Gladstone Ports Corporation Ltd

Beneficial Reuse Options Assessment
PoG Sustainable Sediment Management Project

August 2019

Executive Summary

Gladstone Ports Corporation (GPC) provide and operate the Port of Gladstone (PoG) under the provisions of the Queensland Government *Transport Infrastructure Act 1994* which includes maintaining and providing navigational channels through annual maintenance dredging campaigns. GHD was commissioned by GPC to assess a number of beneficial reuse options for maintenance dredging materials in the Gladstone region.

The options assessment undertaken for this report involved two phases; identification of potential beneficial reuse options, and analysis of the opportunity, potential feasibility and achievability of the options in the context of the PoG. The primary considerations for the assessment were sediment properties of the dredge material, current and likely future maintenance dredging requirements, dredging sediment cycle, methods, processing and placement, and the opportunity for use within the region.

Evaluation objectives and beneficial reuse options were discussed and decided with relevant stakeholders of the broader PoG Sustainable Sediment Management Project. Evaluation objectives were agreed upon to reflect the key issues of importance and define the desired direction of change in relation to each issue, they were environment, resource use, legislative requirement, health and safety, cultural, social, port operations, cost, economics, methodology, innovation and longevity. From a total of 26 options reviewed nine options were selected, with some options combined due to similarities in scope, end results, locations or impacts. The shortlisted options are those listed below.

Option 1 & 2: Land Reclamation – Fishermans Landing and New Reclamation Sites

Land reclamation works involve the use of the maintenance dredge material as fill to raise a low-lying or submerged area such that it may be used as commercial or public land. Potential locations for this use, based on a combination of site availability, economic feasibility and capacity constraints, are the Western Basin Expansion, Fishermans Landing (South), Port Central Expansion and West Banks Island Reclamation. The current land reclamation areas of Western Basin and Fishermans Landing were considered however have been set aside to accommodate future capital dredge material. Sediment required for land reclamation works is sandy or coarse to ensure sufficient strength for construction purposes. Outer and middle channel locations (Wild Cattle, Golding, Auckland and Clinton) provide sediment of this composition.

The key constraints for this option are the availability of suitably low lying portside land and a number of detailed assessment and approvals that would be required. In order to progress this option, a suitable reclamation area must be identified and agreed upon.

Option 3: Shoreline Protection – Coastal Erosion Mitigation

Coastal erosion mitigation was considered as the placement of dredge material being placed onshore to protect exposed areas or structures from erosion. Direct placement would be either onto banks of waterways or coastal frontages (different to beach nourishment) or through the use of geotextile bags or tubes onshore or offshore as foreshore armouring, groynes or submerged breakwaters. Shoreline areas considered for this option were Lilley's Beach, Boyne Island, Tannum Sands Beach, Wild Cattle Island and Colosseum Inlet. Direct placement onto shorelines would require sandy sediments whereas geotextile bags could utilise a range of varying sediments.

Whilst coastal erosion mitigation has the potential to have a positive impact on preserving coastal lands, parks and buildings, high additional costs mean that feasibility will be determined on an as-needs basis and the availability of lower cost, alternative, non-dredging related solutions. In addition, significantly altering the composition of these areas and associated coastal processes requires detailed investigations and careful planning as natural processes may be adversely affected.

Option 5: Beach Nourishment – Onshore Placement

Beach nourishment involves the direct placement of sand / sediment onto areas that have been lost to erosion, it is typically ongoing as coastal processes driving erosion are not mitigated and continue to cause sand loss. Areas considered for onshore placement of materials were Boyne Island, Tannum Sands, Wild Cattle Creek area and Facing Island. It is important that sediments used for beach nourishment would be compatible with the native beach material, generally sandy, and with similar physical characteristics of grain size, grading, composition, density, angularity and colour.

This option would provide a number of environmental and social benefits including more favourable beach profiles for nesting turtles and recreational users however longevity would be a short to medium term solution. Progressing this option would require further consultation with key stakeholders along with a comprehensive cost benefit analysis.

Option 6: Beach Nourishment – Offshore Placement

With similar characteristics to Option 5, beach nourishment through offshore placement relies on natural coastal processes to move the sediment to suitable locations. The approach is often termed “working with nature” and has been employed with great success on similar projects. Locations that would benefit from beach nourishment are Boyne Island, Tannum Sands, Wild Cattle Creek area and Facing Island. As with Option 5, sediments used for beach nourishment need to reflect the native sediment compositions found in these areas.

Offshore placement for beach nourishment is considered a more cost effective alternative to onshore placement due to minimising / eliminating the processing and handling of the dredged material. However, further consultation with key stakeholders and cost benefit analysis would still be required if this option was to progress.

Option 7: Habitat Restoration / Creation – Seagrass

Habitat restoration / creation in relation to seagrass habitats was assessed in line with historic and ongoing research conducted locally by the Seagrass Research Group at CQUniversity and James Cook University. Due to the requirement for a sandy or muddy substrate there is potential that strategic placement of dredge material could increase the area available that is suitable for seagrass growth. Various locations through PoG and the wider Port Curtis area can be considered for seagrass habitat rehabilitation through restoration, enhancement, creation or natural recoverability. A favourable site considered is Shoal Bay, an inlet at Facing Island, as this location provides shelter and nutrient input from mangroves. It is considered that material from all sections of the PoG channels would be suitable for this option, with a mixture of sand and clay / silt being most favourable.

Whilst there are numerous benefits (environmental, social and commercial) from habitat restoration / creation for seagrasses, research in this area is ongoing and uncertainties relate to whether placement of dredge material would increase seagrass meadows, or if other factors play critical roles.

Option 8 & 9: Coastal Habitat Restoration / Creation - Direct and Indirect Placement (Environmental Bunds and Mangrove / Tidal Habitat)

Coastal habitat areas are highly valuable and are under threat from a number of factors including development, tourism, weather events and climate change. The protection and enhancement of coastal habitats is a focus for many State and local authorities as well as industry and the community. Direct placement options in the Port of Gladstone include the restoration of mudflats and mangroves, creation of new coastal habitats in the foreshore environment or offshore in enclosed circular bunds. The creation of an island habitat system was also considered north of the Curtis Island gas plants in The Narrows, or between Curtis Island and Facing Island. Indirect placement options, using the concept of a 'mud motor', included estuarine areas along Curtis Island, Facing Island or The Narrows.

Preferred sediment would be dependent on the purpose of the restoration or creation and also the placement method. Coarse materials would be required for the construction of outer bunds and direct placement to provide sufficient strength for construction purposes, whereas finer silts and clays are preferred for infill placement either direct or indirect.

Key factors affected for this option include environmental, social and economic. Environmental benefits include supporting a wide range of flora and fauna which rely on coastal habitat health and availability, which in turn benefits social and economic factors through the boost to recreational and commercial fishing and tourism. However, this option would require further extensive stakeholder consultation, comprehensive cost benefit and site selection analysis.

Option 11 & 14: Deep Water Habitat / Scallop Beds

The use of dredged material for the option of deep water habitat refers to the rehabilitation of disturbed areas or the enhancement of current areas that are typically flat with no habitat features. Similarly, this option explores the use of dredged material to enhance scallop beds for the Queensland saucer scallop (*Ylistrum balloti*). Currently there are six scallop replenishment areas in Queensland, with the closest being Bustard Heads approximately 30 km from the PoG. All six areas have been closed since 3 January 2017 due to low catch rates, highlighting the need for scallop bed improvements in Queensland. Further consultation with Great Barrier Reef Marine Park Authority (GBRMPA) would be required for the potential opportunities or demand for deepwater habitat works.

Sediment material required would be project dependent with high sand content being preferred for deepwater habitat projects, whereas high clay and silt content is considered most suitable for scallop beds.

This option provides obvious environmental, social and economic benefits as it would enhance environmental conditions and biodiversity at the sites along with providing benefits to recreational and commercial uses such as fishing and diving. In addition, this option proves highly innovative relating to ongoing and upcoming research and if proven to be successful is a good long-term solution. However, cost benefit analysis would be required due to the significant increase in maintenance dredging time as a result of the increase in steaming distance required for disposal.

Option 20 & 21: Lining / Bunding Material

Maintenance dredge material used to form environmental bunds and liners would benefit a number of industrial land users requiring bunds for the containment of potential contaminants such as stormwater management or actual chemicals. Liners are used in confined disposal facilities to contain leachates from entering the surrounding environment. Sediments most beneficial as liners are clays and silts however extensive processing would be required to isolate and blend required fractions of the dredge material.

Although the requirements for environmental bunding and liners are determined on a project-needs basis, many industries within the Gladstone region, including Rio Tinto, Orica, Queenalnd Alumina Limited (QAL) and Gladstone Regional Council (GRC), currently use environmental bunds and liners and could benefit in future projects. The Gladstone State Development Area also has potential for future industrial or infrastructure needs however this is unquantifiable and currently unknown.

Key aspects affected by this option includes the potential economic impact to local land based quarries as supply would be sourced from dredge material instead, and the high cost associated with establishing an onshore processing area.

Option 23: Land Rehabilitation / Land Improvement / Fill

Land rehabilitation, referring to a process of returning damaged land to its natural state, land improvement and fill for construction purposes have the potential to utilise maintenance dredge materials in the Gladstone region for projects / companies such as mine rehabilitation, industrial or commercial construction or flood mitigation along the Boyne and Calliope River. Sediments most beneficial are project-dependent.

Environmental and social benefits from this option include the preservation / revival of coastal land, parks and buildings however the use is not considered finite and requirements for the option are currently unknown. The challenges associated with this option relate to high cost due to extra processing requirements. An aspect that increases viability is the addition of by-products, such as ash, which are readily available to improve sediment properties.

Abbreviations and / or Acronyms

Abbreviation	Description
AMA	Australasian Marine Associates
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand
AREA	Australian Renewable Energy Agency
ASS	Acid Sulfate Soils
BHD	Backhoe Dredge
CHAS	Coastal Hazard Adaptation Strategy
CHMP	Cultural Heritage Management Plan
CO_2	Carbon dioxide
cum	Cubic meter
CSD	Cutter Suction Dredge
DAF	Department of Agriculture and Fisheries (State)
DATSIP	Department of Aboriginal and Torres Strait Islander Partnerships (State)
Deed	A five year Deed of Agreement (the Deed) was agreed between GPC and the Australian Government Department of the Environment and Energy (DoEE) on 14 August 2015
DES	Department of Environment and Science (State)
DMPOI	Dredged Material Placement Options Investigation
DNRME	Department of Natural Resources, Mines and Energy (State)
DoEE	Department of Environment and Energy (Commonwealth)
DSDMIP	Department of State Development, Infrastructure, Manufacturing and Planning (State)
EBSDS	East Banks Sea Disposal Site
EPBC Act	Environment Protection and Biodiversity Conservation Act
ERA	Environmentally Relevant Activity
FHA	Fish Habitat Area
GAWB	Gladstone Area Water Board
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
GHD	GHD Pty Ltd
GHG	Greenhouse Gas
GPC	Gladstone Ports Corporation
GRC	Gladstone Regional Council
JCU	James Cook University
km	Kilometre
LGA	Local Government Area
LMDMP	Long Term Maintenance Dredging Management Plan
LOR	Limit of Reporting
m	Metre
MRTS	Main Roads Technical Specification

Abbreviation	Description
MCU	Material Change of Use
MLES	Matters of Local Environmental Significance
MNES	Matters of National Environmental Significance
MSES	Matters of State Environmental Significance
MSQ	Maritime Safety Queensland
NAGD	National Assessment Guidelines for Dredging
NGER	National Greenhouse and Energy Reporting
PAH	Polyaromatic Hydrocarbons
PASS	Potential Acid Sulfate Soils
PCCC	Port Curtis Coral Coast
PCDD	Polychlorinated Dibenzodioxins
PCDF	Polychlorinated Dibenzofurans
PIANC	Permanent International Association of Navigational Congresses
PoG	Port of Gladstone
PSD	Particle Size Distribution
QAL	Queensland Alumina Limited
Reef 2050	Reef 2050 Long-Term Sustainability Plan (DoEE 2018)
SAP	Sediment Analysis Plan
SARA	State Assessment and Referral Agency
SDA	State Development Area
t CO_2	Tonnes carbon dioxide
TBT	Tributyltin
TEC	Threatened Ecological Community
TMR	Department of Transport and Main Roads
TOC	Total Organic Carbon
TSHD	Trailing Suction Hopper Dredge
UCL	Upper Confidence Limit
UKC	Under Keel Clearance
WALI	Web-based Agricultural Land Information
WBDDP	Western Basin Dredging and Disposal Project
WPI	Weighted Plasticity Index
WQA	Water Quality Action

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1. Introduction

1.1 Background

Gladstone Ports Corporation (GPC) provide and operate the Port of Gladstone (PoG) under the provisions of the Queensland Government *Transport Infrastructure Act 1994* which includes maintaining and providing navigational channels through annual maintenance dredging campaigns. The PoG lies within Port Curtis which is recognised as an important wetland encompassing the harbour and within the boundaries of the Great Barrier Reef World Heritage Area (GBRWHA) as inscribed in 1981. However, all PoG maintenance dredging activities including channels and the East Banks Sea Disposal Site (EBSDS) are inside the Port Limits and not within the Great Barrier Reef Marine Park (GBRMP) as shown in Figure 1-1.

A five year Deed of Agreement (the Deed) was agreed between GPC and the Australian Government Department of the Environment and Energy (DoEE) on 14 August 2015, regarding maintenance dredging. Specifically related to this project the Deed requires GPC to investigate the possibility of avoiding or reducing the need for further dumping of maintenance dredge material into the marine environment. In addition, two specific Water Quality Actions (WQA) of the Reef 2050 Long-Term Sustainability Plan (Reef 2050) (Commonwealth of Australia, 2018) are relevant to this project:

- WQA 17 - Understand the port sediment characteristics and risks at the four major ports and how they interact and contribute to broader catchment contributions within the GBRMP.
- WQA 16 - Develop a state-wide coordinated maintenance dredging strategy.

The objectives of the Sustainable Sediment Management Project (SSM Project) are for GPC to meet their obligations and commitments within the Deed and Implementation Strategy to enable ongoing maintenance dredging and find sustainable long term management option for maintenance dredging. The project as defined in this report forms part of the Sustainable Sediment Management Project.

GHD Pty Ltd (GHD) was engaged by GPC to undertake a sampling and analysis program to characterise the engineering properties of maintenance dredge material and to undertake a comprehensive options analysis of the opportunities for beneficial reuse of maintenance dredge material within the PoG. Specific objectives have been categorised into three key components:

- Task 1a - Sediment Sampling Strategy to assess engineering properties of the maintenance dredge material.
- Task 1b - Sediment Characterisation Report of the engineering properties of the collected material from Task 1a.
- Task 2 - Comprehensive Options Analysis Report outlining the opportunities for beneficial reuse (this document).

Tasks 1a and 1b have been completed and are documented in a separate report, *Sediment Characterisation Report*, (GHD 2019).

1.2 Purpose of this Report

The purpose of this report is to document the approach and findings of the analysis undertaken into beneficial reuse options for maintenance dredge material from within the PoG.

This report provides:

- An overview of the sediment sampling and analysis investigations along with commentary regarding the implications for beneficial reuse options.
- A description of the option identification and assessment approach, including evaluation objectives.
- An overview of each potential beneficial reuse option considered and reasons for the selection of those shortlisted for further assessment.
- A detailed assessment of each shortlisted beneficial reuse option against the agreed evaluation objectives to identify any fatal flaws and provide recommendations for the options warranting further consideration during subsequent stakeholder engagement to be undertaken by GPC.

It has been agreed with GPC that following completion of GHD's option development work (including shortlisting from the original list), the final weighting and selection of preferred option(s) for subsequent stages will be undertaken by GPC in consultation with relevant stakeholders.

1.3 Legislative Background and Reef 2050

The Australian and Queensland Governments are committed to delivering on actions that will support ecologically sustainable use of the GBRWHA encapsulated in the Reef 2050 Long Term Sustainability Plan (herein referred to as Reef 2050) (Commonwealth of Australia, 2018). These actions have been prescribed following considerable review across condition of, impacts to and predicted future condition of reef health, diversity and sustainability.

Actions to be implemented under Reef 2050 have been informed by the Outlook Report 2014 (Commonwealth of Australia, 2014) (with the next report due in 2019) and the comprehensive two-year strategic assessment of the adequacy of extant (at the time) environmental management arrangements at protecting the Reef and the Outstanding Universal Values for which it was inscribed on the World Heritage list (in 1981). Reef 2050 actions relevant to this project include WQA16 and WQA 17 as described in Section 1.1, which relate to the Sustainable Sediment Management Project. In addition, WQA15 is related to developing a dredging maintenance strategy, which in 2018 was marked as complete due to the development of the Maintenance Dredging Strategy for the Great Barrier Reef World Heritage Ports (Department of Transport and Main Roads), 2016).

PoG has been declared one of four GBRWHA priority ports, requiring a master plan in accordance with the requirements of the *Sustainable Ports Development Act 2015*. Under Reef 2050, master planning is also identified as a method for environmental management. The master plan will consider future priority growth while ensuring the values of the GBRWHA are protected.

1.4 Scope and Limitations

This report has been prepared by GHD for GPC and may only be used and relied on by GPC for the purpose agreed between GHD and the GPC as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than GPC arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (various sections). GHD disclaims liability arising from any of the assumptions being incorrect.

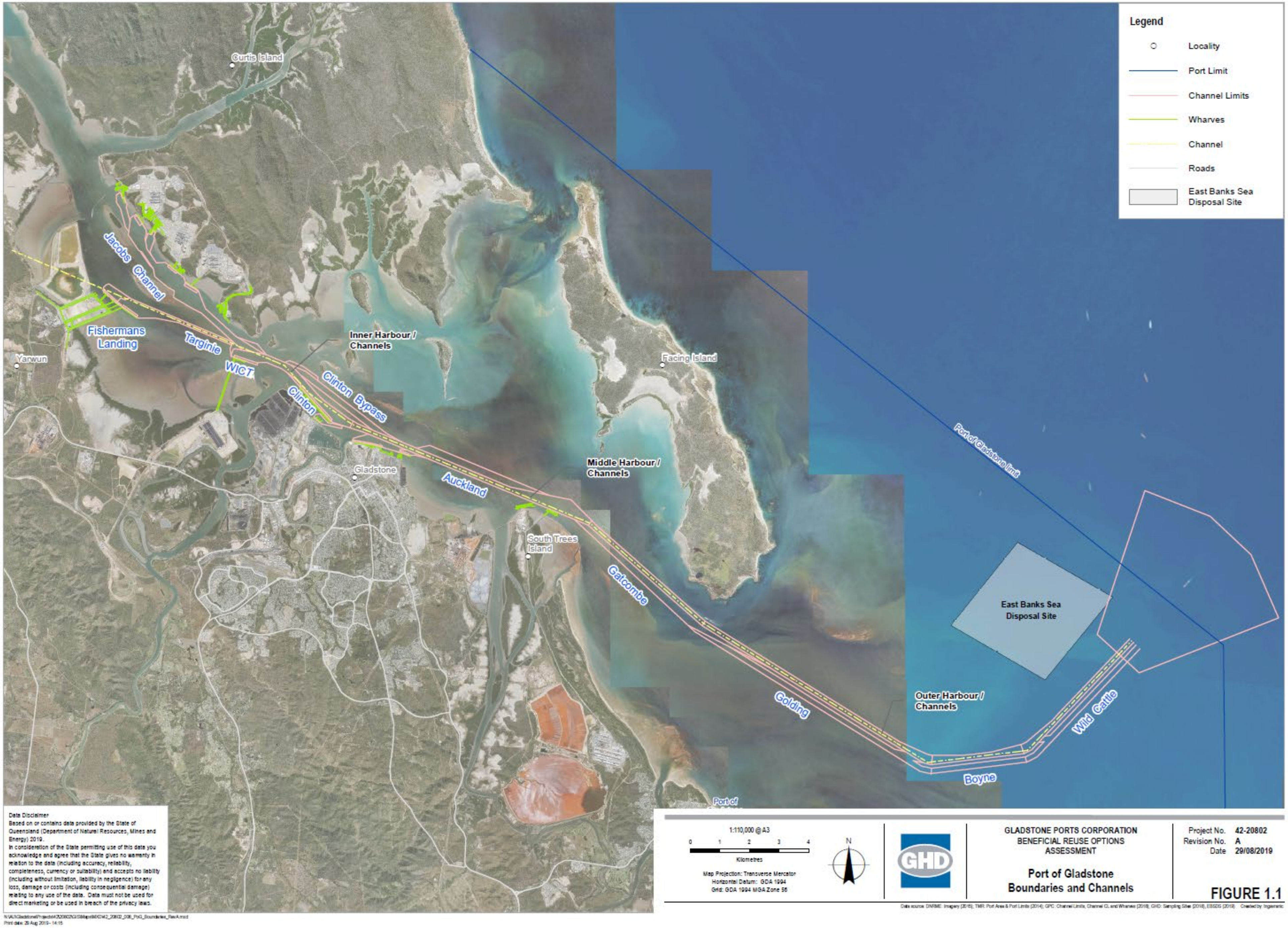
GHD has prepared this report on the basis of information provided by GPC and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The options have been developed to a conceptual level of detail to enable comparative assessment in relation to each of the options. It should be noted that the information provided is not suitable for feasibility analysis, environmental assessment or budget allocation.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the [works / project] can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

The objective of this assessment is not to select a preferred option but to identify any fatal flaws, inform stakeholders of the options and provide recommendations for the options warranting further consideration during the stakeholder engagement to be undertaken by GPC.


Legend
Locality
Port Limit
Channel Limits
Wharves
Channel
Roads
East Banks Sea Disposal Site
Curtis Island
Jacobs Channel
Fishermans Landing
Targinie
WICT
Yarwun
Inner Harbour / Channels
Clinton Bypass
Clinton
Facing Island
Port of Gladstone limit
Gladstone
Auckland
Middle Harbour / Channels
South Trees Island
Gatcombe
East Banks Sea Disposal Site
Golding
Outer Harbour / Channels
Wild Cattle
Boyne
Port of
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BENEFICIAL REUSE OPTIONS ASSESSMENT
Port of Gladstone Boundaries and Channels
Project No. 42-20802
Revision No. A
Date 29/08/2019
FIGURE 1.1
Print date: 29 Aug 2019 - 14:15

2. Maintenance Dredging Requirements

Loss of depth within the channels due to siltation has a significant impact on the draft of vessels that are able to transit and navigate efficiently and safely within the Port. Depths reductions of up to 1 m have been recorded from year to year within the PoG.

2.1 Port of Gladstone Shipping Channels

The PoG consists of approximately 50 km of shipping channel to ensure safe navigable operation of the Port. There are several sections of channel spaning the Inner and Outer Harbour, refer to Figure 1-1. Sediment management practices, i.e. maintenance dredging, ensures that the channel remains at the navigable depths set by Maritime Safety Queensland, refer to Table 2-1.

Table 2-1 PoG Channel and Depths for Maintenance Dredging (GPC, 2015)

Channel	Maintenance Depth (m LAT)
Outer Harbour	
Wild Cattle Cutting	-16.1
Boyne Cutting	-16.1
Golding Cutting	-16.1
Golding / South Bypass	-7.3
Gatcombe Channel	-16.3
Gatcombe Bypass	-12.5
Inner Harbour	
Auckland Channel	-15.8
Auckland Bypass	-6.8
Clinton Channel	-16.0
Clinton Bypass	-13.0
Targinnie Channel	-10.6
Jacobs Channel	-13.0
WICT departure channel	-16.0
Marina (maintained separately, refer Section 2.2)	-4.5

2.2 Maintenance Dredging Quantities

GPC's current maintenance dredging permit estimated a maintenance dredging and sea disposal volume of up to 1,460,000 m^3 over the five year term, with a maximum dredging volume of 340,000 m^3 in any one year.

Maintenance dredging has occurred approximately annually since 1993. Campaign volumes since that time are presented in Table 2-2. In addition, GPC identify that maintenance dredging of the Marina is undertaken about five-yearly with approximately 200,000-250,000 m^3 of material dredged using a cutter suction dredge (CSD) with disposal to land.

Table 2-2 Historical Main Channel Maintenance Dredge Volumes (Port & Coastal Solutions, 2018)

Campaign Year	Volume (m^3)
November 2007	160,972
November 2008	17,955
April 2009	129,044
November 2009	153,000
February 2011	126,000
July 2011	46,500
December 2011	136,500

Campaign Year	Volume (m^3)
December 2012	150,000
February 2014	251,514
July 2014	7,346
November 2014	307,505
June 2015 -	52,000
January 2016	248,000
October 2016	206,968
August 2017	209,456
November 2018	211,102

Since the 2015 permit application, the area requiring maintenance dredging has expanded due to the creation of Jacobs Channel and the channel areas associated with the LNG terminals. For planning purposes and permit applications, GPC has adopted a maintenance dredging volume of 260,000 m^3 per year, noting that volumes are likely to alter from year to year (as demonstrated by the historical maintenance dredge volumes outlined in Table 2-2).

2.3 Existing Sea Disposal Site

Maintenance dredged sediments from the PoG Channel, swing basins and berths have historically been relocated to the EBSDS. The EBSDS is shown in Figure 1-1 and defined by the following coordinates:

23° 53' .84S 151° 29' .02E

23° 52' .83S 151° 27' .10E

23° 51' .53S 151° 27' .91E

23° 52' .54S 151° 29' .84E.

Figure 1-1 illustrates the location of the EBSDS in relation to the dredge footprint. The closest boundaries of the site are 10.6 km from the mainland and 6.1 km from Facing Island. The depth of the sea disposal site ranges from 8 m to 13 m, with an average of 11 m below datum. It is calculated that a capacity of at least 35 million m^3 remains over the entire EBSDS.

The remaining dredged areas, primarily the Marina and Boyne River mouth, are placed on land.

2.4 Historical Maintenance Dredging Equipment

2.4.1 Trailing Suction Hopper Dredge

Historical maintenance dredging operations within the PoG (Main Channel) and other Queensland ports have generally been undertaken using the *Brisbane*, a Trailing Suction Hopper Dredge (TSHD) *Brisbane* based in Queensland and owned and operated by Port of Brisbane Pty Ltd. Vessel particulars are presented in Table 2-3 and an image showing the vessel underway presented in Figure 2-1.

Source: Port of Brisbane

Figure 2-1 TSHD Brisbane

Table 2-3 TSHD Brisbane Vessel Particulars

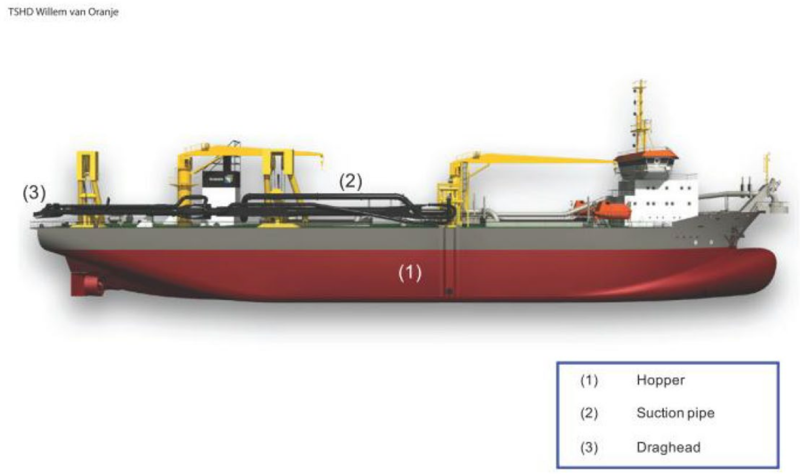
Parameter	Description
Owner	Port of Brisbane Corporation Pty Ltd
Length	85 m
Beam	17 m
Draft (loaded)	6.25 m
Draft (unloaded)	3 m
Minimum operational water depth	7.25 m (assuming 1 m under keel clearance (UKC))
Maximum dredge depth	25 m
Hopper capacity	2,900 m^3
Indicative production rate	45,000 m^3/week (free flowing maintenance dredge sediments subject to wave climate, port restrictions and distance from spoil ground)
Placement capabilities	Bottom dump, rainbowing or pump ashore by bow coupling
Maximum pumping distance	1500 m (depending upon sediment type)
Current location	Brisbane, QLD

GPC's Long Term Monitoring and Management Plan (GPC, 2015) provides a description of the current maintenance dredging methodology which is presented below. The TSHD Brisbane can operate in either automatic, where onboard computers control vessel dredge systems, or manual mode for dredging operations. Further, the onboard computers assist the positioning of the vessel by displaying a differentially corrected GPS position of the vessel track against intended dredge areas.

