Port of Mackay

Appendix E

Beneficial Reuse Assessment

Beneficial Reuse Assessment

Port of Mackay

17 April 2019

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Brisbane QLD 4000
Australia

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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 Mackay. 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 Port.

The beneficial reuse investigations were undertaken in two main stages:

1. Sediment properties investigations

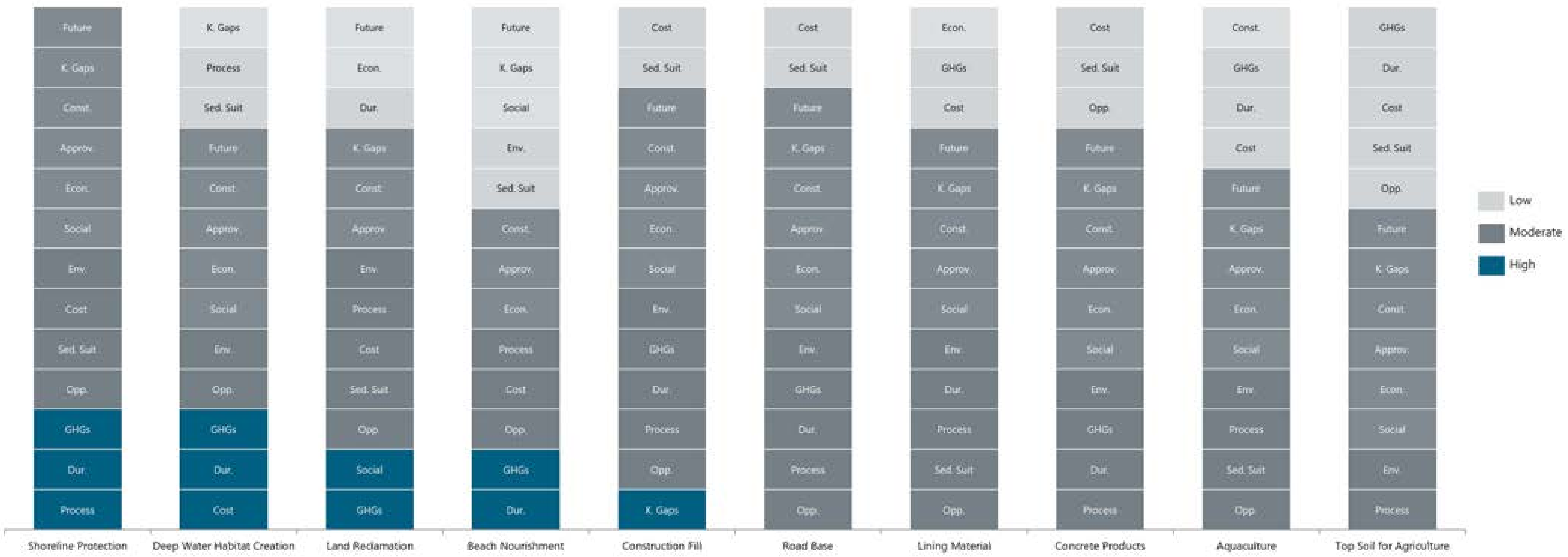
2. Beneficial reuse options identification and analysis.

Performance criteria – The primary considerations of analysis are the properties of the sediment to be dredged, collectively known as sediment suitability. The thirteen 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)
- 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 A.

Port of Mackay: Beneficial Reuse Opportunities - Ranked Performance Evaluation Summary



Options with Highest to Lowest Number of 'High' Performance Evaluations

Figure A: Beneficial reuse options performance summary

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 solution for the Port's maintenance dredge material.

Five reuse options ranked well based on the number of 'high' performance evaluation scores. These options were shoreline protection and deep water habitat creation, which ranked equal highest, land reclamation and beach nourishment ranked equal third followed by construction fill ranked fifth. The 'greenhouse gas' and 'duration' performance criteria were the only common criteria that were rated high across these options (4x for 'greenhouse gas' and 3x for 'duration'). The single high performance rating for construction fill was for 'knowledge gaps'.

Reuse of the dredge material for engineering purposes would require significant treatment and processing of the dredge sediment. Even with time and effort to improve the dredged materials' characteristics it would still likely need to be blended in small proportions with other higher quality materials to be able to be used in applications such as construction fill, road base or concrete products.

While the properties of the dredge sediment may mean it is potentially suitable for reuse in some options (e.g. shoreline protection, land reclamation, lining material or aquaculture) their feasibility relies on demand and (in some cases) the final placement location being favourable, especially in relation to the local ecosystem, including wave climate and currents.

Several reuse options were identified where most of the performance criteria were scored moderate, with only a few low performance criteria. These include options for material use as construction fill, road base, lining material and concrete products. 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 support realisation of six of the beneficial reuse options (construction fill, road base, lining material, concrete products, topsoil for agriculture and aquaculture). Subject to user demand for a 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 principal issue with beneficial reuse options for the Port is the very high proportion of fines (silt/clay) in the 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 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 is suitable for the fine dredge material.

Investigation of potential near-shore habitat 'creation' opportunities for the Port of Hay Point maintenance dredge material is currently underway. The outcomes of these investigations may also be relevant to beneficial reuse of the Port of Mackay dredge material.

Dredging task – There is approximately 75,000m^3 of material to be dredged every three years from the Port for maintenance of depth in operational areas. Dredge material is transported to the Dredge Material Placement Area, approximately 3km north-east of the Port. The material to be dredged is fine silt/clay material (80.3%), mixed with sand (18.9%) and small amounts of gravel material (0.9%). Most of the sediment to be dredged (about 59%) is in the swing basin and channel.

Analysis of the geotechnical properties of 18 samples of the material shows:

- Material typically exhibits high to very high fines (silt and clay) content
- There are limited areas where coarse-grained sediments (sand/gravel) occur, but these appear to prevail at the Port entrance and near Berth Number 4
- Fine-grained sediments may be suitable for low load applications following dewatering and compaction, noting that this material may take many months to many years to consolidate
- Fine sediment is likely to contain high plasticity clay with all but one sample suggesting a 'very high' potential for volume change
- Sediment to be dredged is likely to have very high moisture content and therefore significant effort would be necessary to dry out the sediment to enable 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 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 beneficial reuse analysis of the potential reuse options shows that:

No substantial demand identified – None of the options have a clear existing demand for the reuse of material that would require minimal infrastructure. Several options require significant new infrastructure construction e.g. onshore dredge management ponds or sea wall. No substantive demand for the dredge material was identified for either the concrete products or top soil for agriculture options.

Level of treatment required – All 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 land reclamation, lining material, shoreline protection and aquaculture it is likely that the sediment material could be utilised with relatively less treatment or additives.

Estimated costs – The cost of the current dredge program with placement at sea is about $0.82 million including items such as dredge mobilisation, demobilisation and daily hire for the duration of the five day dredging program. Six of the beneficial reuse options involving onshore treatment and processing are estimated to cost significantly more (up to fifteen times) than the current annual maintenance dredging program. Estimated costs for the first dredging program are high due to the need to build infrastructure (e.g. onshore placement containment area, pump out mooring facilities and pipeline) to enable beneficial reuse. All six options involving onshore temporary storage were of low performance with respect to cost (more than $10 million per dredge program) with three options (land reclamation, shoreline protection and beach nourishment) being of moderate performance (between $3million and $10million per dredge program). Only the deep-water habitat creation option has an estimated cost that is similar to traditional offshore placement (less than $3million/yr.) and is rated to be high performance with respect to cost.

Greenhouse gas emissions – The options that did not require intermediate storage were of high performance (less than 1,500t CO_2 equivalent) with respect greenhouse gas emissions. The options that required onshore placement were of low performance (greater than 3,000t 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 low performance due to the colour of the sediment (brown and grey to dark grey) being unlikely to be acceptable if placed on beaches.

Social implications – The land reclamation option for reusing dredge material was 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. The beach nourishment option was rated as low social performance because dredged material colour if placed on beaches is unlikely to be acceptable to the community.

Economic Opportunities –The reuse options of land reclamation and lining material were 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 some limited economic opportunities for enhancing Port or community capability.

Approvals – The reuse options of shoreline protection, beach nourishment and deep-water habitat creation will require careful scientific investigation and specialist studies and significant effort to gain necessary regulatory approvals. All the options were assessed as moderate performance in terms of there being an existing recognised approval pathway.

Knowledge Gaps – The construction fill option has few knowledge gaps and less than one year of further work would be required to progress the option. Conversely, the two options for reusing dredge material as beach nourishment or deep-water habitat creation 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.

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.

The Port of Mackay (the Port) is located approximately four kilometres north of the Pioneer River mouth in Mackay, on the central Queensland coast (Figure 1-1). The Port is within the Great Barrier Reef World Heritage Area (GBRWHA) but outside of the Great Barrier Reef Marine Park (GBRMP).

The Port commenced operations in 1939 and has continued to develop since this time. Facilities include four operational berths and associated loading/unloading facilities. Multiple commodities pass through the Port, including fuels, refined and bulk sugar, bulk molasses, liquid chemicals, bulk fertilisers, bulk grain, general cargo and iron concentrates.

Sedimentation of the Port occurs naturally and is caused by the transportation of sediment from ocean currents, swell and tides, and cyclonic activity. These sediments require periodic removal from the navigational areas to maintain safe and efficient operational depths. NQBP conducts maintenance dredging within the Port to maintain these depths.

NQBP has commenced work on a strategic assessment for ongoing management of marine sediments at the Port, known as the *Port of Mackay - Sustainable Sediment Management (SSM) Assessment for Navigational Maintenance* ('The SSM Project'). As part of the SSM Project, NQBP commissioned Advisian to assess the properties of marine sediment that naturally accumulate in the navigational areas of the Port (maintenance material) and undertake an investigation of options for beneficial reuse of the marine sediments.

Advisian's work for the SSM project has been undertaken as a two-stage approach:

1. A sampling and analysis program to assess sediment properties including geotechnical, geochemical and cement binder characteristics of the maintenance dredge material

2. Comprehensive identification and analysis of beneficial reuse options for the maintenance dredge material.

The sediment investigations undertaken in the first stage are described in detail in the *Marine Sediment Properties Report, Port of Mackay, Advisian December 2018*, and are summarised in Section 2.1 below. This report presents the outcomes of the second stage of Advisian's work

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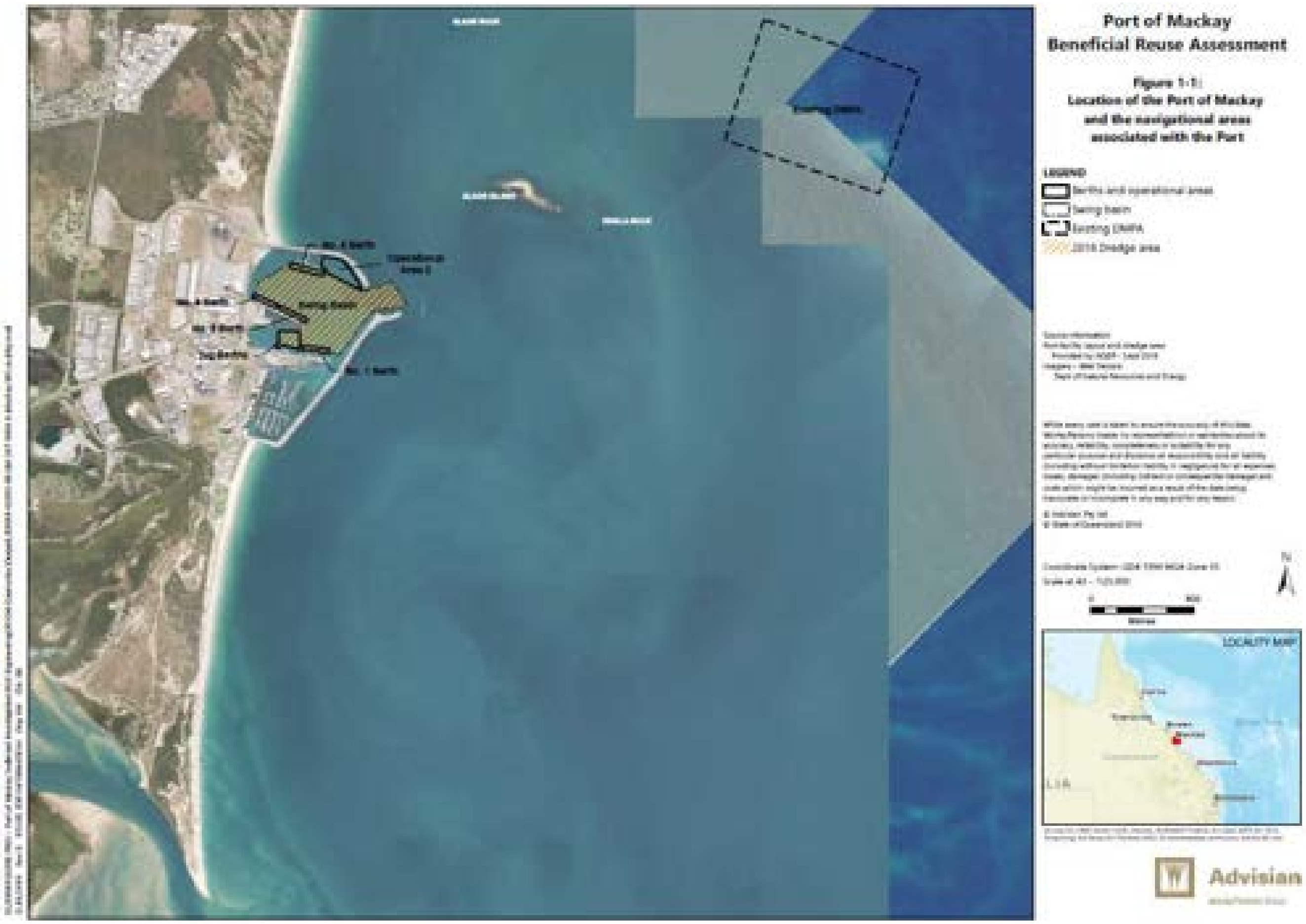

Figure 1-1 Location Plan

2 Maintenance dredge material

2.1 Sediment properties

Targeted field investigations were undertaken in September 2018. The total number of samples taken to support the beneficial reuse assessment was 18, with the selection of sample locations based on an approximately even spatial distribution across each navigational area. This information was supplemented (where relevant) with information derived from sampling for the separate *Port of Mackay Sediment Characterisation Report* (Advisian, 2018a).

2.1.1 Geotechnical characteristics

The sediments encountered in the Port navigational areas were predominantly fine-grained (silt/clay), with only two of the 18 sampling locations (one at the Port entrance and the other at the western extent of the swing basin) being classified as coarse-grained soil. Figure 2-1 shows average particle size distribution proportions across Port areas. Fines content in the samples generally ranged from 44% to 98%, with an average value of 74%. Hydrometer results suggest that silt and clay proportions within the sediments are approximately equal but Atterberg limits results indicate that the materials will behave in a predominantly clay-like manner. The sediment colour was typically brown or grey to dark grey.

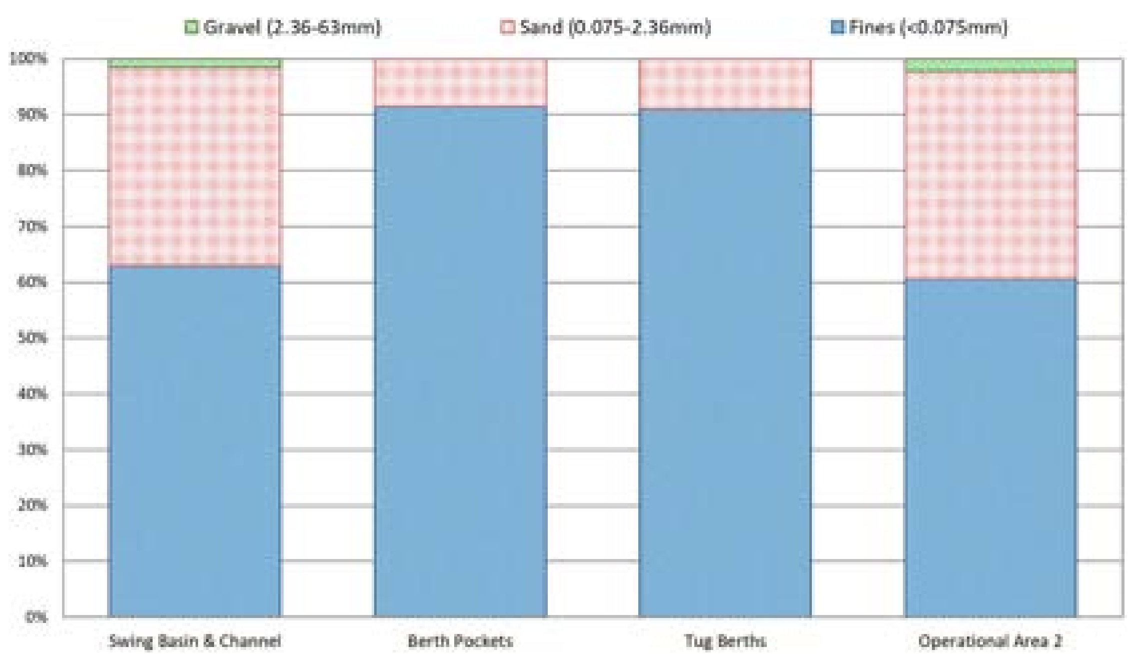

Figure 2-1 Average Particle Size Distribution (gravel / sand / fines proportions) by area

The plasticity of the fine-grained soils at the Port is generally very high, with only one of the fine-grained samples recording a reading of medium plasticity. For all fine-grained samples tested, the moisture contents were found to be higher than the corresponding liquid limits, indicating these in-situ sediments are likely to be sensitive to stress. The natural moisture content of the fine-grained sediments was higher than the liquidity index at most Port areas, indicating that these soils may be stable in an undisturbed state but a sudden change in stress may transform them into a liquid state.

Linear shrinkage (LS) results between 11.0% and 26.5% and plasticity index (PI) results between 28% and 106% were recorded. Most samples tested indicated a generally "very high" potential for volume change.

