshore placement (less than $10million/yr.) and are high performance with respect cost. The options, apart from deep water habitat, only provide a solution for a portion of the dredge material and are in effect additional costs 'on top of' normal dredging costs.
- **Greenhouse Gas**: The options that did not require intermediate storage were of high performance (less than 2500t CO_2 equivalent) with respect greenhouse gas emissions. The options that required onshore placement were of low performance (greater than 8000t CO_2 equivalent) because of emissions associated with the construction of the onshore ponds, material processing and transport to end user.
- **Environment**: Most of the options were rated as being of moderate performance with respect environmental implications i.e. potential nuisance or harm issues identified, but for the most part is considered manageable. Only the beach nourishment option for reuse of the dredge material as an environmental enhancement rated as high performance, due to the net benefit opportunities that exist for positive environmental outcomes.
- **Social**: The land reclamation and beach nourishment options for reusing dredge material are rated as high performance due to the potential for positive social opportunities for local communities. The remaining options were rated as moderate performance, as they are likely to have minor social effects that are for the most part manageable.
- **Indigenous**: The coastal habitat creation options, either by direct or indirect placement, were rated low performance due to potential negative impacts on Traditional Owners' lands and waters (impacts on the Albatross Bay foreshore mangrove and wetland areas) which are considered unlikely to be easily managed. Other options were rated as of moderate performance, as the implications for Traditional Owners are for the most part considered manageable.

Table 5-1: Beneficial reuse options performance summary

Performance Criteria	High Performance	Moderate Performance	Low Performance	Port of Weipa and Amrun Port Beneficial Reuse Options													
				Recycle dredge material as engineering material								Reuse dredge material as an environmental enhancement					Reuse dredge material in an agricultural application
				Land Reclamation	Construction Fill	Road Base	Lining Materials	Concrete Products	Shoreline Protection	Beach Nourishment	Amrun - Shoreline Protection (Offshore Berms)	Coastal Habitat Creation (Direct Placement)	Coastal Habitat Creation (Indirect Placement)	Deep Water Habitat Creation	Amrun - Coastal Habitat Creation (Direct Placement)	Amrun - Deep Water Habitat Creation (Geobags)	Top Soil for Agriculture
Opportunity	**HIGH:** The is an existing demand in a location accessible to the Port, requiring minimal infrastructure needs	**MODERATE:** Potentially a demand reasonably accessible to the Port, requiring infrastructure construction	**LOW:** No demand identified, poor access to the Port, requiring extensive infrastructure construction	Mod.	Mod.	Low	Low	Mod.	Mod.	Mod.	Low	Low	Low	Mod.	Low	Mod.	Low
Sediment suitability	**HIGH:** Reuse option well suited to the dredge material. Requires no additives or treatment (other than dewatering if necessary)	**MODERATE:** Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable	**LOW:** Reuse option poorly suited to the dredge material. Requires substantial treatment, processing and/or additives to make material suitable; or treatment to a suitable level is considered unachievable	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Low
Cost	**HIGH:** Less than $10M annually	**MODERATE:** $10M to $20M annually	**LOW:** More than $20M annually	Mod.	Low	Low	Low	Low	High	Mod.	High	Mod.	Mod.	High	High	High	Low
Process	**HIGH:** The proposed process is well understood and clearly demonstrated in similar environments to the Port using maintenance dredge material	**MODERATE:** The proposed process is sound but there are few examples of it being applied in environments similar to the Port using maintenance dredge material	**LOW:** The proposed process is mostly unproven	High	High	High	Mod.	High	High	High	Mod.	Mod.	Low	Low	Low	Low	Mod.
Duration	**HIGH:** Less than 1 year to construct and function as the proposed final use	**MODERATE:** 1 to 3 years to construct and function as the proposed final use	**LOW:** Greater than 3 years to construct and function as the proposed final use	Low	Low	Low	Mod.	Mod.	High	High	Mod.	Mod.	Mod.	High	Mod.	High	Low
Greenhouse Gas Emissions (GHGs)	**HIGH:** < 2000t CO_2 equivalent in a one year period	**MODERATE:** >2000t and <8000t CO_2 equivalent in a one year period	**LOW:** >8000t CO_2 equivalent in a one year period	Mod.	Low	Low	Low	Low	High	High	High	Mod.	Mod.	High	High	High	Low
Environmental Implications	**HIGH:** Net benefit opportunities exist for positive environmental outcomes, with very minor nuisance or harm issues	**MODERATE:** Nuisance or harm issues identified, but for the most part are considered manageable	**LOW:** Nuisance or harm issues unlikely to be easily managed	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	High	Low	Mod.	Mod.	Mod.	Low	Mod.	Mod.
Social Implications	**HIGH:** Positive social opportunities e.g. jobs exist for local communities and other key user groups	**MODERATE:** Social effects for the most part are considered manageable	**LOW:** Negative social impacts are unlikely to be easily managed	High	Mod.	Mod.	Mod.	Mod.	Mod.	High	Mod.	Low	Low	Mod.	Low	Mod.	Mod.
Indigenous Implications	**HIGH:** Positive outcomes and opportunities exist for Traditional Owners' lands/waters and the local indigenous community	**MODERATE:** Effects on Traditional Owners' lands/waters and indigenous community for the most part are considered manageable	**LOW:** Negative impacts upon Traditional Owners' lands/waters and the indigenous community are unlikely to be easily managed	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Low	Low	Mod.	Low	Mod.	Mod.
Economic Implications	**HIGH:** Positive economic opportunities exist enhancing port or community capability	**MODERATE:** Limited economic opportunities exist enhancing port or community capability	**LOW:** Lost or negative economic opportunities to enhance port or community capability	High	Mod.	Mod.	Low	Mod.	Mod.	Low	Mod.	Low	Low	Mod.	Low	Mod.	Low
Approvals and Permits	**HIGH:** Recognised approvals pathway, with few management issues identified	**MODERATE:** Recognised approvals pathway, with significant management issues identified	**LOW:** Not supported but current legislation or policy would require high level offset considerations	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Low	Low	Low	Mod.	Low	Mod.	Mod.
Constraints	**HIGH:** There are few constraints which are for the most part considered manageable	**MODERATE:** Constraints are identified and there is a degree of uncertainty in the ability to overcome or manage them	**LOW:** Multiple constraints are present that would limit realistic implementation	High	Mod.	Mod.	Mod.	High	Mod.	Mod.	Mod.	Low	Low	Mod.	Low	Mod.	Low
Knowledge Gaps	**HIGH:** There are few knowledge gaps and less than 1 year of further research work would be required to progress the reuse option	**MODERATE:** There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the reuse option	**LOW:** There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option	High	Mod.	High	Mod.	High	Mod.	Low	Low	Low	Low	Low	Low	Low	Mod.
Future considerations	**HIGH:** The reuse option provides a long term solution for the Port for a period greater than 10 years	**MODERATE:** The reuse option would cater for immediate needs and has some scope in the short term (several years), although options would need to be regularly reassessed	**LOW:** The reuse option has only a single or limited application.	Low	Low	Low	Low	Mod.	Low	Low	Low	Low	Low	Mod.	Low	Mod.	Low