The vessel extracts material by lowering two suction heads (one on either side of the vessel) to the seafloor whilst steaming slowly (1 - 3 knots) ahead. Large pumps on-board then draw water through the heads entraining sediments from the seafloor in a similar fashion to a household vacuum cleaner, depositing a mixture of water and sediments into the vessel's central hopper. The dredge heads are not fitted with any mechanical agitation equipment and rely solely on the suction head provided by the on-board pumps. Whilst the vessel has the ability to pump high-pressure water to the dredge head to agitate sediments, this is generally not required unless operating in compacted sands.

The concentration of sediments delivered to the hopper is dependent on a number of factors, such as sediment type and dredging conditions, but is generally in the order of 10 - 30% solids.

That is, 70 - 90% of the material pumped to the hopper is water and must be discharged to achieve effective loading.



Source: Royal Boskalis Westminster N.V

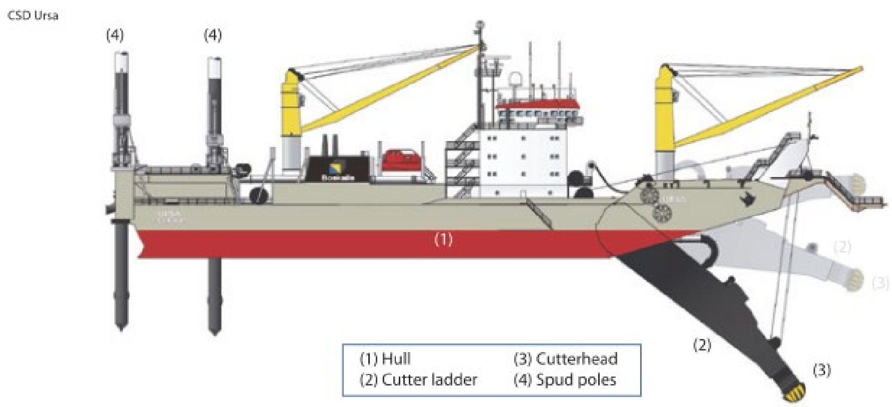
Figure 2-2 Example Trailing Suction Hopper Dredge

2.4.2 Cutter Section Dredge

Maintenance dredging operations within the Gladstone Marina are restricted by both the limited geometry and available water depths of the Marina navigation areas. As such, historical maintenance dredging of the Marina has been undertaken using a cutter section dredge (CSD) discharging via pipeline to a land based dewatering area located adjacent to Alf O'Rourke Drive.

CSDs are designed to remove material ranging from silt to hard clays and soft rock. The ability to dredge harder materials is a function of the power of the cutter head, the power of the side winches and the physical construction of the dredge.

A CSD is generally not self-propelled. It is generally a floating barge with a number of major elements that include a cutter, ladder, onboard pipework and pumps, an onboard power plant, control room and anchoring system (comprising spuds, swing wires and anchors). A cutter suction dredge is shown in Figure 2-3.



Source: Royal Boskalis Westminster N.V

Figure 2-3 Example Cutter Section Dredge

During dredging operations the cutter, located at the end of a ladder, is lowered to the seabed. The cutter revolves through the bed material and in so doing loosens material. Agitated material in the form of a hydraulic slurry is sucked up into the pipe intake, located behind the cutter, by the onboard pumps.

Typically, the solids concentration of the hydraulic slurry would be 10 to 15 percent by volume. The slurry would then be pumped through a discharge pipeline to the nominated disposal area.

This type of dredge works in a controlled manner with the vessel's pontoon normally held in position at the stern by a spud, which is dropped into the seabed. The cutting action is then facilitated by swinging the forward end of the pontoon in an arc across the seabed between two anchors set in front and to the side of the dredge. The dredge works on a fixed centreline. The cutterhead is lowered below water to the required dredging depth. Once the dredge face is cut down to the required depth, the dredge (and hence the cutterhead) is advanced along the centreline by means of moving the carriage in which the spud is mounted. To move forward the dredge is pushed against the spud by a hydraulic ram at a predetermined step size.

At the completion of a step an auxiliary spud is lowered and the main spud raised and returned to its starting position. The main spud is dropped and the auxiliary spud is raised prior to the recommencement of dredging operations. Small cutter dredges may not be fitted with a spud carriage and often advance by 'stepping' through the alternating use of the main working spud and the auxiliary spud.

A large dredge would, typically, have a pump on its ladder and at least one additional inboard pump within the pump room. The discharge pipeline would comprise sections of floating and onshore pipeline. Typical dimensions for the onshore discharge pipeline would be approximately 400 - 800 mm.

Placement of the material from the discharge pipe on to the nominated onshore fill area is typically managed by controlling the direction of flow of the discharge water with conventional land-based plant and equipment such as bulldozers and front-end loaders. The material would be discharged into containment ponds. The containment ponds would incorporate dewatering provisions to collect and redirect decant supernatant and underdrainage back to receiving waters. The progress of the filling area reclamation would usually be controlled by a series of valves and pipeline off-takes to ensure that the material progresses in a prescribed manner.

2.4.3 Backhoe Dredge

A backhoe dredge (BHD) is an excavator mounted on a purpose-built barge, as shown in Figure 2-4.

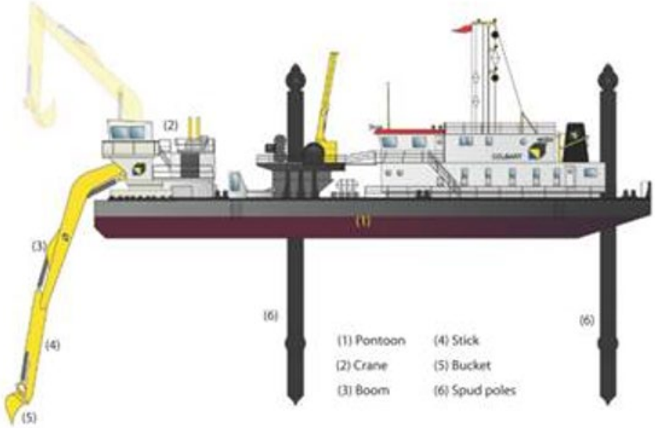
The barge would be supported by three 'spuds' (large diameter piles that can be lowered or raised). The spuds can be lowered into the seabed and hold the position of the barge. Two spuds are located at the bow and a single spud is located at the stern of the barge. The spuds provide a stable, working platform that facilitates excellent control during the completion of the dredging activities. The stern spud can also incorporate a ram against which the barge can push itself forward (with bow spuds raised) in steps. Most of the barges in the market are not self-propelled and would be moved around the site by work boats when all the spuds have been raised.

The BHD would be fitted with a specially designed grab or bucket that minimises turbidity in the water column during dredging operations. The material would be raised slowly within a turbidity curtain prior to its placement in a hopper barge anchored adjacent to the BHD. The use of the specially designed grab or bucket would significantly reduce the amount of material put into suspension. It also has the advantage of minimising the water content of the material.

The excavator can be fitted with position-fixing equipment (both spatially and with depth). This would allow the operator to selectively remove material from the bed of the river and accurately control the operation.

BHDs are mostly used to remove material within a confined working area, where high accuracy of material removal is required or where dewatering of dredged material may prove problematic.

BHDs are also commonly used to remove consolidated material where a TSHD or even CSD could not operate. BHD’s are not typically considered for a maintenance dredging campaigns where a relatively thin layer of material requires removal over a long length of channel due to efficiency considerations, as the grab only takes a localised cut from the seabed one at a time.



Source: Royal Boskalis Westminster N.V.

Figure 2-4 Example Backhoe Dredge

2.5 Implications for Beneficial Reuse of Current Locations and Equipment

Excluding the properties of the sediments themselves, which is covered in Section 3, there are a number of inherent factors which impact upon the opportunities for beneficial reuse within the PoG. These factors are summarised below and described in relation to each potential option within Section 7:

- Maintenance dredge material requires removal from ten main wharf centres and over 50 km of channels. As a result, distances to disposal or beneficial reuse locations are highly variable which generally restricts the suitable dredging equipment to TSHD or BHD and barging operations.
- For material placed using a TSHD or barge, bottom dumping operations must be undertaken in sufficiently deep water to ensure adequate clearance between the hull of the dredge vessel (including the hopper doors) and the placed material.
- Draft restrictions prevent TSHDs or barges from discharging dredged material in close proximity to onshore areas that may be suitable for beach nourishment or land reclamation.
- Similarly, TSHDs are generally limited to an unaided pumping distance of around 1500 m. The relatively wide, gently sloping intertidal areas of the Gladstone region necessitate the dredging of access channels or acceptance of long pumping distances and the use of booster stations which significantly increase the cost of dredging works. Rainbowing or bow-casting of material may also be undertaken however the maximum placement distance is typically limited to around 100 m.
- Material removed using a CSD is similarly restricted to an unaided pumping distance of around 1500 m from the dredge site. The use of booster stations may extend pumping distances however the additional pumping effort reduces efficient and significantly increases the cost of dredging works. As a result, there is a practical limit to the total pumping distance.

- Sedimentation rates and associated maintenance dredging volumes are variable from year to year and are influenced by a variety of factors beyond GPC's control. As a result, multiple dredge campaigns (over a number of years) may be required in order to provide sufficient suitable materials for beneficial reuse options.

3. Sediment Properties

Sediment properties of the maintenance dredge material are detailed in the Sediment Characteristics Report (GHD, 2019). The report provides an overview of the most recent Sediment Analysis Plan (SAP) sampling program undertaken by Australasian Marine Associates (AMA) in 2017, along with a detailed description of the field sampling undertaken in 2018 by GHD and provides interpretation of these results for sediment characterisation and engineering properties.

This section provides a summary of the previous investigation, and interpretation of the implementations for beneficial reuse options. Further review of the sediment and the relation to specific options is provided in Section 7.

3.1 Sediment Investigations

3.1.1 SAP Sampling Program (2017)

SAP sampling field work was undertaken by AMA between 21 - 23 November 2017, and included grab samples and core samples from PoG Main Channels, Gatcombe Heads Harbour, Upper Auckland Inlet, Lower Auckland Inlet and Gladstone Marina.

A range of analyses were undertaken at all sites, including heavy metals, hydrocarbons, acid sulfate soils (ASS), nutrients, dioxins and furans. No major contamination was reported at any of the sites sampled.

Levels of iron, aluminium and manganese returned a higher 95% upper confidence limit (UCL) at the Gladstone Marina and Lower Auckland inlet locations however were not considered a concern as they are naturally abundant (AMA, 2018).

Tributyltin (TBT) concentrations in samples from Gladstone Marina and Lower Auckland Inlet (where dredged material is placed on land) reported a higher 95% UCL in the 0.5 - 1 m sediment horizon than the screening level from National Assessment Guidelines for Dredging (NAGD) (predominately affected by the Lower Auckland results), however the concentration was below the ANZECC / ARMCANZ (2000) marine water quality trigger values for 95% species protection (AMA, 2018).

Polychlorinated dibenzofurans (PCDF) concentrations were lower than the Limit of Reporting (LOR) at all sites (AMA, 2018).

Polychlorinated dibenzodioxin (PCDD) concentrations showed high levels of variability, however differences to this degree are considered not unusual (AMA, 2018). The most toxic PCDD, known as 3,7,8-TetraCDD, was not detected in any samples (AMA, 2018).

3.1.2 Sediment Characteristics (2018)

Field samples were collected from six locations in the PoG in addition to one duplicate sample and two dredge hopper samples collected from the TSHD *Brisbane* hopper dredge. The sediment grab sample sites were spread across the extent of the PoG (upper, middle and outer channel) and the Marina, to capture different properties of the sediments in varying areas. The locations were selected based on a number of considerations including previous sediment data and material classifications and actual areas of the Main Channel (and Marina) that undergo regular maintenance dredging. This provided a representation of the sediments that are dredged and may be available for reuse options. Dredge hopper samples were collected during the dredging of Jacobs Channel GLNG Swing Basin South Side and Wild Cattle South Side, for which the comparison sediment grab samples are Jacobs and Wild Cattle respectively.

Samples were analysed for Total Organic Carbon (TOC) and ASS and engineering / physical properties which included Particle Size Distribution (PSD), moisture content, Atterberg limit, linear shrinkage and bulk density aggregate. Additional properties which included petrographic analysis and shape analysis was undertaken on one sample only; Golding.

TOC and PSD results were in line with previous studies by AMA (2017, 2018). In particular, PSD analysis indicated that sediments in the outer and middle channel locations (Wild Cattle, Golding, Auckland, Clinton) consisted of a higher percentage of coarse sand and gravel materials than those sediments found in the upper channel reaches (Targinnie and Jacobs) and in the Marina (Figure 3-1).

Previous studies have suggested that the differences in sediment composition along the channels are due to a combination of factors including differences in tidal currents, wave action and associated sediment input pathways (Port & Coastal Solutions, 2018). In particular, areas of higher wave action and current flow suspend the finer materials in the water column therefore leaving sand and gravel materials in the sediment. Finer silty sediment was reported in the locations of lower current flow and wave action along with a higher TOC concentration.

PSD results for samples collected from the dredge hopper were expected to contain less fines than those recovered directly from the seabed. This assumed that a percentage of the fines would be lost during recovery and overflow operations. Conversely, PSD tests presented in Figure 3-2 showed higher fines concentrations for those samples recovered from the dredge hopper. This is likely due to the method of sample recovery whereby samples were collected from the surface of the hopper which contains a higher percentage of suspended fines than the bulk of material within the hopper.

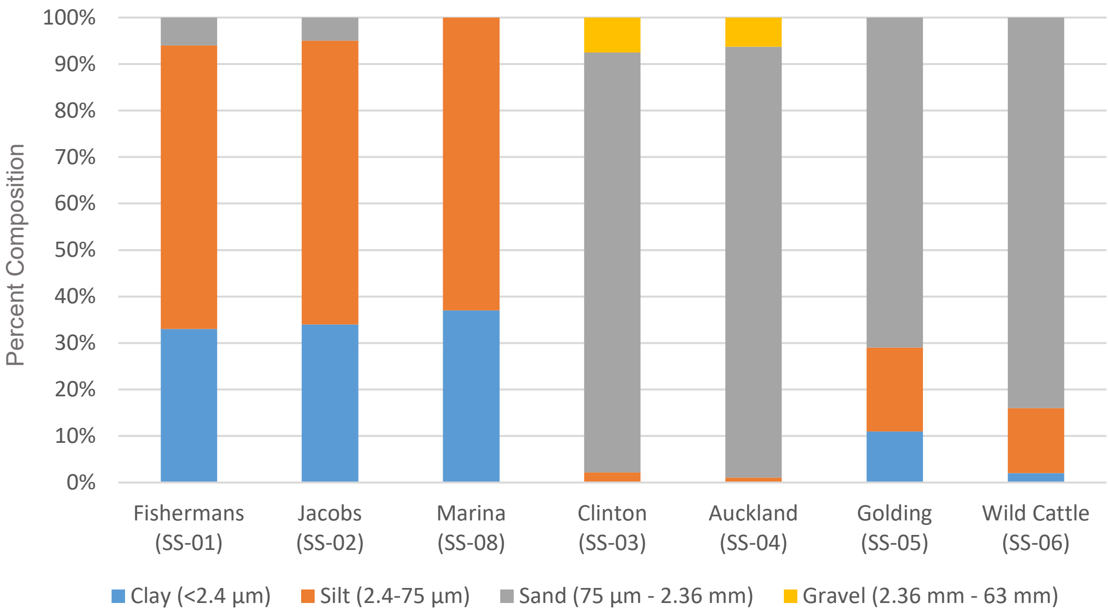


Figure 3-1 PSD Results of Sediment Grab Samples

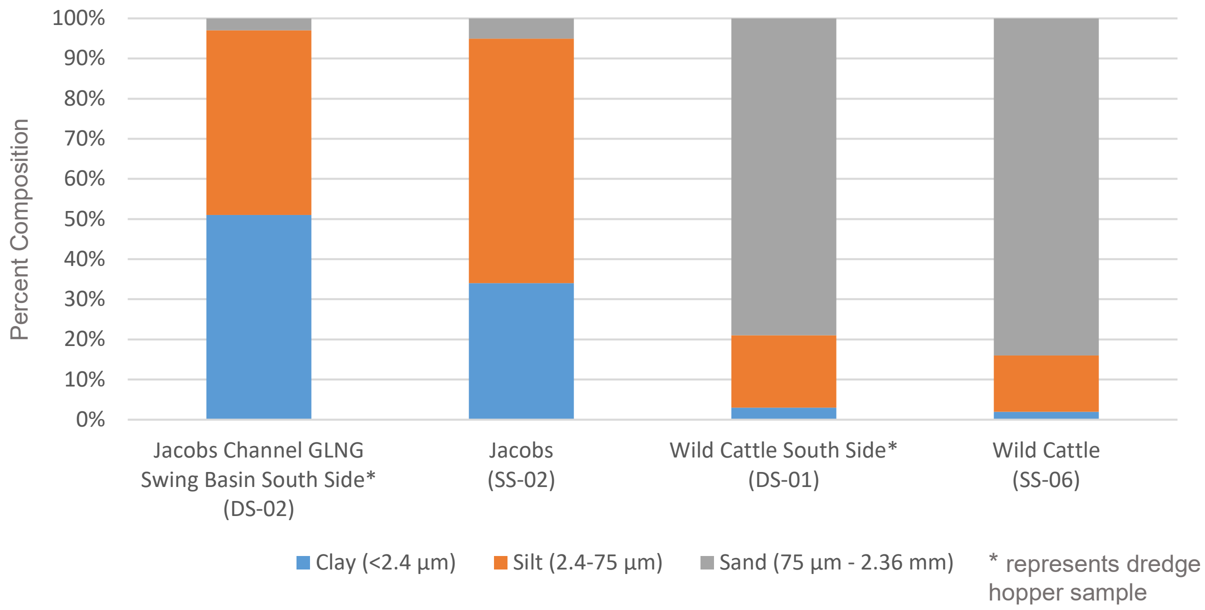


Figure 3-2 PSD Results of Dredge Hopper Samples Compared to Grab Samples

A summary of the parameter results is as follows:

- ASS:
  - Potential ASS are present within the sediments, however there is existing and excess acid neutralising capacity (such as shell fragments) that neutralised the sediments.
- Moisture content:
  - Average moisture content was 179% in the upper reaches of PoG, 24.05 % in the middle reaches, 33.15% in the outer reaches.
  - The high moisture content may present challenges for use of the sediment in its current state, drying or mixing may be required.
- Atterberg limit:
  - >12% of fine material was required for Atterberg limit analysis.
  - Samples tested plotted above the 50% Liquid Limit line with two samples classified as high plasticity clays of inorganic origin and one as medium to high plasticity fine grained soils, either organic clays or inorganic silts.
- Linear shrinkage:
  - High linear shrinkage results were recorded on the fine grained soils highlighting a potential for swelling.
- Bulk density aggregate:
  - Results ranged from 0.88 t/m^3 to 1.36 t/m^3.

3.2 Implications for Potential Beneficial Reuse

Opportunities for the types of reuse are dependent on a range of factors including proximity of available work sites, availability of space for drying material and the engineering properties of the dredged material.

Non-plastic granular dredge spoils are commonly used for land reclamation, and with appropriate construction controls they can be suitable as load bearing fill. Coarse grained dredge spoil may also be processed to produce construction materials such as washed sand, however suitability is dependent on the level of contamination and geotechnical properties of the materials.

High plasticity fine grained materials require a long drying period before they can be used as liners for retentions systems such as dams and landfills. In these applications linear shrinkage and permeability are important, as is consistency of material source.

3.2.1 Engineering Characterisation of Sediment

As per section 3.1.2, the sediment samples are either non-plastic granular sands and gravels, or high plasticity fine grained silts and clays. In order to assess the potential for reuse of dredge spoil for land based engineering purposes, the samples have been classified in accordance with the earth fill classification system outlined in Section 14.2.2 of *Transport and Main Roads Specifications MRTS04 General Earthworks* November 2018 (TMR, 2018b). This classification system categorises earth fill material into classes primarily based on Weighted Plasticity Index (WPI). WPI is calculated by multiplying the Plasticity Index by the percentage passing the 0.425 mm sieve. Material classes range from Class A1 to Class D, with material with a WPI > 4200 classified as unsuitable. Generally Class A1 and B material is suitable for use in homogenous embankments, while Class A2, C and D material can only be used in the core zone of zoned embankments. The classification of sediment grab samples as per MRTS04 is presented in Table 3-1.

Table 3-1 Earth fill material classification of grab samples

Sample Location	Plasticity Index (%)	% Passing 0.425 mm	WPI (Plasticity Index x %0.425)I	Earth fill classification (MRTS04 Table 14.2.2)
SS-01 (Fishermans)	31	100	3100	C
SS-02 (Jacobs)	31	100	3100	C
SS-03 (Clinton)	Non plastic	18	0	Class A2 / Non classifiable
SS-04 (Auckland)	Non plastic	18	0	Class A2 / Non classifiable
SS-05 (Golding)	Non plastic	97	0	Class A2 / Non classifiable
SS-06 (Wild Cattle)	Non plastic	98	0	Class A2 / Non classifiable
SS-08 (Marina)	27	100	2700	C

The samples from the Outer and Middle channel locations (Wild Cattle, Golding, Auckland, Clinton) were classified as Class A2, but due to the apparent near complete lack of fines component they would be difficult to use as earthfill material. The upper channel samples (Fishermans and Jacobs) and the Marina are classified as Class C or D and would only be suitable for use as part of a zoned embankment construction. It may be possible to blend dredge material from a range of sites to improve the engineering characteristics of the final product. Given the need for extensive drying of hydraulic pumped dredge spoil, there may be opportunities for blending to improve the useability of the material, although outcomes are difficult to assess at this stage.

3.2.2 Impacts of Dredging on Engineering Characteristics of Sediments

Whilst sediment samples have been collected and analysed from within the PoG maintenance dredge areas, it is important to note that dredging processes can significantly alter these properties between the dredging sites (natural state) and final disposal location.

Different dredging equipment and techniques result in varying degrees of disturbance to sediments. In general terms, dredging and rehandling results in the loss of fines, changes to Atterberg limits, moisture content / plasticity, strength, reduction in density and associated bulking of dredged sediments.

For example, removal and handling of material using a mechanical dredge such as a BHD or grab dredge removes individual sections of the seabed at close to its insitu density and are ideal for sea placement to be used as fauna reserves. Conversely, hydraulic dredging techniques such as the use of a CSD remove bottom sediments in the form of a hydraulic slurry with typical solids concentrations in the order of 10% to 15% by volume. Similarly, material removed using a TSHD will be initially pumped into the hopper in a similar hydraulic slurry to that created by a CSD. It is possible to achieve some degree of densification of the slurry within the hopper through overflow dredging, whereby waters collecting in the hopper are returned via a green valve below the vessel. Transport, rehandling and placement of dredge sediments can also be expected to further disturb and modify the original insitu properties.

For some recently deposited sand and gravel granular materials, the disturbance of the soil matrix and loss of fines will not significantly change the engineering properties of the sediments. However, for cohesive soils and those containing a significant fines fraction, insitu sediment properties may show little resemblance to those at the final disposal location.

For initial feasibility and options assessment fill quality may be assessed by classifying sediments as granular, relatively free draining soils and fine grained, poorly draining soils.

3.2.3 Sediment Suitability for Reuse

Initial assessment indicates that PoG has high rates of sedimentation and is one of the few Great Barrier Reef (GBR) ports in which sands (and limited gravel and shell fragments) accumulate within dredged areas. As a result, the PoG is well positioned to investigate the beneficial reuse of maintenance dredge material since these sediments have better engineering properties.

The results from the sediment investigations indicate that finer silty sediments are present in the upper channel reaches and Marina. Becoming coarser (containing a higher sand and gravel content) in the outer and middle channels, refer to Figure 3-1. The channel can be characterised into three seabed types:

- Upper channel region of Targinnie, Jacobs and Marina, largely dominated by silts and finer clay fractions.
- Middle channel region of Clinton and Auckland, largely sand with some gravel / shell fragments and minor silt fractions.
- The outer channel region of Golding and Wild Cattle are largely sand with some silt and clay.

The suitability of sediments to be dredged for each of the reuse options is influenced by their engineering/physical properties listed above. For example, dredge material to be used for beach nourishment would need to be compatible with the native beach material. In the Gladstone region, beaches are made up of sand, gravels and shells. The sandy dredge material from the Middle and Outer channels would be more suitable for this application than the silty and finer clay sediments of the upper reaches.

As assessed, there is a variability of sediment types to be dredged throughout the channel and therefore it is unlikely that a single reuse option will require all sediment types as well as meeting the significant demand.

It is necessary to consider a number of reuse options (as per this report), and if appropriate more than one reuse option may be considered as part of further assessments/feasibility.

Staging of dredging operations will therefore be required so that the dredge materials match the sediment requirements for the chosen reuse option. For example, beach nourishment campaigns would need to target sediments from the middle channel areas (Clinton and Auckland) or outer channel areas. This will ensure that the majority of the dredged sediment from these locations is suitable for the beach nourishment works.

The suitability of the different types of dredge materials for each reuse option is further detailed in Section 7.

3.2.4 Breakdown of Future Maintenance Dredging Material

GPC has determined that the required maintenance dredging volumes are expected to increase to approximately 260,000 - 340,000 m^3 per year, where volumes are likely to alter from year to year.

Maintenance dredging campaigns generally target the same / similar locations in the channels due to the build-up of sediment in these areas based on current flow and the designated PoG navigable channel. Based on the historical dredging volumes and anticipated future requirements provided by GPC, the dredging volumes for future maintenance dredging programs are presented in Table 3-2.

The Marina is dredged less frequently. Maintenance dredging of the Marina is undertaken about five-yearly and requiring removal of approximately 200,000 - 250,000 m^3 of material with similar properties to the other Upper Channel dredge locations presented in Table 3-2. Dredging is typically undertaken using a CSD with disposal to land. GPC identify that the current land disposal area has a limited life and an alternative is required in the near future.

Table 3-2 Estimated future maintenance dredging volumes and sediment type

Dredging Locations	Sediment Type (approximate %)	Estimated Dredging Volume (m3)
Outer: Wild Cattle, Boyne and Golding Channels	3-10% clay 20-25% silt 70-80% sand	85,000
Middle: Gatcombe, Auckland and Clinton Channels	<10% gravel 90% sand <5% silt	74,000
Upper: Fishermans Landing, WICT, Targinnie and Jacobs Channels	<35% clay 60% silt <10% sand	100,000

4. Assessment Methodology

The options assessment as presented in this report has involved two phases:

1. Identification of potential beneficial reuse options
2. Analysis of the opportunity, potential feasibility and achievability of the options in the context of the PoG.

4.1 Overall Considerations

The primary considerations of assessment are:

- Properties of the sediment to be dredged.
- Current and likely future maintenance dredging requirements.
- The dredging sediment cycle, and methods of dredging, processing and placement.
- Opportunity for the use within the region. It is considered reasonable for the analysis to provide some consideration of regional context i.e. potential beneficial reuse options may be limited by the location of the potential use relative to the PoG channel. Figure 4-1 displays the PoG channel in a regional context.

To provide context to the potential beneficial reuse options analysis, this section outlines the main dredging and placement methods that were considered.

4.1.1 Beneficial Reuse Method

Potential approaches to the beneficial reuse of dredged material are generally classed as direct use, treatment or intermediate storage.

Direct Use

Options categorised as direct use do not require prior treatment and / or storage of the dredge material. The material is simply dredged and placed directly to be used in such application as embankment construction, land reclamation or habitat restoration or creation.

Treatment Prior to Use

Where the dredge material does meet the potential reuse criteria, a number of techniques can be applied. These techniques usually depend on the sediment properties and the desired reuse.

Physical treatment techniques such as dewatering and separation, are designed to meet the geotechnical requirements. A combination of several techniques are typically required in a treatment chain commencing with material dewatering.

To enable treatment to occur, a placement site on land is required to be established. The placement site requires adequate infrastructure (such as wastewater disposal, access) and is required to be of a suitable size to enable the treatments to occur over an extended timeframe.