The test results suggest that the fine-grained sediments at the Port include a combination of organic and inorganic materials, with organic soils being more prevalent within the Berth Pockets and Tug Berths. The port sediments would be referred to as 'calcareous soil' due to the proportion of carbonate generally ranging from 2% to 10% (i.e. less than 50% and therefore not 'carbonate soils').

Estimations were undertaken which showed a clear trend of decreasing in-situ density with an increase in fines content and suggested that in-situ bulk densities across most of the site fall within the range of 1.2 t/m^3 to 1.6 t/m^3.

Minimum / maximum dry density testing was performed on one of the silty sand samples with results suggesting that the placed dry density of this material may fall in the range of 1.14 t/m^3 to 1.62 t/m^3 depending on the level of compaction or method of placement utilised onshore. Direct shear testing was also performed and indicates that this particular sample material may achieve a friction angle of approximately 36° after compaction and loading. This value is within the lower end of the range generally associated with a 'dense' sand deposit and suggests that the coarse-grained sediment may be suitable for medium loading applications following adequate compaction.

Standard compaction testing was undertaken on a fine-grained sample to provide an indication of the maximum dry density (MDD) that may be achieved during future placement of this type of material and the optimum moisture content (OMC) required to achieve this density. The test resulted in a MDD of 1.45 t/m^3 and an OMC of 23.3%, which corresponds to a bulk / wet density of 1.79 t/m^3. Consolidated undrained (CU) triaxial test results indicate that the fine-grained sediments may be suitable for low to medium loading applications following adequate drying out and compaction (noting that fine-grained material typically requires a long time to adequately drain and consolidate), with the lower end of this range applicable to those locations with highly plastic, organic sediments (e.g. Berth Pockets). The oedometer testing results indicate that the sediment is likely to be within the typical range expected for clays and silts and therefore some of these materials may take many months to many years to consolidate, depending on the level of compaction and drainage path length.

The permeability test results are generally within the range expected for the types of sediments tested, with "poor" drainage characteristics being reported for clay samples and "good" drainage characteristics for a silty sand sample.

2.1.2 Cement binder characteristics

Cement laboratory testing showed the sediment to be almost 100% in crystalline mineral form, chiefly quartz. These materials would not chemically react with other materials to create a geopolymer cement in their current form. Further analysis showed the presence of significant levels of iron and calcium which would further interfere with any geopolymer reactions.

2.1.3 Geochemical characteristics

Analysis indicated that the maintenance dredge material may contain Potential Acid Sulfate Soils (PASS) in concentrations greater than relevant action criteria. However, Acid Neutralising Capacity (ANC) was also detected in all samples with concentrations sufficient to negate acidity. The marine sediments are unlikely to require treatment (e.g. neutralisation using lime) dependent on the dredging and management methods applied.

All samples are considered highly saline and therefore if sediments are placed on land without treatment, salinity is likely to degrade the quality of terrestrial soils and may impact the quality of receiving waters.

Organic material (ranging from 1 to 5.9%) was reported for all samples analysed, albeit in quantities that are considered inadequate to support plant growth. The higher levels of organic material were detected in finer textured samples.

Contamination status is reported separately in the *Port of Mackay Sediment Characterisation Report* (Advisian, 2018a). It is notable that this assessment concluded that as per the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia, 2009) assessment framework, the sediments to be dredged from the Port are considered suitable for unconfined ocean placement in the Dredge Material Placement Area (DMPA). For beneficial reuse options analysis, it is assumed that maintenance dredge material is not contaminated.

2.2 Dredging requirements

NQBP has existing approvals in place for maintenance dredging within the Port, including a ten-year Sea Dumping Permit (2012-2022) and an associated and approved Long-Term Dredge Management Plan (LTDMP). As set out in the LTDMP (WorleyParsons, 2010), there are potentially four major dredge programs within the 10-year approval with each program removing an estimated 130,000m^3 of material.

NQBP commissioned a bathymetric analysis (Ports & Coastal Solutions, 2018) as another component of the SSM Project at the Port. This assessment of future sediment management predicted a maintenance dredging requirement of 500,000m^3 to be relocated over 20 years, equating to a dredge program that would remove an estimated 75,000 m^3 of material every three years. This dredging volume assumes over/insurance dredging of 0.6m to enable the dredging program to maintain declared depths over the period. Bed levelling would be undertaken after maintenance dredging to level the seabed and remove high spots.

Tropical cyclones have the potential to increase sedimentation in the Port of Mackay. Volumes between 35,000m^3 and 50,000m^3 can be deposited during a cyclone with an additional increase in sedimentation in the months following a cyclone event.

The major maintenance dredging at the Port has historically been undertaken through use of the Trailing Suction Hopper Dredge (TSHD) 'Brisbane', under contract to NQBP. This type of dredge is well-suited to the maintenance dredging requirements of the Port. Under the current arrangements the dredge material is placed at the approved DMPA approximately 3km north-east of the port entrance per the conditions set out in the Port's 10-year Sea Dumping Permit.

The marine sediment properties investigations (Advisian, 2018b) assumed a maintenance dredge volume of approximately 135,600m^3 is removed from the Port navigational areas every two to three years. For the purposes of this beneficial reuse assessment a maintenance dredge volume of 75,000m^3 is assumed to be removed from the Port navigational areas every three years. A breakdown of the dredge volume estimates per dredge area is set out in Table 2-1.

Table 2-1 Estimated dredge volumes by area, approximated by PSD and SSM Project

Area	Marine Sediment Properties Report Dredge Volume (m^3)	Assumed Beneficial Reuse Assessment Dredge Volume (m^3)	Proportion of Total Dredging (%)
Swing Basin & Channel	80,000	44,250	59
Berth Pockets	27,000	15,000	20
Tug Berths	1,600	750	1
Operational Area 2	27,000	15,000	20
All areas combined	**135,600**	**75,000**	**100**

The maintenance material is predominantly fine-grained, mixed with smaller proportions of sand and (in some areas) gravel. It is considered impractical to separate sediment types within a dredge area during dredging at the Port. The two locations in which sand dominated the particle size distribution do not represent a sufficient quantity to warrant targeted dredging to support a beneficial use separate from that of the remaining material. As such, it is considered unlikely 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) will be feasible. Consequently, the beneficial reuse analysis is focused on potential reuse options for the fine-grained material and assumes the properties for that material as described in Section 2.1 above.

3 Analysis method

A description of the considerations for analysis is provided below with a description of the method of assessment, including the identification of options, followed by detailed analysis.

3.1 Considerations

The main considerations of the analysis are the properties of the maintenance material and the assumed maintenance dredging requirements.

In addition, it is considered reasonable for the analysis to consider regional context, as potential beneficial reuse options may be limited or facilitated by the location of the potential downstream beneficial use relative to the maintenance dredge areas.

Other considerations including the beneficial reuse route, the dredge and dredge method and broad environmental approval requirements are discussed below. Discussion of beneficial reuse route, dredge and dredge method is largely drawn from Permanent International Association of Navigational Congresses (PIANC) publications such as *Dredged material as a resource: Options and Constraints* (PIANC, 2009).

3.1.1 Beneficial reuse route

The potential feasibility of beneficial reuse options depends heavily on the cycle from dredging to end use. There are several potential approaches which may be used in conveying dredged material towards a beneficial reuse, including direct use, treatment and intermediate storage.

3.1.1.1 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[1].

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[1] 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.

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.

3.1.1.2 Treatment

For dredged material that does not directly meet 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.

3.1.1.3 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 reuse.

3.1.2 Dredge and placement method

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, or the dredge method may enable treatment of sediments during dredging.

A trailer suction hopper dredger may allow 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. 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 methods may be specified for certain types of reuse such as:

- Diffusers may be used to reduce the velocity of a dredged material discharge stream, limit suspension of material and enable coverage of an area with a homogeneous layer of sediments
- Where access for direct unloading is challenged (e.g. shallow areas and/or floating pipeline placement is sub-optimal), placement may be executed using a front discharge from the dredge, propelling material in an arc through the air ('rainbowing') to deposit the material on the water surface or onshore
- Direct placement of material on the seabed from a pipeline or via a diffuser may be undertaken to reduce turbidity through the water column.

Matching of dredging, placement and reuse logistics is a significant consideration in the successful development of a beneficial reuse project. 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. 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.

3.1.3 Environmental approvals

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.

As noted in Section 2.2, NQBP has existing approvals in place for maintenance dredging within the Port, including placement of material at sea within the approved DMPA.

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.

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: ▪ World Heritage properties ▪ National Heritage places ▪ listed threatened species and communities ▪ listed migratory species ▪ Great Barrier Reef Marine Park ▪ Commonwealth marine areas	Dredging and Placement Onshore reuse Offshore reuse
Approval for activities within the Great Barrier Reef Marine Park	*Great Barrier Reef Marine Park Act 1975* Great Barrier Reef Marine Park Authority (GBRMPA)	Activities within the Great Barrier Reef Marine Park	Dredging and Placement 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, Mines and Energy (DNRME)	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

Approval	Legislation and administering authority	Potential trigger / activity covered	Potentially applicable reuse component
Quarry material sales permit	*Forestry Act 1959* Queensland Department of Agriculture and Fisheries (DAF)	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)	Dredging and placement Onshore reuse Offshore reuse
Port Development Approval and Material Change of Use where a use is inconsistent with the Land Use Plan	Planning Act, *Planning Regulation 2017* (Planning Regulation), *Transport Infrastructure Act 1994* (TI Act) and relevant code: Port of Mackay 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
Development in priority port's master planned area	Planning Act, Planning Regulation, Master plan for the Priority Port of Hay Point/Mackay NQBP or Mackay Regional Council (MRC) (dependent on location)	Development identified as assessable in the port overlay for the master planned area (NB applicable when the port overlay has been finalized)	Dredging and placement Onshore reuse Offshore reuse
Material Change of Use, Reconfiguration of a Lot or Operational Works under the Local Government Planning Scheme	Planning Act, Planning Regulation, planning scheme of the MRC MRC	Works in the local government area that are inconsistent with the designation of the planning scheme and / or require approval under the scheme	Dredging and placement Onshore reuse Offshore reuse

Approval	Legislation and administering authority	Potential trigger / activity covered	Potentially applicable reuse component
Operational Work - Tidal works	Planning Act, Planning Regulation, 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: DAF	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 Relevant Activity (ERA) 16 – extractive and screening activities - dredging	Planning Act, Planning Regulation, *Environmental Protection Act 1994* (EP Act 1994) Referral agency: SARA Technical advice: DES	Dredging in offshore lots	Dredging and placement
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 and placement
Operational work - Clearing native vegetation	Planning Act, Planning Regulation, *Vegetation Management Act 1999* Referral agency: SARA Technical advice: DNRME	Clearing of native vegetation	Dredging and placement Onshore reuse

Approval	Legislation and administering authority	Potential trigger / activity covered	Potentially applicable reuse component
Operational work – High impact earthworks in a wetland protection area	Planning Act, Planning Regulation Referral agency: SARA Technical advice: DES	Earthworks in and near wetland protection areas	Dredging and placement Onshore reuse Offshore reuse
Permit to tampering with animal breeding places	*Nature Conservation Act 1994* (NC Act), *Nature Conservation (Administration) Regulation 2006* DES	Tampering with native animal breeding places during clearing and grubbing activities.	Dredging and placement Onshore reuse
Protected plants clearing permit	NC Act, *Nature Conservation (Administration) Regulation 2006* DES	Clearing flora species protected under the NC Act	Dredging and placement Onshore reuse

3.2 Options identification

A multi-disciplinary team was used to consider the available information and identify potential beneficial reuse options. The team's expertise included areas of ports dredging, dredge material management, civil engineering, geotechnical engineering, soil science, concrete and construction material manufacturing and environmental management, with the Advisian team supplemented by input from Royal Boskalis Westminister N.V. and Wagners. The options identification process also leveraged the local knowledge of NQBP staff and, in addition to the considerations set out at Section 3.1, contemplated the outcomes of the beneficial reuse assessment undertaken for the nearby Port of Hay Point (Advisian, 2016).

For potential coastal habitat restoration opportunities consideration was given to a study commissioned by NQBP, *Nearshore environment change detection and accessibility assessment Slade Point to Cape Upstart* (2rog, 2018). This study assessed opportunities for habitat restoration in the area of the Port of Mackay (Campwin Beach north to Cape Upstart) including a regional assessment of changes to the near-shore environment (mangroves and saltmarsh) using time-lapse examination of Landsat satellite imagery. Areas of potential nearshore habitat restoration were prioritised in the study according to dredge accessibility.

3.3 Options analysis

The considerations described above informed the analysis undertaken for each of the options. The analysis includes a discussion of the individual features, processes or characteristics related to each option to enable comparison and 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 a reasonable and practicable configuration to achieve the beneficial reuse outcomes of that option.

3.3.1 Sediment suitability

Analysis of sediment suitability was undertaken based upon the sediment properties. For each opportunity the sediment properties were 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 were considered for 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 suitability assessment is conceptual and as such if a specific beneficial reuse option were progressed, the sediment suitability would require confirmation through further investigations.

3.3.2 Cost and greenhouse gas emissions

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 A and B 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. There are numerous alternatives and sub-options associated with each of the options including for downstream processing applications and geographical location of the reuse. For the purposes of comparative analysis delivery of the dredged material (following processing if relevant) to the beneficial reuse location (detailed in the process description) is used as the boundary of the assessment, e.g. for road base this includes delivery to the assumed location of use.

3.3.2.1 Cost Estimate

The basis of the conceptual cost estimate is pricing of the key activities associated with the offshore and onshore tasks for each beneficial reuse option. Assumptions for vessels, plant and equipment, sailing distance, production rates, local conditions and unit rates were 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, dredging, demobilisation and production rate costs were estimated with consideration of NQBP data and with the assistance of 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 construction to an 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, therefore providing an income stream.

3.3.2.2 Greenhouse gas emissions estimate

The basis of the greenhouse gas emissions calculation is estimation of the emissions associated with the 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 is provided in Appendix B.

3.3.3 Performance summary

To facilitate presentation of the qualitative comparison of the options, a performance evaluation key was developed in consultation with NQBP, as shown in Table 3-2. This key was utilised to develop a summary of performance for each option. This summary is included in the analysis for each option and has been aggregated to enable easy comparison between the options.

Table 3-2 Performance evaluation key

Performance Criteria	High Performance	Moderate Performance	Low Performance
Opportunity	**HIGH:** There is an existing demand in a location accessible to the Port, requiring	**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

Performance Criteria	High Performance	Moderate Performance	Low Performance
	minimal infrastructure needs		
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 $3M per dredge program	**MODERATE:** $3M to $8M per dredge program	**LOW:** More than $8M per dredge program
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
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:** < 1500t CO_2 equivalent in 1 year period	**MODERATE:** >1500t and <3000t CO_2 equivalent	**LOW:** >3000t 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

Performance Criteria	High Performance	Moderate Performance	Low Performance
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
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 by 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 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
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

The beneficial reuse analysis team developed a list of reuse and recycling options for analysis. The options were categorised as reuse for engineering material, environmental enhancement or agricultural applications. Options identified are outlined in Table 4-1 with regional context illustrated in Figure 4-1. Each beneficial reuse option was analysed by the multidisciplinary team.

Table 4-1 Potential beneficial reuse options

Engineering material	Environmental enhancement	Agricultural application
▪ Land reclamation ▪ Construction fill (low strength) ▪ Road base ▪ Lining material ▪ Concrete products (low strength) ▪ Shoreline protection ▪ Beach nourishment	▪ Deep water habitat creation	▪ Aquaculture ▪ Topsoil for agricultural use

The study by 2rog (2018) identified seven near-shore environments (mangrove and saltmarshes) that may benefit from restoration activity between Campwin Beach and Cape Upstart (north-west of Bowen). Six of these options are north-west of Bowen, while the closest site to the Port is approximately 100km to the north of Mackay on Whitsunday Island. Given the distance from the dredge area, none of these habitat restoration options are considered suitable for further investigation of potential beneficial reuse of the Port's maintenance dredge material.

4.1.1 Port of Hay Point dredge material investigation

It is notable that further investigations of potential near-shore habitat 'creation' opportunities for the use of Port of Hay Point maintenance dredge material are currently underway. The outcomes of these investigations once complete may be relevant to the Port of Mackay.

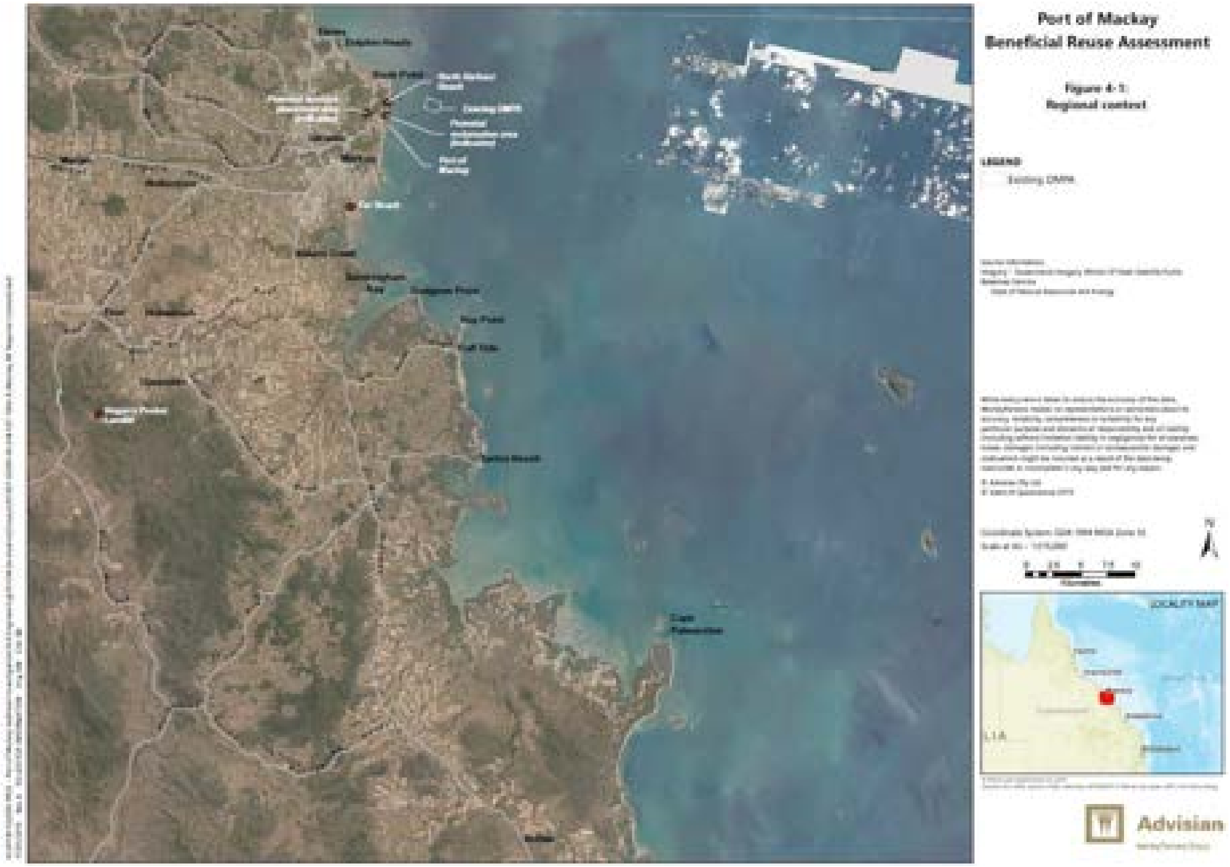

Figure 4-1 Regional context

4.2 Engineering material

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. It often 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. A common method of perimeter enclosure involves construction of an embankment with the seaward face incorporating some form of erosion protection e.g. graded rock or concrete revetment. For some uses, (e.g. wharf facilities) the enclosure may require a vertical face, achieved with steel sheet piling or caisson construction.