Table 5-2: Beneficial reuse option ranked performance evaluation



- **Economic**: Only the option of land reclamation was rated as high performance due to positive economic opportunities for enhancing community capability and opportunities associated with development of upgraded port facilities. The reuses liner material and topsoil for agricultural uses were all rated as low economic performance, due to the likely need for subsidisation for these uses to be acceptable. The remaining options were rated as moderate performance, as they may provide limited economic opportunities for enhancing port or community capability.
- **Approvals**: The reuse of dredge material as an environmental enhancement in coastal habitat creation (direct and indirect placement) and deep-water habitat creation will require careful scientific investigation and specialist studies and significant effort to gain necessary regulatory approvals and consequently are assessed as low performance with respect approvals.
- **Knowledge Gaps**: The land reclamation and concrete products options have few knowledge gaps and less than one year of further work would be required to progress the option. Conversely, each of the three options for reusing dredge material as an environmental enhancement, along with the shoreline protection and beach nourishment options would likely require greater than three years of further research to address knowledge gaps, particularly with respect confirmation of the demand for the use and suitability of the material and placement strategy. The remaining options would likely require one to three years of further research to address multiple knowledge gaps.
- **Future Considerations**: All of options were considered to have a single or limited application. Only the concrete products and deep-water habitat creation options may cater for immediate needs and have some scope in the short term to address maintenance dredging needs, with the ongoing use needing regular assessment.

The analysis indicates that, while there are several options for beneficial reuse that may be feasible, in consideration of all the aspects relevant to the use, there is no clear preferred long term beneficial reuse option solution for maintenance dredge material. For all the options, further investigation regarding demand is required.

Five reuse options ranked well on the number of 'high' performance evaluation criteria, namely land reclamation and beach nourishment, which ranked equal highest, followed by options for shoreline protection, concrete products and deep-water habitat creation. The 'process' performance criteria was the only common criteria that was rated high across these options (four of the five – excluding deep water habitat creation). No other individual performance criteria was assessed as 'high' for more than two of the five highest ranked options. This is an indication that there is diversity in the options assessed and that no option has clearly emerged as superior.