Intermediate Storage

Due to logistical reasons, the dredge material may require intermediate storage between dredging and reuse. These logistical reasons include:

- Difference in timing between dredging and use from planning or environmental reasons
- Difference in the dredging production rates and capacity against the rate of demand for the use

- Difference in capacity of dredging against treatment. Often the rate of treatment is an order of magnitude lower than the production rate of the dredging plant
- To create homogeneity within the dredge material input. Particular treatment processes like mechanical separation require homogenous inflow for proper operation.

The intermediate storage may occur at the placement site or at another site (e.g. near the end use).

4.1.2 Dredge and Placement Method

Dredging Method

A number of dredging methods can treat sediments during dredging and can have implications on the potential feasibility of the available reuse options (also refer to Section 2.4).

For example, a TSHD has some ability to separate the dredge material based on grain size, while operating. If the material being dredged is a mixture of coarser material (sand and gravel) and fines. The coarser material can be allowed to settle in the hopper, while a large proportion of the fines can be washed out, together with the processed water through funnels or weirs in the hopper. This separation of sands from finer material as well as coarse gravels may be beneficial for options where sands have a greater reuse potential (e.g. beach nourishment).

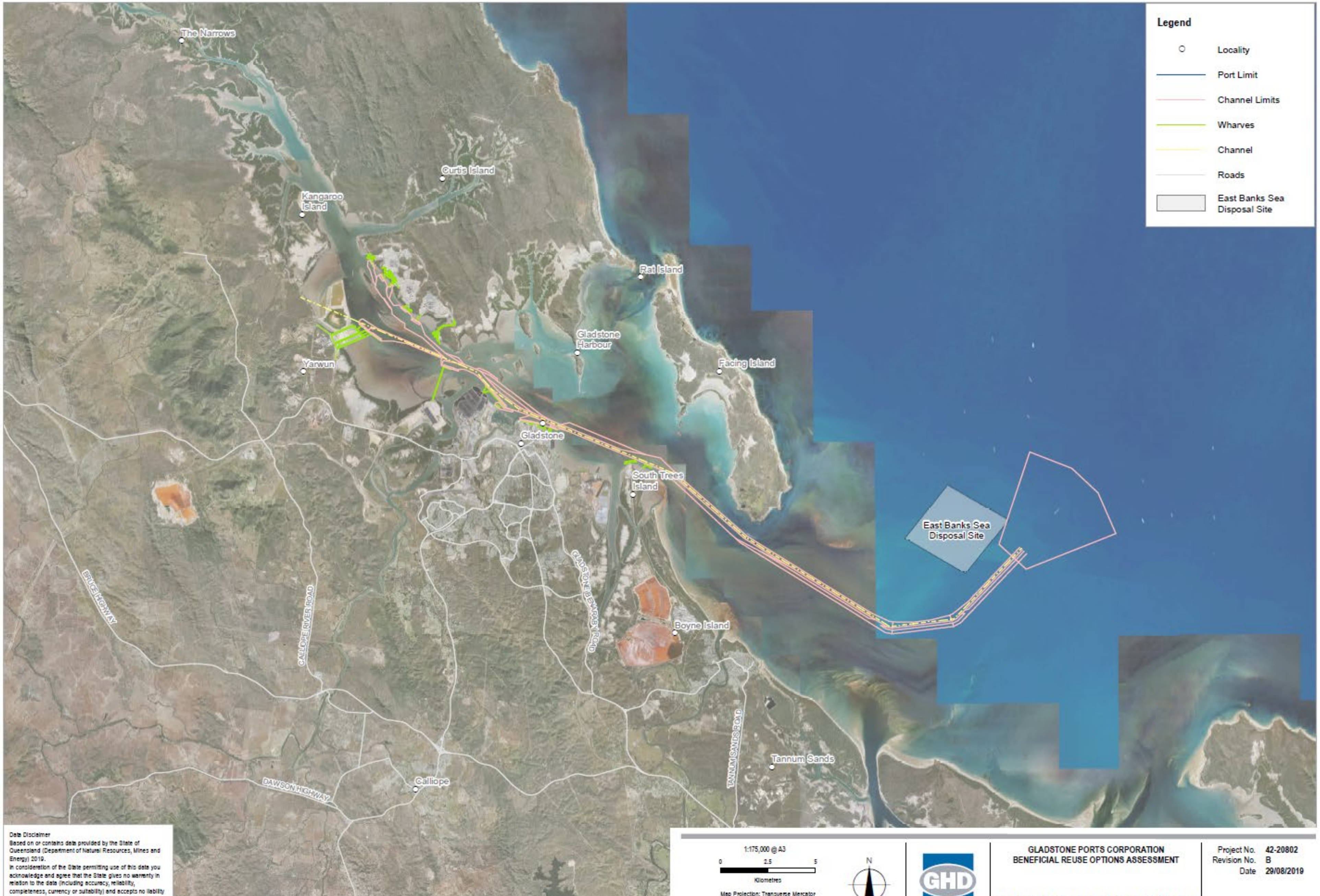
Placement Method

Placement methods are often specified for particular types of reuse options, for example:

- Bottom placement: Material can be placed directly on the seabed via opening of the hopper doors beneath a TSHD or hopper barge (where loaded using a BHD).
- Rainbowing and sidecasting: Where access is limited for direct unloading, for example in shallow areas where the placement of a floating pipeline is problematic. Sediment can be discharged from the bow into the air or discharged from the side of the vessel and deposited on the water surface.
- Pipeline discharge: Material removed using hydraulic techniques can be pumped to the placement location via either marine or land based pipeline. To reduce the velocity of the dredged material discharge stream, diffusers or bash-plates can be used.
- Land based unloading: Where material is barged to shore, land based plant may be used to unload and transport material.

Dredge, Placement and Reuse Logistics

The successful development of a beneficial reuse project requires significant consideration with the matching of dredging, placement and reuse logistics. In particular the timing of dredging and reuse activities should be planned, organised and undertaken concurrently. Intermediate storage in either new or expanded existing storage areas may be necessary if direct matching can’t be achieved.



Geographic Context of the PoG Channel and Regional Area

FIGURE 4.1

4.2 Options Identification

Prior to the assessment of options, potential options were required to be identified. The process for the identification of options included literature review, local knowledge, industry land uses and consultation with GPC.

The literature review was used to gain an understanding of what options have been previously identified, if options have been successfully implemented and if the options may be relevant to the Gladstone region. Section 9 provides a comprehensive reference list for this project, specifically in the identification of options the following literature has been used:

- Overarching literature:
  - Commonwealth of Australia (2018) *Reef 2050 Long-Term Sustainability Plan*
  - Queensland Government (Department of Transport and Main Roads (TMR)) (2016) *Maintenance Dredging Strategy for the Great Barrier Reef World Heritage Area Ports* and the associated Technical Supporting Document (AMA and Haskoning Australia Pty Ltd, 2016)
- Advisian, Worley Parsons Group (2016) *Comprehensive Beneficial Reuse Assessment – Port of Hay Point*, North Queensland Bulk Ports
- U.S. Army Corps of Engineers (2018) *Engineering with Nature – An Atlas*, United States of America
- GPC maintenance dredging documentation
- GPC capital dredging project assessments
- Evidence of other port assessments along the Queensland coast.

In conjunction with the literature review GHD personnel were consulted who had local knowledge of the Gladstone Region to understand the land uses and where spoil or fill material is used. This included a review of the industrial and municipal land uses in the region. As a result options identified in the literature review were able to be focused to potential regional uses, and options that may not have been previously assessed (in the literature review) were able to be identified.

Throughout the process GHD consulted with GPC personnel to gain an understanding of options that may have been thought of internally or as part of previous dredging assessments, and to obtain information from external stakeholders who had contact with GPC (such as the Gladstone Regional Council (GRC)).

The outcomes of the options identification were presented in a comprehensive list. A high level assessment of the comprehensive list was required to be undertaken to shortlist the options to a suitable number for detailed options assessments and later stakeholder engagement. The aim of the shortlisting was to reduce or combine the 26 individual options to 8-12 options so that the options being put to GPC, stakeholders and the community were:

- Plausible (for example if sediment is suitable and if it has been done before as an option)
- Feasible in the PoG context (based on land uses and distance for transport of material)
- Did not present any fatal flaws.

Where a reuse option was identified to meet or potentially meet the above, an initial assessment against the evaluation objectives in Section 4.3.4 was undertaken. Following the initial assessment, and upon confirmation with GPC, the comprehensive list identified shortlisted options for detailed options assessment (as per Section 4.3).

4.3 Options Analysis

To assess the shortlisted options, the following method of analysis has been used. Uncertainties with any aspect / objective have been identified where possible.

4.3.1 Activity Description

An overview of the proposed works associated with each beneficial reuse solution has been provided. The proposed or typical process for use of sediment in the option has been described, including the dredging, placement, treatment works required as well as any infrastructure or management requirements (additional information is provided in Sections 2 and 4.1. This information forms the basis of the objectives analysis described in Section 4.3.4.

4.3.2 Opportunity

An assessment of the known and potential opportunities for the specific option within the region has been undertaken. References to a range of sources have been made where applicable.

4.3.3 Suitability of Sediments

As part of the assessment for each of the proposed reuse opportunities an analysis of the sediment suitability was undertaken, based upon properties determined from results of the laboratory testing of the samples (refer to Section 3).

Options to stage the dredging works or selectively target individual sediment types for suitable beneficial reuse options has been described where applicable.

Following selection of the preferred options, it is envisaged that the further laboratory analysis and field trials would be undertaken in order to define the design parameters required to progress the detailed planning and design phases of the future works.

4.3.4 Evaluation Objectives

Evaluation objectives were discussed and agreed during a workshop held in September 2018 with relevant stakeholders of the broader PoG Sustainable Sediment Management Project.

In general terms, it was agreed that the evaluation objectives must reflect the key issues of importance and must define the desired direction of change in relation to each issue. More specifically, the objectives were required to be:

- Complete - for all things that matter
- Concise - clear and no double-ups
- Sensitive - will change of different options
- Understandable - speak directly to what matters
- Independent - importance of each not linked to performance of another.

The agreed objectives are summarised in Table 4-1 and described in greater detail within Sections 4.3.4.1 to 4.3.4.12.

Table 4-1 Agreed Objectives for Option Evaluation

Aspect	Objective	Description
Environment	Maintain or enhance the environment of the PoG and Protected Areas.	Biodiversity, coastal habitats or morphology that could be altered by the option, particularly concerning areas regarded as protected by legislation.
Resource use	Minimise the use of resources and release of associated emissions.	The use of resources (natural or anthropogenic) that can have an impact of the environment, such as the use of fuel, energy and water, the generation of waste and greenhouse gas emissions
Legislative requirement	Minimise the complexity of statutory processes and meet existing legal requirements.	Non-conformance with legislation significantly restricting the viability of the option. Complex statutory processes involving long time frames and extensive information requirements required to allow the assessment of options and provision of practical condition outcomes.
Health & Safety	Maintain or enhance the Health and Safety of all port users or sediment end users.	Inclusive of personal, public and maritime safety.
Cultural	Enhance the Cultural and Historical Heritage within the Port of Gladstone.	Inclusive of potential impacts to Cultural and Historical sites and values, and tools to enhance their protection.
Social	Enhance social activities and opportunities.	Inclusive of potential impacts to any coastal (water or land based) activities/opportunities and any options to enhance them.
Port operations	Maintain or enhance port operations and future development opportunities.	Ensuring that the option does not impact shipping, operations of a commercial or industrial port user, or potential future development of the port.
Cost	Enhance the cost effectiveness of the option / maintenance dredging activities.	Ensuring that the cost is reflective of any benefit to any of the objectives and GPC shareholders.
Economics	Enhance the economic opportunities for the region.	Inclusive of job creation, increasing the opportunities for tourism or other commercial activities. Eg. Fishing, servicing recreational activities
Methodology	Minimise the uncertainty of the option not working.	By using techniques that have been tried and tested in similar circumstances provides certainty about the management, performance and outcomes associated
Innovation	Enhance the use of innovative options.	To ensure that best practice is continuously improving.
Longevity	Enhance the capability for a long term solution.	To ensure that, based on current knowledge, a long term solution is encouraged.

4.3.4.1 Environment

Objective - Maintain or enhance the environment of the Port of Gladstone and Protected Areas

Description - Biodiversity, coastal habitats or morphology that could be altered by the option, particularly concerning areas regarded as protected by legislation.

The assessment method for the environment objective includes:

- Use of Government desktop databases to determine mapped features. The databases include, but are not limited to:
  - Department of Environment and Energy *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool
  - GBRMPA marine park zoning maps
  - Queensland Globe for a range of factors including
    - Regulated vegetation
    - Protected areas
    - Protected plant trigger areas
    - Waterways and watercourses

        - Coastal aspects
    - Department of State Development, Infrastructure, Manufacturing and Planning (DSDMIP) Mapping Systems (including Development Application and State Planning Policy mapping)
    - DSDMIP State Development Area mapping of precincts
    - GRC Planning Scheme overlay mapping
    - Department of Natural Resources, Mines and Energy (DNRME) MinesOnline mapping for tenure, mining tenure and protected areas
- Previous studies and reports (where available) for certain locations and environmental aspects to further define environmental values
- Publications, literature and other sources of data with respect to determining potential environmental impacts associated with the proposed options

4.3.4.2 Resource Use

Objective - Minimise the use of resources and release of associated emissions. Description - The use of resources (natural or anthropogenic) that can have an impact of the environment, such as the use of fuel, energy and water, the generation of waste and greenhouse gas emissions.

Where the option requires the use of resources these have been outlined and quantified where possible, this includes fuel and water consumption and the production of waste.

Greenhouse gas emissions are part of resource use and estimations have been developed on the basis of conceptual reuse option information for the purpose of comparison between options. The basis of the greenhouse gas emissions calculation is estimation of the emissions associated with the 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. Appendix B provides additional detail on the approach and assumptions. It has been calculated to assist with comparison of options.

Identification (where practical) if the option will have a positive or negative impact upon blue or green carbon, were:

- Blue carbon refers to the carbon captured by the world's oceans and coastal ecosystems (plants and sediments below the plants where plants typically refer to tidal marshes, mangroves and seagrasses)
- Green carbon refers to the carbon stored in the plants and soil of natural ecosystems.

4.3.4.3 Legislative Requirement

Objective - Minimise the complexity of statutory processes and meet existing legal requirements. Description - Non-conformance with legislation significantly restricting the viability of the option. Complex statutory processes involving long time frames and extensive information requirements required to allow the assessment of options and provision of practical condition outcomes.

Environmental and planning approval requirements are considered in the analysis of each of the beneficial reuse options. 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 legislative framework at the time.

Table 4-2 provides an overview of the legislative requirements based on the current legislative framework. Section 6 provides specific detail with regards to approval or permit type and the option that the permit / approval is likely to apply to.

For the options assessment, a review has been undertaken to:

- Determine if there are any high risk works that could be a non-conformance with legislation (e.g. prohibited development)
- Comment on the general complexity of approvals, for example if there are multiple triggers and referral agencies, or if extensive studies / supporting reports are required.

Table 4-2 Summary of Potential Legislative Requirements / Permits

Legislation	Responsible Authority	Summary of Purpose [1]
Commonwealth		
EPBC Act	DoEE	Listing and protection of Matters of National Environmental Significance (MNES) such as world heritage properties, national heritage places, threatened species and communities, migratory species, and Commonwealth marine areas.
Great Barrier Reef Marine Park Act 1975	GBRMPA	Establishment, management and protection of the GBRMP.
State		
Aboriginal Cultural Heritage Act 2003	Department of Aboriginal and Torres Strait Islander Partnerships	Define Aboriginal and Torres Strait Islander cultural heritage. Provides blanket protection of areas and objects as well as for the establishment of the Aboriginal Duty of Care Guidelines.
Coastal Protection and Management Act 1995	Department of Environment and Science (DES)	Protection, conservation, rehabilitation and management of the coastal zone. Ensure decisions about land use and development safeguard life and property from the threat of coastal hazards.
Environmental Protection Act 1994	DES	Protect Queensland’s environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.
Environmental Offsets Act 2014	DES	Counterbalance the significant residual impacts of particular activities on prescribed environmental matters through the use of environmental offsets
Fisheries Act 1994	Department of Agriculture and Fisheries (DAF)	Provide for the use, conservation and enhancement of the community’s fisheries resources and fish habitats
Forestry Act 1959	DAF	Provide for forest reservations, the management, silvicultural treatment and protection of State forests, and the sale and disposal of forest products and quarry material.
Land Act 1994	Department of Natural Resources Mines and Energy (DNRME)	Land to which this Act applies must be managed for the benefit of the people of Queensland by having regard to certain principles.
Native Title (Queensland) Act 1993	DNRME	Provide for the recognition and protection of native title.
Nature Conservation Act 1992	DES	Conservation of nature while allowing for the involvement of indigenous people in the management of protected areas in which they have an interest.

[1] Sourced from the specific pieces of legislation where appropriate

Legislation	Responsible Authority	Summary of Purpose [1]
Planning Act 2009	DSDMIP	Establish an efficient, effective, transparent, integrated, coordinated, and accountable system of land use planning, development assessment and related matters.
Queensland Heritage Act 1992	DES	Provide for the conservation of Queensland's cultural heritage for the benefit of the community and future generations
State Development and Public Works Organisation Act 1971	DSDMIP	Facilitates timely, coordinated and environmentally responsible infrastructure planning and development to support Queensland's economic and social progress.
Transport Infrastructure Act 1994	TMR	Provide a regime that allows for and encourages effective integrated planning and efficient management of a system of transport infrastructure
Vegetation Management Act 1999	DNRME	Regulate the clearing of vegetation to conserve certain values and management the effects of clearing.
Water Act 2000	DNRME	Provides for the protection of water resources and watercourse environments.
Local		
Gladstone Regional Council Planning Scheme	GRC	The planning scheme sets out Gladstone Regional Council's intention for the future development in the planning scheme area, over the next seventeen years to 2031
GPC Land Use Plan 2012	GPC	To govern the location and types of new development and operations at its ports in accordance with the Land Use Plan.

4.3.4.4 Health and Safety

Objective - Maintain or enhance the Health and Safety of all port users or sediment end users.

Description - Inclusive of personal, public and maritime safety.

A review of known health and safety risks has been included. The assessment addresses:

- General Port users and maritime safety (such as shipping impacts)
- Personnel undertaking the works associated with the reuse option (including identification if the option is a standard use with known risks)
- Sediment end users (for example if the sediment is provided to Council, are there Council worker risks)
- Public safety, whether it be associated with the Port / maritime recreational use, access to option sites, transportation or other aspects that may arise.

4.3.4.5 Cultural

Objective - Enhance the Cultural and Historical Heritage within the Port of Gladstone.

Description - Inclusive of potential impacts to Cultural and Historical sites and values, and tools to enhance their protection.

Cultural and spiritual values relate to aesthetic, historical, scientific, social or other significance, to the present generation or past or future generations.

The cultural objective reviews a number of factors to determine relevance to the options:

- World or national heritage properties (as per the EPBC Act)
- Historical heritage that is protected either under the *Queensland Heritage Act 1992* or local heritage items under the Planning Scheme

- Recorded Aboriginal cultural heritage sites and places that are protected under the *Aboriginal Cultural Heritage Act 2003*
- Review of the item with regards to the Aboriginal Cultural Heritage Duty of Care Guidelines and classification of the option (if relevant)
- Review of Aboriginal cultural heritage values and if they may be associated with the option (for example Aboriginal values associated with creeks and coastal areas).

Within each option an assessment is undertaken to determine if there are potential negative impacts, or if the option will potentially enhance or protect cultural or heritage aspects.

4.3.4.6 Social

Objective - Enhance social activities and opportunities. Description - Inclusive of potential impacts to any coastal (water or land based) activities / opportunities and any options to enhance them.

A number coastal (water / land based) activities are significant to the Gladstone community. Such values are varied and include those listed within the *Environmental Protection (Water) Policy 2009* or other social activities:

- Direct water based activities including swimming, water-skiing, jet skiing and sailing
- Indirect water based activities of boating and fishing (where fishing can be onshore or offshore)
- Land and water visual recreations activities such as coastal and inland nature walks
- Other land based activities that can range from parks to buildings / residences to community infrastructure.

It is important that the reuse options look to enhance and not impose the community's ability to perform these activities. Each option includes a review of the potential impacts to any coastal activity, and the opportunities and options to enhance them.

4.3.4.7 Port Operations

Objective - Maintain or enhance port operations and future development opportunities. Description - Ensuring that the option does not impact shipping, operations of a commercial or industrial port user, or potential future development of the port.

Given the importance of port operations to the local economy, it is critical that beneficial reuse options do not impact upon shipping, operations of a commercial or industrial port user, or potential future development of the port.

A review of potential impacts to port operations has been included for each reuse option and the potential methods to mitigate any impacts has been described where relevant.

4.3.4.8 Cost

Objective - Enhance the cost effectiveness of the option / maintenance dredging activities. Description - Ensuring that the cost is reflective of any benefit to any of the objectives and GPC shareholders.

An assessment of the cost effectiveness and benefits of each reuse option in regards to the aspects and interests of GPC shareholders has been included.

This value has been represented in real dollar terms / ranking relative to the other options. It is has been calculated to assist with comparison of options.

These costs were derived from the *Maintenance Dredging Strategy for Great Barrier Reef World Heritage Area Ports: Technical Supporting Document (*AMA and Haskoning Australia Pty Ltd, 2016*).* This document provides support for the Reef 2050 actions, which were developed by TMR. Reef 2050 contains several actions relating to the management of maintenance dredge material, including the examination of opportunities for the beneficial reuse of dredge material for on-land disposal.

4.3.4.9 Economics

Objective - Enhance the economic opportunities for the region. Description - Inclusive of job creation, increasing the opportunities for tourism or other commercial activities. E.g. fishing, servicing recreational activities.

It is preferable that the chosen reuse option(s) promote the economic opportunities in the Gladstone region. For each reuse option a review of the potential economic benefits has been undertaken.

4.3.4.10 Methodology

Objective - Minimise the uncertainty of the option not working. Description - By using techniques that have been tried and tested in similar circumstances provides certainty about the management, performance and outcomes associated.

Given the importance of maintaining a navigable channel and the costs associated with maintenance dredging, it is critical that any preferred beneficial reuse options are proven to provide at least the same benefits to navigability between dredge campaigns. Similarly, it is essential to ensure that any new disposal options selected for development have adequate management controls or have been proven to minimise impacts to environmental, social, cultural and health and safety related issues. This will also relate to the complexity and likelihood of success of legislative requirements, approvals or permits in that adequate (and often proven) management techniques will need to be provided.

Where options have the potential to provide positive outcomes, though the extent of the benefits cannot be quantified, a higher level of uncertainty is considered acceptable. In such instances development of trial placement campaigns may be appropriate.

A brief outline of the proposed methodology has been included for each reuse option including a commentary regarding any uncertainties and examples of port environments where similar solutions have been employed. Details of any trial placement campaigns considered appropriate have been documented in relation to each option.

4.3.4.11 Innovation

Objective - Enhance the use of innovative options. Description - To ensure that best practice is continuously improving.

GPC is striving towards being a high performing organisation with a key guiding principle being the ability to innovate and improve.

New technologies and innovative approaches have the potential to provide improved economic, social, environmental and technical outcomes with respect to maintenance dredging. When the potential for this is known this has been documented.

4.3.4.12 Longevity

Objective - Enhance the capability for a long term solution Description - To ensure that, based on current knowledge, a long term solution is encouraged.

The longevity of each reuse option varies and depends on the design life, demand, availability of suitable sediments. Ideally a long term solution is preferred, i.e. greater than 20 years. Each option is assessed with regards to longevity to identify, for example if it is a short-term or once off option, or if the option is long-term and a repeat use.

4.4 Measures

Measures, or the evaluation ratings, for the evaluation objectives were discussed and finalised based on feedback from the workshop held in September 2018 with relevant stakeholders of the broader PoG Sustainable Sediment Management Project.

In general terms, the measures are proposed to assist in the comparison and weighting of shortlisted items. The measures have been considered in the options analysis, however actual weightings / classifications have not been assigned as this stage. The aim is for stakeholders to apply these weightings at a later date through workshops and other consultation methods.

The agreed measures are summarised in Table 4-3.

Table 4-3 Agreed Measures for Option Evaluation

Measure	Negative Impact	Potential Negative Impact	No Impact / Change	Potential Positive Impact	Positive Impact
Objective	1	2	3	4	5
Environment	High potential to cause negative impact to the environment or a protected area	Low potential to cause negative impact to the environment or a protected area	No impact / change	Low potential to benefit the environment, or protected area	High potential to benefit the environment, or protected area
Resource Use	Very high use of resources and discharge of emissions	High use of resources and discharge of emissions	Moderate / Average use of resources and discharge of emissions	Low use of resources and discharge of emissions	Very low use of resources and discharge of emissions
Legislative Requirement	High potential for complex statutory processes required, or a potential breach in legislation	Low potential for complex statutory processes	Known simple statutory process(es)	Has the potential for simple statutory process with previous approvals	No statutory process required
Health & Safety	High potential to cause a breach in legislation or reduce level of Health and Safety	Low potential to cause a breach in legislation or reduce the level of Health and Safety	No change	Low potential to benefit the level of Health and Safety	High potential to benefit the level of Health and Safety
Cultural	High potential to cause harm to heritage location or value	Low potential to cause harm to heritage location, or value	No impact / change	Low potential to improve protection of a heritage location, or value	High potential to improve protection of a heritage location, or value
Social	High potential to reduced access to the harbour, quality of the experience, or reduce other opportunities.	Low potential to reduce access to the harbour, quality of the experience, or reduce other opportunities	No impact / change	Low potential to improve access to harbour, quality of the experience, or provide other opportunities	High potential to improve access to harbour, quality of the experience, or provide other opportunities

Measure	Negative Impact	Potential Negative Impact	No Impact / Change	Potential Positive Impact	Positive Impact
Objective	1	2	3	4	5
Port Operations	High potential to cause operational delays or restrictions to other activities	Low potential to cause operational delays or restrictions to other activities	No impact / change	Low potential to improve other operations	High potential to improve other operations
Cost	Very high costs	High costs	Moderate / average costs	Low costs	Very low costs
Economics	High potential to reduce economic opportunities for port or port users	Low potential to reduce economic opportunities for port or port users	No impact / change	Low potential to create economic opportunities for port or port users	High potential to create economic opportunities for port or port users
Methodology	Untested methodology and / or multiple unknowns with limited to no certainty of providing an option that can be implemented	Untested in region, and/ or some unknowns, some uncertainty of providing an option that can be implemented.	Untested in region, and / or few unknowns but successfully implemented elsewhere with, some certainty of providing an option that can be implemented	Tested in region (or similar environment) and / or few unknowns and some certainty of providing an option that can be implemented	Well known, tested methodology in region and / or few to no unknowns and certainty of providing an option that can be implemented
Innovation	Very low level of innovation and evidence of continuous improvement	Low level of innovation and evidence of continuous improvement	Moderate level of innovation and evidence of continuous improvement	High level of innovation and evidence of continuous improvement	Very high level of innovation and evidence of continuous improvement
Longevity	One off option	Potential to be a short term option (<5yrs)	Potential to be a medium term option (5 - 10 yrs)	Potential to be a medium to long term option (10 - 20 yrs)	A long term option (>20 yrs)

5. Beneficial Reuse Options Review

The aim of the options review is to identify the comprehensive options and, through assessment, shortlist the list to 10-12 options that will be subject to the details options analysis. The options have been identified as follows. The options in blue are reuse (marine or coastal) and the options in green are recycle.

1. Land Reclamation – Western Basin / Fishermans Landing
2. Land Reclamation – New reclamation site
3. Shoreline Protection – Coastal Erosion Mitigation
4. Shoreline Protection – Offshore Berms or Breakwaters
5. Beach Nourishment – Onshore Placement
6. Beach Nourishment – Offshore Placement
7. Habitat Restoration / Creation – Seagrass
8. Coastal Habitat Restoration / Creation – Environmental Bunds
9. Coastal Habitat Restoration / Creation – Mangrove / Tidal Habitat
10. Habitat Restoration / Creation – Artificial Reef
11. Habitat Restoration / Creation – Deep Water Habitat
12. Habitat Restoration / Creation – Sand Spit Creation
13. Aquaculture (Marine) – Creation of Berms or New Aquaculture Areas
14. Aquaculture (Marine) – Scallop Bed Creation
15. Aquaculture (Onshore)
16. Wetland Restoration
17. Construction Fill
18. Road Construction
19. Concrete Products
20. Lining Material
21. Environmental Bunds
22. Agricultural Use / Manufactured Soils
23. Land Rehabilitation
24. Treatment / Use of Contaminated Material – Biosolids
25. Treatment / Use of Contaminated Material – Ash By-products
26. Climate Resilience.