Sandy or coarse material is preferred for reclamation where the created land must have sufficient strength for construction purposes. It is possible to use 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. 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. Land required for industrial development usually requires sand or coarser material (PIANC, 1992).

4.2.1.2 Opportunity

The land use plan for the Port of Mackay identifies proposed future strategic port land, including a small reclamation area (approximately 16ha) adjacent to the existing north harbour wall (Figure 4-2). The reclamation area identified within the land use plan is to accommodate heavy lift of materials, including break bulk cargo to support future port operations. Another potential land reclamation opportunity was identified within the Half Tide Tug Harbour in the Port of Hay Point (Aurecon, 2012). This area was to accommodate future potential heavy lift of materials for port development. No other reclamation opportunities at or adjacent the Port have been identified.

There is no development timeframe for the Port of Mackay or Half Tide Tug Harbour reclamation opportunities. Only the Port of Mackay opportunity is further analysed as the Half Tide Tug Harbour opportunity is less favourable due to distance from the Port (approximately 20km). As the dredged material is fine-grained for this reuse opportunity the end use of the reclamation area is assumed restricted to one of small imposed loads. This may supplement a reclamation opportunity at that location for heavy loads through provision of material for subsidiary areas where heavy load-bearing uses are not proposed e.g. car parking to support a use.

Figure 4-2 Port of Mackay Land Use Plan, Proposed Future Strategic Port Land (Source: NQBP, 2009 (modified)) with potential reclamation area adjacent to north harbour wall (shaded blue)

4.2.1.3 Suitability of Mackay sediments

The volumes to be dredged are relatively small; however, dredged material may be suitable for a small reclamation project, not having future heavy load requirements i.e. a small part of the land reclamation opportunity identified in the Port of Mackay Land Use Plan.

As part of the assessment of the proposed land reclamation (low 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 4-2 (suitability categories as per Section 3.3.1).

Table 4-2 Suitability of dredge sediment for proposed low 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	Potentially suitable with treatment/processing
Linear Shrinkage	Potentially suitable with treatment/processing
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

4.2.1.4 Process description

Dredging and placement

Various types of dredging equipment may be used to develop land reclamation, including a Trailing Suction Hopper Dredge, Backhoe or Cutter Suction Dredge. Backhoes and Cutter Suction Dredges typically rely on barges or fixed pipelines to transport material from the dredge area to the placement site and have limited manoeuvrability. A Trailing Suction Hopper Dredge has greater mobility and can dredge and transport material to a placement location, or to a discharge point (and pipeline if necessary), dependent on draft restrictions. Depending on vessel, material and reclamation location, booster stations may be required to deliver material to the reclamation area. Given the requirement of the working Port it is considered that a Trailing Suction Hopper Dredge is the most appropriate dredge type for this beneficial reuse option.

Given that the dredge 'Brisbane' is based in Queensland and has historically been used for maintenance dredging at the Port, it is considered reasonable to assume that this or a similar dredge may be used for future dredging. The 'Brisbane' has the facility to pump out its hoppers through a nozzle mounted on the bow into a pipeline; however, there are numerous 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 pump-out coupling, pipeline and a mooring system for the dredge during pump-out. The draft of the dredge affects how closely it may approach shore, and consequently the pumping distance required to a potential reclamation area adjacent to the north harbour wall. The design depth of the harbour entrance and swing basin is 8.5m below Lowest Astronomical Tide (LAT). A dredge such as the 'Brisbane' has a draft of 6.25m, and with allowance of under keel clearance of 1m, the fully-laden dredge would be limited to where water depths are 7.25m. It is understood that the 'Brisbane' has a maximum pumping distance of 1.5km.

For the purposes of analysis, it is assumed that the dredge would moor at a pump-out point within the swing basin (adjacent to the north harbour wall at the existing Berth No. 5) and pump through a pipeline (to be installed on existing infrastructure) to the reclamation area. As the pumping distance is less than 1.5km, it is assumed that no booster pump is required.

The dredge is assumed to operate almost continuously i.e. typically 24 hours a day, seven days a week with minimal downtime. It is estimated that a straightforward dredge and place material at sea program would be five days duration. More complex dredge and pump ashore options involving additional hook up and pump out cycle time would be 10 days duration.

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 north harbour wall area is unclear, based on an assumption of material to be dredged for one campaign (75,000m^3) being placed on average 3m deep in an area adjacent to the north harbour wall, the area that may be occupied by dredge material is approximately 75,000m^2 (e.g. an area of 7.5ha, 150m wide and 500m long, depth between 0m to 6m (average 3m) to accommodate the bulked dredge material (approximately 225,000m^3)). An estimated 6m high outer wall is anticipated to be required to cope with the large tidal range. The proposed future strategic port land identified north of the harbour wall has an area of about 16ha which potentially provides capacity for the material from several dredging programs.

As the material to be dredged is predominately fine-grained, and the area is subject to waves and currents, enclosure of the reclamation area would be required to provide protection against erosion. The enclosure would likely incorporate a rock armoured revetment wall. Based upon the assumed dimensions (400m wide and 400m long) it is estimated that a perimeter revetment wall surrounding the reclamation area of approximately 8,400m^2 face area (internal and external faces), will require rock armouring.

Construction of the perimeter embankment would require importation of rock and sea wall material. For the purposes of analysis, the volume of material requiring importation to create the embankment is estimated to be approximately 39,200m^3, which is assumed to be brought to site on trucks from the nearby Port quarry or a location within the Mackay region (less than 40km round trip). The rock wall would require an internal liner (geofabric or similar) to contain the fine sediment material within the perimeter embankment. Construction of the reclamation area will require the use of earthworks plant and machinery (such as large excavators greater than 30 tonne). For the purposes of analysis, it is assumed that construction of the perimeter embankment may take approximately 30 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 fine material is likely to take a long time (potentially years) to drain and consolidate, such that it is available for subsequent low load bearing land use.

4.2.1.5 Potential constraints

Potential constraints associated with this option include:

- Land created is unlikely to have suitable strength for industrial (heavy load-bearing applications)
- Demand for reclaimed land of low strength within or adjacent the Port, or elsewhere in the region is considered likely to be substantially less than the 16ha of land identified as potentially being created through reclamation using maintenance dredge material
- Construction of the perimeter enclosure for the reclamation requires an estimated 39,200m^3 of suitable rock sea wall material, access to which in the local area may be difficult
- Dewatering needs to be managed to avoid potential impacts of discharge water quality (entrained fined material), near the reclamation area

- Infrastructure development would need to consider potential impact of extreme events (e.g. cyclones), including for pump-out and onshore rock wall infrastructure
- The 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 rocks to adjacent marine environment
- Limited area within the vicinity of the port requiring reclamation, and as such the use is unlikely to meet long term maintenance dredging needs
- Dredging and placement will cause some constraints to navigation, particularly the availability of Berth No. 5
- Potential acid sulphate soils, while unlikely to be a significant issue, will require consideration and potentially management during reclamation
- Location of infrastructure (e.g. pump-out coupling and pipeline route) will be constrained by existing uses (port users)
- Area to be reclaimed is within the GBRWHA, and as such development of land here may be subject to community and regulatory agency scrutiny
- Area to be reclaimed is currently used by the local community for recreational purposes including occasional surfing activity
- Land access including native title related issues may be an issue for the reclamation location.

4.2.1.6 Potential implications

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

- Creation of land within the port area with limited suitability for port uses (low-load uses only) may reduce area available for future port uses
- Reclamation will cause a small reduction in the extent of the GBRWHA, and will cause some (manageable) impacts to water quality in areas adjacent to the dredging and reclamation areas
- Construction of the reclamation area will cause loss of amenity to the local community, although recreational use adjacent to the reclamation area may be able to be re-established post-construction.

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. Dependent on how material is sourced to construct the project (e.g. the perimeter embankment) approvals associated with onshore reuse may also be required.

The *Sustainable Ports Development Act 2015* identifies the Ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as land reclamation. Whilst potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for land reclamation is not inconsistent with existing Queensland Government legislation and policy.

4.2.1.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the land reclamation option is provided in Table 4-3. 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 \$122/m^3 measured in situ.

Table 4-3 Land reclamation summary cost estimate table

Key activity	Land reclamation
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	\$820,000
Pipeline mobilisation and demobilisation	\$2,000,000
Workboat	\$100,000
Dredge and pump to placement location	\$680,000
Reclamation area	
Construction of reclamation area including rock armour	\$5,101,000
Processing material, including dewatering	\$167,000
Monitoring and management	\$250,000
Total	**\$9,118,000**

4.2.1.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the land reclamation option is 1,464 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

4.2.1.10 Knowledge gaps

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

- Demand for land for port 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 perimeter embankment
- 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 may enable reclamation of an area of approximately 16ha, around the north harbour wall, albeit that the immediate need for such a large area for low load-bearing purposes is considered unlikely. It may be that this area can be expanded over time; however, without there being a sufficient existing or likely future need for low load-bearing lands within the immediate area of the port, it is considered that this land reclamation option potentially provides capacity for material limited to several successive dredging programs but not a long-term maintenance dredging beneficial reuse solution.

Generally, the land reclamation option described is achievable however it is unlikely there would be sufficient demand for this type of low load bearing reclaimed land use.

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 is provided in Table 4-4.

Table 4-4 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:** $3M to $10M per dredge program

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)	**High:** <1500 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
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	**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.

4.2.2 Construction fill

4.2.2.1 Activity description

Dredged material may be used as a construction fill for various purposes. This may 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). Well graded (particle size distribution), sandy or coarse material is preferred for construction fill to have sufficient strength for construction purposes.

Dredged material, such as sand or gravel, may be used as construction fill for high strength applications (e.g. beneath pavement or foundations), although screening and the addition of imported materials is typically necessary to achieve the desired grading and strength. Dewatering is normally required given high water content of dredged material and desalination may be required depending on the construction use. Fine-grained soils (silts and clays) do not have the necessary physical properties for industrial fill in most civil works projects, though they may be suitable for low strength uses such as for use in parks (PIANC, 1992).

4.2.2.2 Opportunity

Due to the high fines (silt and clay) content and associated low strength characteristics of the Port's dredge material it is likely able to be used only 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'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. This may enable manufacture of a construction fill material that will achieve better compaction and higher strength; however, treatment and processing of dredge sediment in this manner is likely to significantly decrease this alternative's cost competitiveness, noting that generally construction fill is spoil material that is able to be reused in is current state.

Utilisation of the dredge material with some minimal processing involving screening and blending to produce a low strength fill is considered the most likely to be feasible of the construction fill options, and as such, is the subject of analysis below. The identified opportunity may include use for land improvement where the quality of existing land is not adequate for the anticipated use and/or where the land elevation is subject to flooding. Currently there is no identified need or end user in the Mackay region for the type or quantity of low strength construction fill material that may be produced from the dredge material. Use in other construction related opportunities as road base / pavement, lining material or in concrete products is discussed in sections 4.2.3, 4.2.4 and 4.2.5 respectively.

The fine sediment material with high 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, albeit that this is likely to be low in any case. The opportunity requires onshore placement and processing of the dredge material. The analysis assumes that onshore placement may be undertaken on Strategic Port Land located to the west of Slade Point Road (as identified by the yellow circle on Figure 4-3), as this land is owned by NQBP, is designated in the Land Use Plan (NQBP, 2009) for port operations uses, and is likely to be of sufficient size. The material, once processed may then be transported to construction sites in the Mackay region for use as low strength construction fill.

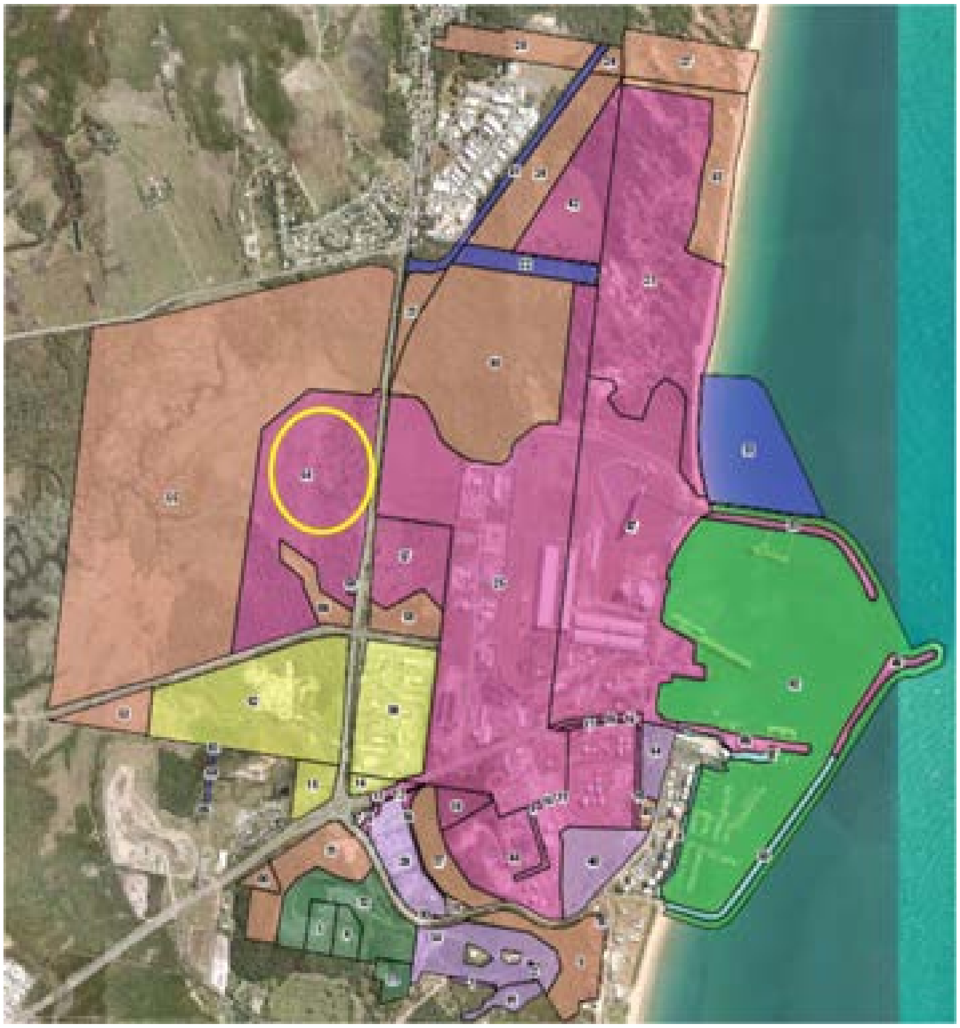

Figure 4-3 Potential onshore placement area (identified by yellow circle) (Source: NQBP, 2009 (modified))

4.2.2.3 Suitability of Mackay sediments

As part of the assessment of the proposed low strength 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 4-5.

Table 4-5 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/processing
Moisture content	Potentially suitable with treatment
Plasticity Index	Potentially suitable with treatment/processing
Linear Shrinkage	Potentially suitable with treatment/processing
Density test	Potentially suitable with treatment
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	n/a

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 material onshore; 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.

The dredging task is similar to that described for the land reclamation option and it is assumed that a dredge such as the 'Brisbane' or similar would be used along with compatible pump out infrastructure. The pump-out infrastructure would be more likely to be permanent for onshore placement than reclamation, as onshore placement is able to provide a longer term beneficial reuse opportunity than reclamation.

For the purposes of analysis, it is assumed that the dredge would moor at a pump-out point within the swing basin (adjacent to the north harbour wall at the existing Berth No. 5) and pump through a pipeline (to be installed on existing infrastructure) to the onshore placement area. The distance (in a direct line) from the swing basin to the potential onshore placement location is approximately 2.5km. However, given that there are likely to be constraints to pipeline location due to existing port users, it is assumed that the pipeline is approximately 3km in length and will require a booster pump station to convey the dredge material via pipeline over this distance.

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 campaign would last approximately 10 days due to slower pump out and placement rates.

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 to the west of Slade Point Road is constrained by:

- Extent of available and suitable land, including topographical and environmental constraints
- Volume of the placement area required for handling and treatment of material, including whether the placement area is used for a single or multiple maintenance dredging campaigns
- Need for the intake to be as close as possible to a dredge pump-out point, and for a suitable marine discharge outlet point.

Sizing of the onshore placement area need 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 campaigns (i.e. to accept approximately 75,000m^3 of material every three years) it has been assumed that the depth of placement of the dredged material would be between 0.5m and1m. As such, the area of land required to support onshore placement would be approximately 10ha., 200m wide x 500m long.

The 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.

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 approximately 39,200m^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 approximately 15 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. 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 limited screening, blending and mixing, and no desalination is required, given the general low-value, low strength construction fill use proposed.