If a suitable land reclamation area is available, the option for reuse through direct placement potentially offers economic benefits in terms of construction jobs and increased Port capacity. Similarly, if an appropriate location is identified for beach nourishment, then direct placement of targeted sand dredge material may provide enhancement of the area's foreshore.

Reuse of the dredge material as an engineering material is contingent on obtaining the coarse component of the dredge sediment, namely the sand. Selective dredging of the known locations with high sand content may be feasible to segregate sand into a designated area of an onshore management area for screening and washing ready for use. Notwithstanding this, the potentially available quantity of sand far exceeds the current known demand.

While the dredge sediment is likely to be suitable to reuse for use in the environmental enhancements (coastal habitat creation, and deep-water habitat creation), shoreline protection and beach nourishment options their feasibility relies on demand and the final placement location being favourable especially in relation the local benthic ecosystem and the wave climate and currents.

There are several reuse options where most of performance criteria were scored moderate, with only a few low performance criteria, namely construction fill, road base and lining material. This finding may be interpreted as these options having few unknowns or constraints to their implementation. These options all involve the construction of an onshore management area and potential long term treatment.

The region is remote and has a tropical climate with a distinct summer monsoonal wet season and is very dry throughout the other months. Onshore placement and treatment of all the dredge material is impractical due to the large area required. The monsoonal high rainfall restricts the drying period to 5 months of the year which is insufficient time to dewater the extremely wet fine (silt/clay) material before having to relocate it to permit the next years dredge material intake.

If an onshore placement area were constructed this may create the potential for five of the beneficial options to be realised (construction fill, road base, lining material, concrete products and topsoil for agriculture). Subject to user demand for an end product, a single reuse option or combination of reuse options is possible once the material is placed onshore, enabling portions of the material to be directed to different reuse as demand arises. Irrespective of which onshore treatment option or the volumes involved the cost of placement of material onshore for treatment and processing will always be a very expense beneficial reuse option.

At the Port of Weipa about 400,000m^3 of the annual dredge material is fine grained (silt/clay) and about 100,000m^3 is coarse material (sand/gravel). Several potential hybrid options exist to target a portion of coarse grained material (sand) for specific beneficial reuses including: land reclamation, construction fill, road base, concrete products, beach nourishment and deep-water habitat creation. The balance of material, typically 400,000m^3/yr. of silt/clay material, unsuitable for reuse could be managed as it is currently through offshore placement. If smaller volumes (5000 to 100,000m^3/yr.) of targeted sand material were place in an onshore treatment area for processing a smaller onshore dredge material placement area could be utilised or potentially a large 50ha area would be adequate for several years of annual dredging programs.

One of the main issues with the potential beneficial reuse of maintenance dredge material for the Port of Weipa is the extremely large volume of material to be managed (estimated at 500,000m^3/yr.) and the absence of clear demand for that material. Several potentially feasible beneficial reuse options have been identified that could use a small proportion of the available dredge material in the short term or for a single use project; however, there is no clear long-term option or combination of options that will cater for the large quantity of dredge material in any year, nor the cumulative volume of multiple years.

Amrun Port

Approximately 19,000m3/yr. of sediment material is required to be dredged from Amrun Port for maintenance of depth in the Port's operational areas. Almost all the Amrun Port dredge sediments is fine grained material. The dredged material is placed at the Amrun Dredge Material Placement Area which is located approximately 14 km offshore directly west of the Port.

Most of the material to be dredged is fine silt/clay material (86%), mixed with sand (13%) and very small amounts of gravel material (1%). The majority (approximately 90%) of sediment material to be dredged is in the berths with the balance of material from the Departure Channel.

Comparative analysis of the potential Amrun Port reuse options shows that:

- **Opportunity**: None of the options have a clear existing demand for the reuse of sediment material that would not require significant further investigation planning, design, negotiation and approvals. No substantive demand for the dredge material was identified.
- **Sediment Suitability**: The option for coastal habitat rehabilitation by direct placement was assessed as having moderate performance with respect sediment suitability, indicating that the material would require some treatment or processing before placement in a coastal habitat. The reuse options for shoreline protection and deep-water habitat were assessed as moderate sediment suitability as the fine sediment material is suitable to be utilised if placed in geobags/tubes to avoid remobilisation.
- **Cost**: All the beneficial reuse options are estimated to cost significantly more (more than 10 times) than the traditional dredging approach, due to additional works associated with either direct placement via pipeline or using barges and double handling to fill geotubes,
- **Process**: For each of the three options, the proposed process is unproven and there are few examples of the reuse being applied to maintenance dredge material in environments similar to Amrun Port. Shoreline protection in the form of offshore berms may not ultimately reduce sedimentation in the berth. Given that the existing coastal environment is not degraded, direct placement to enhance or create habitat may be unnecessary and have negative impacts. Deep water habitat creation has some potential to provide recreational fisheries benefits; however, would require significant scientific investigation to assess the demand and viability of the potential use.
- **Environment**: Coastal habitat creation by direct placement was assessed as low with respect environmental performance, given that there is not a clear demand for creation and the potential for negative impacts associated with the option. Similarly, the environmental implications of the shoreline protection option may outweigh intended benefits. The establishment of an artificial reef through the deep-water habitat creation option has some potential to create recreational fisheries benefit.
- **Indigenous**: The coastal habitat creation option was rated as low performance with implications for Traditional Owners, given that there may be negative impacts upon Traditional Owners' lands/waters which are unlikely to be easily managed.