Table 5-1 provides an assessment of these options with an aim to determine if the option is shortlisted for this Beneficial Reuse Options Assessment.

Some options that are not shortlisted may be suitable for detailed assessment at a later date due to factors such as changes in technology, community views, government policies and/or regional land uses.

As part of GPC's Long Term Maintenance Dredging Management Plan (LMDMP) commitments options are required to be reviewed regularly and as such the list of available options may be altered as part of future projects.

Table 5-1 Review of potential beneficial reuse options and shortlisting

Option and Description		Shortlisted
1	**Land Reclamation – Western Basin / Fishermans Landing** With respect to maintenance dredging material, material would be transported via TSHD / pipeline to the existing reclamation areas. Alternatively, material could be mechanically unloaded at onshore transfer points or pumped using a CSD and pipeline where dredge areas are located in close proximity to disposal locations. Whilst the reclamation area is already established, the ultimately capacity is limited and has been set aside to accommodate future capital dredge material as outlined in the GPC masterplan (TMR, 2018a).	✘ Excavation and reuse of previously placed sediments would be required in order to create sufficient capacity to accommodate future maintenance dredge materials.
2	**Land Reclamation – New reclamation site** Material would be transported via TSHD / pipeline to a new reclamation area within GPC port limits. Alternatively, material could be mechanically unloaded at onshore transfer points or pumped using a CSD and pipeline where dredge areas are located in close proximity to disposal locations. Prior to completion of the Western Basin Dredging and Disposal Project and as part of the EIS for the Gatcombe and Golding Cutting Channel Duplication Project (Aurecon, 2019), an assessment was undertaken of alternative shoreline reclamation areas. The assessment concluded that nearby areas contained sensitive marine environments including seagrass, mangroves, coastal wetlands and associated benthic communities. Furthermore, these areas were noted as significant habitats for fish, prawns and molluscs, as well as feeding grounds for dugong and turtles. As a result of these characteristics, Western Basin was selected as the most appropriate location for spoil disposal.	✓ Opportunity exists for reclamation works. However an assessment of the option is required to make a decision on this common reuse option.
3	**Shoreline Protection – Coastal Erosion Mitigation** Coastal erosion along coastlines occurs as a result of natural processes and can be exacerbated by weather events. It is further reported that climate change has the potential to increase coastal erosion, for example by sea level rise, higher frequency and severity weather events (e.g. cyclones). GRC recognise the importance of understanding shoreline erosion and implementing protection actions. GRC obtained funding to progress Phase 1 and Phase 2 Coastal Hazard Adaption Strategy (CHAS) for the region in December 2018 (GRC, 2019). The outcomes of the CHAS are not expected to be available for this Beneficial Reuse project. The known areas of erosion risk where mitigation (such as placement of sand / clay / other) may be recommended during the CHAS or have been identified in previous studies include: • Boyne Island, Tannum Sands and Wild Cattle Creek area • Facing Island. • Shoreline protection options include: • Direct placement on the banks of waterways or coastal frontages, using sand • Placement in geotextile bags or tubes (using coarse and fine material) either onshore or offshore as: o Revetments o Groynes o Slope buttressing o Temporary protection dykes	✓ There are known erosion concerns within the region and there are different methods of dredged material use available. Therefore shoreline protection is considered viable for further assessment as an option.

Option and Description		Shortlisted
	○ Containment dykes Depending upon erosion mitigation site and location there could be minimal onshore processing, however the likelihood of use of the material for direct placement is unknown. Geotextile bags can be used in a number of ways. The bags can be used as an alternative to rock armouring or compliment rock armouring. There are methods available for use during dredging that minimise the processing of material required.	
4	**Shoreline Protection – Offshore Berms or Breakwaters** The use of submerged offshore berms is a type of shoreline protection that can use geotextile bags (as per Option 3). Natural berms or bars may form via sand deposition. Berms can act to reduce wave energy reaching the shoreline by causing waves to break offshore. Berms may also be used to redirect or reduce subaqueous sediment transport pathways such as longshore drift. The Gladstone region (mainland and western shorelines off the islands) is predominately impacted by longshore drift and other coastal processes that are not primarily driven by onshore/offshore wave action. Therefore offshore berms would provide only limited shoreline protection. The eastern shorelines of the islands are subject to wave action, however there are high value marine environmental values in these areas. The values include the GBRMP and mapped coral reefs (TMR, 2018a). The reefs act in a way as natural berms, in addition parts of Curtis Island are protected natural profiles (rocky shorelines) are less susceptible to erosion than other exposed coastlines in Queensland. Placement of berms (if geotextile bags) could be strategically placed, however it is considered that the level of shoreline protection obtained would be minor and outweighed by potential environmental impacts.	✗ Where use may be appropriate (the islands) the environmental impact of constructing berms is likely significant and therefore the option is not considered further.
5	**Beach Nourishment – Onshore Placement** Beach nourishment is the replacement of sand / sediment that has been lost to erosion. It is typically a process that is ongoing as coastal processes continue to cause sand loss. The known areas of erosion risk highlighted in previous studies include: • Boyne Island, Tannum Sands and Wild Cattle Creek area • Facing Island. Beaches in the Gladstone region are made up of sand, gravel and shells, etc. and have a consistent beach colouring. Beaches in the region are important for recreational use (including tourism), habitat and specifically for turtle nesting. Where beaches are steep or have narrow strip of sand above high tide, both recreational use and turtle nesting can be adversely affected and would benefit from beach nourishment. Ideally, the borrow material used for beach nourishment would be compatible with the native beach material. In particular, it should have similar physical characteristics in terms of: • grain size and grading (or slightly coarser) • composition (quartz and shell content) • density • angularity (angular or well rounded) • colour. Poorly matched beach nourishment material can result in undesirable changes to the beaches. These can include: • material which is too fine is likely to be moved seaward more quickly under wave action	✓ Beach nourishment is considered viable for further assessment for select sections of the channels where maintenance dredge sediments are expected to match the sediment characteristics of the region's beaches.

Option and Description		Shortlisted
	• material which is too coarse is likely to result in a steeper beach profile • finer and poorly sorted material (wide range of particle sizes) is likely to result in the redistribution of the coarser fraction over the upper portion and finer fraction over the lower portion of the beach profile • aesthetic alterations (e.g. colour). In addition, it is important to confirm that the sand does not contain inherent fines that may adsorb contaminants (such as heavy metals, organic compounds and nutrients etc.), which have the potential to adversely affect the environment. The findings of the recent sediment sampling and analysis confirm that the sediment characteristics of maintenance dredge sediments are variable throughout the channel and berth areas. Consequently, it is expected that future maintenance dredge material from select sections of the channels will be suitable for use as beach nourishment material where maintenance dredge sediments are shown to match the sediment characteristics of the destination beaches. In particular, it is envisaged that material would be sourced from the outer sections (Wild Cattle, Boyne and Golding Channels) and middle sections (Gatcombe, Auckland and Clinton Channels) of the maintenance dredge areas. Suitable material would typically be dredged and transported as close as possible to the proposed nourishment location using a trailing suction hopper dredge. Material would then be transferred to the nearshore zone and upper portion of the beach profile using an onshore discharge pipeline and or a technique known as bow casting or rainbowing.	
6	**Beach Nourishment – Offshore Placement** Feasibility of offshore beach nourishment would be largely determined by the need for nourishment works and the suitability of the future maintenance dredge materials in accordance with the considerations outlined in Option 5. Where materials are deemed suitable, offshore placement enables the dredge to adopt a direct placement approach via the hopper doors on the hull of the vessel. This allows cost effective placement of material with minimal construction impact to the existing beach environment. When designed correctly, offshore placement utilise natural sediment transport pathways to rework the placed material into shallower areas where beach nourishment is required. Potentially suitable areas of erosion risk highlighted in previous studies include: • Boyne Island, Tannum Sands and Wild Cattle Creek area • Facing Island.	✓ Beach nourishment is considered viable for further assessment for select sections of the channels where maintenance dredge sediments are expected to match the sediment characteristics of the region's beaches.
7	**Habitat Restoration / Creation – Seagrass** Seagrasses are marine plants with the same basic structure as terrestrial (land) plants. They form meadows in estuaries and shallow coastal waters with sandy or muddy bottoms. Seagrasses thrive in shallow coastal waters where there is shelter (such as a sand bar) from drying winds and from wave action and strong currents which could create turbulent muddy water. As part of GPC's LMDMP, GPC are required to undertake long-term health and extent surveys as seagrass is a sensitive receptors to light and water quality impacts. Seagrasses are also negatively impacted by weather events (e.g. extreme rainfall events increases turbidity entering rivers, and hence coastal areas).	✓ Seagrass habitat restoration/creation is considered suitable for further analysis due to the known need for it, and potential environmental benefits.

Option and Description		Shortlisted
	Monitoring that has been undertaken by GPC, and previously by DAF shows that seagrass extent within the Gladstone region has decreased over the years with increases in 2018. This fluctuation occurs for a number of natural reasons such as foraging, weather (flooding and resultant increased turbidity) and tidal windows. Seagrass restoration or rehabilitation projects are seen as favourable for a number of reasons including increasing habitat / food sources for dugongs, provision of sediment protection from erosion due to currents, increase (reestablishment of) blue carbon stores, and many other reasons. The methods of rehabilitation are broad, but generally include improvement of water quality, reinstatement / improvement of seagrass beds / sediment profiles, and / or transplantation of seagrass. As studies have shown that seagrass extent within the Gladstone region has fluctuated, it is considered that this options is suitable for further analysis due to environmental and social / economic benefit (improving fish habitat). In addition, the sediment material from dredging may be suitable due to fine texture, organic content, and because it is from the marine environment (as opposed to bringing in material from land).	
8	**Coastal Habitat Restoration / Creation – Environmental Bunds** A coastal habitat activity that has been investigated and used elsewhere is use of coarse dredge material to create environmental bunds seaward from a coastal habitat area, with the placement of finer dredge material on the land side of the bund. This has the potential to create or restore mudflats where marine plants can grow, resulting in an increase in the coastal habitat area. There is also potential that an environmental bund could be created in front of some of the PoG rockwalls with they are determined to be suitable for mangrove habitat. Subsequently the option provides an overall positive blue and / or green carbon impact (noting that initial placement may negatively impact blue carbon), and depending upon location and ultimate method, can protect habitat areas from climate change (e.g. sea level rise). Areas suitable for this type of restoration would be estuarine areas, where there are no beach areas, e.g. where mudflats are currently located. Within proximity to the dredging activities these areas are upstream from river mouths (where bunds would not be suitable due to channel widths) or associated with Curtis and Facing Islands and smaller islands in the PoG. Creation of enclosed environmental bunds and filling with fine material can also be used to create new coastal habitat. The environmental bunds could be constructed to form a closed system where an island type habitat is created. Previous investigations for this type of project have been in offshore shallow water areas. The PoG currently includes a number of small islands (such as Diamantina Island and Worthington Island) and there could be capacity for a created area to be established in the Narrows or between Curtis Island and Facing Island. In these areas there would be minor to no impact upon Port operations, while also being in an area that is protected from offshore coastal/marine processes.	✓ The use of environmental bunds is a known and proven method of habitat creation. While the potential within the region may be limited, it is considered that further assessment of the option is viable.

Option and Description		Shortlisted
9	**Coastal Habitat Restoration / Creation – Mangrove / Tidal Habitat** Indirect nourishment is a potential option that uses an option of a 'mud motor', where fine sediment in the local system is increased and natural currents used to increase siltation / sedimentation in the coastal habitat over a longer period. Direct nourishment is also an option and is similar to -Option 8 but without bunding. Refer to Option 8 for further detail. For this option the dredge material is considered suitable, with the finer materials from the inner channels being preferred. These forms of nourishment have a higher potential for water quality / turbidity impacts than Option 8, but due to slower build-up of sediment, reporting indicate that the benthic environment can tolerate the method better, this would result in preservation of blue carbon and potential improvement.	✓ The use of material for habitat is a proven use (as per Option 8) and the PoG has sediment that is suitable for the use. There are many similar factors between Options 8 and 9 and as such the shortlisted option is a combined option. Note, Option 9 is in part related to the separate reduction in dredging options assessment.
10	**Habitat Restoration / Creation – Artificial Reef** An artificial reef is a man-made underwater structure to promote marine life. Artificial reefs are generally designed to provide hard surfaces to which algae and invertebrates such as barnacles, corals, and oysters attach; the accumulation of attached marine life in turn provides intricate structure and food for assemblages of fish. It is considered that an artificial reef own is on its not a direct option for beneficial reuse of sediment. However, sediment may be used in the restoration / creation of deep water habitat (Option 11), which, when used in combination of structures, can constitute an artificial reef.	✗ For the purpose of this assessment artificial reef is considered a potential consequence of deep water habitat, i.e. Option 11.
11	**Habitat Restoration / Creation – Deep Water Habitat** Dredge material can be placed offshore to create features / bedforms that enhance and fit in with the local deep water habitat. The enhancement of deep water habitat would increase biodiversity, positively impact upon the fisheries sector and potentially add to blue carbon. Consideration of the location and type of dredge material is needed as fine material in an active area would be susceptible to resuspension. There are limits to the type and volume of material that could be used. Deep water habitat works would likely occur within the GBRMP and would need approval from the GBRMPA and other authorities. As the works aim to improve biodiversity, if a suitable location is found then GBRMPA may support the option.	✓ Due to the potential for increased or improved habitat features this option is considered suitable for further assessment.
12	**Habitat Restoration / Creation – Sand Spit Creation** A sand spit is a deposition bar or land form that is located along coast lines typically at coastal points or river mouths. Sand spits are considered valuable coastal habitat but may be washed away during large flood or swell events. Currently, in the Gladstone region, river mouths experience deposition in a way that creates marine navigation hazards. The addition of sand spits has the potential to worsen the situation, while also impacting upon intertidal areas. In addition, creation of a long term sand spit in an area which is not naturally suited would likely require costly engineering measures to ensure stability of the placed sand.	✗ Following review of the potentially suitable sites in the vicinity of the PoG, the opportunity for sand spit creation within the region is considered low

Option and Description		Shortlisted
13	**Aquaculture (Marine) – Creation of Berms or New Aquaculture Areas** The Web-based Agricultural Land Information (WALI) identifies that there are currently no marine based aquaculture areas in the region, with the closest being near Emu Park (DAF, 2018a). The Queensland Government (through DAF) recognise the potential for aquaculture within Queensland, however the extent of any new marine aquaculture within the region is unknown.	✘ Due to there currently being no marine aquaculture areas, this option is not being assessed further. It is recommended that this option could be reviewed at a future date if the opportunity arises.
14	**Aquaculture (Marine) – Scallop Bed Creation** The Queensland Saucer scallop (*Ylistrum balloti*) was concluded to have been overfished in 2016 after being one of the state's most valuable species. This has led to the six scallop replenishment areas being closed since January 2017 (DAF, 2018b). There is evidence that the there is a correlation between adult scallops and the substrate (e.g. concentration of mud). Scallop habitats are typically at 30 - 60 m in depth. James Cook University are currently undertaking studies with regards to scallop distribution, habitat preference and improvement of mortality rates (Daniell, 2018).	✓ Although information regarding scallop habitat (as a fisheries resource) is presently being studied and may be unknown, the current challenge with the replenishment areas indicate that this option should be assessed further. Based on the information presented in this table it is considered that the option can be combined with Option 11 (deep water habitat).
15	**Aquaculture (Onshore)** Dredge material may be suitable for use in construction of impoundments (i.e. berms with impervious liners) to create ponds for aquaculture needs. Depending upon the aquaculture species, the berms may need replacement following harvesting, resulting in potential ongoing use of dredged material. Although material use may be ongoing, it is considered that the current use requirements for sediment material would be very minor, for example a truck load a year. Therefore this would not constitute a viable option. WALI has identified five aquaculture localities within approx. 100 km of the PoG (DAF, 2018a). Aerial imagery identifies that three of the localities have formed ponds / berms. Historically (1990s) there was a prawn farm located near the South Trees Inlet, this area has since been rehabilitated. WALI further identifies land that may be suitable for aquaculture including land at Boyne Island and land north of Gladstone near Raglan (DAF, 2018a). The Queensland Government (through DAF) recognise the potential for aquaculture within Queensland, however the extent of any new aquaculture within the region is unknown.	✘ There is only a very minor demand at present for material.
16	**Wetland Restoration** The DES Wetland*Info* portal identifies current wetland extents and types, previous wetland projects, and other wetland data within the Gladstone Local Government Area (LGA) (DES, 2018). DES identify 828.6 km^2 of wetlands in the LGA, where the majority are estuarine and marine environment.	✘ There are no known wetland areas (inland) that have been identified as requiring rehabilitation by the use of material such

Option and Description		Shortlisted
	Within the LGA there are only minor designated wetland protection areas (i.e. high value wetlands), where these are associated with the islands in the region and minor riverine areas (State of Queensland, 2019). In addition to the wetland protection areas, there are high ecological wetlands mapping within the PoG that encompass seagrass areas (refer to Option 7). The projects identified within the WetlandInfo portal are primarily associated with revegetation, erosion and sediment control, weed management and water quality improvements. GRC have adopted a Biodiversity Conservation Strategic Plan which includes reference to wetland areas (AEC Group Pty Ltd, 2016). Where wetlands are identified as a goal or strategy, the Plan generally relates to biodiversity aspects (such as species). Specific wetland areas or uses that would benefit from rehabilitation are not identified.	as dredge material. Therefore this option has not been assessed further. Coastal habitat that may be identified as estuarine wetlands has been addressed in Options 8 and 9.
17	**Construction Fill** Construction fill is required for a range of land uses and is needed when the site does not have adequate volumes available, or the material on site is not of suitable quality. Sandy dredged material can be used for higher strength applications (e.g. for load bearing purposes), with clayey or silty material used for low strength applications. To enable use of dredged material for construction (either high or low strength uses) the material would need to be transported to a placement site with processing activities of dewatering, desalination and screening (as a minimum). There is potential that this option would create completion for land based fill sourecs. Within Gladstone, the type of land uses that may be suitable for use of dredged material as construction fill are summarised as follows: • Urban / estate development (high strength) • Park creation (high or low strength) • Site works / establishment for industry (high strength) • Land improvement (refer to Option 23 Land Rehabilitation). Construction fill needs within the Gladstone Region are dependent upon specific projects (i.e. not a continual reliable use) and geotechnical requirements.	✓ This option is proposed to be considered further as part of Option 23 as both require processing of material and use is on a project basis.
18	**Road Construction** Road construction requires a range of materials depending upon the nature of the project. Both TMR and Councils have responsibilities to improve and maintain the current road networks. Primarily in the region this includes regular construction of re-pavement, road widening or road duplication projects. TMR identify the essential material properties for fill material of gravel, sand and clay / silt within Main Roads Technical Specification 04 (MRTS04) General Earthworks. • Class A1 is the common type of material and is difficult to find in Gladstone. It requires PSD >0.075 of 15-30% and an Emerson class of >3. • Class A2 (and higher) is typically used in the middle of embankments and PSD and Emerson are not defined, but may be as a result of design projects. The sediment characteristics identified that Emerson class (and plasticity index) were only able to be undertaken on Fishermans, Jacobs and the Marina sample, they are only suitable for Class A2 material and higher due to PSD. Therefore, only a limited amount of dredged material could be used.	✘ There are specific and strict requirements for fill material for road construction which is unlikely to be achieved by dredge material unless used for larger project in the core of embankments. It is also considered that local quarries (or material won from within road reserves) satisfy the current need. Therefore road construction has not been considered further at this stage.

Option and Description		Shortlisted
	However, where there are large embankments, there is potential that the core of the embankment could be made of unsuitable material. This would be relevant for large projects, and GHD is aware of it being undertaken for the GRC Kirkwood Road project. While there are new roads proposed and currently under design (e.g. at Agnes Water) the future requirement for unsuitable material is unable to be quantified. Minor roads are also required as part of industry development and other private construction projects that may be able to utilise lower performance material (e.g. reduced requirement for imported material). Such use would be on a project specific basis and would be minor quantities. The dredged material would need to be transported to a placement site with processing activities of dewatering, processing (including desalination as salinity can cause lifespan issues), screening and combined with imported material.	
19	**Concrete Products** Dredged material may be used in the production of concrete materials including: • Bricks / blocks / tiles • Low strength concrete • Mudcrete for use in land reclamation. Dredge material would be required to be combined with a binder after the material has undergone onshore placement and processing (including treatment to remove salts). The creation of concrete products would use sand, as clay particles are not conducive to concrete products and colour can be a factor. Land based local or regional sources of sand for concrete products would be cheaper and more reliable to obtain due to high processing costs for dredge material. Mudcreting involves the mixing of dredged sediments with cement and activated carbon to form a stabilised material of low permeability. Whilst the blended material offers higher strength than untreated sediments, the resulting product remains a low strength material. This approach is typically utilised where contaminated sediments require stabilisation prior to disposal in order to minimise the long term mobilisation of contaminants. The high cost of stabilising sediments renders this approach unfeasible for disposal of clean maintenance dredge materials.	✘ Given the large volumes of relatively low value and high cost material, the use of maintenance dredge sediments in concrete products is not considered feasible and has not been considered further.
20	**Lining Material** A liner is required for confined disposal facilities where leachate has the potential to enter the environment. Liners are low-permeability material typically used at sites that have potentially contaminated materials (storage and / or management). Within the region, liners are used at Council landfills (such as Benaraby), wastewater treatment sites (treatment ponds) and industrial sites where onsite waste management or storage of chemicals is undertaken (such as Rio Tinto and Orica caustic bladders at Fishermans Landing). To enable use of dredge material in liners, onshore placement and processing (screening, desalinisation, etc.) would be required. The high percentage of fines in some areas could be of benefit for lining material.	✓ The use of dredged material for lining is being assessed further, as material is likely to be suitable (in terms of low-permeability) and there are ongoing opportunities for such material.
21	**Environmental Bunds** A number of industrial land uses require the construction of bunds to contain potential contaminants, whether it be stormwater management or containment of actual chemicals.	✓ The use of dredged material for environmental bunds

Option and Description		Shortlisted
	Industry within Gladstone that uses environmental bunds includes (but is not limited to): • Rio Tinto - Fishermans Landing and Aldoga • Orica - Fishermans Landing • QAL - South Trees and Boyne Island • GRC - Wastewater Treatment Plants. As environmental bunding is for containment of contaminants, permeability is a factor (similar to liners). The core of a bund may be suitable for material that does not meet the permeability factors of liners. To enable use of dredge material in bunds, onshore placement and processing (screening, desalinisation, etc.) would be required. The requirements for bunding is on a projects needs basis, where some existing industrial sites only require replacement bunding if there has been an incident.	is being assessed further. Material is likely to be suitable and there are ongoing opportunities for such material.
22	**Agricultural Use / Manufactured Soils** Dredged material may be used to improve soil structure, however at a minimum, onshore placement and processing is required to manage salinity. In other beneficial reuse assessment, e.g. the Port of Hay Point in the Mackay region, improvement of soil structure was assessed for agriculture uses for dredge material, (such as those associated with the sugar industry). The Gladstone Development Board identified that 77% of the Fitzroy Region is agricultural land, with a gross value of $1.4 billion (2015-2016). It was identified that 74% of the gross value is cattle and calves, 5% cotton, 3% sorghum (Gladstone Development Board, 2018). The Australian Bureau of Statistics (2018a) data for the Fitzroy Basin (e.g. including Rockhampton, Banana, Gladstone and Central Highlands LGAs) for the 2016-2017 period reported: • Total agriculture gross value of $1.897 billion • Livestock accounting for 76% • Cropping accounting for 24% (where cereal and non-cereal crops account for 80% of the cropping gross value). The total cropping land area is reported as 344,833 ha, approximately 2.3% of the total Fitzroy Basin land area. In comparison, within the Reef Catchments area (Mackay, Whitsunday and Isaac LGAs) cropping comprises nearly 20% of the land area (ABS, 2018b). Review of WALI identifies that within the Gladstone LGA there are only isolated properties with cropping land (equating to less than 1% of the LGA), but there is potential cropping land mapped in the Boyne Valley and Ambrose areas (DAF, 2018a). The use of the potential cropping areas are unknown and as such cannot be relied upon as part of this assessment.	✘ Due to the low agricultural land use within the region, logistics of transporting material via road and the high processing of dredged sediments that would be required, agricultural soils improvement have not been further assessed as a reuse option.
23	**Land Rehabilitation** Land rehabilitation includes rehabilitation of land that has been subject to previous intrusive disturbance (such as quarries and mines) or improvement of current land surfaces as a mitigation for flood impacts and climate resilience. In addition, rehabilitation may occur as a general method of land management, or to enable future use of the land (e.g. new urban development). GRC have Q100 mapping within their Planning Scheme overlays. It shows a flood risk at a number of locations, including the port and land associated with the Boyne River (including downstream from Awoonga Dam) and Calliope River (including Police Creek).	✓ Land rehabilitation includes a number of potential uses. Although the opportunities available are not definitive, the ability to use fine or coarse dredge material is of benefit. Therefore this option is being considered further.

Option and Description		Shortlisted
	The type of material for use during land rehabilitation depends upon the site. For example if protection from erosion was provided via topsoil and grass or vegetation, or rock armour, fine or coarse material could potentially be used. To enable use of dredge material in liners, onshore placement and processing (screening, desalinisation, etc.) would be required.	
24	**Treatment / Use of Contaminated Material – Biosolids** Biosolids are the waste material / sludge produced from wastewater treatment plants. GRC have historically had concerns with regards to their biosolids management and have implemented biosolid optioneering and management procedures. The applicably to maintenance dredge material reuse would be if the biosolids could be mixed with dredge material to create a substance / material that is suitable for other use (such as agriculture / top soil enhancement). Within Gladstone there are current options assessments and plant trails being undertaken for the use of biomass in the creation of resources. Therefore, there may not be a requirement in the near future for the management of biosolids. One of these is the Northern Oil Advanced Pilot Plant project at Yarwun, run by Southern Oil, is utilising biomass to produce crude oil. The funding arrangements with the Australian Renewable Energy Agency stated that the plant would be able to use biosolids from wastewater treatment (Australian Renewable Energy Agency, 2016). However, based on details available in public documentation it is unclear if this is occurring, or will occur in the future. There are also other industries looking at uses of biosolids / biomass that may be a more productive use of the biosolids.	✘ Due to the likelihood that management of biosolids will be undertaken by other means in the future it is considered that biosolids will not be assessed as a separate option at this stage.
25	**Treatment / Use of Contaminated Material – Ash By-products** Ash by-products are a result of a number of industries, the closest to the PoG being Cement Australia and the NRG Gladstone Powerstation. In the native form, the ash by-products do not process any significant properties for reuse. However, there is potential that when ash material is added to maintenance dredge material, the properties of the material are enhanced and make dredge material more suitable for other uses such as land rehabilitation (Option 23) and construction fill (Option 17).	✘ This option is not proposed to be assessed separately as ash material acts as an addition to dredge material. Therefore, ash by-products will be considered in other relevant options.
26	**Climate Resilience** Climate resilience refers to actions that can be undertaken to mitigate against climate change. In terms of a reuse option it would relate to actions / options that are relating to mitigating against the increasing frequency / severity of weather events, storm surge or sea level rise. Climate resilience as a separate option encompasses a number of potential actions. These potential actions have been identified as separate options, for example habitat creation, land rehabilitation / food mitigation and coastal protection. Therefore climate resilience is not proposed to be assessed as its own option.	✘ Addressed within other options, not as a separate option.

Based on the outcomes of Table 5-1, the following options have been shortlisted for analysis:

- Option 1 and 2: Land Reclamation - Fishermans Landing and New Reclamation Sites
- Option 3: Shoreline Protection - Coastal Erosion Mitigation
- Option 5: Beach Nourishment - Onshore Placement
- Option 6: Beach Nourishment - Offshore Placement
- Option 7: Habitat Restoration / Creation - Seagrass
- Option 8 and 9: Coastal Habitat Restoration / Creation - Direct and Indirect Placement (Environmental Bunds and Mangrove / Tidal Habitat)
  – Option 8 and 9 were combined due to their similarities in scope of objective analysis. Within the detailed assessment differentiators will be separately discussed (such as location).
- Option 11 and 14: Deep Water Habitat / Scallop Beds
  – Option 11 and 14 were combined due to similarities in end results, locations and impacts. Within the detailed assessment differentiators will be separately discussed (such as the scallop beds providing that specific fisheries resource).
- Option 20 and 21: Lining / Bunding Material
  – Option 20 and 21 were combined due to their similarities in scope of objective analysis. Within the detailed assessment differentiators will be separately discussed.
- Option 23: Land Rehabilitation / Land Improvement / Fill
  – Option 17 has been added to the Option 23 assessment due to their similarities in scope of objectives analysis. Within this option the enhancement of sediment with ash or other by-products will be considered.