The marine discharge point is assumed to be through the port drainage network, which discharges through the Bassett Basin (a Declared Fish Habitat area) towards the mouth of the Pioneer River. The discharge would require ongoing monitoring and management during the dredging, placement and dewatering activities. For the purposes of analysis, it is assumed that construction fill (low strength) would be delivered to the Mackay city area requiring an approximately 50km round trip from the onshore placement area, with excavators, loaders and trucks used for loadout.

4.2.2.5 Potential constraints

Potential constraints associated with this option include:

- 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 source of material
- Construction of the bunds for the onshore placement ponds requires 39,200m^3 of material, much of which may require importation, and access to this material may be difficult
- Rainfall levels in the region will influence the speed at which dewatering may occur
- Infrastructure development would need to consider potential impact of extreme events (e.g. cyclones), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Potential acid sulphate 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 access to Slade Point Road and may require road upgrades.

4.2.2.6 Potential implications

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

- Development of a potential source of construction fill (low strength) in the region, albeit that it would unlikely be cost competitive without subsidisation
- Onshore placement may cause sterilisation of land designated for port operations
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas, with potential impacts to the Basset Basin Fish Habitat Area requiring consideration
- Onshore placement may cause some (manageable) impacts to adjacent wetland habitat areas, part of which are designated as a Buffer use in the Port of Mackay Land Use Plan
- 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 Slade Point Road.

4.2.2.7 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 this option. Dependent on how material is sourced to construct the project (e.g. the perimeter embankment), approvals associated with onshore reuse may also be required.

The *Sustainable Ports Development Act 2015* identifies the Ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as construction fill. While potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for construction fill is not inconsistent with existing Queensland Government legislation and policy.

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 4-6. 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 $202/m3 measured in situ.

Table 4-6 Construction fill (low strength) summary cost estimate table

Key activity	Construction fill
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$100,000
Dredge and pump to placement location	$680,000
Onshore	
Dredge management ponds	$5,900,000
Processing material, including dewatering	$167,000
Processing material including limited screening/blending/mixing	$1,450,000
Monitoring and management	$250,000
Transport road transport to construction fill use	$788,000
Total	**$15,155,000**

4.2.2.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the construction fill (low strength) option is 2,918 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.

4.2.2.10 Knowledge gaps

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

- Demand for low strength construction fill
- Availability of suitable construction materials for the 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 dredge pump-out areas to enable design of fit for purpose structures, including mooring requirements and dewatering discharge location
- Detailed design including consideration of dredging, placement, construction and ongoing use of the placement area.

4.2.2.11 Future considerations

The dredged material is likely to be able to be dewatered and processed within the assumed three-year period between dredging campaigns, and as such, assuming there is a demand for the material so that it may be removed from the onshore placement ponds, the area is likely to be available for ongoing use for onshore placement. The construction fill material may provide a form of cost-recovery should opportunistic uses 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 is provided in Table 4-7.

Table 4-7 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	**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 $10M per dredge program
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:** >1500 and <3000 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
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	**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

4.2.3 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 course material. The specific characteristics of these constituent materials are combined, placed and compacted to create road pavements. In some circumstances dredged material may be used to supply some, or all the components required for road base.

4.2.3.2 Opportunity

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

A significant road construction project in the Mackay region is the Mackay Ring Road Project, which is proposed to be executed in two stages (as shown in Figure 4-4):

- Stage 1 provides an improved link for the Bruce Highway from the south at Stockroute Road to the northern suburbs at Bald Hill Road
- Stage 2 provides improved access from the Bruce Highway to the Port of Mackay and northern suburbs.

Stage 1 is currently under construction and is due for completion in 2020, while Stage 2 may occur beyond this timeframe. A further stage (3) is identified to provide further linkage to the Port.

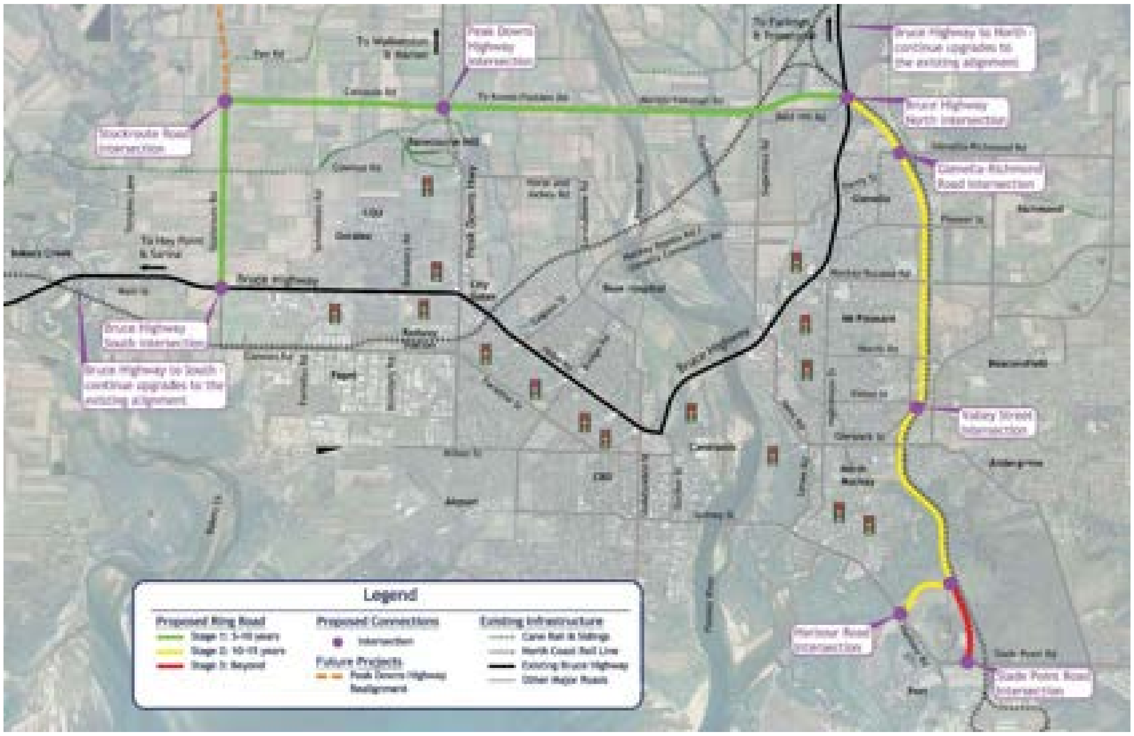

Figure 4-4 Mackay Ring Road Project (Department of Transport and Main Roads)

Notwithstanding that there is a significant existing road construction project underway, 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 sand material to meet pavement specifications. Established commercial quarry operations in the Mackay region supply road base materials in accordance with Queensland Department of Transport and Main Roads (TMR) specifications at around \$50/m^3, 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 were willing to provide it at a substantially subsidised cost rate.

4.2.3.3 Suitability of Mackay 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 TMR technical specifications for pavements are adopted as the road construction 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 properties have been assessed for all the samples tested across the dredge area against the TMR Specification (MRTSO5 Nov. 2018) unbound pavement requirements for typical mid-range standard base course gravel Type 2 and Type 3 sub base and least stringent subtype 2.5 and 3.5[2], along with other essential properties described in Table 4-8.

Table 4-8 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 28% and106%
Liquid Limit (LL)	maximum 40%	ranges between 45% and 140%
Linear Shrinkage (LS)	maximum 7.5%	ranges between 11.0% and 26.5%
Other Properties		
Moisture Content	typically, between 5% and 20%	ranges between 28% to 198.9%
Salinity	>0.250% TSS high risk[3]	Ranges between 1.11% to 2.46%

Most of the dredge sediment material tested does not meet the TMR Type 2/3 pavement material properties criteria in Table 4-8 or sit within the Grading Envelope E for road base specification because it contains excessive fine material, refer Figure 4-5. 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.

[2] TMR Specification MRTS05 Unbound Pavements Nov 2018, 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.

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

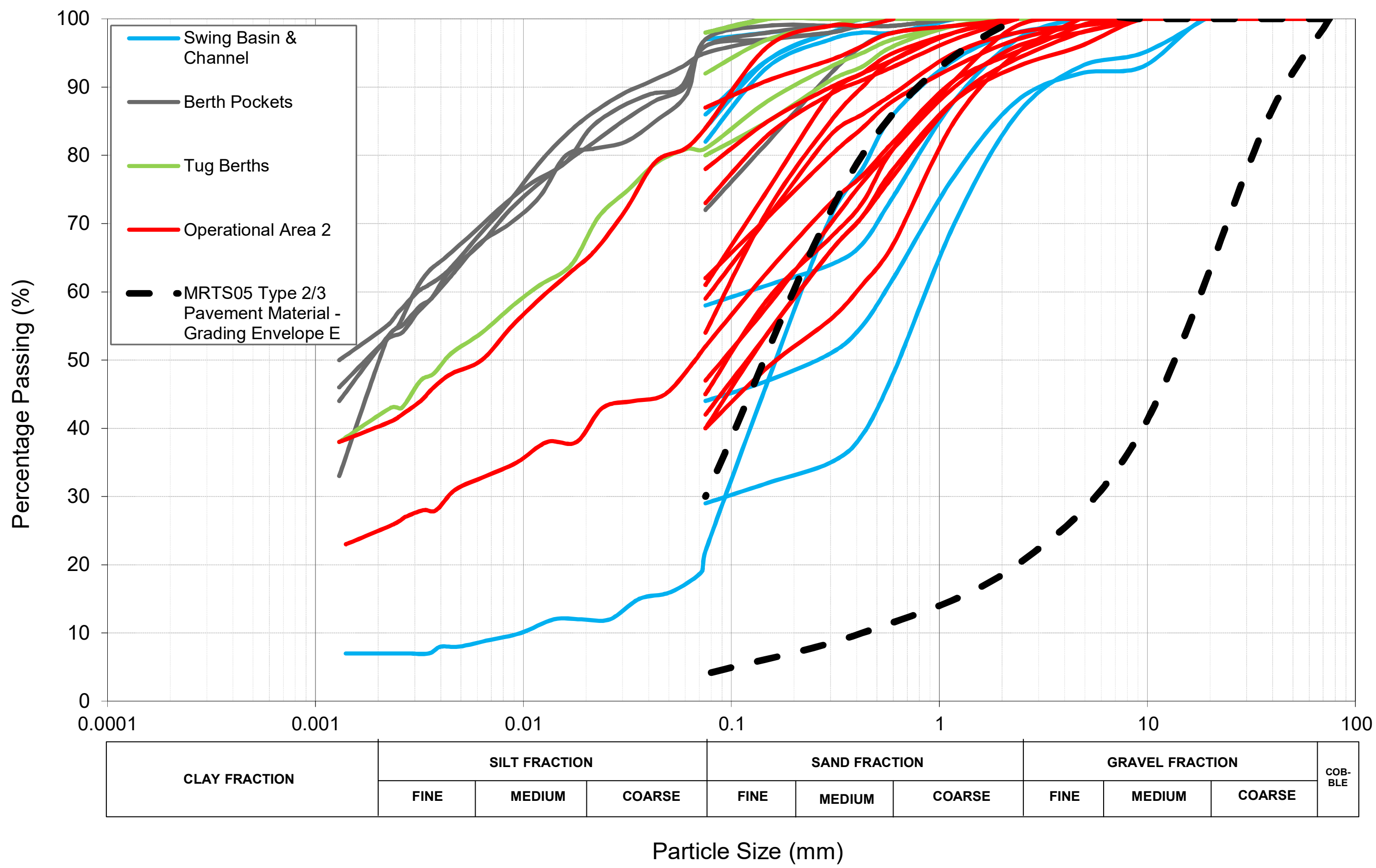

Figure 4-5 Type 2 and 3 Grading E Envelope, least stringent (MRTS05 Unbound pavements) comparison with Sediment Sample Particle Size Gradings

The dredge material particle size distribution is dominated by the fine (clay/silt) <0.075mm portions with very little sand and coarse material (gravel) almost absent. This unbalanced distribution of fine particle size means that the 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 (Swing Basin and Channel, Berth and Pockets, Tug Berth and Operational Area 2) is indicative of very high plasticity clay. Linear shrinkage results (ranging from 11.0% to 26.5%) reveal a very high potential for volume change (swelling) in fine grained materials, most of which were above the critical potential for expansion limit of 8%. Only one of the fine-grained samples (OP2_18 Operational Area 2) recoded a reading of medium low plasticky and "low" potential for volume changes, most likely due to this sample having a lower than average fines content. The silty sand sample (SB_45) exhibited non-plastic behaviour. Most of the Port's sediment is fine material with high plasticity and a "high" to "very high" potential for swelling which makes the material unsuitable for road base/pavement material.

The moisture content is important to determine the amount of effort required to dry out 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 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 198.9% can be characterised as extremely wet and, without significant treatment and processing to reduce moisture content, would be unsuitable for road base/pavement material.

Salinity can shorten the expected lifespan of a road pavement by accelerating the rate of deterioration[4]. 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 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 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 material will be a constituent part of a low specification road base/pavement

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

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.

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 4-9.

Table 4-9 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

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.

Infrastructure and management requirements

In addition to the onshore infrastructure and management requirements identified for construction fill, 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 to make it suitable for road base.

The high salt level will be reduced by exposure to rainfall to achieving leaching of the salts and periodic 'mixing and turning over' the stored material by an excavator over an extended period of time (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 material will be stockpiled by particle size and can then be batched, and if necessary blended with imported material, to create a road base material to achieve the required particle size distribution and properties.

For the purposes of analysis, it is assumed that road base would be delivered to the Mackay city area requiring a less than 50km round trip.

Relevant standards

The industry standard for road construction materials in Queensland is the Queensland TMR Specification Category 5: Pavements, Subgrade 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 39,200m^3 of material, much of which may require importation, and access to this material may be difficult
- Mackay's 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 (e.g. cyclones) for pump-out operations 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 access to Slade Point Road and may require road upgrades.

4.2.3.6 Potential implications

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

- Development of a potential source of road base in the region, albeit that it would be unlikely cost competitive without subsidisation
- Onshore placement may cause sterilisation of land designated for port operations
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas, with potential impacts to the Basset Basin Fish Habitat Area requiring particular consideration
- Onshore placement may cause some (manageable) impacts to adjacent wetland habitat areas, part of which are designated as a Buffer use in the Port of Mackay Land Use Plan
- 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 Slade Point Road.

4.2.3.7 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. Depending on how material is sourced to construct the project (e.g. the perimeter embankment), approvals associated with onshore reuse may also be required.

The *Sustainable Ports Development Act 2015* identifies the Ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as road base. While potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for road base is not inconsistent with existing Queensland Government legislation and policy.

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 4-10. 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 \$207/m^3 measured in situ.

Table 4-10 Road base material summary cost estimate table

Key activity	Road base
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$100,000
Dredge and pump to placement location	$680,000
Onshore	
Dredge management ponds	$5,900,000
Processing material, including dewatering and desalination	$250,000
Processing material including extensive screening/blending/mixing	$1,600,000
Monitoring and management	$350,000
Transport road transport to road base use	$788,000
Total	**$15,488,000**

4.2.3.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the road base option is 2,993 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.

4.2.3.10 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 and improved understanding of comparative cost of production
- Availability of suitable construction materials for the 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 dredge pump-out areas to enable design of fit for purpose structures, including mooring requirements and dewatering discharge location
- Detailed design including consideration of dredging, placement, construction and ongoing use of the placement area.

4.2.3.11 Future considerations

The dredged material is likely to be able to be dewatered and processed within the assumed three-year period between dredging campaigns, and as such, assuming there is a demand for the material so that it may be removed from the onshore placement ponds, the area is likely to be available for ongoing use for onshore placement. The availability of a local project willing to use the dredge material as road base and availability of significantly less expensive TMR registered quarry sources makes road base production from dredge material 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 4-11.

Table 4-11 Road base performance summary

Performance Criteria	Performance rating
Opportunity	**Moderate:** Potentially a demand reasonably accessible to the Port, requiring 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

Performance Criteria	Performance rating
Cost	**Low:** More than $10M per dredge program
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:** >1500 and <3000 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
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	**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

4.2.4 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 4-6 and Figure 4-7 shows CDFs without and with a typical liner system respectively.

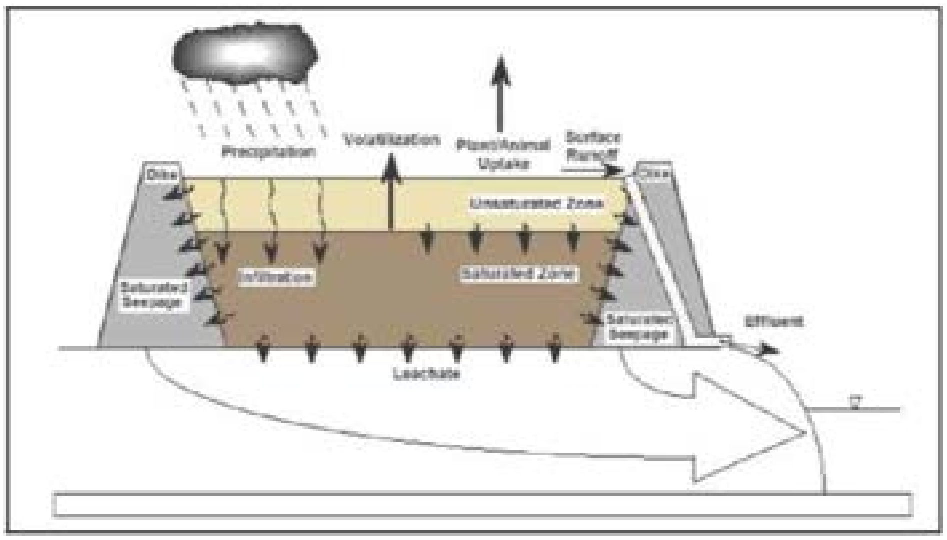

Figure 4-6 Potential contaminant loss pathways for CDFs without a leachate control system

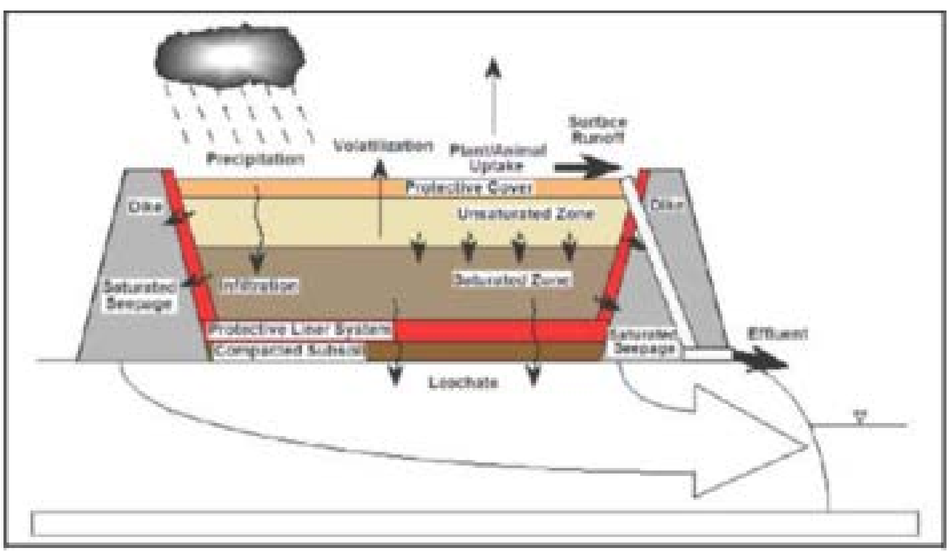

Figure 4-7 Potential contaminant loss pathways for CDFs with a leachate control system

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 Mackay Regional Council CDF, located at Hogan's Pocket, about 50km by road to the south-west of Mackay. 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 Mackay 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.