- **Economic**: Deep-water habitat creation was rated as medium performance given the potential for positive economic opportunities relating to recreational fishing and noting that an opportunity may exist for funding assistance to support a local recreational fishing project.
- **Approvals**: Each of the identified options is likely to require careful scientific investigation, specialist studies and significant effort to gain necessary regulatory approvals and consequently they were assessed as low performance with respect approvals.
- **Future Considerations**: All of options were considered to have a single or limited application. Only the deep-water habitat creation options may cater for immediate needs and has some scope to expand to address short-term future maintenance dredging needs.

The main issues that challenge the identification of potentially suitable beneficial reuse options are the relatively small volume of material to be managed, the material type and the port's location, including its remoteness. Due to the dredge material's characteristics there are not considered to be any viable options to reuse the dredge material as an engineering material or in an agricultural application. In any case conveyance of the dredge material to an onshore placement area at Amrun (for processing and treatment required for an engineering use) would be extremely challenging due to many constraints including limited available storage area and the significant engineering, environmental and cultural heritage issues associated with traversing the shoreline's turtle nesting habitat and culturally significant coastal cliffs.

The dredge material from the port is most suited to use as an environmental enhancement; however, the remoteness of the port dictates that there is little demand in adjacent areas for environmental enhancement. The analysis indicates that, while there are some options for beneficial reuse of Amrun Port maintenance dredge material that may be feasible, in consideration of all the aspects relevant to the use there is no clear long term preferred beneficial reuse option that is well suited to meet the port's ongoing maintenance dredging needs. The potential option to build an artificial reef as a recreational fishing project emerged as a potentially feasible option among a scarcity of practical reuse options; however, this option would provide only a short-term option for beneficial reuse and further detailed scientific investigation would be required to assess its viability.

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Appendix A Conceptual Cost Estimate

Appendix A. Table 1 - Preliminary Estimated Cost of Port of Weipa and Amrun Port Beneficial Reuse Options

	Beneficial Reuse Option													
	Recycle Dredge material as an engineering material								Reuse Dredge material as an environmental enhancement					Reuse in agriculture
Key Activity	1. Land Reclamation	2. Construction Fill	3. Road Base	4. Lining Material	5. Concrete Products	6. Shoreline Protection	7. Beach Nourishment	8. Amrun - Shoreline Protection (Offshore Berms)	9. Coastal Habitat Creation (Direct Placement)	10. Coastal Habitat Cretaion (Indirect Placement)	11. Deep Water Habitat Creation	12. Amrun - Coastal Habitat Creation (Direct Placement)	13. Amrun - Deep Water Habitat Creation (Geobags)	14. Topsoil for Agriculture
Offshore														
TSHD mobilisation, demobilisation, dredge program hire	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$400,000	$2,500,000	$2,500,000	$2,500,000	$400,000	$400,000	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$5,000,000		$7,000,000	$7,000,000		$7,000,000		$5,000,000
Workboat	$500,000	$320,000	$320,000	$320,000	$320,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000	$320,000
TSHD Dredge and pump ashore	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$7,500,000		$7,500,000	$7,500,000		$7,500,000		$5,000,000
TSHD Dredge and seabed placement											$2,500,000			
Tug and Barge mobilisation and demobilisation						$2,000,000		$2,000,000					$2,000,000	
Place nearshore with tug, barge and geobags						$800,000		$800,000					$800,000	
Onshore														
Dredge management ponds construction		$14,500,000	$14,500,000	$14,500,000	$14,500,000									$14,500,000
Processing dewatering/desalination/ripening	$1,000,000	$500,000	$1,000,000	$1,000,000	$1,000,000									$1,000,000
Processing screening/blending/mixing		$4,000,000	$5,500,000	$5,500,000	$4,000,000									$5,500,000
Sheet piling for reclaimation area	$4,000,000													
Monitoring and management	$250,000	$250,000	$500,000	$500,000	$500,000	$250,000	$500,000	$250,000	$500,000	$500,000	$250,000	$500,000	$250,000	$250,000
Transport - road transport from site to end user		$6,000,000	$6,000,000	$3,000,000	$6,000,000									$6,000,000
Totals	$18,250,000	$38,070,000	$40,320,000	$37,320,000	$38,820,000	$6,050,000	$16,000,000	$3,950,000	$18,000,000	$18,000,000	$5,750,000	$15,900,000	$3,950,000	$40,070,000
$/m^3	37	76	81	75	78	12	32	208	36	36	12	837	208	80