6. Legislative Requirements

Environmental legislative requirements are considered in the analysis of each of the beneficial reuse options. As there are likely to be common environmental legislative requirements across each of the options, a summary of key approvals is provided in Table 6-1. For each approval identified, an indication is given as to which options are applicable.

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 to the works at the time. Consultation with the Australian or Queensland Government agencies was not undertaken for this project at this stage.

Table 6-1 Potential environmental approvals required

Approval	Legislation and administrating authority	Potential trigger / activity covered	Potentially applicable option
Approval for a controlled action	EPBC Act DoEE	Potential for significant impacts on: • Nationally important wetlands • World heritage property • National heritage place • Listed threatened species and ecological communities • Migratory species • GBRMP.	Options that are likely to occur within the GBRWHA, and / or have impact on listed species / communities or wetlands. Options that this may potentially be applicable to include: • Option 2 • Option 3 • Option 5 / 6 • Option 8 / 9.
Approval for activities within the Great Barrier Reef Marine Park (Permit)	*Great Barrier Reef Marine Park Act 1975* GBRMPA	Activities that occur within the GBRMP. Offshore disposal of dredge material within a marine park is only to be considered after all onshore and beneficial reuse options have been assessed and exhausted, as outlined in the Queensland Governments Maintenance Dredging Strategy for the GBRWHA Ports.	Options that may occur within the GBRMP depending on placement) are: • Option 4 • Option 7 • Option 8 / 9 • Option 10 / 11 • Option 14. The eastern side of Curtis Island is located within the GBRMP. If offshore placement is to occur in this area, a permit will be required.

Approval	Legislation and administrating authority	Potential trigger / activity covered	Potentially applicable option
Sea dumping permit	*Environmental Protection (Sea Dumping) Act 1981*	Where offshore placement of dredge material is undertaken.	Options that will results in offshore placement of dredge material and may require a sea dumping permit include: • Option 6 • Option 10 / 11 • Option 14.
Land owners consent for works on state-owned land	*Planning Act 2016* DNRME	Where works trigger approval under the Planning Act and are proposed on lots owned by the State.	Options that will be located on state land will require land owners consent. This could be marine or land based uses.
Resource allocation for quarry material	*Planning Act 2016*, *Forestry Act 1959* and *Coastal Protection and Management Act 1995* DAF and / or DES	Where works are proposed on lots owned by the State and involve interference with quarry material (i.e. where material is removed from the seabed and placed on land).	Options that will be located on state land that will involve interference with quarry material will require a resource allocation notice. This may include Options 1 - 14.
Land owners consent for Gladstone Port	GPC	Where works are proposed on strategic port land and require a port application/development application, written land owner consent will be required from GPC's Port Strategy and Development Department prior to an application being made for any planning or development approvals related to land owned or leased by GPC.	Options that will be located within strategic port land and require a port application/development application will also require land owners consent. This is primarily options that require placement on land (Options 15 - 26).
Port application / development application and Material Change of Use (MCU)	*Planning Act 2016*, *Transport Infrastructure Act 1999* GPC	Where works are proposed on strategic port land, as well as where the new use is inconsistent with the Land Use Plan.	Options that will be located within strategic port land will require a port application / development application and potentially an MCU if the placement of the beneficial reuse changes use of the land. This is primarily options that require placement on land (Options 15 - 26).
Gladstone State Development Area (SDA) approval for new land use.	*State Development and Public Works Organisation Act 1971* DSDMIP	Where the use of beneficial reuse within a state development area results in a material change of use.	Options that will be located within the Gladstone SDA and require approval for new land use may include options that are land reclamation (Options 1 and 2), coastal protection options (Options 3 - 5) and those that require placement on land (Options 15-26).

Approval	Legislation and administrating authority	Potential trigger / activity covered	Potentially applicable option
MCU and Operational Works under the Gladstone Regional Council Planning Scheme	*Planning Act 2016* and Gladstone Regional Council Planning *Scheme 2017* GRC and DSDMIP	Works in the local government area that are assessable under a local government planning scheme and / or require approval under the scheme. These may include: • Operational works for earthworks • Material change of use.	Options that will be located outside of the port area and Gladstone State Development Area will likely trigger an MCU or operational works under the GRC Planning Scheme. This is primarily options that require placement on land (Options 15 - 26) but may also include coastal protection (Options 3 - 6).
Operational work - tidal works	*Planning Act 2016, Planning Regulation 2017* (Planning Regulation), *Coastal Protection and Management Act 1995* Referral agency: Queensland State Assessment and Referral Agency (SARA) Technical advice: DES, MSQ	Operational works for tidal work is required when: • Works are occurring in, on or above land under tidal water or land that will or may be under tidal water because of development on or near the land. • Works designed to be exposed to tidal water because of shoreline fluctuations • Works designed to prevent the erosion of land by the sea • Works within the boundaries of a canal.	Options that are likely to trigger an operational works for tidal works include all marine / coastal options (Options 1 - 14) and other options if infrastructure is present within the coastal management district.
Operational work - removal, damage or destruction of marine plants	*Planning Act 2016*, *Fisheries Act 1994* Referral Agency: SARA Technical advice: DAF	Where beneficial reuse is to involve the removal, damage or destruction of marine plants.	Options that are likely to trigger an operational works for removal, damage or destruction of marine plants are all options. However, infrastructure for land based options (Options 15 - 26) may be located to avoid marine plant disturbance.
Operational work - clearing native vegetation	*Planning Act 2016*, *Vegetation Management Act 1999* Referral Agency: SARA Technical advice: DNRME	Where beneficial reuse results in clearing of native vegetation.	Where an option results in the need to clear native vegetation, an operational work for clearing native vegetation will be required. This is primarily options that require placement on land (Options 15 - 26).

Approval	Legislation and administrating authority	Potential trigger / activity covered	Potentially applicable option
Operational works in Fish Habitat Area (FHA)	*Planning Act 2016* / *Fisheries Act 1994* Referral Agency: SARA Technical advice: DAF	Operational work in a declared fish habitat area	Where an option results in impacts on a FHA, an operational works in a FHA will be required. However, it is unlikely that any of the options will result in impacts on a FHA, the closest FHA is Wild Cattle Island.
Operational work - in a wetland protection area	*Planning Act 2016* Referral Agency: SARA Technical advice: DES	Where beneficial reuse is to occur in a wetland protection area.	Where an option results in impacts on a wetland, an operational works in a wetland protection area may be required. As identified in Option 16 there are only minor wetlands, and these are likely to be avoided.
MCU for Environmentally Relevant Activity (ERA) 16 - extractive and screening activities - dredging	*Planning Act 2016*, *Planning Regulation 2017*, *Environmental Protection Act 1994* Referral agency: SARA Technical advice: DES	Where dredging >1,000 t per year and / or screening >5,000 t per year (where screening is of relevance to onshore processing).	Options that are likely to trigger an MCU for an ERA for placement in offshore lots may include: • Option 6 • Option 10 / 11 • Option 14.
Tampering with animal breeding places	*Nature Conservation Act 1994*, Nature Conservation (Administration) Regulation 2006 DES	Where beneficial reuse results in tampering with native animal breeding places during clearing and grubbing activities.	Options that are likely to interfere with native animal breeding places include: • Option 5 • Option 8 / 9 • Option 23.
Offsetting	*Queensland Environmental Offsets Policy* *Environmental Offsets Act 2014* DES EPBC Act DoEE	Where beneficial reuse is to result in a significant residual impact on a prescribed environmental matter that will or is likely to remain despite on-site mitigation measures for the prescribed activity and is likely to be significant. Prescribed environmental matters include; MNES, Matters of State Environmental Significance (MSES) and Matters of Local Environmental Significance (MLES).	Offsetting will depend on site selection and size of impacts.

Approval	Legislation and administrating authority	Potential trigger / activity covered	Potentially applicable option
		Prescribed environmental matters likely to be present within the Gladstone area include: • World and national heritage areas • GBRMPA • Listed threatened species, migratory species and ecological communities • Declared fish habitat area • Wildlife habitat • Regulated vegetation (Category, B, C or R) • Essential habitat • High ecological significance wetlands.	
Cultural Heritage Management Plan (CHMP) or similar	*Aboriginal Cultural Heritage Act 2003* Department of Aboriginal and Torres Strait Islander Partnerships	Works will be required to be undertaken in accordance with the Duty of Care Guidelines. Works undertaken in category 3 or 4 can reasonably and practically proceed without further cultural heritage assessment. However, if works are to occur in an area that falls under Category 5, it is generally a high risk and the activity should not proceed without a cultural heritage site investigation being undertaken. Where activities are proposed in a Category 5 area, notification to the Aboriginal Party is required to seek advice on whether the area is of Aboriginal Cultural Heritage value, and if it does, how best to manage and avoid harm to any Aboriginal Cultural Heritage.	Where options are to occur in a Category 5 area or known Aboriginal cultural heritage sites / values, further investigations will be required.
Native Title Assessment	*Native Title Act 1993* Department of Justice and Attorney - General	Where beneficial reuse is to occur on land where native title is not extinguished, a native title assessment will be required.	Where options are to be placed on land where native title has not been extinguished.

7. Beneficial Reuse Analysis

This section presents the beneficial reuse analysis, as per Section 4.3, for the options that were shortlisted in Section 5.

7.1 Option 1 and 2: Land Reclamation – Fishermans Landing and New Reclamation Sites

7.1.1 Activity Description

Overview

Land reclamation works involve the use of the maintenance dredge material as fill to raise a low-lying or submerged area such that it may be used as commercial or public land. Existing land reclamation areas have been established such as the Western Basin / Fishermans Landing sites and investigations have been previously undertaken into the feasibility of establishing new reclamation areas.

Process Description

A TSHD would dredge and transport the material to a pipeline. In the event that the disposal location was sufficiently close to the dredge site, a CSD could also be used to convey material via pipeline to the reclamation site. Similarly, in the event that a BHD is used to undertake maintenance dredging, material could be mechanically unloaded using land based plant at an onshore rehandling facility. The construction of a perimeter bund seaward of the reclaimed infill, to hold back the infill and protect against the local coastal processes, is usually required. Depending on the dredge material type, location and severity of the coastal process, the bund can be constructed from materials such as quarried material or select dredge material and armoured using rock or concrete armour units. Consideration must be given to the large tidal range of PoG and care taken during design and construction to ensure that dredged material does not escape from the reclamation area in an uncontrolled manner.

7.1.2 Opportunity

Whilst the Western Basin and Fishermans Landing reclamation areas are already established, the ultimate capacity is limited and has been set aside to accommodate future capital dredge material as outlined in the GPC Masterplan (TMR 2018a).

Prior to completion of the Western Basin Dredging and Disposal Project, an assessment was undertaken of alternative new shoreline reclamation areas. The assessment concluded that nearby areas contained sensitive marine environments including seagrass, mangroves, coastal wetlands and associated benthic communities. Furthermore, these areas were noted as significant habitats for fish, prawns and molluscs, as well as feeding grounds for dugong and turtles.

More recently, a dredged material placement options investigation (DMPOI) was undertaken as part of the EIS for the Gatcombe and Golding Cutting Channel Duplication Project (Aurecon, 2019). The DMPOI identified a number of areas as potential sites for land reclamation works to be progressed in conjunction with the use of the existing Western Basin reclamation area as part of the Channel Duplication Project (Figure 7-1).

Potential locations were reduced to the following short list of four based on a combination of site availability, economic feasibility and capacity constraints:

- Western Basin Expansion
- Fishermans Landing (South)
- Port Central Expansion
- West Banks Island Reclamation

The shortlisted locations are shown in Figure 7-2.

Based on a multi criteria analysis approach which assessed a suite of issues and aspects against agreed objectives, the Western Basin Expansion site was identified as the preferred dredged material placement option in conjunction with the use of the existing Western Basin reclamation area (Aurecon, 2019).

7.1.3 Suitability of Sediments

For land reclamation works sandy or coarse material is preferred. This is to ensure that the reclaimed land has sufficient strength for construction purposes. The outer and middle channel locations (Wild Cattle, Golding, Auckland, Clinton) consist of a higher percentage of coarse sand materials and would be suitable infill for reclamation works. Finer materials that are used in the formation of the remaining area generally require a significant time to consolidate. 'Wick drains' or surcharging can be used to accelerate the consolidation processes, however, the resulting strength of the soil will still be low. As a result, land reclaimed via finer materials will be limited to parklands or where the loading will be small unless extensive blending and ground improvement works are undertaken.

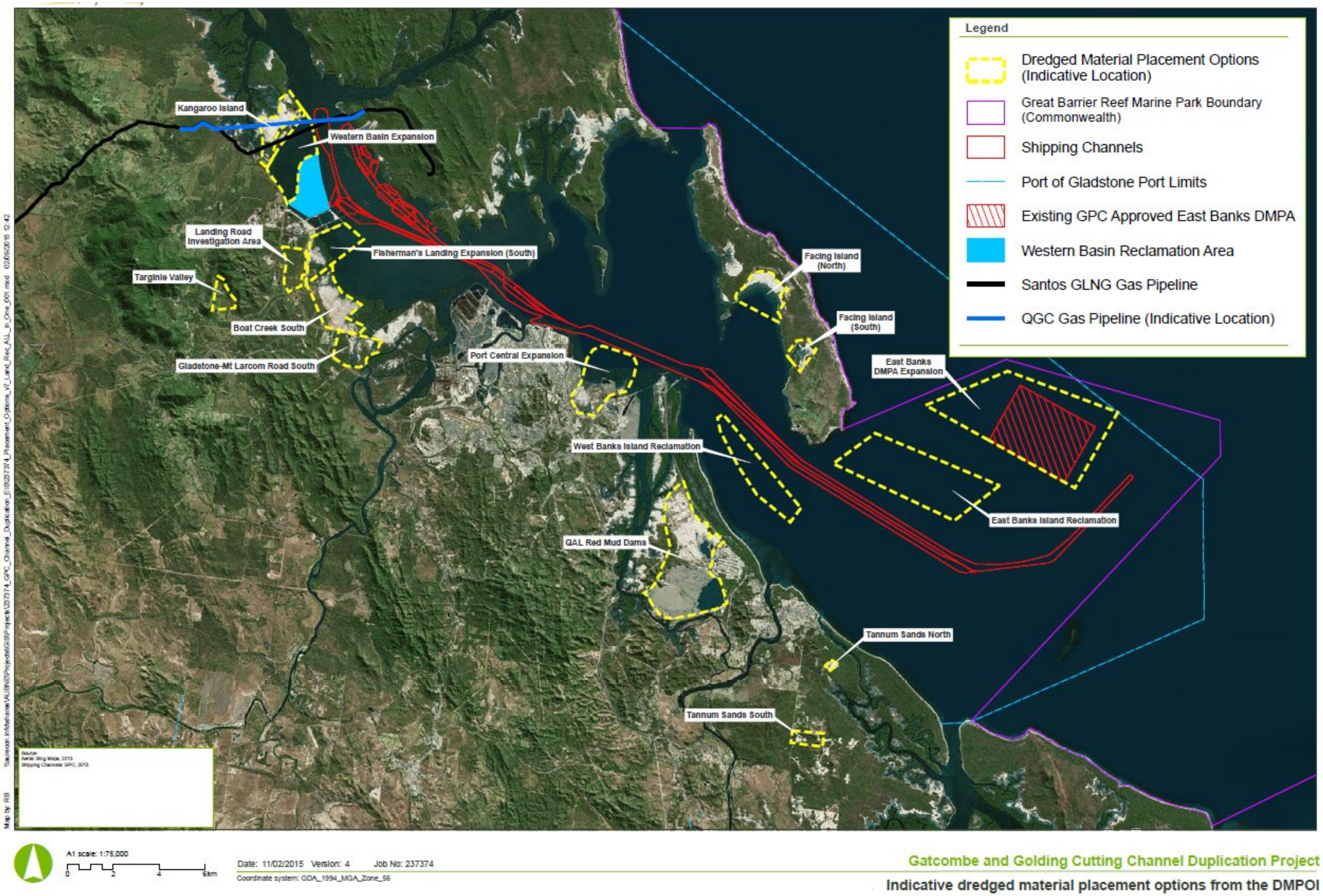


Figure 7-1 DMPOI Potential sites for land reclamation works (Aurecon, 2019)

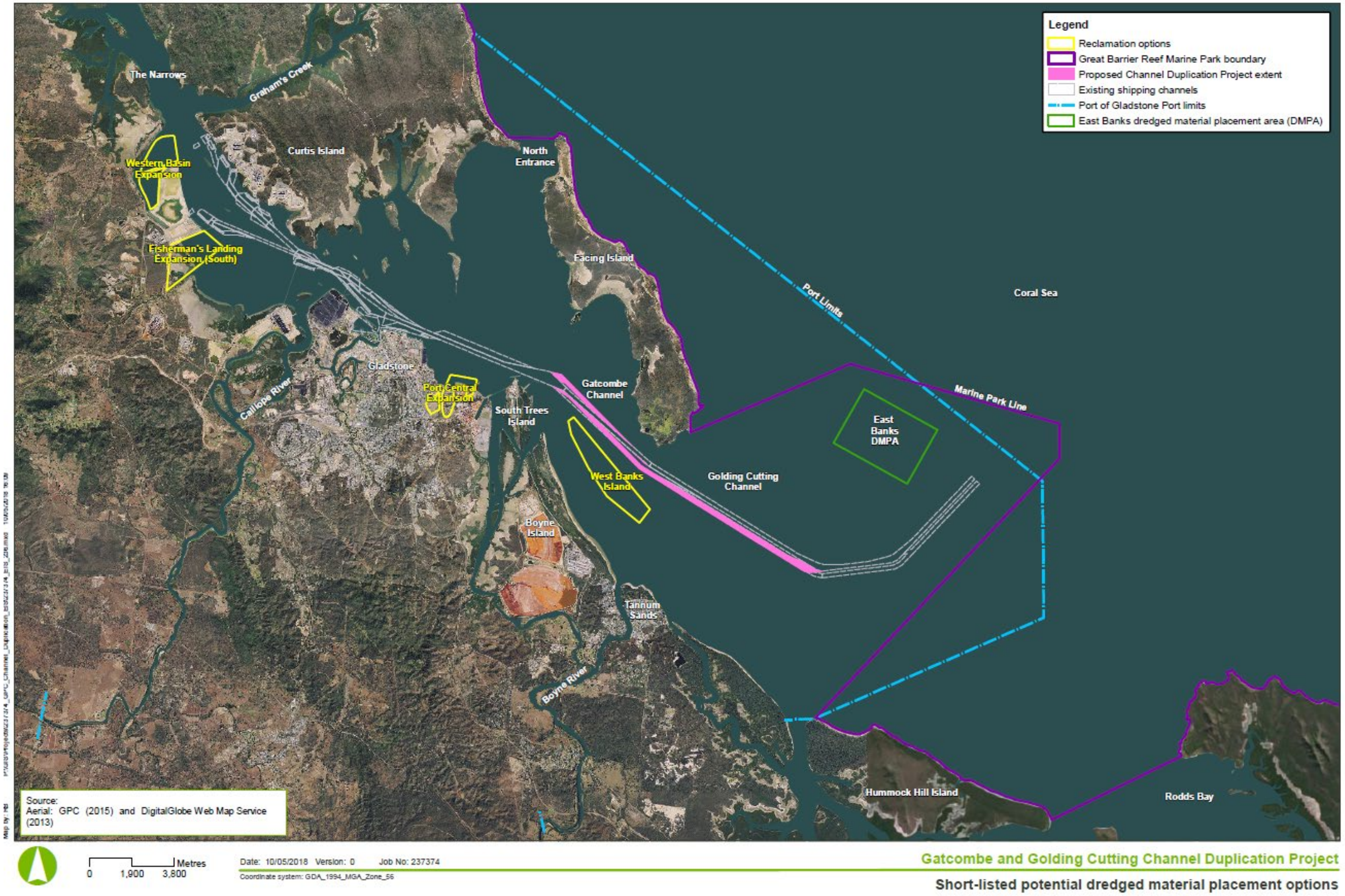


Figure 7-2 Shortlisted sites for land reclamation works (Aurecon, 2019)

7.1.4 Environment

Where the intent is to use the reclaimed land to support expansion in port, industrial or commercial activities. This increases the available land without clearing the existing mature vegetation on parcels of land around the PoG with close proximity to waterside infrastructure.

An alternative is to use the reclaimed land to support environmental areas a local example of this is Spinnaker Park. This will provide a direct environmental benefit in the creation of potential habitat areas.

As outlined in Section 7.1.2, the potential reclamation areas contain sensitive marine and land flora and fauna which may be heavily impacted by these works. These impacts are summarised as follows:

- Disposal of dredge material will likely smother and sterilise the existing benthic environment at the site. These areas were noted as significant habitats for seagrasses, fish, prawns and molluscs, as well as feeding grounds for dugong, turtles and shorebirds (at intertidal sites).
- Protection of mangrove communities is a benefit where the reclamation area is separated from an existing mangrove area by at least 40 m. In this instance the reclamation area acts as a buffer for minor wave / tidal action (GHD, 2009). Mangroves within the Gladstone region are habitat for the threatened water mouse, may be Threatened Ecological Community (TEC) for salt marsh (EPBC Act) and provide other valuable functions.
- A temporary increase in localised turbidity levels during placement is expected. Turbidity subsequently has the potential to impact marine ecosystem's health (including fish and the benthic environment).
- Increase in localised turbidity during and post placement as a result of mud waves. A poorly designed or constructed perimeter bund may promote mud waves or result in sediment leaching. These can lead to the creation of localised turbidity plumes.
- After construction, if the reclaimed land includes environmental areas, there are indirect benefits such as acting as a sediment trap for land runoff.
- The creation of new land may impact upon the local coastal process (e.g. protection works may change local current velocities and the associated longshore drift of sediments). The severity of this impact is unknown at this stage and would depend on the location and extent of works.

7.1.5 Resource Use

Fuel will be used in the transportation and placement of the dredge infill material to the deposition site. Fuel for some processing activities is also required.

Depending upon the design, it is highly likely that there will be a requirement to construct the perimeter bund (or part of the bund) from other deposits, such as land based quarries, this will add to resource use (e.g. fuel).

The Greenhouse Gas (GHG) assessment calculated an estimated 16,400 t CO_2 over five years of the option being undertaken.

There is a potential for a localised loss of blue carbon due to smothering of benthic environments. This would be site specific and appropriate site selection would minimise the loss.

7.1.6 Legislative Requirement

The offshore placement of capital dredge material, as outlined in the Queensland Governments Maintenance Dredging Strategy for the GBRWHA Ports, is prohibited in Queensland. As mentioned in Section 7.1.2, this requirement limits the opportunity of this Option as Fishermans Landing reclamation area has been set aside to accommodate material for future capital dredging works.

Overall, land reclamation itself is undertaken within Queensland and specifically with the PoG as part of capital dredging project, therefore an approval pathway exists, although approvals can be complex pending location and extent. The potential issue arises when there are definitive environmental impacts, such as marine plant (e.g. seagrass) disturbance and impacts to coastal processes. When such impacts exist the State will issue approvals, however they will be heavily conditioned with potentially extensive offsets required. .

7.1.7 Health and Safety

As with any maritime construction project ,there are a number of health and safety risks associated with processing and placement of materials for land reclamation works, these include (but are not limited to):

- Collisions between vessels and plant
- Vessel collisions with floating pipelines in the nearshore zone
- Heavy machinery operation
- Fuel and other chemical spillage
- Machine, plant or personnel falling into or swept into water during construction
- Geotechnical risks associated with large areas of unconsolidated materials
- Exposure of the public to the works area (the direct coastal site, onshore processing site and transportation routes) and subsequent risks of injury.

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.1.8 Cultural

Land reclamation can sterilise or restrict access to land with Aboriginal or European cultural significance. The Port Curtis Coral Coast (PCCC) group represents the Traditional Owners for the Gladstone Area. Impact assessment for the PoG have previously identified that the marine precinct and cultural landscape is important for country connection (Aurecon, 2019). Of relevance to reclaimed land is:

- Water is of social, cultural, economic and spiritual important
- Traditional Owners are concerned by cumulative impacts upon sea and country
- Access to the foreshore and marine areas is valued for economic development, access for cultural activities and obtaining food
- Preserving tangible cultural heritage (such as stone artefacts) (Aurecon, 2019).

Therefore, liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) are required, as a minimum, during the site selection process.

7.1.9 Social

Social concerns may arise from the environmental impacts detailed in Section 7.1.4, in particular the localised impacts to fish resources, sterilisation and access to coastal areas.

A social benefit from land reclamation works include the creation of land, or prevention of clearing coastal land and parks that are, or will be valued by the local community for recreational purposes (depending upon ultimate end land use).

7.1.10 Port Operations

The reclaimed land can be used to expand Port operations or industrial / commercial activities that will benefit the Port.

Modifying the transport and placement methodology has the potential to reduce dredge production rates and extend the duration of dredging works. There will be an increase in maintenance dredging time due to the disposal method of pumping / pipeline when compared to bottom dumping (for example over an hour per load to discharge compared to ten minutes). Dredging will be completed in accordance to previous campaigns with operations to be conducted to minimise disruptions with Port operations since shipping movements have right of way over dredging works.

7.1.11 Cost

Mobilisation and demobilisation costs represent a significant proportion of the overall costs associated with each maintenance dredging campaign. GPC currently takes advantage of shared mobilisation costs by timing maintenance dredging activities to coincide with the TSHD Brisbane's similar campaigns in other Queensland ports. In the event that alternative or additional plant and equipment is required, cost penalties are likely to be severe.

Table 7-1 details the approximate unit costs for reuse Option 1 and 2 (Australasian Marine Associates 2016).

Table 7-1 Approximate costs items for Option 1 and 2

Cost Item	Cost
Pump/pipeline transport to on-land disposal site[2]	$4.4 to $8/cum
Dewatering (land farming, evaporation, natural artificial compaction, geobags etc.)	$7 to $112/cum
Stabilisation of potential acid sulfate soil (PASS)[3]	$33 to $169/cum
Separation (settling ponds, sieves, hydrocodone etc.)[3]	$7 to $27/cum
Land reclamation site construction	$7.5 to $13/cum
Total	$58.9 to $329/cum

Based on the unit rates presented above, placement of the full annual maintenance dredge volume within an existing reclamation area is expected to cost approximately $9.2 million. In the event that a new reclamation area is required, annual costs would equate to approximately $17.7 million where the cost of establishment is spread over 20 years.

[2] Unit rates are for transport / disposal only and exclude dredging cost.
[3] If required

7.1.12 Economics

It is envisaged that relatively little job creation would result from the dredging and placement, which will likely be conducted by a non-local contractor (Aurecon, 2019). The potential for job creation for bund construction, and sediment infilling and maintenance of the reclaimed land is dependent upon the site used. The use of an existing reclaimed land site would not create any significant job positions as maintenance material would be in addition to existing capital disposal.

The establishment of a new reclaimed land site would create part time work which could be undertaken by local contractors if the skills are available. The EIS for the Gatcombe and Golding Cutting Channel Duplication Project (Aurecon, 2019) identified projected workforce demand the capital works project. The workforce demand for maintenance dredging is anticipated to be lower than capital works due to the volume of material handled.

The expansion of Port, industrial or other commercial activities is likely to have a significant impact on job creation and income into the Gladstone region. This extends to include the construction works conducted on the reclaimed land. In addition, local quarries will be utilised for the supply of materials for the perimeter bunds (depending on the material requirements of the bund).

7.1.13 Methodology

The containment bunds, would be constructed by direct placement with land based plant. The material to be used as infill would be dredged, transported and placed at the disposal site via a combination of overland and submerged or floating pipeline.

Given the length of channel over which suitable sediments would be dredged (middle and outer dredge areas), a TSHD would be the most likely dredge selection. In the event that the disposal location was sufficiently close to the dredge site as may be the case for the Port Central Expansion and West Banks Island reclamation sites, a CSD could be used to convey material via pipeline to the reclamation site. Consideration must be given to the large tidal range of PoG and care taken during design and construction to ensure that dredged material does not escape from the reclamation area in an uncontrolled manner.