Hydraulic conductivity is an important design parameter that influences liner material selection. 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 (Berth Pockets (B1_07, B3_14, B4_01, B5_10) and Operational Area 2 (OP2_18)) achieved permeability values of $1.7x10^{-10}$ and $2.8x10^{-10}$ m/s respectively, 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.

Due to high fine clay and silt content lining material suitable for a CDF may be produced from the maintenance dredge material. There is currently one major landfill owned by the Mackay Regional Council at Hogan's Pocket. Liner material requirements for this facility are unknown. The dredge sediment material would require treatment and processing to improve its suitability as a lining material.

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 4-12.

Table 4-12 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

4.2.4.4 Process description

Dredging and placement

Given that the identified opportunity for use of material is distant from the port, intermediate onshore placement and treatment is required for this option. The dredging and placement requirements for this option are as identified for construction fill at Section 4.2.2.

Infrastructure and management requirements

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

The dewatered sediment material will need to be extracted for the storage pond and sorted into various particle sizes be a screening plant. The material is stockpiled by particle size and can then 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 may 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 Hogan's Pocket landfill requiring an approximately 100km 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:

- 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 of, or demand for material
- Construction of the bunds for the onshore placement ponds requires 39,200m^3 of material, much of which may require importation, and access to this material may be difficult
- The balance of dredged material that is not suitable for use as lining material would require to be managed with onshore or offshore placement

- 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 (e.g. cyclone), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the onshore placement area
- Potential acid sulphate 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 access to Slade Point Road and may require road upgrades.

4.2.4.6 Potential implications

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

- Development of a potential source of liner material in the region, albeit that it would be unlikely cost competitive without subsidisation
- Onshore placement may cause sterilisation of land designated for port operations
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas, with potential impacts to the Basset Basin Fish Habitat Area requiring particular consideration
- Onshore placement may cause some (manageable) impacts to adjacent wetland habitat areas, part of which are designated as a Buffer use in the Port of Mackay Land Use Plan
- 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 Slade Point Road.

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.

The recently introduced *Sustainable Ports Development Act 2015* identifies the ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as a liner. Whilst potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for a liner is not inconsistent with existing Queensland Government legislation and policy.

4.2.4.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the lining material option is provided in Table 4-13. 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 \$210/m^3 measured in situ.

Table 4-13 Lining material summary cost estimate table

Key activity	Road base
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	\$820,000
Pipeline mobilisation and demobilisation	\$5,000,000
Workboat	\$100,000
Dredge and pump to placement location	\$680,000
Onshore	
Dredge management ponds	\$5,900,000
Processing material, including dewatering and desalination	\$250,000
Processing material including extensive screening/blending/mixing	\$1,600,000
Monitoring and management	\$350,000
Transport road transport to road base use	\$1.013,000
Total	**\$15,713,000**

4.2.4.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the lining material option is 3,330 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.

4.2.4.10 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 proposed location of the dredge pump-out areas to enable design of fit for purpose structures, including mooring requirements and 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 placement area
- Site access requirements including potential road upgrades.

4.2.4.11 Future considerations

The dredged material is likely to be able to be dewatered and processed within the assumed three year period between dredging campaigns, and as such, assuming there is a demand for the material so that it may be removed from the onshore placement ponds, the area is likely to be available for ongoing use for onshore placement.

It is considered that the volume of fine grained sediment that may be derived from a dredging program (about 50,000m^3 of the 75,000m^3 dredged) would be sufficient for the creation of a liner system for a CDF, depending on the specifications and ongoing requirements of the CDF e.g. a CDF of 200m by 200m with a 1m thick liner, would require approximately 40,000 m^3 of liner material. It is unclear whether there would be demand for the lining material, and particularly ongoing demand to provide a long-term solution for receipt of dredged material.

4.2.4.12 Performance summary

A summary of the performance of the lining material option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-14

Table 4-14 Lining material 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

Performance Criteria	Performance rating
Cost	**Low:** More than $10M per dredge program
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:** >3000 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
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	**Moderate:** There are multiple knowledge gaps and 1-3 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

4.2.5 Concrete products

4.2.5.1 Activity description

Two different 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 above), 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 market for sand supply. To meet the stringent material specifications for manufacturing concrete construction products the dredge material would require:

- Selective dredging to target the sand which is not practical given the low proportions and small quantities available
- Treatment of sand to remove the chlorides (salt) which will otherwise affect mix strength properties
- Treatment to remove internally held salt which will 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.

4.2.5.2 Opportunity

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

- Bricks, blocks and pavers
- Low strength concrete (<5MPa) flowable fill type concrete as a sub-base for construction pads and pavements or as back fill for trenches.

The reuse of dredged material in the manufacture of concrete bricks, blocks and pavers is unsuitable due to the material's properties and is also unable to be cost competitive in this market sector, and as such, is not considered further.

Low strength concrete or flowable fill may be used as a sub-base layer beneath an engineered pavement with higher strength. The higher strength pavement may include quarry supplied, well graded and highly specified base course material or a rigid pavement concrete slab and engineered foundations.

Utilisation of dredge sediments combined with a Portland cement additive to create a low performance, low strength flowable fill concrete for use as sub-base or trench backfill is considered the most likely to be feasible of the concrete product options, and as such, is the subject of analysis below.

4.2.5.3 Suitability of Mackay sediments

Cement laboratory material testing was undertaken using both the X-ray diffraction (XRD) and X-ray fluorescence (XRF) test methods to provide a quantitative analysis (% weight) of mineral composition and chemical element composition respectively, to assess the potential suitability as a binding agent in products including concrete, bricks and stabilised engineering fill material.

Three samples (TB05 (A&B), SB-45 and SB-02A) were selected for XRD and XRF testing. All three samples were shown in the XRD test to be almost 100% in crystalline mineral form, chiefly quartz. These materials would not chemically react with other materials to create a geopolymer cement in their current form.

The sediment samples have a very high moisture content and excessive fines (silt/clay) and cannot be easily used in concrete products without treatment and processing. 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 makes the sediment unsuitable for structural concrete. The very high clay content interferes 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-performance flowable fill material option described above.

The Portland cement additive approach would be the simplest treatment of the fine sediment material; however, Portland cement is an expensive additive (bulk cement costs approximately $200/t) and its manufacture is a large source of carbon emissions. The high-water content in the fine sediments is likely to be problematic for this process. The dredged material would need to be dewatered and dried before use.

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 capacity for the design purpose.

As part of the assessment of the proposed concrete products (low strength flowable 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 4-15.

Table 4-15: Suitability of dredge sediment for proposed low strength flowable fill concrete product.

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

Sediment Material Property	Suitability
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)
Organic Material	Likely suitable
Other	
Cement laboratory testing	Potentially suitable with treatment/processing

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.

Infrastructure and management requirements

Material to be used for concrete products will need to be placed onshore in a treatment area and undergo similar treatment (dewatering) as that identified for construction fill. A shorter storage period in the treatment area may be desirable as a 'wetter' sediment enhances the flowability of the low strength concrete mix. Addition and blending of Portland cement to manufacture a low performance, low strength flowable fill concrete would require the installation and operation of a pug mill to continuously mix material to achieve a thoroughly mixed and homogeneous product. The pug mill would include a cement silo, clean water supply and a conveyor system all operated by a diesel engine. Ideally the material would be reclaimed from the treatment area at a time when the material's moisture content is close to optimum to run the pug mill 'wetter' so large quantities of water are not required to be added to make the concrete 'flowable' for the placement of the low strength concrete mix.

The conveyor system would be used to elevate and load the mixture into a fleet of tip trucks or concrete agitator trucks for delivery to the end user. Tip trucks could be used for bulk placement and transport over short distances (<5km) or agitator trucks for transport over longer distances. Agitator trucks with chutes are better suited to more precise placement such as trench backfill.

For the purposes of analysis, it is assumed that the low strength concrete product would be delivered to the Mackay city region requiring an up to a 50km round trip.

Relevant standards

Australian Standards relevant to the concrete products under consideration include:

- AS 3700:2018 "Masonry Structures"
- AS 1379:(R2017) "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 (Nov 2018)".

4.2.5.5 Potential constraints

Potential constraints associated with this option include:

- Given that sediment is dredged periodically (approximately 75,000m^3 every three years), it is considered unlikely that demand would be large or consistent enough to justify development of a new concrete products business specifically for the dredge material
- 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
- Construction of the bunds for the onshore placement ponds requires 39,200m^3 of material, much of which may require importation, and access to this material may be difficult
- 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 (e.g. cyclone), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the onshore placement area
- Potential acid sulphate 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 access to Slade Point Road and may require road upgrades
- The addition of Portland cement will increase the strength characteristics of the flowable fill sub-base material noting that:
  - Generally, the addition of more Portland cement results in a higher strength concrete material; however, the material will never achieve strength as high as concrete, due to the high content of fines (silt and clay) and their inability to bind as aggregates can
  - The high expense of the Portland cement additive limits its cost effectiveness to typically between 2% and 5% by weight.

4.2.5.6 Potential implications

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

- Development of a potential source of low-performance, low strength flowable fill sub-base material in the region, albeit that it would likely only be able to supplement requirements of an existing business, or be useful for applications on port land
- Onshore placement may cause sterilisation of land designated for port operations
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas, with potential impacts to the Basset Basin Fish Habitat Area requiring particular consideration
- Onshore placement may cause some (manageable) impacts to adjacent wetland habitat areas, part of which are designated as a Buffer use in the Port of Mackay Land Use Plan
- 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 Slade Point Road.

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.

The recently introduced *Sustainable Ports Development Act 2015* identifies the ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as concrete products. While potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for concrete products is not inconsistent with existing Queensland Government legislation and policy.

4.2.5.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the concrete products (low strength flowable fill) option is provided in Table 4-16. 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 $224/m3 measured in situ.

Table 4-16 Concrete products (low strength flowable fill) summary cost estimate table

Key activity	Road base
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$100,000
Dredge and pump to placement location	$680,000
Onshore	
Dredge management ponds	$5,900,000
Processing material, including dewatering and desalination	$250,000
Processing material including extensive screening/blending/mixing	$1,600,000
Pug mill	$1,339,000
Monitoring and management	$350,000
Transport road transport to road base use	$788,000
Total	**$16,827,000**

4.2.5.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the concrete products (low strength flowable fill) option is 2,993 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.

4.2.5.10 Knowledge gaps

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

- Demand for concrete products (particularly low-performance, low strength sub-base flowable fill material) and improved understanding of comparative cost of production

- Obtain samples of the dredge sediment material to prepare trial mixes to see how specific mixes react and test blends of various proportions of Portland cement, fly ash and lime to determine optimum mix design for performance characteristics and cost
- Coastal dynamics and processes specific to the proposed location of the dredge pump-out areas to enable design of fit for purpose structures, including mooring requirements and 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 placement area
- Site access requirements including potential road upgrades.

4.2.5.11 Future considerations

The dredged material is likely to be able to be dewatered and processed within the assumed three year period between dredging campaigns, and as such, assuming there is a demand for the material so that it may be removed from the onshore placement ponds, the area is likely to be available for ongoing use for onshore placement.

As noted above, production of low-performance low strength flowable fill material from the dredged material is unlikely to support a new business given high relative costs and limitations to supply (limited dredge quantities); however, it may be used opportunistically for the port or other uses in the vicinity of the port.

4.2.5.12 Performance summary

A summary of the performance of the concrete products (low strength flowable fill) option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-17

Table 4-17 Concrete products (low strength flowable fill) 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 $10M per dredge program
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

Performance Criteria	Performance rating
Duration	**Moderate:** 1 to 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	**Moderate:** >1500 and <3000 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
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	**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

Coastal management options for which dredge material may have some use include the introduction of shoreline protection measures (e.g. through the use of geotextile tubes or bags) and beach nourishment. Shoreline protection opportunities are discussed in this section and beach nourishment is discussed in Section 4.2.7.

4.2.6.1 Activity description

Dredged material (including sand, clay and rock) may be used to provide shoreline protection to assist erosion management. 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. A number of shoreline protection options may be utilised:

- Direct placement on the 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 further erosion.

Geotubes and geobags 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 including revetments, groynes, artificial reefs, slope buttressing, temporary protection dykes, offshore breakwaters and containment dykes.

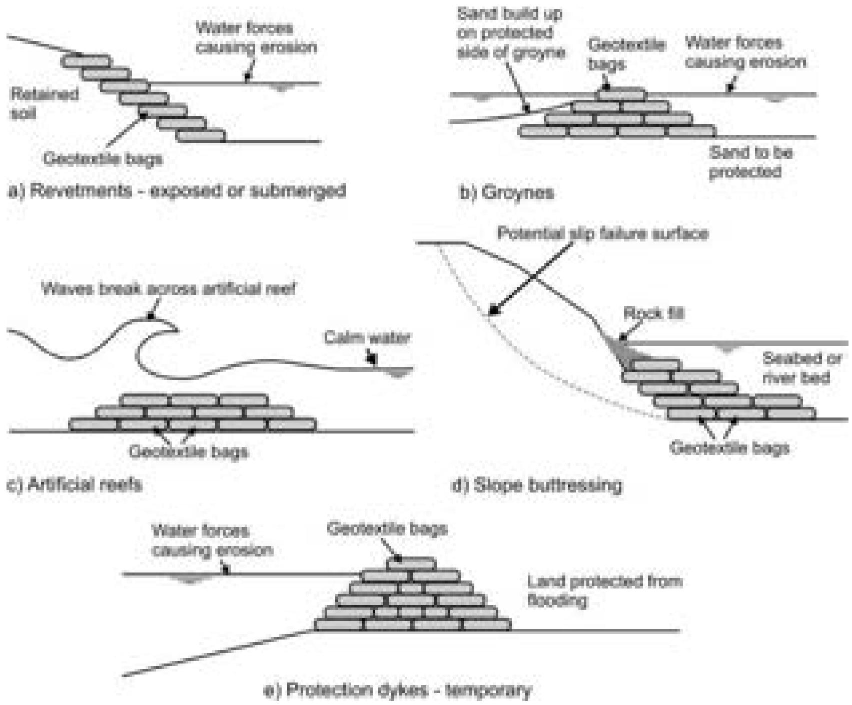

Figure 4-8 Geobag applications, source: Pilarczyk (2000)

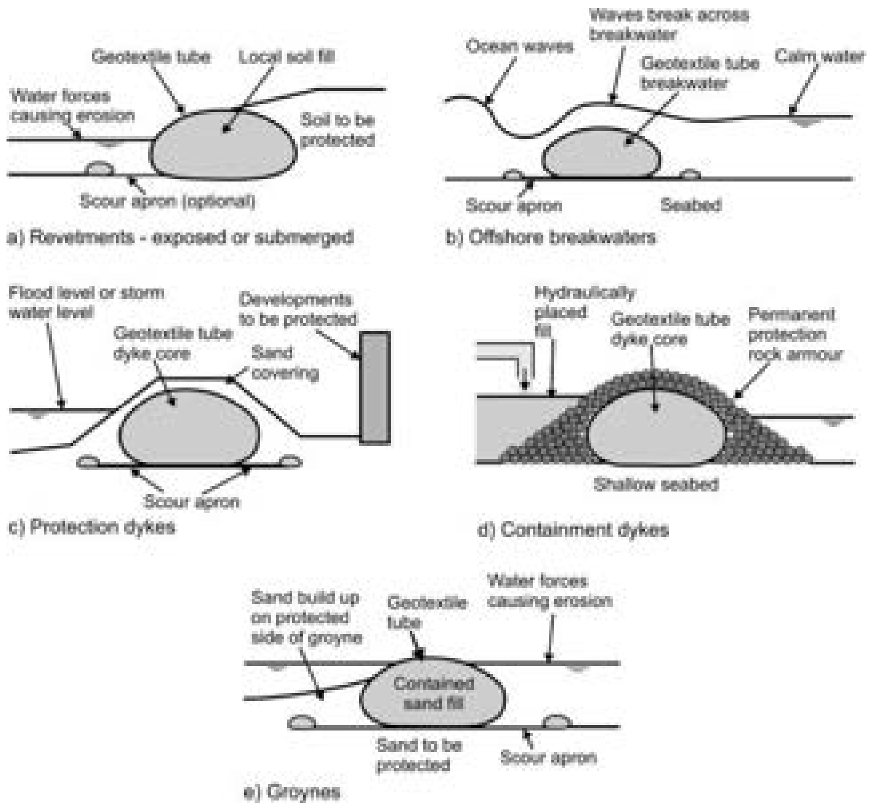

Figure 4-9 Geotube applications, source: Pilarczyk, (2000)

Geobags can be filled hydraulically on a pontoon and placed by crane, and geotubes can be filled hydraulically at the placement site from a hopper barge with a pump which liquefies the dredge material in the hopper. Alternatively, 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 in the placement site. 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).