Basis of Estimate (Assumptions):

Offshore Estimated Costs

1 Sediment material dredge volume 500,000m^3/yr. for Port of Weipa and 19,000m^3/yr. for Amrun Port.

2 'TSHD Brisbane' (or similar dredge vessel) $2.00M for 24 day dredging program based upon NQBP data (years 2007 to 2018). Assume $0.5M for TSHD mobilisation and demobilisation based up NQBP cost data. Total for TSHD 500,000m3 annual dredging campaign $2.50M/yr. No allowance for surveying, bed levelling, contract management, environmental monitoring. Amrun assume TSHD 5 day dredging program for shoreline protection, coastal habtiat creation and deep water habitat creation options, $400,000, assuming Amrun

3 Pipeline mobilisation and installation/construction including pump out mooring ($3 to $4M) and demobilisation ($2M to $3M). Assume $5M for up to 1.5km length, less complex pipeline transport to dredge pond storage 32 days duration dredge program (5 pond options plus land reclaimation, shoreline protection, beach nourishment, Amrun shoreline protection and Amrun deep water habitat creation). Assume $7M for longer length up to 5km including 1No. booster station and more complex operations restricted by tides and slower production rates, estimated 50 days dredge program duration, pump ashore process options (coastal habitat restoration (direct and indirect placement) and Amrun coastal habitat restoration (direct placement).

4 Workboat assume aluminium cat 10m length, day rate at $10,000/day. Assume 32 days dredge program for straightforward pump ashore to dredge ponds storage (5 pond options) =$320,000. Assume 50 days dredge program for more complex pump ashore operations (land reclamation, shoreline protection, beach nourishment, coastal habitat restoration (direct and indirect placement) and three Amrun options = $500,000.

5 Dredge and pump ashore ($10-$15/m^3), assume 'TSHD Brisbane' (or similar dredge vessel), hopper capacity 2900m3, dredge volume 500,000m3, estimate 172 trips, TSHD coupled to pump ashore pipeline. Assume $5M (500,000m3 at $10/m3) for straightforward pump ashore to dredge ponds storage (5 pond options, land reclamation with discharge within 20km of dredge area and with low tide access to nearshore, 24/7 operation, 32 days dredging program. Assume $7.5M (500,000m3 at $15/m3)for more complex pump ashore option, discharge operations more restricted by tides, slower production rates, up to 20km sailing distance, 50 days dredge program duration, (shoreline protection, beach nourishment, coastal habitat restoration (direct and indirect) and Amrun coastal habitat restoration direct).

6 Dredge and seabed placement ($5-$10/m^3). Assume $5/m^3 for 500,000m^3 = $2.5M (habitat creation).

7 Tug (2No.) and Barge (2No.) mobilisation and demobilisation and hire $2.0M. Tug and Barge transport (split hopper) for shoreline protection and deep water habitat creation (geobags) options.

8 Place dredge sediment into geobags on barge and place filled geobags nearshore with tug and barge $40/m^3, 20,000m^3= $800,000. Assume fill geobag at a location within 10km radius of dredge area, estimate 2 tugs, 2 barges 60 hour per week, 28 day placement campaign 240 hour per tug. (shoreline protection (geobags), Amrun shoreline protection (offshore beams - geobags), Amrun deep water habitat creation (geobags)). Assumes TSHD is concurrently supplying dredge material to barge geobags operation and also disposing of balance of material (majority) to offshore DMPA.

9 No allowance of downtime due to weather or sea state.

Onshore Estimated Costs

10 Onshore construction of dredge management ponds 50ha area (5 pond options), sediment material placed 3.0m deep (bulk factor 3x) for treatment. Estimate pond embankment dimensions 500m wide x 1000m long x 3.0m deep (bulking factor x3), bund walls volume 97,200m^3 (constructed) at $150/m^3 supply and place a combination of site and imported material including pond liner = $14.5M. Transport imported material assumes 97,200m^3 bulk factor x1.2 (116,640m^3), truck and dog 20m^3 capacity, 10 trucks doing 5832 trips @ 2hour 50km round trip = 11,664 total hours or 117 days. Estimate 30 weeks construction 60h/week, 2 x 36t excavator, 2x 19t wheel loader, 1x water truck. 10 hours/day, 6 days per week, 30 weeks = 1800h ea. vehicle

11 Processing treatment for dewatering and desalination and soil ripening in dredge management pond assume 2500h per year, excavator 36t and D6 Dozer at $150/h each = $750,000 and 2x 4WD passenger vehicles = $100,000. Assume $1M where soil ripening or a higher level of treatment processing and desalination required for end use (road base, lining material, concrete products, topsoil for agriculture). Assume $500,000, 2300h (38 weeks) where less treatment processing and desalination is required for reuse option (construction fill).