Alternatively, material excavated using a BHD could be barged to shore and mechanically unloaded at onshore transfer points.

Reclamation is a well-practiced solution and therefore there is a high certainty of the approach being successful.

7.1.14 Innovation

The reuse of locally dredged materials for land reclamation is a well-practised solution in Australia and is therefore not considered to be new or innovative. Nevertheless there are opportunities to employ innovative design and construction techniques to work with nature for individual components of the works such as interim bunding.

7.1.15 Longevity

If designed correctly, the reclaimed land is a long term solution for holding spoil used to infill the area. On-going maintenance will be required at each site to ensure their longevity.

However, it is important to note that there are finite number of foreshores sites suitable for land reclamation works in the Gladstone region. Under the GPC Masterplan (TMR 2018), placement of capital dredge material within identified land reclamation sites will be prioritised over placement of maintenance dredge material.

Given the regular frequency of maintenance dredging operations and the volume of material generated by each campaign, land reclamation works should be considered a finite placement Option.

7.2 Option 3: Shoreline Protection – Coastal Erosion Mitigation

7.2.1 Activity Description

Overview

Coastal erosion typically occurs as a result of natural processes and can be exacerbated by extreme weather events. As a result of predicted climate change it is modelled that coastal erosion may be further exacerbated by an increased frequency / severity of weather events, worsening storm tide inundations and / or sea level risk.

Dredge material can be placed onshore to protect exposed areas or structures from erosion. This option considers the use of dredged material to reduce the extent or rate of erosion but does not relate to beach nourishment, which is covered in Section 7.3.

Process Description

A number of shoreline protection options are available to mitigate the effects of erosion, which include:

- Direct placement on the banks of waterways or coastal frontages where local sediments have been eroded and dredged materials are sufficiently coarse to remain stable.
- Placement in geotextile bags or tubes either onshore or offshore as:
  - Foreshore armouring (as an alternative to exposed rock armour revetments, buried “backstop” protection, bunds and dune restoration)
  - Groynes
  - Submerged breakwaters.

As discussed in Section 2, maintenance dredge material is required to be removed in relatively thin layers over the length of the channel and berth areas. In light of the large and variable distances between the maintenance dredge areas and potential foreshore protection sites, it is expected that the TSHD commissioned to undertake the maintenance dredging activities would be the most cost effective method of removal and transport of sediments.

For coarse materials suitable for direct placement, the TSHD would discharge dredged materials to land via pipeline to an onshore dewatering area or via rainbowing.

For finer materials requiring placement within geotextile bags of tubes, there are a number of potential methodologies available. Hydraulic filling of large scale geotubes could be undertaken within the TSHD, with an adjacent split hopper barge. Whilst this approach minimises the requirements for rehandling sediments, disposal is restricted to creation of submerged breakwaters in relatively deep water. Alternatively, material could be pumped ashore for direct hydraulic filling of bags / tubes or dewatered prior to mechanical loading into bags or tubes using land based plant.

In either case, it is important to note the draft restrictions and maximum pumping distances described in Section 2.

7.2.2 Opportunity

The Coastal Management Outcomes documented in the 2013 State of Queensland Coastal Management Plan state that,

> *Where defence of coastal assets is the most suitable option, beach nourishment; which restores sediment supply and transport, is the preferred option over hard structures (such as sea walls), which can interfere with natural coastal processes. Where seawalls are considered, beach nourishment should be also be undertaken to balance the loss of sediment locked up behind the walls* (State of Queensland, 2013).

GRC obtained funding to progress Phase 1 and Phase 2 CHAS for the region in December 2018. It is understood that the GRC intends to complete the initial phases of their CHAS by June 2019. Phase 1 and 2 of a CHAS are basically to plan for the CHAS's later stages and scope the areas of interest. On this basis, the outcomes of the CHAS are not expected to be available for this Beneficial Reuse assessment.

Nevertheless, the known areas of erosion risk where mitigation (such as placement of dredged material for foreshore protection) may be recommended during the CHAS or have been identified in previous studies include:

- Boyne Island
- Tannum Sands
- Wild Cattle Creek area
- Facing Island.

Shorelines within these areas have been experiencing on-going erosion over recent years, which has been exacerbated by extreme storm events such as recent Tropical Cyclones. The key previous assessments undertaken in the Gladstone region include:

- Boyne Island & Tannum Sands Shoreline Erosion Management Plan (Ecosure, 2014)
- Boyne Island and Tannum Sands Coastal Study Report (GHD, 2015a)
- Boyne Island Coastal Study Concept Design and Approvals Scoping (GHD, 2015b).

The 2014 Shoreline Erosion Management Plan documented relevant issues and recommended management measures for Lilley's Beach, Boyne Island, Tannum Sands Beach, Wild Cattle Island and Colosseum Inlet. Priority management actions were generally restricted to management controls and minor works, including:

- Dune fencing to prevent vehicle access to sensitive ecosystems
- Revegetation and stabilisation of dunes and significant habitats
- Monitoring - of beach use patterns, erosion rates, photo-monitoring
- Restrict access to dunes and sensitive beach areas
- Signage to direct traffic and improve community awareness
- Enforce the current beach permit system
- Assessment of stormwater outlets and modification where required
- Assessment and / or removal of permanent structures
- Minor works such as coir logs and sand nourishment
- Maintenance of the status quo
- Retreating from Colosseum Inlet by not renewing leases.

These priority management actions are similar to GPC's Biodiversity Offset Strategy (GPC, 2012). The Strategy includes a number of actions, including habitat enhancement and restoration actions project.

The design outcomes of the 2015 study focussed on Wild Cattle Creek and included recommendations for ongoing monitoring and survey, as well as two immediate civil works projects (GHD, 2015b). The first being immediate drainage channel realignment works adjacent to the Creek mouth. The second being sand push works where 10,000 m^3 of sand is sourced from the existing lobe at the Creek mouth and / or beach nourishment works where sand is sourced outside the active beach zone. The study noted that where beach nourishment is not considered effective in maintaining a suitable buffer, consideration should be given to constructing a 'last line of defence' revetment structure.

In summary, whilst there is opportunity for beneficial reuse of dredged sediments for foreshore protection, existing legislation dictates that foreshore protection is to be pursued only once other options have been discounted. It is also important to note that the volume of material required for foreshore protection purposes is vastly smaller than the quantities requiring removal during each maintenance dredging campaign.

7.2.3 Suitability of Sediments

Sediments suitable for beneficial reuse as shoreline protection can be grouped by two main placement categories:

- Direct placement on the banks of waterways or coastal frontages
- Placement in geotextile bags or tubes either onshore or offshore.

The first being those suitable for direct placement on the banks of waterways or coastal frontages where local sediments have been eroded and dredged materials are sufficiently coarse to remain stable. This includes materials removed from the central regions of Clinton and Auckland Channels which comprise of largely sand with minor silt fractions. This material typically accounts for 59,800 m^3 during each maintenance dredging campaign (based on 2017 data).

The second being those suitable for placement in geotextile bags or tubes either onshore or offshore. This includes materials removed from Fishermans, Jacobs Channel and Marina, which are largely dominated by silts and finer clay fractions. Materials from the outer zones of Golding and Wild Cattle Channels are also considered suitable, being largely sand with some silt and clay. This material typically accounts for 150,000 m^3 during each maintenance dredging campaign (based on 2017 data).

7.2.4 Environment

Shoreline protection works aim to improve the long term viability of foreshore coastal environments such as estuarine areas (including wetlands), salt marsh, beach fronts and other areas of high value (seagrasses, mangroves etc.). These areas support vulnerable species such as the water mouse (*Xeromys myoides*) (identified as vulnerable under the EPBC Act), sea turtles and dugongs, and are important in supporting biodiversity in the region.

Coastal processes will need to be considered in detail to ensure the protection measures do not negatively affect other coastal process. For example, coastal groynes will prevent sediment loss downstream of the groyne. However, immediately upstream of the groyne can experience increased sediment loss, as replacement of sediment has been disrupted. Even relatively minor changes in material type may lead to unintended impacts upon coastal processes and biota.

Testing will be required to confirm that the sediments do not contain inherent fines that may adsorb contaminants (such as heavy metals, organic compounds and nutrients etc.) which have the potential to adversely affect the environment. The sediments will also need to be tested to confirm that ASS are not present or have been suitable neutralised by natural materials. The findings of the sediment characteristic report identified that ASS are present at some sites, but so is excess neutralising capacity. If sediment is used it is recommended that further assessment be undertaken to confirm that ASS is suitably neutralised.

Previous GPC studies (refer to Section 3) conducted indicate that the sediment quality scores were uniformly very good across all zones of Port Curtis due to low levels of metals (cadmium, copper, lead, nickel and zinc) and total Polyaromatic Hydrocarbons (PAHs). Arsenic and nickel were the only parameters that were somewhat elevated; in particular, arsenic in the Outer Harbour and nickel in Auckland Inlet and The Narrows. However, concentrations of these metals are frequently elevated in naturally occurring sediments. Based on available data it is considered that the dredged sediment do not pose a contamination risk for the reuse option.

An increase in localised turbidity levels during placement until stabilisation is expected. Turbidity subsequently has the potential to impact marine ecosystem's health (including fish and the benthic environment). The development and implementation of a turbidity management plan will help manage this risk.

This option reduces the environmental impacts associated with the mining, processing and transporting of quarry materials from other deposits in the region and may improve protection of coastal fauna habitats, such as for the water mouse, FHAs and seagrass.

Onshore Placement and Processing

For coastal protection options that require the transport and material to an onshore processing site the environmental impacts would be dependent upon the location and size. An option that is preferred is to use a previously disturbed site within 2 km of the coast / PoG channel(s). This would:

- Reduce the direct vegetation and fauna impacts from clearing
- Have been subject to previous land sterilisation / disturbance therefore minimal indirect impact to vegetation and fauna (e.g. connectivity, noise, light)
- Likely be close to transport / access roads minimising the extent of the total footprint.

Whether a previously disturbed site (as above) is used or not, the following environmental impacts will be required to be considered and managed:

- Erosion and sediment control
- Stormwater management
- Dust, air quality and light pollution
- Noise
- Visual amenity
- Vegetation and fauna aspects for the transport of material from the dredge to the site (i.e. location of the pipeline).

7.2.5 Resource Use

Direct placement or coarse sediments may be undertaken in some environments with minimal onshore processing. In most cases, however, dewatering and profiling of dredged materials will be required in order to achieve the project objectives.

The likely resources required for shoreline protection methods with an onshore component include:

- Temporary onshore placement will sterilise a portion of land
- Screening to separate the desired sized particle which will utilise plant and equipment (use of fuel and water)
- Potential waste products from the screened material (i.e. larger sediment) and requirement to manage that separately (either a use or dispose of)
- Transport of the material to the site (fuel).

There are opportunities to minimise the resource use for other shoreline protection methods. For example geotextile bags can be filled hydraulically on a pontoon and dropped in place via a crane. Similarly, geotextile tubes can be hydraulically filled and place via a hopper barge.

Lastly, another positive resource use impact is a potential reduction in the volume of resources from quarries (and the associated processing) in the region if their use was no longer needed.

The GHG assessment calculated an estimated 10,900 to 24,900 t CO_2 emissions over five years of the method being undertaken

There is an expected neutral impact of the options on blue or green carbon as the impact would depend upon the location and if the protection is for coastal habitat areas may slightly improve future blue carbon.

7.2.6 Legislative Requirement

Provided the appropriate Australian Standards and requirements of the site are met the legislative requirements are considered standard (as per section 6) with approvals to include workable conditions.

7.2.7 Health and Safety

Health and safety risks are associated with the placement and processing of materials, similar to other options (refer to Section 7.1.7). In particular, are a number of health and safety risks that are associated with processing and placement of materials for shoreline protection works, these include (but are not limited to):

- Collisions between vessels and plant
- Vessel collisions with floating pipelines in the nearshore zone
- Potential for heavy machinery operating in otherwise public onshore areas (depending upon location)
- Fuel and chemical spillage
- Machine, plant or personnel falling into or swept into water during construction
- Exposure of the public to the works area (the direct coastal site, onshore processing site and transportation routes) and subsequent risks of injury.

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.2.8 Cultural

Coastal protection projects can be selected with the goal of protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) as a minimum.

Where there are Aboriginal cultural significant sites or values along the coast, shoreline protection has the potential to increase protection of the sites and values from coastal processes or climate change related impacts. The PCCC who represent the Traditional Owners, identify that marine or coastal areas and general cultural landscape are important for country connection. Furthermore, access to the foreshore is highly values by the Traditional Owners (Aurecon, 2019).

In addition to preserving values, there is potential that the local Aboriginal Rangers can be used for ongoing monitoring of the coastal protection works and subsequent rehabilitation work if required.

For locations that require coastal protection for other reasons (such as infrastructure or parks) there may be known or unknown cultural values due to coastal areas being of important to Traditional Owners (Aurecon, 2019). Therefore, liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) are required as a minimum during the site selection process. This may then lead to the protection of sites or values (as above).

7.2.9 Social

Social benefits from coastal protection works include the preservation of coastal land, parks, buildings (commercial and residential) that are significant for the local community. Prior to selecting a specific site for shoreline protection works, consideration should be given to the potential recreational and aesthetic impacts associated with the introduction of a coarser material to foreshore areas.

Onshore Placement and Processing

There are areas in proximity to the coast and the PoG channel that have been previously disturbed (e.g. GPC land). It is considered that disturbed port land is used, it is unlikely to be in proximity to sensitive receptors such as residences. Therefore, social impacts would be negligible.

7.2.10 Port Operations

Dredging will be completed in accordance to previous campaigns, with operations to be conducted to minimise disruptions with Port operations.

Modifying the transport and placement methodology has the potential to reduce dredge production rates and extend the duration of dredging works. Provided the dredged works are planned accordingly, an extended program is not expected to impact upon port operations since shipping movements have right of way over dredging works. The actual program impact would depend upon the final method of transporting material, and additional plant and equipment committed to the project.

Onshore Placement and Processing

The location of the placement / processing site will ultimately determine the potential impact upon land based port users and if impacts can be mitigated. The following is required to be considered:

- Sterilising a portion of strategic Port land may negatively impact available Port land for future development, site selection would select a site that has minimal development potential for other port based use
- Provision of pumping and pipelines may provide localised temporary impediment to land use or access to other areas (for example a poly pipe above ground would restrict use of the land for the period)

- Traffic management will need to be considered, if the site is in an area that is subject to existing heavy traffic use, increased traffic may impact upon the efficiency of the road network
- Indirect environmental impacts are to be considered, such as dust and noise, for adjacent land uses
- If the site is located in an area that is not regularly used, or does not have suitable infrastructure (such as access roads), the construction of the placement site and access may open up an area of the port to further development / use.

The extent of impacts would ultimately depend upon the volume of material being placed / processed and the timeframe for this placement / processing.

7.2.11 Cost

Mobilisation and demobilisation costs represent a significant proportion of the overall costs associated with each maintenance dredging campaign. GPC currently takes advantage of shared mobilisation costs by timing maintenance dredging activities to coincide with the TSHD Brisbane's similar campaigns in other Queensland ports. In the event that alternative or additional plant and equipment is required, cost penalties are likely to be severe.

In addition to the direct costs associated with construction materials such as geotextile bags and tubes, any modifications to the transport and placement methodology which reduce dredge production rates result in an extended program and therefore increases the cost of the maintenance dredging campaign. Similarly, double or triple handling of dredged material would significantly increase maintenance dredging costs.

Whilst the additional cost per cubic metre of dredged sediments would be very high, it is important to note that the additional costs would relate to a relatively small quantity of material required for foreshore protection, for example, 10,000 m^3 at Wild Cattle Creek.

It should also be noted that the excavation, transport via road and reuse of sediment previously placed in existing reclamation areas would likely be more economical than establishment of a dedicated pipeline and onshore dewatering facility at the site of proposed foreshore protection.

Direct placement of coarser materials would attract a moderate increase over offshore placement, equating to approximately $9.2 million for placement of 160,000 m^3.

7.2.12 Economics

Potential negative economic impacts will occur as a result of land based quarries no longer needing to supply sediment materials for shoreline protection works. However, this will have commercial savings for GRC and other proponents.

It is envisaged that relatively little job creation would result from the dredging, which will likely be conducted by a non-local contractor. Depending upon the contract engagement model adopted, there is potential for local earthworks companies to be used for construction and maintenance of shoreline protection structures. Ongoing monitoring will be required which will create minor jobs in the region.

Preservation of local parks and infrastructure on the foreshore may potentially protect some jobs that are coastal reliant, such as those jobs that are driven by the tourism industry that rely on a healthy foreshore.

7.2.13 Methodology

The dredge material would typically be removed and transported as close as possible to the proposed shoreline protection site via TSHD. For protection methods requiring direct placement, the material would be transferred to the nearshore zone using a discharge pipeline. The material would be dewatered onsite and reworked to suit the beach profile, as outlined in Section 7.2.1.

For the dredge materials that require onshore processing before being used in shoreline protection works, a discharge pipeline will transfer the dredge materials via the TSHD to the temporary onshore disposal site for it to be processed, dewatered, transported to the protection site and used to fill geotextile sand containers.

These transport and dewatering methods are considered routine for Australian dredging operations. Similarly, the reuse of locally dredged materials is a well-practised solution in Australia. There is an overall high certainty of the approach being successful, however the specific successfulness on site would depend upon further studies (e.g. coastal processes).

7.2.14 Innovation

The shoreline protection options mentioned in Section 7.2.1 and the reuse of locally dredged materials is a well-practised solution in Australia and is therefore not considered to be new or innovative. Nevertheless, the reuse of maintenance dredge material for shoreline protection in Queensland is relatively uncommon since maintenance dredge sediments are typically fine grained and not suitable for reuse. If undertaken, there is potential for continual improvement as modelling and coastal data of the Gladstone region increases.

7.2.15 Longevity

If designed correctly, these shoreline protection options can provide a long-term solution to migrating the risks of erosion for the sites mentioned in Section 7.2.2. On-going maintenance will be required for each structure to ensure its longevity.

Nevertheless there are a finite number of foreshores sites requiring shoreline protection in the Gladstone region. Given the regular frequency of maintenance dredging operations and the volume of material generated by each campaign, shoreline protection works cannot be considered a long term placement option.

7.3 Option 5: Beach Nourishment – Onshore Placement

7.3.1 Activity Description

Overview

Beach nourishment is the replacement of sand / sediment that has been lost to erosion. It is typically ongoing as the coastal processes that drive erosion are not mitigated by nourishment and continue to cause sand loss.

The beach nourishment profile would be developed to ensure that material would be placed during each nourishment campaign in a manner that had most benefit to the beach. In particular, some sections of the beach system may be more depleted than others and in greater need of beach nourishment.

Material should be placed in a manner that takes advantage of the natural processes. For instance, due to the predominant south-easterly wave direction there is a net sand movement north. To take advantage of this the nourishment proposal should bias the placement of material to the south.

The sub-aerial nourishment is important as it provides immediate improvement of the beach amenity and provides the community with the visual perception of the improvement works. The sub-aqueous nourishment is important as it can immediately interact with the wave climate within the more active portion of the beach profile and provide sand where it is needed most.

The relative proportioning of this placement material is a function of a number of factors that include:

- Improved beach amenity
- Public perception of the success of the project
- Operational characteristics of the type of plant and equipment most likely to be involved in the completion of the works
- Replication of natural coastal processes (nearshore wave climate and littoral drift) by the creation of nearshore sand slugs
- The time taken for the nearshore material to be reworked onshore
- Relative cost of completing the works.

Process Description

As discussed in Section 2, maintenance dredge material comprises relatively thin layers over the length of the channel and berth areas. In light of the large and variable distances between the maintenance dredge areas and potential beach nourishment sites, it is expected that the TSHD commissioned to undertake the maintenance dredging activities would also complete the beach nourishment works.

Improved outcomes can be achieved through “profile nourishment” which involves placement of the sand onto both the sub-aerial and sub-aqueous portions of the beach profile. This approach minimises the rapid readjustment of the profile and the perceived “loss” of material from the sub-aerial beach. Profile nourishment requires a combination of placement methods including:

- Bottom dumping of sand in the nearshore area
- Rainbowing / spraying of sand off the bow of the vessel into the shallower surf zone
- Pumping sand ashore via a discharge pipeline directly onto the sub-aerial beach profile.

Bottom dumping involves the dredge and / or barges approaching the nearshore portion of the active beach profile to within the safe operational limits of its navigable depth. The doors or valves constructed on the bottom of the hull of the dredge are opened and as the load is dumped, the navigable depth is maintained.

Some dredges and / or barges are fitted with pump ashore capability. Pumping ashore comprises the fluidising of material in the hopper and pumping of material from the hopper to the subaerial (onshore) portion of the beach profile via a discharge pump, outlet and pipeline. Typically the solids concentration of the slurry would be in the order of 10 percent to 15 percent by volume. The pump ashore operation would normally involve the vessel anchoring in a mooring area that is located within the safe operational limits of its navigable depth (as outlined in Section 2) and the coupling of its pump ashore discharge outlet to a discharge pipeline intake manifold attached to a floating buoy anchored to the seabed. The discharge pipeline would comprise sections of floating, submerged and onshore pipeline.

A discharge outlet would be located onshore from which deposited material would be reworked by an onshore crew using land based plant and equipment such as bulldozers and front-end loaders. The onshore outlet can be moved by extending sections of pipeline. Depending on the existing beach profile, nature of the dredge material and environmental sensitivities of the site, it may be possible to pump dredged sands directly onto the beach. Coarse materials tend to form a typical beach slope as they settle out of suspension whilst finer materials will form a flatter beach profile.

A greater level of control over the resulting beach profile and discharge of return waters can be achieved by discharging within a bunded area in the upper portion of the beach profile to allow dewatering prior to reworking. Bunds may be constructed using existing beach sands to achieve the required permeability and infiltration required. Land based equipment such as trucks and dozers are typically used to relocate the discharge pipe outlet at regular intervals and to profile the nourishment material once placed.

Bow casting is similar to the pump ashore method of discharge except that rather than coupling the pump ashore discharge outlet to the discharge pipeline, material is simply pumped or cast out of the pump ashore outlet some 50 metres or so in front of the bow of the vessel.

7.3.2 Opportunity

Beaches in the region are important for recreational use (including tourism), habitat and specifically for turtle nesting. Where beaches are steep or have a narrow strip of sand above high tide, both recreational use and turtle nesting can be adversely affected by coastal erosion and would benefit from beach nourishment.

As noted in Section 7.2, the Coastal Management Outcomes documented in the 2013 State of Queensland Coastal Management Plan state that,

> *Where defence of coastal assets is the most suitable option, beach nourishment; which restores sediment supply and transport, is the preferred option over hard structures (such as sea walls), which can interfere with natural coastal processes. Where seawalls are considered, beach nourishment should be also be undertaken to balance the loss of sediment locked up behind the walls* (State of Queensland, 2013).

GRC obtained funding to progress Phase 1 and Phase 2 CHAS for the region in December 2018. It is understood that the GRC intends to complete the initial phases of their CHAS by June 2019. Phase 1 and 2 of a CHAS are basically to plan for the CHAS's later stages and scope the areas of interest. On this basis, the outcomes of the CHAS are not expected to be available for this Beneficial Reuse assessment.

Nevertheless, the known areas of erosion risk where mitigation (such as placement of dredged material for foreshore protection) may be recommended during the CHAS or have been identified in previous studies include:

- Boyne Island
- Tannum Sands
- Wild Cattle Creek area
- Facing Island.

Shorelines within these areas have been experiencing on-going erosion over recent years, which has been exacerbated by extreme storm events such as recent Tropical Cyclones. The key previous assessments undertaken in the Gladstone region include:

- Boyne Island & Tannum Sands Shoreline Erosion Management Plan (Ecosure, 2014)
- Boyne Island and Tannum Sands Coastal Study Report (GHD, 2015a)

- Boyne Island Coastal Study Concept Design and Approvals Scoping (GHD, 2015b).

The 2014 Shoreline Erosion Management Plan documented relevant issues and recommended management measures for Lilley's Beach, Boyne Island, Tannum Sands Beach, Wild Cattle Island and Colosseum Inlet. Priority management actions were generally restricted to management controls and minor works, including:

- Dune fencing to prevent vehicle access to sensitive ecosystems
- Revegetation and stabilisation of dunes and significant habitats
- Monitoring - of beach use patterns, erosion rates, photo-monitoring
- Restrict access to dunes and sensitive beach areas
- Signage to direct traffic and improve community awareness
- Enforce the current beach permit system
- Assessment of stormwater outlets and modification where required
- Assessment and / or removal of permanent structures
- Minor works such as coir logs and sand nourishment
- Maintenance of the status quo
- Retreat from Colosseum Inlet by not renewing leases.

The design outcomes of the 2015 study focussed on Wild Cattle Creek and included recommendations for ongoing monitoring and survey, as well as two immediate civil works projects (GHD, 2015b). The first being immediate drainage channel realignment works adjacent to the Creek mouth. The second being sand push works where 10,000 m^3 of sand is sourced from the existing lobe at the Creek mouth and / or beach nourishment works where sand is sourced outside the active beach zone.

In summary, beach nourishment is the preferred policy approach to dealing with coastal erosion in Queensland and there are a number of local sites which would benefit from placement of dredged material.

Typical maintenance dredging volumes from the Golding, Boyne and Wild Cattle Cuttings are in the order of 5,000 m^3 per campaign (Port and Coastal Solutions, 2018). Required nourishment volumes are comparable to those dredged from suitable areas during a typical campaign. However, it is important to note that dredge volumes are variable and are metocean conditions between campaigns.

7.3.3 Suitability of Sediments

Beaches in the Gladstone region are made up of various sediment types including sand, gravel and shells, etc. and have a consistent beach colouring (GHD, 2015b).

Ideally, the borrow material used for beach nourishment would be compatible with the native beach material. In particular, it should have similar physical characteristics in terms of:

- Grain size and grading (or slightly coarser)
- Composition (quartz and shell content)
- Density
- Angularity (angular or well rounded)
- Colour.

Poorly matched beach nourishment material can result in undesirable changes to the beaches. These can include:

- Material which is too fine is likely to be moved seaward more quickly under wave action
- Material which is too coarse is likely to result in a steeper beach profile
- Finer and poorly sorted material (wide range of particle sizes) is likely to result in the redistribution of the coarser fraction over the upper portion and finer fraction over the lower portion of the beach profile
- Aesthetic alterations (e.g. colour).

In addition, it is important to confirm that the sand does not contain inherent fines that may adsorb contaminants (such as heavy metals, organic compounds and nutrients etc.), which have the potential to adversely affect the environment.

The findings of the recent sediment sampling and analysis confirm that the sediment characteristics of maintenance dredge sediments are variable throughout the channel and berth areas. With three distinct seabed types (AMA 2018, and as confirmed by GHD 2019):

- Fishermans, Jacobs Channel and Marina, largely dominated by silts and finer clay fractions
- Central regions of Clint and Auckland, largely sand with minor silt fractions
- The outer zones of Golding and Wild Cattle are largely sand with some silt and clay (where the Golding Cutting has more silt and clay than in Wild Cattle Cutting).

Based on the sediment properties known to date it is likely that the outer channel south of the entrance will be most suitable for nourishment materials. Using the 2017 maintenance dredge volumes as an example, there may be up to 69,000 m^3 of material that is of suitable PSD. However, this sediment did have a grey colouring which will require further review. Consequently, it is expected that future maintenance dredge material from select sections of the channels will be suitable for use as beach nourishment material where maintenance dredge sediments are shown to match the sediment characteristics of the destination beaches.

7.3.4 Environment

Beaches in the region provide habitat for a range of species, specifically turtle nesting (Ecosure, 2014). Turtle nesting can be adversely affected where beaches have been effected by erosion resulting in steep banks or narrow strips of sand above high tide. Beach nourishment would temporary replenish sand at the beach and restore more favourable beach profiles for turtle nesting.

Sediments need to be analysed to confirm their suitability at each nourishment site. Poorly matched beach nourishment material can result in undesirable changes to the beaches as described above.

The potential for ASS and contamination are as per the discussion in Section 7.2.4. Where based on current data the risk is low, but further testing and / or regular review as per maintenance dredging permits will be required.

Localised turbidity may also pose a risk to water quality and coastal ecosystem health, however, development and implementation of a turbidity management plan will help manage this risk.

During onshore placement of sediment for beach nourishment there are environmental factors that will require further consideration to minimise risk and manage potential impacts.