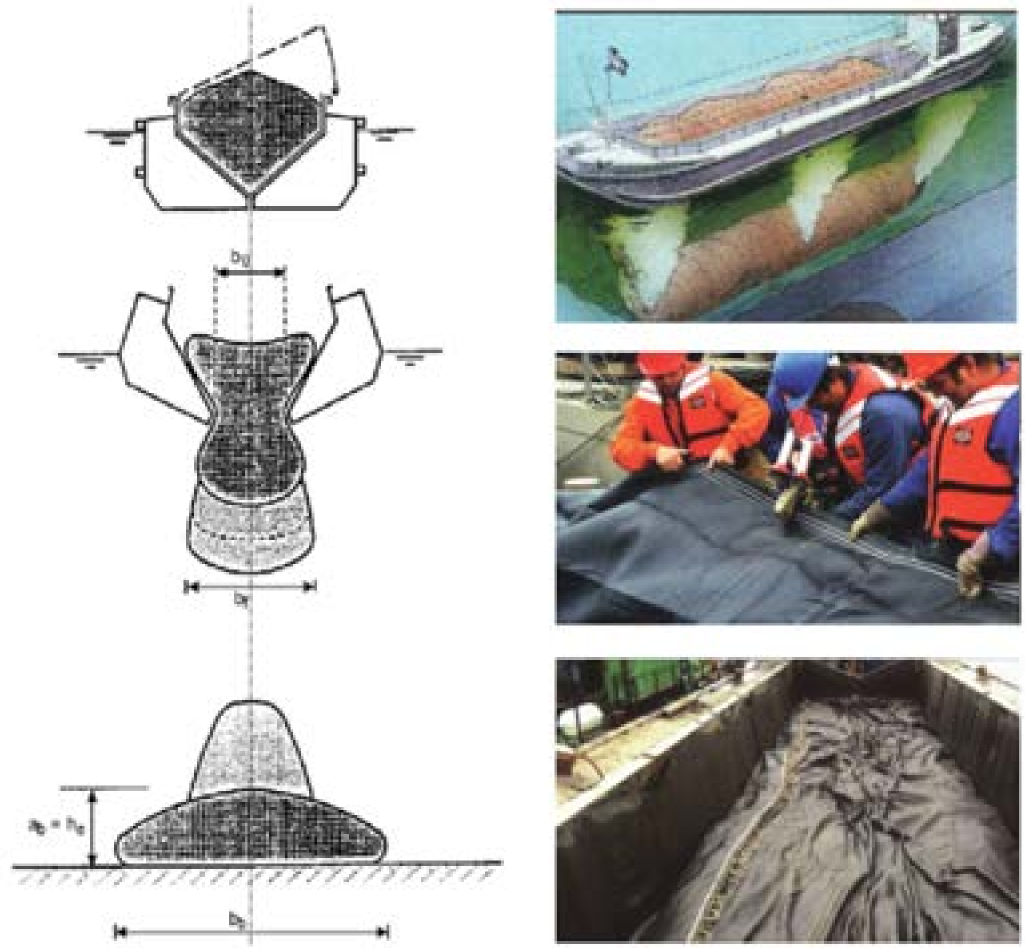

Figure 4-10 Geotube / geocontainer placement, source: TenCate (2016)

4.2.6.2 Opportunity

The Mackay Coast Study (EPA, 2005), which studied an area from Bakers Creek to Shoal Point north of Mackay identified a number of areas of active coastal recession that may require management actions. These include parts of Far Beach (between Bakers Creek and the Pioneer River) and the northern section of Harbour Beach (north of the Port of Mackay). Coastal management works previously undertaken at parts of Far Beach include the construction of rock walls to protect existing infrastructure and counter the erosion trend (MRC and Reef Catchments, 2013), Figure 4-11

Figure 4-11 Shoreline protection (rock walls) at Far Beach (source: EPA, 2005)

In addition, extreme events may cause significant coastal erosion from time to time. A number of beaches in the Mackay region were impacted by Cyclone Debbie in 2017, including Lamberts Beach to the north of the Port (Figure 4-12). It is understood that beach nourishment activity has been undertaken by the Mackay Regional Council at Lamberts Beach.

Figure 4-12 Beach erosion at Lamberts Beach (source: Michael Kennedy in Daily Mercury (19/09/17))

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

Given that coastal recession that may require management action has previously been identified for Far Beach (EPA, 2005) and that shoreline protection works have been undertaken in this area, for the purposes of further beneficial reuse analysis consideration is given to the conceptual use of geobags for shoreline protection at Far Beach.

4.2.6.3 Suitability of Mackay sediments

Most of material is fine-grained and direct placement is unlikely to effectively address wave attenuation or any coastal erosion issues, as the material would easily be remobilized and is not likely to remain in place. As such only the option of placement in geotubes is considered further.

As part of the assessment of the proposed shoreline protection reuse opportunity (geotubes) described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-18.

Table 4-18: Suitability of dredge sediment for proposed shoreline protection (geobags) 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	Potentially suitable with treatment/processing
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 reuse option of placing sediment into geobags to create shoreline protection requires very little if any treatment or processing of the material. The geotextile tube material will need to be a fine weave to retain the fine sediment.

4.2.6.4 Process description

Dredging and placement

Dredge material would be dredged and transported to the site of shoreline protection works. Given the depth limitations offshore of Far Beach (i.e. extensive tidal flats exposed during low tides), and the need for dredge manoeuvrability 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 barges, which would be hydraulically filled at the dredging area, and would transport the dredged material in geobags to the placement site.

For the purposes of the analysis it has been assumed that the Trailing Suction Hopper Dredge will load the barges at the dredging area and the barges will travel approximately 10km to a placement site e.g. Far Beach. 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 campaign would last approximately 10 days due to slower production rates involved with filling geobags.

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 barges) to execute the works may be limited
- Large tidal range in the region 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 geobags
- Potential acid sulphate soils, may require consideration in development of the shoreline protection concept
- Agreement for access to the land for the proposed works
- Suitable geofabric material able to contain the fine clay/silt material, yet permeable to allow the filled geotube to 'sink' into position.

4.2.6.6 Potential implications

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

- Provides a potentially cost-effective shoreline protection option (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 of structures may cause some impacts to existing habitat and community uses.

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.

The recently introduced *Sustainable Ports Development Act 2015* identifies the ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as shoreline protection. Whilst potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for shoreline protection is not inconsistent with existing Queensland Government legislation and policy.

4.2.6.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the shoreline protection option is provided in Table 4-10. 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 $89/m3 measured in situ.

Table 4-19 Shoreline Protection (geobags) summary cost estimate table

Key activity	Road base
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Workboat	$100,000

Key activity	Road base
Tug and barge mobilisation and demobilisation	$2,500,000
Place dredge material into geobags	$3,000,000
Onshore	
Monitoring and management	$255,000
Total	**$6,670,000**

4.2.6.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the shoreline protection option is 270 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.

4.2.6.10 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 Mackay
- Coastal dynamics 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 option for beneficial reuse of dredged material is heavily dependent on the need for shoreline protection. While the quantity of material per dredge program (75,000m^3) may be suitable to place in geobags, typically traditional construction methods (placed rock) may be more economical than geobag structures when considering small coastal structures. In general, the larger the scale of the project the greater the potential savings in CO_2 emissions and cost that can be achieved through the use of geobag technology (Sheehan & Harrington 2012). Due to the volume, time between dredge programs and demand constraints it is considered that the shoreline protection reuse option may have limited application.

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 is provided in Table 4-20.

Table 4-20 Shoreline protection 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:** \$3M to \$10M per dredge program
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:** <1500 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
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	**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

4.2.7 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

As noted previously, the Mackay Coast Study (EPA, 2005) identified a number of areas of active coastal recession that may require management actions including the northern section of Harbour Beach (north of the Port of Mackay shown in Figure 4-13). The study suggests that coastal recession at this beach is the result of the combined effect of the Mackay Harbour breakwaters and commercial sand extraction.

Beaches are typically made up of a number of materials including sand, gravel, pebbles, cobbles, rock or shells. Material on the beaches within the vicinity of the Port of Mackay that may require management action is likely to comprise of a much sandier material than that identified within the maintenance dredge material. Notwithstanding this, for the purposes of analysis it has been assumed that beach nourishment may be applied at the northern section of Harbour Beach.

Figure 4-13 Beach adjacent to the Port of Mackay including Harbour Beach north (source: EPA, 2005)

4.2.7.3 Suitability of Mackay sediments

Beach nourishment generally requires selective dredging of pure sand. The Port's 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 fines (clay and silt) mean that this material is more readily susceptible to remobilisation by the tidal range and currents.

The Port of Mackay sediment samples were dominated by fine (silt/clay) fraction with only minor proportions of sand in the particle size distributions. The quantity of sand in the dredged sediments is small and mixed with fines, and as such the sand may not be effectively targeted in dredging operations. Due to the likelihood of fines being readily remobilised by waves and currents at the beach nourishment location further investigation and local placement trials would be required to confirm if the fine material is suitable.

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 4-21.

Table 4-21: Suitability of dredge sediment for proposed beach nourishment reuse

Sediment Material Property	Suitability
Geotechnical	
Material colour	not likely to be suitable
Particle Size Distribution	Potentially suitable with treatment/processing
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
Organic Material	Likely suitable
Other	
Cement laboratory testing	N/A

The fine (clay/silt) material is unlikely to be suitable for beach nourishment reuse due to colour; however, if fine material with small quantities of sand and/or sand added to dredge material is determined by further investigation to be beneficial to place on the northern section of Harbour Beach then the sediment may be partially useful in beach nourishment.

4.2.7.4 Process description

Dredging and placement

Sediment material would be dredged and transported to the site of beach nourishment works. Given the depth limitations around Harbour Beach (north) and the need for dredge manoeuvrability 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 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 3km from the dredging area to access the pump-out point.

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 campaign would last approximately 10 days due to the slower rates of pump out and placement.

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 brown or grey to dark grey colour of the fine sediment material is unlikely to be visually acceptable for reuse on any lighter coloured sandy beach
- Large tidal range in the region may present significant operational constraints, dependent on the beach nourishment option.
- Dredge material placed onshore may be eroded and transported elsewhere following placement and may only provide a wider beach temporarily, noting that the fine dredge material is likely to be highly susceptible to erosion
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly the pipeline to the beach nourishment area
- Potential acid sulphate soils, may require consideration in development of the beach nourishment concept
- Agreement for access to the land for the proposed works.

4.2.7.6 Potential implications

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

- Placement of the dredge material on a sandy beach may cause a negative community response, given the difference in material types, with dredge material being significantly finer and darker in colour than the existing beach material
- 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 and placement may cause temporary impacts to existing benthic habitat and community use of the beach

- 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.

4.2.7.7 Approvals

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

The recently introduced *Sustainable Ports Development Act 2015* identifies the ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), with beach nourishment explicitly identified as a beneficial reuse. While potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for beach nourishment is not inconsistent with existing Queensland Government legislation and policy.

4.2.7.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the beach nourishment options is provided in Table 4-22. 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 \$53/m^3 measured in situ.

Table 4-22 Beach Nourishment summary cost estimate table

Key activity	Construction fill
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	\$820,000
Pipeline mobilisation and demobilisation	\$2,000,000
Workboat	\$100,000
Dredge and pump to placement location	\$680,000
Onshore	
Monitoring and management	\$350,000
Total	**\$3,950,000**

4.2.7.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the beach nourishment option is 346 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.

4.2.7.10 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 Mackay
- Coastal dynamics and processes specific to the proposed location of the beach nourishment to enable effective targeting of placement, and design of pump-out facilities
- Detailed design including consideration of dredging and pump out facilities.

4.2.7.11 Future considerations

This option for beneficial reuse of dredged material is heavily constrained by demand. It may have limited application (if at all). It is considered unlikely that dredging would provide a long-term suitable source of material for beach nourishment 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 4-23

Table 4-23 Beach nourishment performance summary

Performance Criteria	Performance rating
Opportunity	**Moderate:** Potentially a demand reasonably accessible to the Port, requiring 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	**Moderate:** \$3M to \$10M per dredge program
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	**High:** Less than 1 year to construct and function as the proposed final use

Performance Criteria	Performance rating
Greenhouse Gas Emissions (GHGs)	**High:** <1500 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
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	**Low:** The reuse option has only a single or limited application.

4.3 Environmental enhancement

4.3.1 Deep water habitat creation

4.3.1.1 Activity description

Maintenance dredge material may be used to enhance deep water habitat, which may see biodiversity benefits for those areas enhanced. 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.

De Jong et al. (2016) describes a pilot project undertaken in the North Sea which sought to encourage species recolonisation and promote productivity and biodiversity in deep extraction pits that were previously dredged for sand. The base of the extraction pits is typically flat, with low levels of biodiversity. The pilot project involved selective dredging, leaving behind sand ridges in the designated areas which sought to mimic natural sand waves observed in other parts of the seabed. Figure 4-14 conceptualises the habitat creation outcome that is sought. Monitoring of these areas of habitat creation indicates that four to five times more fish occur inside the habitat creation area than outside it, along with greater species richness.

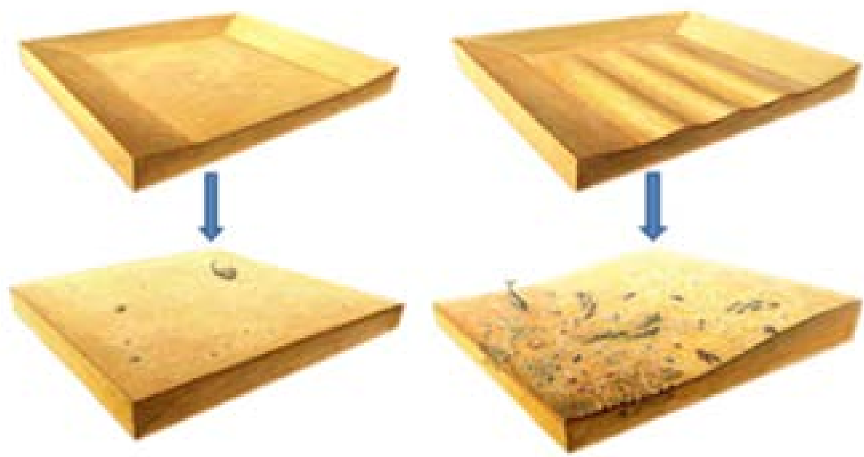

Figure 4-14 Concept of deep water habitat improvement for sand mine areas (source: De Jong et al., 2016)

4.3.1.2 Opportunity

Dredge material from the Port of Mackay 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 seabed adjacent to the existing Port of Mackay DMPA is relatively flat and featureless and consists of silty sands. The DMPA is within the Great Barrier Reef World Heritage Area, but outside of the Great Barrier Reef Marine Park. Given this location and lack of existing features it may be possible to enhance the local habitat adjacent to, or within the existing DMPA through the selective placement of dredge material, albeit that prevailing currents and wave action act to mobilise dredge material at the DMPA and may impact features that are created.

4.3.1.3 Suitability of Mackay sediments

In the example described above, habitat was created through selective dredging of sand to create bedform features to encourage local habitat. The Mackay dredge sediment has a high proportion of fine silt and clay (dark colour) 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.

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 Table 4-24.

Table 4-24 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
Organic Material	Likely suitable
Other	
Cement laboratory testing	n/a

As about 70% of the sediment material is fine (clay/silt) it is not likely to be suitable for the deep water habitat creation reuse; however, if a suitable offshore fisheries habitat location was identified, with sediment characteristics similar to those of the material to be dredged, along with favourable water current patterns, direct placement of sediment material for deep water habitat creation may provide an opportunity for beneficial reuse. Further consideration would be required of the characteristics of the sediment material to be dredged and the current and wave patterns of the potential placement location, along with the potential impacts (positive and negative) on offshore ecosystems and potential for fisheries development.

4.3.1.4 Process description

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 to achieve 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 up to approximately 5km from the dredging area to the habitat creation site. Direct placement of the sediment may be undertaken by bottom release from the hoppers or via a diffuser to reduce turbidity through the water column. 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 campaign would last five days.

4.3.1.5 Potential constraints

Potential constraints associated with this option include:

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

4.3.1.6 Potential implications

Potential implications of this option, considering potential 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 the offshore placement previously undertaken at the port would be expected.

4.3.1.7 Approvals

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

The *Sustainable Ports Development Act 2015* identifies the Ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as deep water habitat creation. Whilst potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for agricultural material is not inconsistent with existing Queensland Government legislation and policy.

4.3.1.8 Costs

A summary breakdown of the estimated costs associated with construction of the deep water habitat creation option is provided in Table 4-25. 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 $\$21/m^3$ measured in situ.

Table 4-25 Deep water habitat creation summary cost estimate table

Key activity	Construction fill
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Workboat	$100,000
Trailing Suction Hopper Dredge seabed placement	$375,000
Onshore	
Monitoring and management	$250,000
Total	**$1,545,000**

4.3.1.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the deep-water habitat creation option is 194 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 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 Mackay, 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.

4.3.1.11 Future considerations

This quantity of material to be dredged may be sufficient for a pilot project; however, the suitability of the option 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.

4.3.1.12 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 is provided in Table 4-26.

Table 4-26 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	**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 $3M per dredge program
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:** < 1500 CO_2 equivalent in a one year period
Environmental Implications	**Moderate:** Nuisance or harm issues identified, but for the most part are considered manageable

Performance Criteria	Performance rating
Social Implications	**Moderate:** Social effects 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 Agricultural applications

4.4.1 Topsoil for agricultural use

4.4.1.1 Activity description

Dredged material may be used to improve soil structure for agricultural use. Maintenance dredging in harbours, access channels, and rivers produces mixtures of sand, silt, clay, and organic matter. 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

The sugar industry in the Mackay region has a history of applying soil additive such as mill mud, fly ash and dunder. Therefore, should disposing of the ripened dredge material as a soil additive be considered, the machinery required is commonly available, although the physical properties of the ripened dredge material requires consideration.