Appendix A. Table 1 - Preliminary Estimated Cost of Port of Weipa and Amrun Port Beneficial Reuse Options

	Beneficial Reuse Option													
	Recycle Dredge material as an engineering material								Reuse Dredge material as an environmental enhancement					Reuse in agriculture
Key Activity	1. Land Reclamation	2. Construction Fill	3. Road Base	4. Lining Material	5. Concrete Products	6. Shoreline Protection	7. Beach Nourishment	8. Amrun - Shoreline Protection (Offshore Berms)	9. Coastal Habitat Creation (Direct Placement)	10. Coastal Habitat Cretaion (Indirect Placement)	11. Deep Water Habitat Creation	12. Amrun - Coastal Habitat Creation (Direct Placement)	13. Amrun - Deep Water Habitat Creation (Geobags)	14. Topsoil for Agriculture
Offshore														
TSHD mobilisation, demobilisation, dredge program hire	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$2,500,000	$400,000	$2,500,000	$2,500,000	$2,500,000	$400,000	$400,000	$2,500,000
Pipeline mobilisation and demobilisation	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$5,000,000		$7,000,000	$7,000,000		$7,000,000		$5,000,000
Workboat	$500,000	$320,000	$320,000	$320,000	$320,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000	$320,000
TSHD Dredge and pump ashore	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$7,500,000		$7,500,000	$7,500,000		$7,500,000		$5,000,000
TSHD Dredge and seabed placement											$2,500,000			
Tug and Barge mobilisation and demobilisation						$2,000,000		$2,000,000					$2,000,000	
Place nearshore with tug, barge and geobags						$800,000		$800,000					$800,000	
Onshore														
Dredge management ponds construction		$14,500,000	$14,500,000	$14,500,000	$14,500,000									$14,500,000
Processing dewatering/desalination/ripening	$1,000,000	$500,000	$1,000,000	$1,000,000	$1,000,000									$1,000,000
Processing screening/blending/mixing		$4,000,000	$5,500,000	$5,500,000	$4,000,000									$5,500,000
Sheet piling for reclamation area	$4,000,000													
Monitoring and management	$250,000	$250,000	$500,000	$500,000	$500,000	$250,000	$500,000	$250,000	$500,000	$500,000	$250,000	$500,000	$250,000	$250,000
Transport - road transport from site to end user		$6,000,000	$6,000,000	$3,000,000	$6,000,000									$6,000,000
Totals	$18,250,000	$38,070,000	$40,320,000	$37,320,000	$38,820,000	$6,050,000	$16,000,000	$3,950,000	$18,000,000	$18,000,000	$5,750,000	$15,900,000	$3,950,000	$40,070,000
$/m^3	37	76	81	75	78	12	32	208	36	36	12	837	208	80

Basis of Estimate (Assumptions):
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6 Dredge and seabed placement ($5-$10/m^3). Assume $5/m^3 for 500,000m^3 = $2.5M (habitat creation).

7 Tug (2No.) and Barge (2No.) mobilisation and demobilisation and hire $2.0M. Tug and Barge transport (split hopper) for shoreline protection and deep water habitat creation (geobags) options.

8 Place dredge sediment into geobags on barge and place filled geobags nearshore with tug and barge $40/m^3, 20,000m^3= $800,000. Assume fill geobag at a location within 10km radius of dredge area, estimate 2 tugs, 2 barges 60 hour per week, 28 day placement campaign 240 hour per tug. (shoreline protection (geobags), Amrun shoreline protection (offshore beams - geobags), Amrun deep water habitat creation (geobags)). Assumes TSHD is concurrently supplying dredge material to barge geobags operation and also disposing of balance of material (majority) to offshore DMPA.