These include:

- Undertake the placement outside turtle nesting (usually summer) and hatching periods (typically seven to twelve weeks following laying) (GBRMPA, 2019. If beach nourishment occurs over a nest it may increase hatching mortality due to depth of cover, or it may introduce a number of barriers for hatchling movement to the sea.
- Selection of locations that do not contain marine plants will meet legislative requirements and minimise impact upon fisheries resources.
- If a location is selected that has benthic substrate (e.g. mudflats) the placement of sand may result in the die back of benthic macroinvertebrates.

7.3.5 Resource Use

Fuel will be used in the transportation of nourishment material to the nearshore zone and in the profiling of the upper portion of the beach.

A positive resource use impact is a reduction in the volume of sediments and resources from other deposits (and the associated processing) in the region.

The GHG assessment calculated an estimated 10,900 t CO_2 over five years of the option being undertaken for sand sediments.

There is an expected neutral impact of the options on blue or green carbon as the method would aim to reduce potential impacts to the ecosystems.

7.3.6 Legislative Requirement

Provided the appropriate Australian Standards, Government guidelines and requirements of the site are met the legislative requirements are considered standard (as per Section 6) with approvals to include workable conditions.

7.3.7 Health and Safety

Health and safety risks are associated with the placement and processing of materials, similar to other options (refer to Section 7.2.7). In particular, there are a number of risks associated with processing and placement of materials for beach nourishment, these include (but are not limited to):

- Collisions between vessels and plant
- Vessel collisions with floating pipelines in the nearshore zone
- Heavy machinery operating in otherwise public onshore areas
- Fuel spillage
- Machine, plant or personnel falling into or swept into water during construction
- Exposure of the public to the works area (the direct coastal site) and subsequent risks of injury.

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.3.8 Cultural

Beach nourishment projects can be selected with the goal of protecting sites with Aboriginal or European cultural significance. The PCCC who represent the Traditional Owners, identify that marine or coastal areas and general cultural landscape are important for country connection.

Furthermore, access to the foreshore is highly values by the Traditional Owners (Aurecon, 2019). Beach nourishment with a goal of protected sites will require liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) as a minimum. In addition to preserving values, there is potential that the local Aboriginal Rangers can be used for ongoing monitoring of the coastal protection works and subsequent rehabilitation work if required.

7.3.9 Social

Beaches in the region are important for recreational use. Where beaches are steep or have a narrow strip of sand above high tide, recreational use can be adversely affected due to excessive erosion. Beach nourishment would temporarily replenish sand at the beach and restore more favourable beach profiles for recreational use.

Beach nourishment will also preserve coastal land, parks and buildings (commercial and residential) adjacent to the beach area.

It should be noted that public foreshore areas would be closed to the public during beach nourishment operations.

7.3.10 Port Operations

Dredging will be completed in accordance to previous campaigns with operations to be conducted to minimise disruptions with Port operations.

Modifying the transport and placement methodology has the potential to reduce dredge production rates and extend the duration of dredging works. Provided the dredged works are planned accordingly, an extended program is not expected to impact upon port operations since shipping movements have right of way over dredging works. The actual program impact would depend upon the final method of transporting material and additional plant and equipment committed to the project.

7.3.11 Cost

Modifications to the transport and placement methodology which reduce dredge production rates result in an extended program and therefore increases the cost of the maintenance dredging campaign. Similarly, double handling of dredged material to pump ashore, dewater and re-profile the resulting beach would significantly increase maintenance dredging costs.

Table 7-2 details the approximate unit costs for reuse Option 5 (Australasian Marine Associates 2016).

Table 7-2 Approximate cost items for Option 5

Cost Item	Cost
Pump / pipeline transport to on-land disposal site[4]	$4.4 to $8/cum
Sand Dispersion / shaping	$11.4/cum

Based on the unit rates presented above, placement within an existing reclamation area is expected to cost approximately $9.2 million for placement of 160,000 m^3 of suitable sands from the outer and middle dredged areas.

It should also be noted that the excavation, transport via road and reuse of sediment previously placed in existing reclamation areas (where suitable) would likely be more economical than establishment of a dedicated pipeline and onshore dewatering facility at the site of proposed foreshore protection.

[4] Unit rates are for transport / disposal only and exclude dredging cost.

7.3.12 Economics

Potential negative economic impacts will occur as a result of land based quarries no longer needing to supply sediment materials for beach nourishment works. However, beach nourishment is not a significant revenue stream for quarries within the Gladstone region so impacts are not expected to be significant.

It is envisaged that relatively little job creation would result from the dredging, construction and monitoring of beach nourishment, which will likely be conducted by a non-local contractor due to the specific requirements and skills needed. There will be a requirement for ongoing monitoring which could be undertaken by a local contractor, with potential minor rework of beach profiles also able to be undertaken locally.

Beaches in the region are an important assets for the local tourism industry. Beaches are also important for recreational use and habitat, specifically for turtle nesting which draw tourists to the area every year and would benefit from beach nourishment.

7.3.13 Methodology

The nourishment material would typically be dredged and transported as close as possible to the proposed nourishment location using a trailing suction hopper dredge. Material would then be transferred to the nearshore zone and upper portion of the beach profile using an onshore discharge pipeline and or a technique known as bow casting or rainbowing. The dredging and placement of locally sourced nourishment material is a well-practised solution in Australia and as such there is a high certainty of the approach being successful.

7.3.14 Innovation

The dredging and placement of locally sourced nourishment material is a well-practised solution in Australia including numerous river entrances in Queensland.

7.3.15 Longevity

As a coastal protection practise, beach nourishment is a short to medium-term solution and is typically repetitive to ensure its long-term success. It does not address the physical forces that cause beach loss, but replaces the lost sand. The nourishment material will eventually be lost through longshore drift or erosion and will need to be replenished.

Whilst the required nourishment volumes are smaller than those dredged during a typical maintenance campaign, it is expected that beaches would require ongoing nourishment. Consequently, there are expected to be opportunities to reuse approximately 5,000 to 10,000 m^3 of dredged material for beach nourishment at each location every 5 to 10 years subject to metocean conditions between campaigns.

7.4 Option 6: Beach Nourishment – Offshore Placement

7.4.1 Activity Description

Overview

Offshore placement enables the dredge to place material on the seabed directly via the hopper doors on the hull of the vessel. Offshore placement then relies on natural coastal processes to move the sediment to suitable locations, including beaches. This approach is often termed "working with nature" and has been employed with great success on similar projects undertaken by other managers of Queensland waterways such as Gold Coast City Council.

Process Description

As discussed in Section 2, maintenance dredge material comprises relatively thin layers over the length of the channel and berth areas. In light of the large and variable distances between the maintenance dredge areas and potential beach nourishment sites, it is expected that the TSHD commissioned to undertake the maintenance dredging activities would also complete the beach nourishment works.

Nourishment material will be dredged and transported using a trailing suction hopper dredge in a similar manner to onshore beach nourishment. However, rather than “profile nourishment” where the material is placed across the entire beach profile, the material would be placed in comparatively deep water via the hopper doors on the hull of the vessel.

When designed correctly, offshore placement utilises natural sediment transport pathways to sort and rework the placed material into shallower areas where beach nourishment is required. Careful planning and placement during high tides in required to ensure that sufficient water depths are available to allow placement in the active portion of the beach profile. Timeframes for visible benefits to the upper portion of the beach profile are significantly longer than direct beach placement however offshore placement offers significant advantages with respect to maintenance dredging timeframes and costs. No land based equipment is required and beach areas may remain open to the public.

7.4.2 Opportunity

As described in Section 7.3.2, there is an opportunity to use the dredge sediment as nourishment material. Offshore placement of the nourishment material is a cost effective alternative to Option 5, allowing cost effective placement of material with minimal construction impact to the existing beach environment.

Known areas of erosion risk where offshore beach nourishment may be feasible include:

- Boyne Island
- Tannum Sands
- Wild Cattle Creek area
- Facing Island.

For preliminary assessment purposes, indicative placement volumes at each site may be in the order 50,000 m^3 of sandy material, with each site requiring renourishment every 5 to 10 years subject to metocean conditions between campaigns.

7.4.3 Suitability of Sediments

The suitability of sediments associated with the offshore placement of nourishment material has been identified in Option 5 (refer to Section 7.3.3).

7.4.4 Environment

Impacts associated with the offshore placement of nourishment material has been identified in Option 5 (refer to Section 7.3.4). The exception to this is a lower risk of impact with regards to turtle nesting and hatching as the process mimics natural coastal processes and occurs over a longer timeframe.

Seagrasses are benthic primary producer habitats that provide a range of functions in the maintenance of coastal / estuarine ecosystems, which include (GPC 2018):

- Promotion of biodiversity values, through supporting unique fish assemblages
- Provision of food resources for dugongs and green turtles

- Provision of habitat for adult and juvenile stages of many fish and invertebrate species
- Maintain food webs that support important fisheries
- Stabilisation of sediment and sediment nutrient cycle.

Extensive coastal seagrass meadows are present within the erosion risk sites mentioned in Section 7.3.2. These communities are at risk of being buried by the offshore placement of nourishment material. Loss of these communities can potentially affect the larger ecosystems through the loss of the functions listed above.

There is also a potential risk, if the placement is designed incorrectly that the nourishment material is not reworked into shallower waters.

An increase in localised turbidity levels during placement until stabilisation is expected. Turbidity subsequently has the potential to impact marine ecosystem's health (including fish and the benthic environment). The development and implementation of a turbidity management plan will help manage this risk.

7.4.5 Resource Use

The resource use associated with the offshore placement of nourishment material has been identified in Option 5 (refer to Section 7.3.5).

Relative to Option 5, offshore placement is more productive and require less resources (fuel).

The GHG assessment calculated an estimated 7,400 t CO_2 over five years of the option being undertaken for sand sediments.

There is a potential for a localised loss of blue carbon due to smothering of benthic environments. This would be site specific and appropriate site selection would minimise the loss.

7.4.6 Legislative Requirement

Provided the appropriate Australian Standards, Government guidelines and requirements of the site are met the legislative requirements are considered standard (as per section 6) with approvals to include workable conditions. Pending upon the location of placement, both Commonwealth and State approvals are likely required, this adds to the complexity however the approval pathway is achievable. Contrary, if seagrass is to be directly impacted by the placement the State agencies may decide not to approve the use unless mitigation and regrowth can be demonstrated.

What is uncertain is whether environmental offsets will be required. If a location is selected that does not contain seagrass meadows then environmental offsets are unlikely. Alternatively, if seagrass is to be disturbed by dredge material placement the cost of offsets may be prohibitive.

7.4.7 Health and Safety

Health and safety risks are associated with the placement and processing of materials, similar to other options (refer to Section 7.2.7). An alteration to this is that placement of material is undertaken offshore and as such direct health and safety risks to the public are limited to water users.

With appropriate management at the site worker and public safety is manageable.

7.4.8 Cultural

Beach nourishment projects can be selected with the goal of protecting sites with Aboriginal or European cultural significance. The PCCC who represent the Traditional Owners, identify that marine or coastal areas and general cultural landscape are important for country connection. Furthermore, access to the foreshore is highly values by the Traditional Owners (Aurecon, 2019). Beach nourishment with a goal of protected sites will require liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) as a minimum. In addition to preserving values, there is potential that the local Aboriginal Rangers can be used for ongoing monitoring of the coastal protection works and subsequent rehabilitation work if required.

7.4.9 Social

The social impacts from offshore placement of beach nourishment material are identified in Option 5 (refer to Section 7.3.9). As the offshore placement has a risk of turbidity and impact to the benthic environment there is a localised and short-term impact to recreational fishing anticipated.

7.4.10 Port Operations

Dredging will be completed in accordance to previous campaigns with operations to be conducted to minimise disruptions with Port operations.

Relative to Option 5 (Section 7.3.10), the dredging duration for offshore placement is shorter as bottom dumping is likely to be acceptable (for example ten minutes for bottom dumping a load compared to over an hour for other discharge methods). Therefore, minimising potential disruptions to port operations and the overall dredging schedule.

7.4.11 Cost

Provided that no additional management controls are required and the placement areas are within the sailing distance to the existing EBSDS, then no additional direct dredging costs would be incurred and in some cases, a cost saving may be achieved due to lower steaming distances.

Design and approvals considerations are required to ensure that the placement of the nourishment material is correct to ensure it is reworked by sediment pathways to areas where beach nourishment is required. This is likely to involve additional coastal modelling (or review of current GPC modelling).

Additional coastal modelling, design and approvals considerations and ongoing monitoring would be required, equating to an additional $1 million.

7.4.12 Economics

The economic impacts from offshore placement of beach nourishment material are identified in Option 5 (refer to Section 7.3.12). However, there due to the offshore placement there will be a lower requirements for placement, processing and reworking.

In addition, offshore placement of the nourishment material is a cost effective alternative to Option 5.

7.4.13 Methodology

The nourishment material would typically be dredged and transported as close as possible to the proposed nourishment location using a trailing suction hopper dredge. Material would then be place offshore via hopper doors on the hull of the vessel. The material would then move into shallower waters via sediment transport pathways and reworked to where beach nourishment is needed.

The dredging and offshore placement of locally sourced nourishment material is a well-practised solution in Australia, including recent nourishment campaigns undertaken by Gold Coast City Council. It is important to note however that such operations have not previously been undertaken at Gladstone. Consequently, detailed investigations and thorough planning would be required to ensure favourable outcomes. It is considered that there is a moderate certainty of the approach being successful.

7.4.14 Innovation

The dredging and offshore placement of locally sourced nourishment material is a well-practised solution in Australia. Nevertheless, offshore beach nourishment is rarely undertaken by ports in northern Queensland because the bulk of maintenance dredge material is relatively fine grained and not suitable for beach nourishment. If undertaken, there is potential for continual improvement as modelling and coastal data of the Gladstone region increases.

7.4.15 Longevity

The longevity for offshore placement of nourishment material has been identified in Option 5 (refer to Section 7.3.15).

7.5 Option 7: Habitat Restoration / Creation – Seagrass

7.5.1 Activity Description

Overview

Seagrasses are marine plants with the same basic structure as terrestrial (land) plants. They form meadows in estuaries and shallow coastal waters with sandy or muddy bottoms. They provide a range of critically important and economically valuable ecosystem services.

The growth of seagrass depends upon a number of factors including:

- Nutrients which can be obtained from nearby mangroves
- Adequate light penetration
- Shallow coastal waters that do not dry out
- Shelter (such as a sand bar) from drying winds and from wave action and strong currents which could create turbulent muddy water.

Due to the requirement for a sandy or muddy substrate there is potential that strategic placement of dredge material could increase the area available that is suitable for seagrass growth.

Process Description

The process for use of dredged material would be similar to Option 5 (refer to Section 7.3.1) where it is expected that the TSHD commissioned to undertake the maintenance dredge activities would also complete the seagrass habitat works.

Placement methods include:

- Bottom dumping of material in a nearshore area
- Rainbowing / spraying of material off the bow of the vessel into the zone
- Pumping material directly to designed locations.

7.5.2 Opportunity

Seagrasses within Port Curtis form part of Port Curtis wetland values and provide other important processes. The master plan for the PoG identified known seagrass extents based on 2002, 2009 and 2013 to 2016 data (TMR, 2018a) as depicted in Figure 7-3. This previous monitoring, and subsequent monitoring since 2016 has identified that seagrass extent fluctuates due to a number of factors including natural weather events.

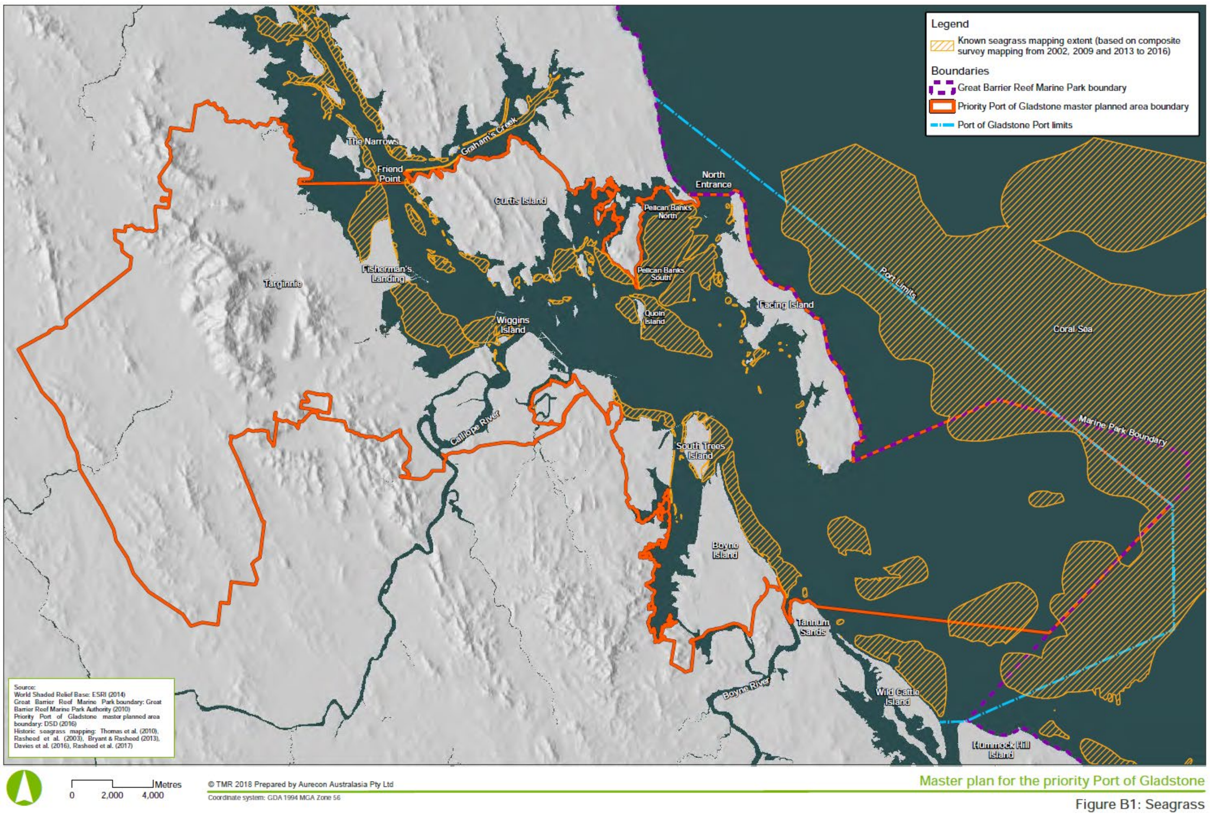


Figure 7-3 Master Plan Seagrass Extents (TMR, 2018a)

The Seagrass Research Group at CQUniversity undertakes projects in the Port Curtis region to assess seagrass habitat extents, fluctuations and potential rehabilitation (Jackson, 2018), In addition James Cook University (JCU) undertake annual monitoring of seagrasses on behalf of GPC. It has been identified that rehabilitation can occur via the following means:

1. Restoration (suitable habitat is present but isolation or other impacts may impede natural recovery)
2. Enhancement (suitable habitat may be present but improvement would allow self-sustaining seagrass meadows to be established)
3. Create (new habitats are created and / or seagrasses are transplanted to an area that has no local seagrasses
4. High natural recoverability (suitable habitat and seagrasses are known to re-establish on their own due to connectivity) (Jackson, 2018).

There have been projects where the transplant of seagrasses has been successful over a five year period, where at five years the transplanted seagrass could not be distinguished from natural seagrass (for example as documented in Bastyan and Cambridge, 2008). However, there have been limited studies within Queensland, and the studies that have occurred have shown differing results (York and Smith, 2013). The difference between the success of a Moreton Bay transplant study in comparison to a Gold Coast transplant study have been attributed to the Moreton Bay transplant site being larger and in less turbid water (York and Smith, 2013).

Potential suitable seagrass transplant sites have been identified for Port Curtis. One of these sites includes Shoal Bay, an inlet at Facing Island, refer to Appendix A (Jackson, 2018). This location provides shelter and nutrient input from mangroves. This would partly align with, the GPC Biodiversity Offset Strategy (GPC, 2012). Due to potential limited seagrass transplant trails in Queensland, this option, if progressed, may be best undertaken as a trial project.

7.5.3 Suitability of Sediments

Seagrasses inhabit a range of substrates from rock to mud, where meadows are more common on softer substrates of mud and sand. It is considered that material from all sections of the PoG Channel are suitable, where a mixture of sand and clay / silt would be of benefit.

The volume of material required for Shoal Bay (or other areas) would depend on the bathymetry and the desired water depths for the seagrass colonisation or transplantation.

7.5.4 Environment

Restoration or creation of seagrass meadows will have a number of environmental benefits, these include (but are not limited to):

- Promotion of biodiversity values, through supporting unique fish assemblages
- Provision of food resources for dugongs and green turtles
- Provision of habitat for adult and juvenile stages of many fish and invertebrate species
- Maintain food webs that support important fisheries
- Stabilisation of sediment and sediment nutrient cycle.

The placement of dredge material for seagrass habitat will require the consideration and management of negative environmental impacts of:

- An increase in localised turbidity levels during placement until stabilisation is expected. Turbidity subsequently has the potential to impact marine ecosystem’s health (including fish and the benthic environment)Turbidity impact may be an ongoing risk that requires monitoring if seagrass establishment is delayed or takes time, it is expected that modelling and preparation will limit the risk of this
- The existing biodiversity of the location and area including current benthic conditions
- If Shoal Bay is used mitigation measures will be required for the adjacent reef areas.

7.5.5 Resource Use

The resource use associated with the placement of material for seagrass habitat has been identified in Option 5 (refer to Section 7.3.5).

Relative to Option 5, seagrass habitat is more productive and require less resources (fuel) due to the close proximity of Shoal Bay to the PoG Channel.

The GHG assessment calculated an estimated 9,200 t CO_2 over five years of the option being undertaken assuming no reworking of sediments is required.

There will be an increase in blue carbon for Port Curtis. The increase would depend upon seagrass establishment rates and densities, and whether there are negative impacts to the surrounding habitats.

7.5.6 Legislative Requirement

Provided the appropriate Australian Standards, Queensland guidelines and requirements of the site are met, the legislative requirements are considered standard (as per section 6) with approvals to include workable conditions.

7.5.7 Health and Safety

Health and safety risks are associated with the dredging and placement of materials, similar to other options (refer to Section 7.2.7). An alteration to this is that placement of material is undertaken offshore or near shore and as such direct health and safety risks to the public are limited to water users at the time.

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.5.8 Cultural

It is considered that placement of material for seagrass habitat, such as at Shoal Bay can be undertaken with the goal of avoiding or protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) as a minimum. In addition, PCCC who represent the Traditional Owners have identified an importance associated with water (social, cultural, economic and spiritual) and marine areas for economic development, access for cultural activities and obtaining food (Aurecon, 2019). The enhancement of seagrass habitat in the PoG has the potential to have an indirect benefit to Traditional Owners.

7.5.9 Social

Recreational fishing (including crabbing and other crustaceans) will be negatively impacted in the short term during placement, processing and establishment due to turbidity or other localised impacts. However, after establishment and growth of the seagrass (potentially five years (Bastyan and Cambridge, 2008)) recreational fishing can potentially benefit from the restoration / creation of seagrass habitats, by supporting fish communities.

7.5.10 Port Operations

The dredge will be required to make trips to Shoal Bay, or alternate locations. Shoal Bay is closer to parts of the PoG Channel than the EBSDS and may result in a reduction in the maintenance dredging duration. However, modifying the placement methodology (the partial placement via pumping or rainbowing) has the potential to reduce dredge production rates and extend the duration of dredging works. In consideration of this it is considered that overall the maintenance dredging schedule impact will be negligible. Dredging will be completed in accordance to previous campaigns with operations to be conducted to minimise disruptions with Port operations since shipping movements have right of way over dredging works.

7.5.11 Cost

The cost of dredging works to create habitat restoration areas will be heavily dependant on the method of placement and the distance material is required to be transported from the dredge site to the placement location. Given that the dredge will be required to make trips to Shoal Bay, or alternate locations closer to parts of the PoG Channel than the EBSDS, bottom dumping operations could be undertaken at no additional dredging costs in excess of those required for the annual maintenance dredging campaign. However, placement of material into shallow areas is expected to require extensive bunding and complex pumping or rainbowing operations. Based on historical dredging costs and approximate unit costs for habitat restoration presented in past studies (AMA and Haskoning Australia Pty Ltd, 2016), the approximate costs associated with placement of 260,000 m^3 is expected to be in the order of $13 million.

7.5.12 Economics

The economic effects associated with the restoration / creation of seagrass habitats have been identified in Option 5 (refer to Section 7.3.12). It is envisaged that relatively little job creation would result from the dredging and placement of material for seagrass areas, which will likely be conducted by a non-local contractor. Depending upon the seagrass establishment method chosen (e.g. natural growth verse placement), there would be jobs created that could be undertaken by local or non-local contractors (based on skill level required).In addition, seagrass areas may be of use to local conservation groups or Universities for study (monitoring and reporting).

Commercial fishing can potentially benefit indirectly from the restoration / creation of seagrass habitats, by supporting fish communities.

7.5.13 Methodology

Dredged material would be removed, transported and placed at the disposal site. Due to the length of channel over which material requires removal, a TSHD with pump out and booster stations would be the best combination for this option.

The use of maintenance dredge material for habitat restoration is a relatively new solution in Australia. There have been a number of successful deployments of both methods in the Netherlands, Ijssel Delta for direct and Port of Harlingen for indirect. Therefore there is a moderate certainty of the approach being successful, pending seagrass establishment / transplant.

7.5.14 Innovation

The placement of dredge material to restore or create seagrass habitat is a new solution in Queensland and could be seen as innovative, in addition it would be subject to ongoing innovation. There is potential that studies by Universities, ongoing GPC surveys in the port, and continual improvement as modelling and coastal data of the Gladstone region increases will improve methods and outcomes for this option. If undertaken, there is potential for continual improvement as modelling and coastal data of the Gladstone region increases.

7.5.15 Longevity

The longevity depends upon the location chosen. It is considered that at least three dredging programs would be required to establish a larger area where depth as required (e.g. due to settling). When seagrasses have become established at the site ongoing placement of dredge material will not be required.

7.6 Option 8 and 9: Coastal Habitat Restoration / Creation – Direct and Indirect Placement

7.6.1 Activity Description

Coastal habitat areas are valuable for a number of reasons including provision of fish habitat, filtering of surface water runoff, protection of the coastline and habitat for a variety of other fauna including birds, to name a few. They are under threat from a number of factors including (but not limited to) development (industrial or urban), tourism, weather events (such as cyclones) and climate change (sea-level risk and increased frequency / severity of weather events). Protection and enhancement of coastal habitats is a focus for many State and local authorities as well as industry and the community.

Direct Placement of Dredge Material

Overview

The creation of environmental bunds and backfilling with maintenance dredge material can be used to restore mudflats and mangroves or create new coastal habitats. There are two potential alternatives under direct placement of dredge material. The first being within the foreshore environment and the other offshore in enclosed circular bunds (similar to the creation of an island or increasing the size of an existing island).

Process Description

For the first alternative, coarse dredge material can be directly placed to form underwater bunds, seaward from a coastal habitat area. Following which, finer dredge material would be placed on the landside of the bund. The retained material (inside the bund) may form mudflats which can support the growth of mangrove habitats and other marine plants.

For the second alternative, coarse dredge material can be placed to form enclosed environmental bunds offshore, which is subsequently filled with fine materials. Depending upon the location of the island, it is likely that the foreshore would require armouring to prevent erosion of the island foreshore by wave wind and tide action. Armouring could be constructed from rock, concrete armour units, geo bags / tubes, gabion baskets or rock bags. Ideally the armouring would be constructed from materials able to utilise the maintenance dredge materials and contribute to intertidal habitat through complex voids and intertidal pools, however this would be subject to confirmation. Similarly to the first alternative, this placement of dredge material would be intended to form intertidal mudflats which would promote the growth of marine plants, resulting in the formation of a new island type habitat. This habitat would be separate from other land / islands, potentially creating a safe place for bird nesting / foraging which would not be available with intertidal options.

Indirect Placement of Dredge Material

Overview

Indirect nourishment is a potential option that uses the concept of a ‘mud motor’ to increase siltation / sedimentation in the coastal habitat over a long period. This approach removes finer sediments from dredged areas and strategically places them within alternative sediment transport pathways.

Process Description

The indirect placement of (fine) maintenance dredge material will increase the availability of sediments that can be transported within the local system by coastal process. This will increase siltation / sedimentation rates along coastal habitats promoting the growth of mudflats.