It may be possible to use the dredge material for agricultural use after dewatering, oxidising and leaching to remove salt. Two options may be considered for the reuse of the dredge material for agricultural use:

- The dredge material could be deposited in a bunded and drainage-controlled area, allowed to ripen[5] and then used in-situ for growing vegetation
- 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 in the vicinity of the placement area, such as sugarcane or pastures.

Given that areas adjacent to the port are designated for port uses, the most likely feasible option with potential for long-term beneficial reuse is onshore placement of material, followed by processing, transport and application to agricultural areas elsewhere in the region.

There are low quality sandy soils such as those south of Sarina around Koumala (approximately 65km south of the Port of Mackay (Figure 4-1) that are currently used for growing sugar cane and that may benefit from additions of clayey material derived from dredging. The option of dredging material, with storage and processing at a placement area at the port followed by transport to these sugar cane growing areas around Koumala is the focus of analysis below.

4.4.1.3 Suitability of Mackay sediments

There are regions low quality sandy soils, such as south of Sarina around Koumala, that are currently used for growing sugar cane that may benefit from additions of clayey material derived from dredging. There may also be opportunities to place material on pastures, particularly if nutrients are added.

As part of the assessment of the proposed agricultural reuse opportunity described above, the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-27.

Table 4-27 Suitability of dredge sediment for proposed agricultural topsoil 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

[5] 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.

Sediment Material Property	Suitability
Density test	Potentially suitable with treatment/processing
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	Likely 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 dredge material requires treatment (dewatering and desalination) and processing (soil ripening, blending, 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 4.4.2.

Infrastructure and management requirements

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 75,000m^3 the area needed for ripening would be 15ha if deposited 500mm thick. As such the onshore infrastructure requirements described for the construction fill option would be similar for this option. In addition to these requirements, material to be used for agricultural use 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 exposure to rainfall to achieving leaching of the salts and periodic 'mixing and turning over' the stored material by an excavator over an extended period of time (up to three years). The chemical characteristics of the samples analysed suggest that acidification of the sediments following dredging is unlikely.

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 material would be stockpiled by particle size and can then be batched, and if necessary blended with imported material, to create agricultural soil material to achieve the required particle size distribution and properties.

For the purposes of analysis, it is assumed that material would be delivered to the agricultural facilities in the region near Koumala requiring an approximately 130km round trip.

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 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 material will be opportunistic only i.e. not a continuous source of material
- Construction of the bunds for the onshore placement ponds requires 39,200m^3 of material, much of which may require importation, and access to this material may be difficult
- 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 (e.g. cyclone), including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the onshore placement area
- Potential acid sulphate 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 access to Slade Point Road and may require road upgrades.

4.4.1.6 Potential implications

Potential implications of this option, considering potential 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
- Onshore placement may cause sterilisation of land designated for port operations
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas, with potential impacts to the Basset Basin Fish Habitat Area requiring consideration
- Onshore placement may cause some (manageable) impacts to adjacent wetland habitat areas, part of which are designated as a Buffer use in the Port of Mackay Land Use Plan
- 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 Slade Point Road.

4.4.1.7 Approvals

Approvals associated with dredging and placement and offshore reuse (as identified in Table3-1) will be required for the construction and operation of this option. Dependent on how material is sourced to construct the project (e.g. the perimeter embankment), approvals associated with onshore reuse may also be required.

The *Sustainable Ports Development Act 2015* identifies the Ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use as agricultural material. Whilst potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material for agricultural material is not inconsistent with existing Queensland Government legislation and policy.

4.4.1.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the topsoil for agriculture option is provided in Table 4-28. 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 $211/m^3$ measured in situ.

Table 4-28 Topsoil for agriculture summary cost estimate table

Key activity	Road base
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Pipeline mobilisation and demobilisation	$5,000,000

Key activity	Road base
Workboat	$100,000
Dredge and pump to placement location	$680,000
Onshore	
Dredge management ponds	$5,900,000
Processing material, including dewatering and desalination	$250,000
Processing material including extensive screening/blending/mixing	$1,450,000
Monitoring and management	$250,000
Transport road transport to road base use	$1,363,000
Total	**$15,813,000**

4.4.1.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the topsoil for agricultural use option is 3,054 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.

4.4.1.10 Knowledge gaps

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

- Demand for agricultural materials and improved understanding of comparative cost of production
- 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 dredge pump-out areas to enable design of fit for purpose structures, including mooring requirements and 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 be ripened and disposed off-site before the subsequent dredging operation (assuming three years between campaigns) i.e., one site of 15 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 area is likely to be available for ongoing use for onshore placement.

Prior to use of the dredge material for agricultural purposes it would have to be comprehensively characterised with respect to potential contaminants. Other properties such as nutrient content and clay mineralogy would assist in determining the most appropriate use and location for disposal of the materials.

4.4.1.12 Performance summary

A summary of the performance of the topsoil for agricultural use option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-29.

Table 4-29 Topsoil for agricultural use 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 $10M per dredge program
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:** >3000 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

Performance Criteria	Performance rating
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	**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

4.4.2 Aquaculture

4.4.2.1 Activity description

Onshore aquaculture impoundments require materials that can be used to create berms that will contain water, ponds with impervious liners, and impoundments within ponds to isolate age or species groups and provide water treatment areas. These needs may be met by the appropriate use of dredged materials. Dredged materials may be placed in a closed containment area, with ponds created for the commercial production of prawns. Usage of dredge materials has been undertaken previously in locations such as Texas, USA (PIANC, 2009).

4.4.2.2 Opportunity

A number of options exist with respect use of dredged material for aquaculture industry development including:

- Use of material as a liner in existing onshore aquaculture facilities, which may be replaced from time to time following harvest
- Development of new aquaculture facilities in the vicinity of the port to utilise dredged material
- Development of new aquaculture facilities in the intertidal and shallow sub-tidal habitat.

Development in the intertidal or shallow subtidal areas would be significantly more challenging (technically, financially and in terms of regulatory approval requirements) than the other options, given that these areas are part of the GBRWHA.

Development of new facilities in the vicinity of the port may be possible; however, this would require development of a new business and land adjacent to the port is dedicated for port uses. As such, the use in dredge material in existing facilities is considered the most likely to be feasible. There are known to be existing prawn farming facilities at Ilbilbie, some 85km south of the Port of

Mackay. Demand for materials at this facility is unknown; however, the option of dredging material, with storage and processing at the port followed by transport to these facilities near Ilbilbie is the focus of analysis below.

4.4.2.3 Suitability of Mackay sediments

The dredge material could potentially be used for the construction of aquaculture pond embankments for commercial production of seafood. The fine materials (clay and silt) could potentially be used as liner for the impoundment embankment to retain water in the ponds.

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 $1x10^{-7}$ m/sec or less when compacted. Clean dredged fine-grained material when allowed to settle and condense 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 realised through modification of the 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.

The measured permeabilities for samples from the Berth Pockets (B1_07, B3_14, B4_01, B5_10 combined) and Operational Area 2 (OP2_18) are 1.7×10^{-10} m/s and 2.8×10^{-10} m/s respectively. These permeabilities are typical of clay materials and are suitable to meet permeability criteria to be acceptable for use as hydraulic barriers in a lining material in the embankments of aquaculture ponds. The sample for the Swing Basin and Channel (SB_45) has a measured permeability of 1.9×10^{-5} m/s which is not suitable for use as a lining material.

As part of the assessment of the proposed aquaculture reuse opportunity described above the sediment suitability, based upon properties determined from results of the laboratory testing of the samples, is outlined in Table 4-30.

Table 4-30 Suitability of dredge sediment for proposed aquaculture 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

Sediment Material Property	Suitability
Strength and Consolidation	Potentially suitable with treatment/processing
Permeability	Likely suitable
Geochemical	
PASS	Likely suitable
Salinity	Likely suitable
Organic Material	Likely suitable
Other	
Cement laboratory testing	n/a

The measured permeabilities of select sediment samples indicate a portion of the material may be suitable for lining material.

4.4.2.4 Process description

Dredging and placement

The dredging and placement requirements for this option are as identified for construction fill at Section 4.4.2.

Infrastructure and management requirements

In addition to the onshore infrastructure and management requirements identified for construction fill, material to be used for aquaculture may require more extensive processing to separate and / or mix material suitable for use in aquaculture ponds.

The material will need to be extracted from the storage pond and sorted into various particle sizes by a screening plant. The materials would be stockpiled by particle size and can then be batched, and if necessary blended with imported material, to create material suitable for use in pond embankments, including clay liner for aquaculture facilities.

For the purposes of analysis, it is assumed that the material would be delivered to existing aquaculture facilities in the region, requiring an approximately 170km round trip.

4.4.2.5 Potential constraints

Potential constraints associated with this option include:

- Complex process of mixing, treatment, extraction, processing by screening, stockpiling and then potential blending and batching with imported material to manufacture material suitable for use in aquaculture
- Production of material for aquaculture facilities may be more process intensive than other methods of production, and as such the cost of supply may need to be subsidised by NQBP to create demand
- Likely to be a limited requirement for material for aquaculture facilities in the region, and as such, dredged material as source of this material will be opportunistic only i.e. not a continuous source of material
- Construction of the bunds for the onshore placement ponds requires 39,200m^3 of material, much of which may require importation, and access to this material may be difficult
- The balance of the dredged material not suitable for use in aquaculture would require management through either onshore or offshore placement
- 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, including for pump-out and onshore infrastructure
- Limited information regarding existing conditions on site (including geotechnical conditions, potential for seepage from ponds and suitability of material that may be locally sourced) which will affect engineering design
- Sea and weather conditions may affect operability of the supporting infrastructure, particularly pipeline to the onshore placement area
- Potential acid sulphate 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 access to Slade Point Road and may require road upgrades.

4.4.2.6 Potential implications

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

- Development of a potential source of material for use in aquaculture facilities in the region, albeit that it would be unlikely cost competitive without subsidisation
- Onshore placement may cause sterilisation of land designated for port operations
- Onshore placement will cause some (manageable) impacts to water quality in areas adjacent to the dredging and marine discharge areas, with potential impacts to the Basset Basin Fish Habitat Area requiring consideration
- Onshore placement may cause some (manageable) impacts to adjacent wetland habitat areas, part of which are designated as a Buffer use in the Port of Mackay Land Use Plan

- 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 Slade Point Road.

4.4.2.7 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 this option. Dependent on how material is sourced to construct the project (e.g. the perimeter embankment), approvals associated with onshore reuse may also be required.

The *Sustainable Ports Development Act 2015* identifies the Ports of Hay Point and Mackay as priority ports, and stipulates that material generated from capital dredging of these areas must be beneficially reused (as a condition of any approval), which may include use in aquaculture facilities. Whilst potential approval of maintenance dredging is not subject to this condition, it is considered that the beneficial use of maintenance dredge material in aquaculture facilities is not inconsistent with existing Queensland Government legislation and policy.

4.4.2.8 Costs

A summary breakdown of the estimated costs associated with construction and operation of the aquaculture option is provided in Table 4-31 . 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 $216/m^3 measured in situ.

Table 4-31 Aquaculture summary cost estimate table

Key activity	Road base
Offshore	
Trailing Suction Hopper Dredge mobilisation and demobilisation	$820,000
Pipeline mobilisation and demobilisation	$5,000,000
Workboat	$100,000
Dredge and pump to placement location	$680,000
Onshore	
Dredge management ponds	$5,900,000
Processing material, including dewatering and desalination	$250,000

Key activity	Road base
Processing material including extensive screening/blending/mixing	$1,600,000
Monitoring and management	$350,000
Transport road transport to road base use	$1,463,000
Total	**$16,163,000**

4.4.2.9 Greenhouse gas emissions

The estimated Green House Gas emissions associated with the aquaculture option is 3,120 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.

4.4.2.10 Knowledge gaps

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

- Demand for material from the aquaculture industry to support the use and improved understanding of comparative cost of production of material currently used
- Coastal dynamics and processes specific to the proposed location of the dredge pump-out areas to enable design of fit for purpose structures, including mooring requirements and 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.

4.4.2.11 Future considerations

The dredged material is likely to be able to be dewatered and processed within the assumed three year period between dredging campaigns, and as such, assuming there is a demand for the material so that it may be removed from the onshore placement ponds, the area is likely to be available for ongoing use for onshore placement. Market demand from the aquaculture industry would dictate whether the use provides a long-term beneficial reuse for the dredged material.

4.4.2.12 Performance summary

A summary of the performance of the aquaculture option based on the use of the performance criteria described in Section 3.3.3 is provided in Table 4-32.

Table 4-32 Aquaculture 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 $10M per dredge program
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:** >3000 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
Economic Implications	**Moderate:** Limited economic opportunities exist enhancing 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	**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

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.

Ten potential beneficial reuse options were developed and then evaluated against thirteen performance criteria. Only two reuse options had three out of thirteen criteria rated as 'high' performance with the remaining reuse options only having two or less 'high' ratings. This may be interpreted as the dredge material having few suitable beneficial reuse options. The performance ratings and a comparison of the beneficial reuse options analysed is provided in Figure 5-1 and Figure 5-2.

Conclusions of the analysis for the beneficial reuse options are summarised below.

No substantial demand identified – None of the options have a clear existing demand for the reuse of material that would require minimal infrastructure. Several options require significant new infrastructure construction e.g. onshore dredge management ponds or sea wall. No substantive demand for the dredge material was identified for either the concrete products or top soil for agriculture options.

Level of treatment required – All 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 land reclamation, lining material, shoreline protection and aquaculture it is likely that the sediment material could be utilised with relatively less treatment or additives.

Estimated costs – The cost of the current dredge program with placement at sea is about $0.82 million including items such as dredge mobilisation, demobilisation and daily hire for the duration of the five day dredging program. Six of the beneficial reuse options involving onshore treatment and processing are estimated to cost significantly more (up to fifteen times) than the current annual maintenance dredging program. Estimated costs for the first dredging program are high due to the need to build infrastructure (e.g. onshore placement containment area, pump out mooring facilities and pipeline) to enable beneficial reuse. All six options involving onshore temporary storage were of low performance with respect to cost (more than $10 million per dredge program) with three options (land reclamation, shoreline protection and beach nourishment) being of moderate performance (between $3million and $10million per dredge program). Only the deep water habitat creation option has an estimated cost that is similar to traditional offshore placement (less than $3million/yr.) and is rated to be high performance with respect to cost.

Greenhouse gas emissions – The options that did not require intermediate storage were of high performance (less than 1,500t 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 low performance due to the colour of the sediment (brown and grey to dark grey) being unlikely to be acceptable if placed on beaches.

Social implications – The land reclamation option for reusing dredge material was 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. The beach nourishment option was rated as low social performance because dredged material colour if placed on beaches is unlikely to be acceptable to the community.

Economic Opportunities –The reuse options of land reclamation and lining material were 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 some limited economic opportunities for enhancing Port or community capability.

Approvals – The reuse options of shoreline protection, beach nourishment and deep-water habitat creation will require careful scientific investigation and specialist studies and significant effort to gain necessary regulatory approvals. All the options were assessed as moderate performance in terms of there being an existing recognised approval pathway.

Knowledge Gaps – The construction fill option has few knowledge gaps and less than one year of further work would be required to progress the option. Conversely, the two options for reusing dredge material as beach nourishment or deep water habitat creation 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.

Performance Criteria	High Performance	Moderate Performance	Low Performance	Port of Mackay 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 Material	Concrete Products	Shoreline Protection	Beach Nourishment	Deep Water Habitat Creation	Top Soil for Agriculture	Aquaculture
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.	Mod.	Mod.	Low	Mod.	Mod.	Mod.	Low	Mod.
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.	Low	Low	Mod.	Low	Mod.	Low	Low	Low	Mod.
Cost	**HIGH:** Less than $3M per dredge program	**MODERATE:** $3M to $8M per dredge program	**LOW:** More than $8M per dredge program	Mod.	Low	Low	Low	Low	Mod.	Mod.	High	Low	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	Mod.	Mod.	Mod.	Mod.	Mod.	High	Mod.	Low	Mod.	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	Mod.	Mod.	Mod.	Mod.	High	High	High	Low	Low
Greenhouse Gas Emissions (GHGs)	**HIGH:** < 2000t CO2 equivalent in a one year period	**MODERATE:** >2000t and <5000t CO2 equivalent in a one year period	**LOW:** >5000t CO2 equivalent in a one year period	High	Mod.	Mod.	Low	Mod.	High	High	High	Low	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.	Low	Mod.	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.	Low	Mod.	Mod.	Mod.
Economic 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	Low	Mod.	Mod.	Low	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
Approvals	**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	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
Constraints	**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.	Mod.	Mod.	Low
Knowledge Gaps	**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	Mod.	High	Mod.	Mod.	Mod.	Mod.	Low	Low	Mod.	Mod.
Future considerations	**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	Low	Mod.	Mod.	Mod.	Mod.	Mod.	Low	Mod.	Mod.	Mod.