9 No allowance of downtime due to weather or sea state.

Onshore Estimated Costs

10 Onshore construction of dredge management ponds 50ha area (5 pond options), sediment material placed 3.0m deep (bulk factor 3x) for treatment. Estimate pond embankment dimensions 500m wide x 1000m long x 3.0m deep (bulking factor x3), bund walls volume 97,200m^3 (constructed) at $150/m^3 supply and place a combination of site and imported material including pond liner = $14.5M. Transport imported material assumes 97,200m^3 bulk factor x1.2 (116,640m^3), truck and dog 20m^3 capacity, 10 trucks doing 5832 trips @ 2hour 50km round trip = 11,664 total hours or 117 days. Estimate 30 weeks construction 60h/week, 2 x 36t excavator, 2x 19t wheel loader, 1x water truck. 10 hours/day, 6 days per week, 30 weeks = 1800h ea. vehicle

11 Processing treatment for dewatering and desalination and soil ripening in dredge management pond assume 2500h per year, excavator 36t and D6 Dozer at $150/h each = $750,000 and 2x 4WD passenger vehicles = $100,000. Assume $1M where soil ripening or a higher level of treatment processing and desalination required for end use (road base, lining material, concrete products, topsoil for agriculture). Assume $500,000, 2300h (38 weeks) where less treatment processing and desalination is required for reuse option (construction fill).

12 Processing screening/blending/mixing reuse material post-treatment for end user with $1M screening plant and equipment at assumed production rate 50m^3/h, 10,000h (4No. screening plants for 2,500hour/yr.)=$4M, with 2x excavator 36t and 2x 19t wheel loader 2500h each at $150/h $1,500,000. Assume $5.5M for end uses requiring higher level of processing (road base/pavement, lining material, top soil for agriculture). Assume $4.0M for onshore end uses requiring less processing (construction fill, concrete products).

13 Sheet piling perimeter wall for reclamation area, assume 20ha area 200m long (berth) x 75m wide, average depth 5m (min depth 0m to 10m depth). Sheet piling (add 1/3 length for toe height) berth 200m length x 13m high, side walls 75m long x 6.5m high (avg.) 3,925m^2 x $700/m^2=$2.50M. plus whalers 610m length x $300/m= $78,000. Total sheet piles $2.58M , plus 25% remote location = $3.225M. Mobilisation and demobilisation piling rig and barge $250,000. Sheet piling rig $300/hr. for 20 weeks (1000h) $300,000. say $4M.

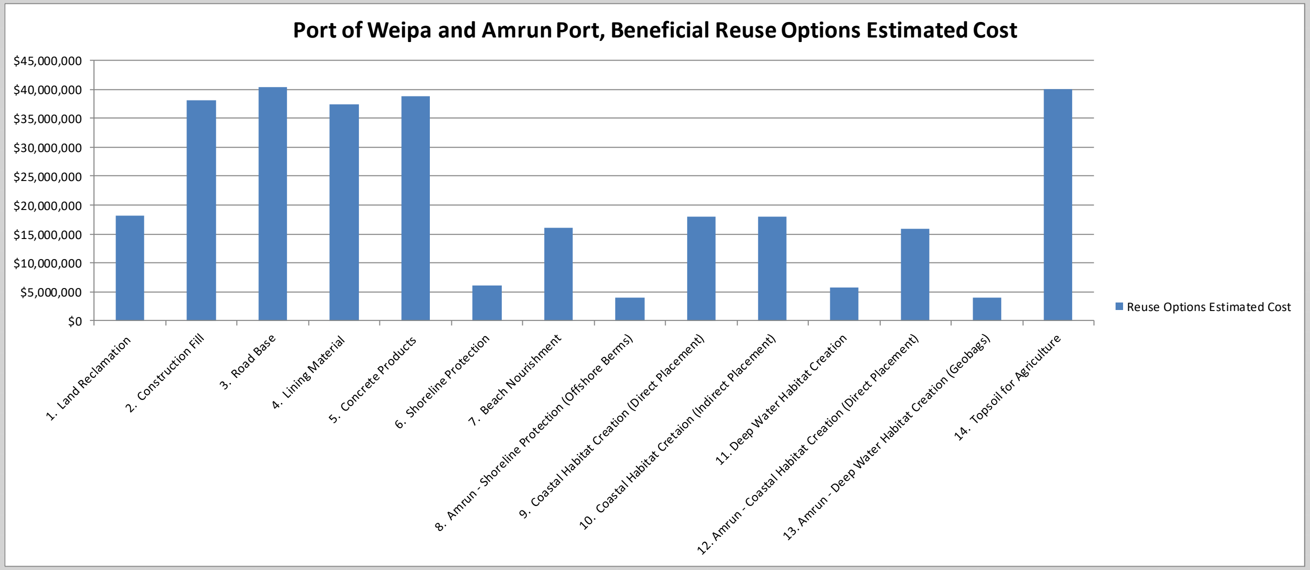
14 Monitoring and management, estimate $175,000 per year for site monitoring, investigation and reporting plus laboratory testing $75,000 . Assume $250,000 for end uses requiring a lower level or material quality control (land reclamation, deep water habitat creation, shoreline protection (geobags) and topsoil for agriculture). Assume $500,000 for end uses requiring a higher level of materials quality control (road base/pavement, lining material, beach nourishment and costal habitat restoration).