Figure 5-1 Beneficial reuse options performance summary

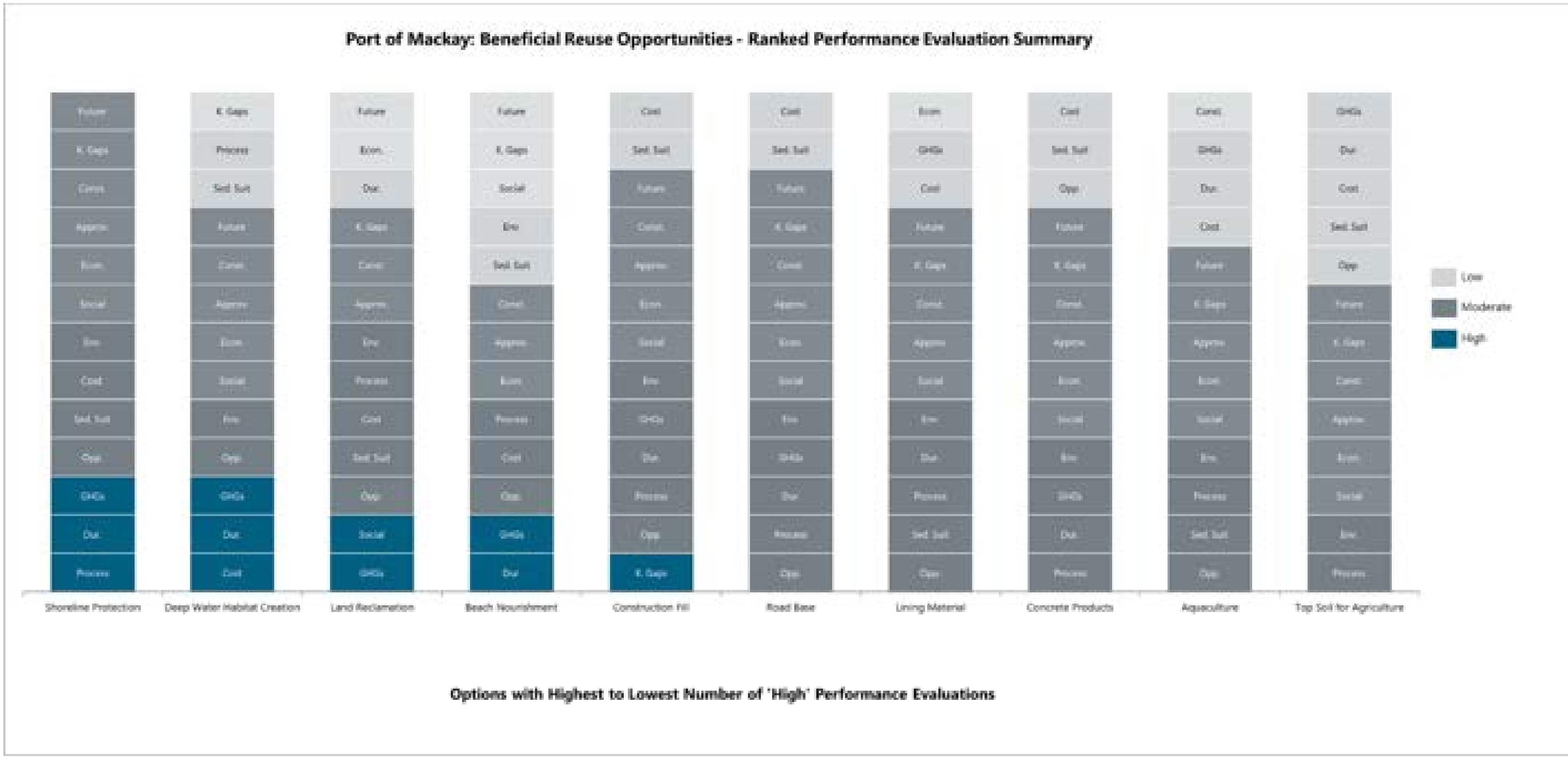

Figure 5-2 Beneficial reuse options performance summary

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 solution and for all the options, further investigation regarding demand is required.

Five reuse options ranked well based on the number of 'high' performance evaluation scores. These options were shoreline protection and deep water habitat creation, which ranked equal highest, land reclamation and beach nourishment ranked equal third followed by construction fill ranked fifth. The 'greenhouse gas' and 'duration' performance criteria were the only common criteria that were rated high across these options (4x for 'greenhouse gas' and 3x for 'duration'). The single high performance rating for construction fill was for 'knowledge gaps'.

Reuse of the dredge material for engineering purposes would require significant treatment and processing of the dredge sediment. Even with time and effort to improve the dredged materials' characteristics it would still likely need to be blended in small proportions with other higher quality materials to be able to be used in applications such as construction fill, road base or concrete products.

While the properties of the dredge sediment may mean it is potentially suitable for reuse in some options (e.g. shoreline protection, land reclamation, lining material or aquaculture) their feasibility relies on demand and (in some cases) the final placement location being favourable, especially in relation to the local ecosystem, including wave climate and currents.

Several reuse options were identified where most of the performance criteria were scored moderate, with only a few low performance criteria. These include options for material use as construction fill, road base, lining material and concrete products. 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 support realisation of six of the beneficial reuse options (construction fill, road base, lining material, concrete products, topsoil for agriculture and aquaculture). Subject to user demand for a 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 principal issue with beneficial reuse options for the Port is the very high proportion of fines (silt/clay) in the 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 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 is suitable for the fine dredge material.

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Appendix A Conceptual Cost Estimate

Appendix A. Table 1 - Preliminary Estimated Cost of Port of Mackay Beneficial Reuse Options

	Beneficial Reuse Option									
	Recycle Dredge material as an engineering material									
Key Activity	1. Land Reclamation	2. Construction Fill	3. Road Base	4. Lining Material	5. Concrete Products	6. Shoreline Protection	7. Beach Nourishment	8. Deep Water Habitat Creation	9. Topsoil for Agriculture	10. Aquaculture
Offshore										
TSHD mobilisation, demobilisation, dredge program hire	$820,000	$820,000	$820,000	$820,000	$820,000	$820,000	$820,000	$820,000	$820,000	$820,000
Pipeline mobilisation and demobilisation	$2,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$2,000,000		$5,000,000	$5,000,000
Workboat	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
TSHD Dredge and pump ashore	$680,000	$680,000	$680,000	$680,000	$680,000		$680,000		$680,000	$680,000
TSHD Dredge and seabed placement								$375,000		
Tug and Barge mobilisation and demobilisation						$2,500,000				
Place dredge material into geobags						$3,000,000				
Onshore										
Dredge management ponds construction		$5,900,000	$5,900,000	$5,900,000	$5,900,000				$5,900,000	$5,900,000
Processing dewatering/desalination/ripening	$167,000	$167,000	$250,000	$250,000	$250,000				$250,000	$250,000
Processing screening/blending/mixing		$1,450,000	$1,600,000	$1,600,000	$1,600,000				$1,450,000	$1,600,000
Concrete products pug mill					$1,339,000					
Rock sea wall for reclamation area	$5,101,000									
Monitoring and management	$250,000	$250,000	$350,000	$350,000	$350,000	$250,000	$350,000	$250,000	$250,000	$350,000
Transport - road transport from site to end user		$788,000	$788,000	$1,013,000	$788,000				$1,363,000	$1,463,000
Totals	$9,118,000	$15,155,000	$15,488,000	$15,713,000	$16,827,000	$6,670,000	$3,950,000	$1,545,000	$15,813,000	$16,163,000
$/m^3	122	202	207	210	224	89	53	21	211	216

Basis of Estimate (Assumptions):

Offshore Estimated Costs

1 Sediment material maintenance dredge volume 75,000m^3/ every 3 years for Port of Mackay based upon NQBP Bathymetric Report 500,000m^3 over 20 years (Dec. 2018).

2 'TSHD Brisbane' (or similar dredge vessel) $0.82M for 5 day dredging program with dredge material placement offshore, including mobilisation and demobilisation based upon NQBP Mackay email. No allowance for surveying, bed levelling, drag barring, contract management, environmental monitoring.

3 Pipeline mobilisation and installation/construction including pump out mooring ($1M to $1.5M) and demobilisation ($0.5M to $1M). Assume $2M for up to 0.5km length for less complex pipeline transport to land reclamation area north harbour wall and beach nourishment assume 10 days duration. Assume $5M for longer length up to 3km including 1No. booster station to deliver to dredge pond storage and process options with more complex operations restricted by landuse, tides and slower production rates (6 pond options). Assume 10 days duration dredge program pump ashore to ponds.

4 Workboat assume aluminium cat 10m length, day rate at $10,000/day. Assume 10 days dredge program for straight forward pump to reclamation area = $100,000 for pump ashore to dredge ponds storage (6 pond options) and deep water habitat creation. Also assume 10 days dredge program for more complex pump ashore operations (land reclamation) and shoreline protection, beach nourishment options = $100,000.

5 Assume $0.82M (75,000m^3 - approx. $11/m^3) for straightforward 5 day dredge program and placement at deepwater habitat creation placement area. Dredge and pump ashore ($10-$15/m^3 Boskalis data). Assume 'TSHD Brisbane' (or similar dredge vessel), hopper capacity 2900m^3, dredge volume75,000m^3, estimate 26 trips, TSHD coupled to pump onshore pipeline. Assume total $1.5M (additional $0.68M for twice as long duration) for more complex pump ashore options and discharge operations more restricted by landuse, tides, slower production rates, up to 5km sailing distance, 24/7 operation 10 days dredge program duration, (6 pond options, land reclamation, shoreline protection, beach nourishment).

6 Dredge and seabed placement ($5-$10/m^3 Boskalis data). Assume $5/m^3 for 75,000m^3 = $0.375M (deep water habitat creation).

7 Tug (2No.) and Barge (2No.) mobilisation and demobilisation and hire $2.5M. Tug and Barge transport (split hopper) for shoreline protection (geobags) options.

8 Place dredge sediment into geotubes on barge and place nearshore with tug and barge $40/m^3, 75,000m^3= $3M. Assume fill geobag at a location within 3km radius of dredge area, estimate 2 tugs, 2 barges 10 hour per day 10 day placement campaign, 100 hours per tug. (shoreline protection (geobags), Assumes TSHD is concurrently supplying dredge material to barge geobags operation and utilising all dredge material (no disposal offshore placement area).

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

Onshore Estimated Costs

10 Onshore construction of dredge management ponds 10ha area (6 pond options), sediment material placed 1.0m deep for treatment. Estimate pond embankment dimensions 200m wide x 500m long x 3.0m deep (bulking factor x3), bund walls volume 39,200m^3 (constructed) at $150/$m^3$ supply and place a combination of site and imported material including pond liner = $5.9M. Transport imported material assumes 39,200m^3 bulk factor x1.2 (47,040m^3), truck and dog 20m^3 capacity, 10 trucks doing 2352 trips @ 1.5hour 30km round trip = 3,528 total hours or 35 days. Estimate 15 weeks construction 60h/week, 2 x 36t excavator, 2x 19t wheel loader, 1x water truck. 10 hours/day, 6 days per week, 15 weeks = 900h ea. vehicle.

11 Processing treatment for dewatering and desalination and soil ripening in dredge management pond assume 12 weeks or 720h per year, excavator 36t and D6 Dozer at $150/h each = $216,000 and 1x 4WD passenger vehicles = $20,000. Assume $250,000 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, aquaculture). Assume $167,000, 480h (8 weeks) where less treatment processing and desalination is required for reuse option (land reclamation and 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, 1,500h (1No. screening plants for 1,500hour/yr.)=$1M, with 1x excavator 36t and 1x 19t wheel loader 1500h each at $150/h $450,000 (total $1,450,000). Assume $450,000 for onshore end uses requiring less processing (construction fill, top soil for agriculture). Assume $600,000 (total $1,600,000, 2000h) for end uses requiring higher level of processing (road base/pavement, lining material, concrete products, aquaculture).

13 Processing utilising a pug mill to create homogeneous concrete mix, daily rate $3,500/day including a pug mill operator. Production rate 200m^3/hr (375h or 37.5 days assume $131,000. Bulk portand cement additive assume $200/t by weight and 3.5% $16.10/$m^3$ for 75,000m^3 = $1,208,000. Assume total $1,339,000.

14 Rock armouring for reclamation area assume 16ha area, approx. 400m wide x 400m long, depth 6m (min. depth 3m to max depth 6.0m side wall to beach) = 36,000m^3 rock amour, supply and place estimate $100/$m^3$ = $3.6M. Transport imported material assumes 36,000m^3 bulk factor x1.3 (46,800m3), truck and dog 20m^3 capacity, 10 trucks doing 2340 trips @ 1.5hour 30km round trip = 3,510 total hours $120/hr or 44 days transport = $421,200. 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. vehiclex$120/hr. =$1,080,000. (total $5,101,000)

15 Monitoring and management, estimate $175,000 per year for site monitoring, investigation and reporting plus laboratory testing $75,000 . Assume $250,000/yr. for end uses requiring a lower level or material quality control (land reclamation, construction fill, deep water habitat creation, shoreline protection (geobags) and topsoil for agriculture). Assume $350,000/yr. for end uses requiring a higher level of materials quality control (road base/pavement, lining material, concrete products, beach nourishment and aquaculture).

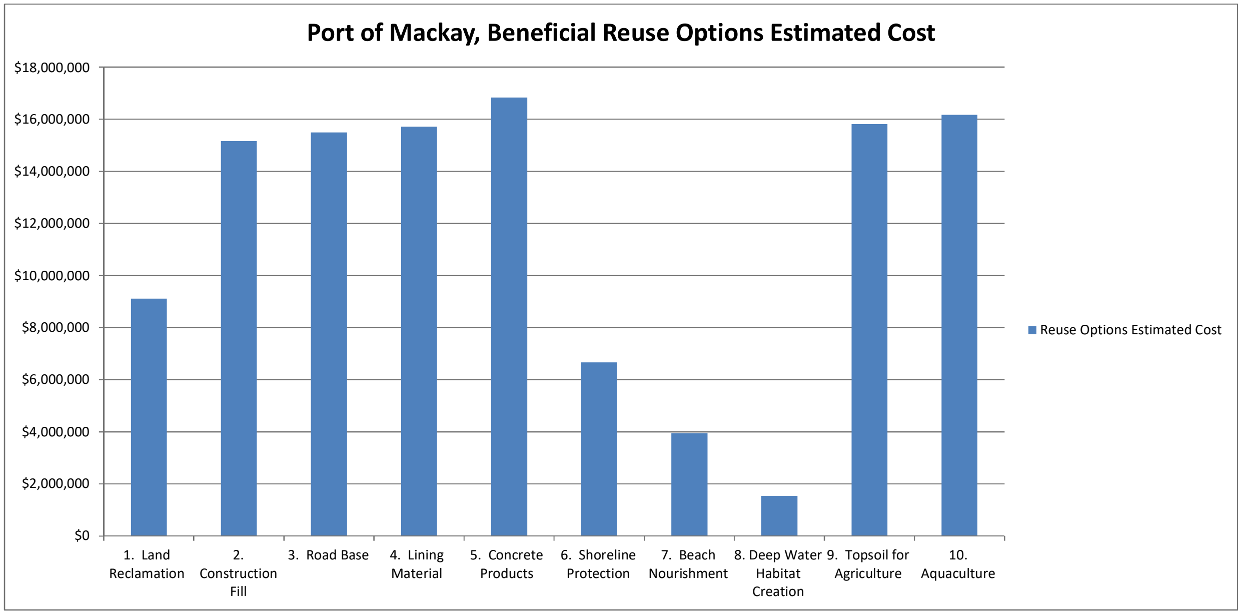
16 Transport processed sediment material off site to end user. Estimate 200m^3/h loading for 36t excavator and 19t wheel loader 375h at $150/h each =$113,000. Assumed 50km round trip for (construction fill, road base options, concrete products) 20m^3 truck and dog 3,750 x 1.5 hour trips 5,625h at $120/h = $675,000 (total $788,000). Assume 100km round trip for lining material to Hogan's' Pocket Landfill 50km south west of Mackay 20m^3 truck and dog 3,750 x 2 hour trips 7,500h at $120/h = $900,000 (total $1,013,000). Assume 130km roundtrip for topsoil for agriculture to Koumala 65km south of Mackay for topsoil for agriculture 20m^3 truck and dog 3,750 x 2.5 hour trips 9.375h at $120/h = $1,250,000 (total $1,238,000). Assume 170 km round trip for Aquaculture to Ilbilbie 85km south of Mackay 20m^3 truck and dog 3,750 x 3 hour trips 11,250h at $120/h = $1,350,000 (total $1,463,000).

17 Mobilisation rate depends on location of vessels and pipeline at the time.

18 No allowance for sediment trap dredging (south east corner of Swing Basin).

19 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.

20 No contingency.



Appendix B Greenhouse Gas Emissions Calculations

Appendix B - Greenhouse Gas Emissions Calculations for Port of Mackay Beneficial Reuse Options

			Beneficial Reuse Options									
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. Deep Water Habitat Creation	9. Topsoil for Agriculture	10. Aquaculture
Dredging	TSHD	Fuel oil	304	304	304	304	304	152	304	152	304	304
	Tug for tug and barge spread	Diesel						76				
	Workboat	Diesel	41	41	41	41	41	41	41	41	41	41
	Floating pipeline booster station	Diesel		87	87	87	87				87	
Dredge Pond construction	Excavator 36t	Diesel		294	294	294	294				294	294
	Wheel Loader 19t	Diesel		220	220	220	220				220	220
	Water truck	Diesel		73	73	73	73				73	73
	Tip truck and dog 20m^3	Diesel		288	288	288	288				288	288
Processing screening/blending/mixing	Excavator 36t	Diesel		245	245	327	245				327	327
	Dozer D6	Diesel		225	225	299	225				299	299
	Passenger vehicle	Diesel	20	20	20	20	20				20	20
	Screening plant	Diesel		81	81	108	81				108	108
Processing dewatering/desalinatio	Excavator 36t	Diesel	78	78	118	118	118				118	118
	Wheel Loader 19t	Diesel	72	72	108	108	108				108	108
Rock Sea Wall	Excavator 36t	Diesel	294									
	Wheel Loader 19t	Diesel	220									
	Water truck	Diesel	147									
	Tip truck and dog 20m^3	Diesel	287									
Transport	Excavator 36t	Diesel		245	245	245	245					
	Wheel Loader 19t	Diesel		184	184	184	184					
	Tip truck and dog 20m3 (1.5h, 2.0h)	Diesel		459	459	612	459					
	Tip truck and dog 20m3 (2.5h, 3.0h)	Diesel									765	919
Pug Mill	Pug Machine	Diesel					20					
		Total (tonnes CO_2 equivalent)	1,464	2,918	2,993	3,329	2,993	270	346	194	3,054	3,120

	1. Land Reclamation	2. Construction Fill	3. Road base	4. Lining Material	5. Concrete Products	6. Shoreline Protection	7. Beach Nourishment	8. Deep Water Habitat Creation	9. Topsoil for Agriculture	10. Aquaculture
Dredging	346	432	432	432	432	270	346	194	432	346
Dredge Pond construction	-	876	876	876	876	-	-	-	876	876
Processing screening/blending/mixing	20	571	571	754	571	-	-	-	755	754
Processing dewatering/desalination/ripening	150	150	225	225	225	-	-	-	225	225
Rock Sea Wall	948	-	-	-	-	-	-	-	-	-
Transport	-	888	888	1,041	888	-	-	-	765	919
Pug Mill	-	-	-	-	20	-	-	-	-	-
Total (tonnes CO2 equivalent)	1,464	2,918	2,993	3,329	2,993	270	346	194	3,054	3,120