15 Transport processed sediment material off site to end user. Estimate 200m^3/h loading for 36t excavator and 19t wheel loader 2,500h at $150/h each =$750,000. Assumed 50km round trip, 20m^3 truck and dog 25,000x2hour trips 50,000h at $120/h = $6,000,000. Assume $3M for 1 hour round trip for lining material if used at nearly Weipa landfill facility.

16 Mobilisation rate depends on location of vessels and pipeline at the time.

17 No allowance for on costs such as project management, administration, design, approvals, specialist engineering or scientific studies or construction of an access road to intermediate storage location.

18 No contingency.



Appendix B Greenhouse Gas Emissions Calculations

Appendix B. Table 1 - Greenhouse Gas Emissions Calucations for Port of Weipa and Amrun Port Beneficial Reuse Options

			Beneficial Reuse Option													
			Recycle Dredge material as an engineering material								Reuse Dredge material as an environmental enhancement					Reuse in agriculture
Area	**Key Activity**	**Fuel Type**	1. Land Reclamation	2. Construction Fill	3. Road base	4. Lining Material	5. Concrete Products	6. Shoreline Protection	7. Beach Nourishment	8. Amrun - Shoreline Protection (Offshore Berms)	9. Coastal Habitat Creation (Direct Placement)	10. Coastal Habitat Creation (Indirect Placement)	11. Deep Water Habitat Creation	12. Amrun - Coastal Habitat Creation (Direct Placement)	13. Amrun - Deep Water Habitat Creation (Geobags)	14. Topsoil for Agriculture
Dredging	TSHD	Fuel oil	974	974	974	974	974	974	1,521	152	1,521	1,521	974	152	152	974
	Tug for tug and barge spread	Diesel						183		183					183	
	Workboat	Diesel	207	132	132	132	132	207	207	207	207	207	207	207	207	132
	Floating pipeline booster station	Diesel									434	434		434		
Dredge Pond construction	Excavator 36t	Diesel		392	392	392	392									392
	Wheel Loader 19t	Diesel		147	147	147	147									147
	Tip truck and dog 20m^3	Diesel		794	794	794	794									794
Processing dewatering/desalination/ripening	Excavator 36t	Diesel	327	163	327	327	327									327
	Dozer D6	Diesel	299	150	299	299	299									299
	Passenger vehicle	Diesel	54	54	54	54	54									54
	Screening plant	Diesel		813	813	813	813									813
Processing screening/blending/	excavator 36t	Diesel		817	817	817	817									817
	Wheel Loader 19t	Diesel		748	748	748	748									748
Sheet Piling	Tug for barge	Diesel	107													
	Piling Rig	Diesel	163													
Transport	Excavator 36t	Diesel		408	408	408	408									408
	Wheel Loader 19t	Diesel		306	306	306	306									306
	Tip truck and dog 20m^3	Diesel		4,083	4,083	2,041	4,083									4,083
			2,130	9,981	10,294	8,253	10,294	1,363	1,728	542	2,162	2,162	1,181	793	542	10,294

	1. Land Reclamation	2. Construction Fill	3. Road base	4. Lining Material	5. Concrete Products	6. Shoreline Protection	7. Beach Nourishment	8. Amrun - Shoreline Protection (Offshore Berms)	9. Coastal Habitat Creation (Direct Placement)	10. Coastal Habitat Creation (Indirect Placement)	11. Deep Water Habitat Creation	12. Amrun - Coastal Habitat Creation (Direct Placement)	13. Amrun - Deep Water Habitat Creation (Geobags)	14. Topsoil for Agriculture
Dredging	1,181	1,106	1,106	1,106	1,106	1,363	1,728	542	2,162	2,162	1,181	793	542	1,106
Dredge Pond construction	-	1,333	1,333	1,333	1,333	-	-	-	-	-	-	-	-	1,333
Processing dewatering/desalination/ripening	680	1,180	1,493	1,493	1,493	-	-	-	-	-	-	-	-	1,493
Processing screening/blending/mixing	-	1,565	1,565	1,565	1,565	-	-	-	-	-	-	-	-	1,565
Sheet Piling	269	-	-	-	-	-	-	-	-	-	-	-	-	-
Transport	-	4,797	4,797	2,756	4,797	-	-	-	-	-	-	-	-	4,797
Total	2,130	9,981	10,294	8,253	10,294	1,363	1,728	542	2,162	2,162	1,181	793	542	10,294