This is the notion behind the ‘mud motor’ concept. A ‘mud motor’ typically places dredged material in a tidal current where the tidal current moves the sediment to a suitable location. It is partly related to an option that has been assessed under the separate project within the Sustainable Sediment Management Project which has looked at reducing dredging, however this habitat option is more focused on certain areas.

Indirect nourishment would have a higher potential for water quality / turbidity impacts than direct placement, but provided the initial placement campaign is undertake with adequate control provisions, then the broader benthic environment would be expected to tolerate this method better due to slower build-up of sediment.

7.6.2 Opportunity

Indirect placement of dredge material to form environmental bunds is a known and proven method of habitat creation. There are a number of estuarine areas along Curtis Island and Facing Island that are suitable for this type of restoration. Such locations are where there are no beach areas, e.g. where mudflats are currently located and are within close proximity to the dredging activities. Of relevance to this option, the GPC Biodiversity Offset Strategy includes a number of actions, including habitat enhancement and restoration actions / projects (GPC, 2012).

Similar to above, direct placement of dredge material is also a known and proven method of habitat creation. There is potential to create an island habitat system via direct placement. The Gladstone harbour currently includes a number of small islands (such as Diamantina Island, Quoin Island and Worthington Island) and there could be capacity for a created area to be established in The Narrows or between Curtis Island and Facing Island.

The potential opportunity for the creation of a bund seaward of land to increase mud flat / coastal areas in the Gladstone area is lower due to the operations of the Port and the relatively close proximity of deep water to the coast.

There are a number of sites upstream (The Narrows) that are within close proximity to the dredging sites that would not be suitable for environmental bunds (either enclosed or not) due to channel width but would benefit from indirect placement.

7.6.3 Suitability of Sediments

Coarse material is required for the construction of the outer bunds for the direct placement options to provide sufficient strength for construction purposes. Sandy / coarse material is available within the outer harbour zones. Finer silts and clays are preferred for the infill and is the main sediment type required for either indirect or direct placement. The Jacobs Channel and the Marina are largely dominated by the finer clay and silt fractions and will be the primary source of infill.

The volume availability for each sediment type will need to be verified and coordination between the dredging of each sediment type will needed to be performed.

7.6.4 Environment

Coastal habitats like mudflats and mangroves provide a range of functions similar to seagrass communities (as outlined in Section 7.4.4), in addition to supporting migratory and resident birds, land fauna such as reptiles, insects and small mammals (like the vulnerable water mouse) are supported. Further, mudflats and mangroves promote the growth of seagrass by providing essential nutrients into the ecosystem (DES, 2019). Coastal habitats also improve water quality within an ecosystem by trapping sediment and nutrients.

Both direct and indirect placement can increase localised turbidity, with the latter generally posing a higher potential for water quality / turbidity impacts. Turbidity subsequently has the potential to impact marine ecosystems health (including fish and the benthic environment). However, water quality impacts for both methods can be managed through a turbidity management plan and a stage approach.

Both placement methods have the potential to smother local seagrass (refer to Section 7.4.4) and benthic communities, which may take days, months or years to recover. Site selection will be required to consider seagrass meadow locations, with avoidance a preferred outcome.

Direct and indirect placement have different levels of impact upon the benthic environment. Due to slower build-up of sediment from indirect placement, the benthic communities can tolerate the method better. In addition, the sediment properties at the location of indirect placement will develop from natural siltation process which increases the likelihood of success of restoration (Advisian, 2016).

The potential for ASS and contamination are as per the discussion in Section 7.2.4. Where based on current data the risk is low, and due to sediment remaining in a wet state (or tidal area) the risk of ASS is negligible.

Site selection will also need to consider coastal processes including sediment dynamics and transport in the local area. If an area is not suitable assessed sediment transport may be impacted negatively meaning accretion of sediment in areas where it does not currently occur. Coastal modelling and review, as well as ongoing monitoring as part of GPC practices would minimise this risk.

7.6.5 Resource Use

The resource use of sediments associated with the offshore placement of nourishment material has been identified in Option 5 (refer to Section 7.3.3).

Consistent with Option 5 and 6, indirect placement of dredge material is more productive and requires less resources (fuel).

The GHG assessment calculated an estimated 9,200 to 17,600 t CO_2 (the range being due to the varied methods over five years of the option being undertaken.

A review of green and blue carbon impacts has identified:

- The enhancement of such features increases the local green and blue carbon environment.
- This is a negative blue carbon impact during placement that negates the positive blue carbon impacts. However, after the benthic environment has recovered / stabilised the net blue carbon impact is positive.

7.6.6 Legislative Requirement

Provided the appropriate Australian Standards, Queensland guidelines and requirements of the site are met, the legislative requirements are considered standard (as per section 6) with approvals to include workable conditions.

As per Option 6, the exception to this would be if seagrass were to be disturbed and the extent of this. If a location is selected that does not contain seagrass meadows then environmental offsets are unlikely. Alternatively, if seagrass is to be disturbed by dredge material placement the cost of offsets may be prohibitive. Refer to Section 7.5.6.

7.6.7 Health and Safety

Health and safety risks are associated with the placement and processing of materials, similar to other options (refer to Section 7.2.7), with the exception that the onshore risks are not present for this option.

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.6.8 Cultural

Placement sites can be selected with the goal of protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) as a minimum.

Where there are Aboriginal cultural significant sites or values along the coast, coastal habitat options that enhance coastline habitat have the potential to increase protection of the sites and values from coastal processes or climate change related impacts. The actual potential for this would depend upon the location selected. The PCCC who represent the Traditional Owners, identify that marine or coastal areas and general cultural landscape are important for country connection. Furthermore, access to the foreshore is highly values by the Traditional Owners (Aurecon, 2019).

In addition to preserving values, there is potential that the local Aboriginal Rangers can be used for ongoing monitoring of the restoration / creation projects and subsequent rehabilitation / maintenance work if required.

7.6.9 Social

Recreational fishing (including crabbing and other crustaceans) will be negatively impacted in the short term during placement, processing and establishment due to turbidity or other localised impacts. However, after establishment and growth habitat areas (long-term), recreational fishing can potentially benefit from the restoration / creation of coastal habitats.

Additionally, pending location, aesthetic values of the coast will be enhanced in the long-term, this would offset any short-term visual amenity impacts.

7.6.10 Port Operations

Modifying the transport and placement methodology has the potential to reduce dredge production rates and extend the duration of dredging works. There will be an increase in maintenance dredging time due to the disposal method of pumping / pipeline in some instances when compared to bottom dumping (for example over an hour per load to discharge compared to ten minutes). Dredging will be completed in accordance to previous campaigns with operations to be conducted to minimise disruptions with Port operations since shipping movements have right of way over dredging works.

7.6.11 Cost

The cost of dredging works to create habitat restoration areas will be heavily dependent on the distance material is required to be transported. Where placement locations are in close proximity to the dredge sites, this option may be progressed with moderate additional costs, equating to approximately $9.2 million for placement of 260,000 m^3. Location would determine whether perimeter bunding and armouring would be necessary to ensure the long term stability of the placement area. If required this would significantly increase the costs associated with this option.

7.6.12 Economics

The economic effects associated with the restoration / creation of coastal habitats have been identified in Option 3 (refer to Section 7.2.12). It is envisaged that relatively little job creation would result from the dredging and actual material placement. However, local contractors may have skills that enable them to undertake construction and maintenance of habitat areas. In addition, coastal habitat areas may be of use to local conservation groups or Universities for study (monitoring and reporting).

Commercial fishing can potentially benefit from the restoration / creation of coastal habitats by supporting fish communities. The extent of economic benefit will be site specific and may be minimal if habitat is improved in no-go zones, but this will be outweighed by the benefit of increased coastal habitat.

The potential for increase in habitat areas and aesthetic values could enhance the current tourism industry, for example the addition of sites or points of interest to the Curtis Ferry Services schedule or other similar tourism operators.

7.6.13 Methodology

For both methods the dredged material would be dredged, transported and placed at the disposal site. The environmental bunds for the direct placement method, would be constructed either by:

- Rainbowing
- Hydraulically using a floating pipeline and spreader pontoon.

Due to limitations on manoeuvrability within the navigational areas, a TSHD with pump out or a small CSD and spreader barge would be well suited to this option.

Both placement methods are a relatively new solution in Australia. There have been a number of successful deployments of both methods in the Netherlands, Ijssel Delta for direct and Port of Harlingen for indirect. Therefore there is a moderate certainty of the approach being successful.

7.6.14 Innovation

The placement of dredge material to restore or create coastal habitat is a relatively new solution in Queensland and would be subject to ongoing innovation. There is potential that studies by Universities, ongoing GPC surveys in the port, and continual improvement as modelling and coastal data of the Gladstone region increases will improve methods and outcomes for this option.

7.6.15 Longevity

It is considered that direct placement options may require more than three dredging programs / years to establish, with indirect placement potentially requiring longer due to the slower process (i.e. natural processes). There are a number of potential locations that may be available for habitat restoration / creation, refer to Section 7.4.2, a staged approach could be used. For example, direct placement in an enclosed system, island like, could be the trail project, and is successful a bund adjacent to an area of current shoreline could next be progressed. This would extend the longevity of this options and enable continual improvement.

In addition, maintenance may be required to re-establish previously created areas if there are extreme weather events (for example) that erode away a part of the area.

7.7 Option 11 and 14: Deep Water Habitat / Scallop Beds

7.7.1 Activity Description

Overview

Deep water habitat areas cover a broad range of depths. The use of dredged material would relate to the rehabilitation of disturbed areas or the enhancement of current areas that are typically flat with no habitat features. The aim is for dredged material to be strategically placed in ridges or similar features / bedforms to:

- Create direct habitat features
- Increase the bed surface area for the benthic ecosystem and alter the hydraulic load
- Attract other habitat features (such as marine debris) to promote the deep water ecosystem.

In a similar manner, dredged material may be used to enhance scallop (Queensland saucer scallop (*Ylistrum balloti*)) beds where scallop beds are located in deeper water and scallop habitats are typically at 30 - 60 m in depth. James Cook University are currently undertaking studies with regards to scallop distribution, habitat preference and improvement of mortality rates (Daniell, 2018). Recent studies indicate that there is a correlation between scallops abundance and concentrations of mud. This suggests that scallop stock may be improved by restoring or establishing deep water habitat.

Process Description

As per Option 5, beach nourishment, it is considered that the TSHD commissioned to undertake the maintenance dredging would also complete the deep water habitat / scallop bed works. Material can then be placed in accordance with the design and TSHD dredge capabilities.

7.7.2 Opportunity

Deepwater Habitat

The GBRMP includes many different habitat types including deepwater (>30 m deep) seagrass meadows and coral reefs. Therefore, there is potential that deep water habitat environments may be able to be rehabilitated or enhanced. At the time of this assessment the potential opportunities or demand for deepwater habitat works is unknown. If the option was further advanced consultation with the GBRMPA is recommended.

Scallop Beds

There are six scallop replenishment areas in Queensland where the replenishment areas are designated to alter over the years. The areas include:

- Two off Yeppoon (approximately 280 km from the PoG)
- Two off Bustard Head (approximately 30 km from the PoG)
- Two off Hervey Bay (approximately 170 km from the PoG).

In recent years the commercial fishing industry in Queensland have expressed concern about the declining scallop catches, particularly in areas (such as Gladstone) that have traditionally sustained profitable fishing. The annual scallop catch report has shown the lowest numbers since its inception with catch rates today 5% of what they were between 1977 and 1979 (DAF, 2018b). This lead to the closure of all six areas from 3 January 2017. This presents demonstrated need for scallop bed improvements in Queensland.

The reduction in catch rates is likely to be a combination of factors. In 2016 it was reported that scallop populations were impacted by catch rates, freshwater flow, chlorophyll-*a*, water temperature and properties of the Capricorn Eddy (DAF, 2016). Recently however, there has been research that indicates a link between clay / silt material (mud) and preferred scallop habitat (Daniell JJ, 2018). This later research is currently underway, should the linkages remain (or be improved) than a need for clay / silt material (such as from dredging) could become apparent.

7.7.3 Suitability of Sediments

The type of material required depends upon the actual project. The sediment from different areas of the channel is likely suitable as follows:

- High sand content, the outer zones of Golding and Wild Cattle, is suitable for the formation of ridges and in the formation of set bedforms (the likely deepwater habitat projects)
- Clay, silt and / or sand from any portions of the channel may be suitable if a specific project requires it (unlikely)
- Based on recent research high clay and silt content, Fishermans and Jacobs Channel, would be suitable for scallop beds.

As the sediment is remaining in a similar state (i.e. under water) other sediment properties are not expected to play a key role with the exception of Total Organic Carbon (TOC) (or similar parameters) for scallop beds should the research indicate such.

7.7.4 Environment

The aim of deepwater habitat would be a net improvement to environmental conditions at the location. The improvement relates to increases in biodiversity values of benthic, coral, marine mammals and fish. The actual improvement would depend upon the projects purpose and location.

As with other options (refer to Section 7.6.4), negative impacts to the environment will require detailed assessment and management. This includes:

- Selection of a site that does not currently provide biodiversity values, or where values are present the values are low and would benefit from enhancement
- Consideration of coastal processes including sediment dynamics and transport
- Turbidity management during and following placement.

The potential for ASS and contamination are as per the discussion in Section 7.2.4. Where based on current data the risk is low, and due to sediment remaining in a wet state (or tidal area) the risk of ASS is negligible.

7.7.5 Resource Use

Fuel will be used in the transportation and placement of the dredge infill material to the deposition site due to potential distances of up to 30 km.

The GHG assessment calculated an estimated 17,600 t CO_2 over five years of the option being undertaken.

There is an expected neutral impact of the options on blue carbon.

7.7.6 Legislative Requirement

Activities that occur within the GBRMP, prohibit the offshore placement of capital dredge material, as outlined in the Queensland Governments Maintenance Dredging Strategy for the GBRWHA Ports (TMR, 2016).

The placement of maintenance dredge material in offshore areas is a known legislative process, such as the EBSDS. However, it is anticipated that any deepwater habitat or scallop beds would be located within the GBRWHA and GBRMP. This adds a layer to the approval process in triggering EPBC referral and marine park permits. The likelihood of approval for this option would depend upon a number of aspects including the project type, impacts and benefits. To minimise the risk of the option not being approved early consultation with the GBRMPA is recommended (they would also provide advice on the feasibility).

7.7.7 Health and Safety

Health and safety risks are associated with the placement of materials, similar to other options (refer to Section 7.2.7). An alteration to this is that placement of material is undertaken offshore and as such direct health and safety risks to the public are limited to water users. An increased health and safety risk for this option would be associated with the steaming of the TSHD Brisbane to the disposal site due to increased time on the TSHD Brisbane.

With appropriate management at the site worker and public safety is manageable.

7.7.8 Cultural

There are low to no historical values associated with deepwater areas provided shipwreck sites are avoided.

7.7.9 Social

The social impacts or benefits depend upon the location and purpose of the project. The enhancement of deepwater habitat and scallop beds has the potential to support fish communities for recreational activities, and may support recreational diving (in the long-term).

7.7.10 Port Operations

Dredging will be completed in accordance to previous campaigns with operations, however the proposed placement method is currently via the TSHD which would require steaming up to 30 km. This travel would increase the current dredge program within the PoG to a level that could / would not be sustainable.

7.7.11 Cost

Whilst the dredging and placement methodology would be identical to that currently employed, the steaming distance and cycle time would be greatly increased and would therefore attract a significant cost penalty. Increasing the minimum steaming distances to around 20 nM could be expected to increase current dredging and disposal costs by a factor of two to three, equating to a cost of approximately $5.5 million for disposal of finer sediments from the upper portion of the maintenance dredge areas only.

7.7.12 Economics

It is envisaged that relatively little job creation would result from the direct dredging, construction and maintenance of areas. The benefit lies in the use of the area that is created. Commercial fishing in general can potentially benefit from improved deep water habitats.

Specifically, the scallop bed enhancements (if research supports them) would improve the scallop industry in the region. In 2014-2015 the gross value of scallops was about $4 million, down from $16 million in the early 1990s (DAF, 2016), while improvement of one scallop bed area is not anticipated to generate $4 million, it indicates that scallop fishing is an industry in Queensland looking for improvement. While scallop fishing is the end use, there are also intermediate and ongoing uses that involve research projects, through the Queensland Government or Universities, which may provide input into feasibility, modelling or monitoring.

7.7.13 Methodology

The dredged material would be dredged, transported and placed at the disposal site. The placement of dredge material to enhance deepwater habitat has occurred before internationally, not Australia. An international project was the Ecoshape pilot project that was undertaken in the Netherlands (De Jong, 2016) in which depth and texture of sand mining locations were optimised from an ecological perspective. The correlation of sediment with scallop populations is new and limited information is available. The use of dredged material for this purpose would be a new use and the risks associated with accurate placement of material at depth would need modelling and management. Therefore this option has a low to moderate certainty that the approach(es) would be successful.

7.7.14 Innovation

The option in its current form is innovative as it relates to newer and upcoming research (scallop beds). As a result the feasibility of this option, if advanced, will require additional research and potential innovation (for example alterations in placement methods to having the TSHD travel large distances). In addition there is potential that studies by Universities and greater modelling / understanding of processers within the GBR will improve methods and outcomes for this option.

7.7.15 Longevity

As a deep water habitat enhancement, the placement of dredged material is a short to medium-term solution. The demand for deepwater projects will depend upon further feasibility assessments and research of scallop populations / beds.

7.8 Option 20 and 21: Lining / Bunding Material

7.8.1 Activity Description

Overview

A number of industrial land uses require the construction of bunds to contain potential contaminants, whether it be stormwater management or containment of actual chemicals.

Maintenance dredge material can be used to form environmental bunds. Coarse materials would be utilised for the slopes and the outer portions of the bunds. While the finer clays and silts would be used to form the core of the bund and the liners.

A liner is required for confined disposal facilities where leachate has the potential to enter the environment. Liners are low-permeability material typically clays and silts used at sites that have potentially contaminated materials that are stored onsite or managed / treated onsite. Leachate is produced when water enters the contaminated materials either by rainfall, runoff or inflow of groundwater. This leachate then has the potential to leave the contaminated materials and cause contamination of the surrounding environment.

Process Description

To enable use of dredge material in environmental bunds or liners, onshore placement and processing (screening, desalinisation, etc.) would be required.

Pumping ashore comprises the fluidising of material in the hopper and pumping of material from the hopper to the temporary onshore disposal and / or processing site via pipelines and pumps (if required). Typically the solids concentration of the slurry would be in the order of 10 percent to 15 percent by volume. The pump ashore operation would normally involve the vessel berthed at a suitable / dedicated pump out berth (or anchoring in a mooring area that is located within the safe operational limits of its navigable depth (as outlined in Section 2) and the coupling of its pump ashore discharge outlet to a discharge pipeline intake manifold attached to a floating buoy anchored to the seabed). The discharge pipeline would comprise sections of floating, submerged and onshore pipeline. A discharge outlet would be located onshore from which deposited material would be reworked in the processing area by crew using land based plant and equipment (such as bulldozers and front-end loaders), scrolling or machine passes to drain water, and / or wick or horizontal drains.

To enable the controlled segregation of varying classes of material, an onshore dewatering / processing area would be required to be established comprising a series of subdivided basins separated by adjustable weirs and or pipelines. This provides control over water retention times and velocities to separate varying materials according to size, density and settling velocity.

Once dewatered, there is a complex process of mixing, treatment, extraction, processing by screening, stockpiling and then potential blending and batching with imported material to manufacture environmental bund and liner material.

7.8.2 Opportunity

A number of industries within the Gladstone region that use environmental bunds include (but are not limited to):

- Rio Tinto - Fishermans Landing and Aldoga
- Orica - Fishermans Landing
- QAL - South Trees and Boyne Island
- GRC - Wastewater Treatment Plants
- Council landfills - Benaraby.

However, the requirements for bunding and liners are on a projects needs basis, where some existing industrial sites only require replacement if there has been an incident.

Within the region, the Gladstone State Development Area is set aside for industry, infrastructure corridor and major public works. Therefore, there are opportunities that new industrial land uses will be established that require some form of environmental bunding or lining material. The potential for this future use is unquantifiable however.

7.8.3 Suitability of Sediments

The high percentage of fines in sections of the channel could be of benefit for bunding or lining material due to the potential low-permeability of the sediment once dredged, processed and placed. However, bunding and lining material requires specific properties with regards to:

- Chemical compatibility (leachate can result in degradation of liners if suitable material is not used)

- Hydraulic conductivity (permeability) for liners is required at $1x10^{-8}$ to $1x10^{-5}$ cm/s once compacted, the achievability of this from the PoG sediment would be unknown until after material has been processed and tested

It is envisaged that a suitable liner and bund material could be created using the maintenance dredge sediments. However, it is important to note that extensive processing would be required to isolate and blend the available clay and silt fractions of the sediments.

The Marina is currently dredged by separate campaigns (refer to Section 2.2) where material is currently disposed of on land. The sediment from the Marina, following processing, may be suitable for liners or bunds.

7.8.4 Environment

The negative environmental impact associated with onshore placement, processing and transport of materials is to be considered (as outlined in section 7.2.4).

After processing has been undertaken, the use of dredged material as a liner or bunding material minimises the requirements for sourcing such material elsewhere (such as from land based quarries) and the environmental impacts associated with that. Onsite use of dredge material as a liner or bunding material would result in the same environmental impacts as other material (e.g. site storage until use, erosion risk of exposed surfaces).

7.8.5 Resource Use

The resources required for this option include:

- Onshore placement will segregate a portion of land
- Screening to separate the desired sized particle which will utilise plant and equipment (use of fuel and water)
- Potential waste products from the screened material (i.e. larger sediment) and requirement to manage that separately (either a use or dispose of)
- Transport of the material to the facility (fuel).

A positive resource use impact is a reduction in the volume of clay resources from quarries (and the associated processing) in the region.

The GHG assessment calculated an estimated 38,140 t CO_2 over five Marina dredging events. The option considered appropriate infrastructure and sites would be available that do not require establishment, as transport distances are unknown a low base rate was adopted.

Blue and green carbon impacts are considered neutral as appropriate sites would be selected.

7.8.6 Legislative Requirement

Provided the appropriate Australian Standards, Queensland guidelines and requirements of the site are met the legislative requirements are considered standard (as per section 6) with approvals to include workable conditions.

7.8.7 Health and Safety

Health and safety risks are associated with the placement, dewatering and processing of materials, similar to Option 3 (refer to Section 7.2.7). Additional health and safety risks arise from transport of the material to site via the truck and road network, which could be over 20 km for some sites, and facility / site worker use of material.

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.8.8 Cultural

The potential for impacts upon Aboriginal cultural values is neutral as the only new impact is associated with placement / processing and a suitable site that minimises cultural impact is likely available. Similarly, potential impacts upon historical heritage are considered neutral as a suitable site with no direct historical heritage is likely available.

Each sub-option or project (i.e. ultimate destination of the material) will have site specific cultural values and at this stage such values are unable to be quantified.

7.8.9 Social

The use of dredged material for lining or bunding material provides not positive or negative impacts or opportunities with regards to social aspects. There are economics impacts that relate to social (such as increasing competition for local quarries), refer to Section 7.8.12.

With regards to onshore placement and processing, there are areas in proximity to the coast and the PoG channel that have been previously disturbed (e.g. GPC land). It is considered that if disturbed port land is used for onshore placement and processing it is unlikely to be in proximity to sensitive receptors such as residences. Therefore, social impacts would be negligible.

7.8.10 Port Operations

Port operations will be required to be considered in the designation of an onshore placement area to minimise disruptions. Option 3 provided an assessment of the impact on port operations for onshore placement / processing, these would apply to this option (refer to Section 7.2.10).

If sediment material from the Marina is disposed of on land (as is current practice) and processed the impact upon Port operations is considered similar to current impacts, i.e. temporary infrastructure for pumping to the site. Such impacts are manageable.

However, if material from the Inner or Middle Channel was to be used, modifying the transport and placement methodology has the potential to reduce dredge production rates and extend the duration of dredging works (for example over an hour per load to discharge via pumping / pipeline compared to ten minutes for bottom dumping). Provided the dredged works are planned accordingly, an extended program is not expected to impact upon port operations since shipping movements have right of way over dredging works. The actual program impact would depend upon the final method of transporting material and additional plant and equipment committed to the project.

Due to sediment suitability and impact upon port operations, the following sections consider use of the CSD and dredging from the Marina only.

7.8.11 Cost

Table 7-3 details the approximate unit costs for reuse Option 20 and 21 (AMA 2016).

Table 7-3 Approximate costs for Option 20 and 21

Cost Item	Cost
Site clearance	$3,200 to 4,800/ha
Pump / pipeline transport to on-land disposal site[5]	$4.4 to $8/cum
On-road transport by truck	$0.0085 to $0.35/cum/km

[5] Unite rate are for transport / disposal only and exclude dredging costs

Cost Item	Cost
Dewatering (land farming, evaporation, natural / artificial compaction, geobags etc.)	\$7 to \$112/cum
Stabilisation of PASS[6]	\$33 to \$169/cum
Separation (setting ponds, sieves, hydrocylones etc.)[10]	\$7 to \$27/cum
On-land containment area	\$9.3/cum
Total	\$60.7 to \$325.3/cum[7]

Production of lining or bunding material from maintenance dredged material requires a number of interim steps including transport, pump ashore, dewatering, washing, blending, onshore transport and final placement. As a result, this option is considered one of the most expensive beneficial reuse option, equating to an annual maintenance dredging cost of approximately \$12.5 million for processing of 260,000 m^3.

7.8.12 Economics

A review of economics has identified the following:

- The use of material for project would create competition with local resource providers. Potential negative economic impacts will occur as a result of land based quarries no longer needing to supply materials for liners or bunding where material is not sourced from the specific site.
- Little job creation from dredging and placement in a processing area, which will likely be conducted by a non-local contractor.
- Minor job creation from processing and transport the dredge material, which will likely be conducted by a local contractor.
- Potential for commercial savings for industries using dredged material for the liner or bunding material (in comparison to quarry material, not site material).

7.8.13 Methodology

For this option, the discharge pipeline will transfer the dredge materials to the temporary onshore disposal and / or processing site. The material will then be processed (screened, desalinated, etc.) either onsite or transported to an offsite plant. Once processed the material would be stockpiled, before being transported to be used as either a liner or outer / inner bund material.

Whilst reuse of dredged material is increasingly common, the industry knowledge is not well developed in relation to the creation of liner or bund materials. Therefore there is a low to moderate certainty of the approach being successful.

7.8.14 Innovation

The onshore placement and processing of dredged materials as liner or bund material is a relatively new solution in Australia and could be innovative, although the placement of dredge material in an onshore processing site is not.

The requirements for the use of low-impermeable material for liners is current practice, having been a legislative requirement, and best practice, for a number of years.

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6 If required
7 Excludes prices rates for site clearance and on-road transport by truck.

There have been recent developments in the field of mudcreting whereby dredged sediments are mixed with cement and activated carbon in order to improve the strength and reduce the permeability of the resulting material. This is typically employed where low strength or contaminated sediments require reuse. Similar blend rations could be employed to create a liner material however it is likely that the costs associated with this approach would be prohibitive where contaminated sediments are not involved.

7.8.15 Longevity

The requirements for liners and bund material are project based and as such definitive volumes, frequency and duration is unable to be quantified. While liners and bund material are typically required at the initiation of a land use (with land uses that have contamination potential), i.e. a once off supply, there are ongoing needs including site expansion or maintenance works (such as sites that routinely remove material from the lined area where the liner may need replacement). However maintenance and ongoing works for liners and bunds will be of much smaller volumes than initiation.

7.9 Option 23: Land Rehabilitation / Land Improvement / Fill

7.9.1 Activity Description

Overview

Dredged material can be utilised in land rehabilitation works, where land rehabilitation refers to a process of returning damaged land to its natural state (or similar to its natural state). In addition to land rehabilitation, land improvements can be undertaken, while land improvements do not refer to reinstating a previous disturbed site, they are related in that filling and earthworks are required. A similar option is the use of dredged material for construction fill. Land rehabilitation, improvements and construction fill may be required for a number of reasons, these include (but are not necessarily limited to):

- Land rehabilitation:
  - Land that has been subject to previous intrusive disturbance, such as quarries and mines, to infill voids and prepare the site for future land uses
  - Land that has been subject to contamination or industrial land uses and requires remediation in the form of excavation of contaminated soil and fill with clean material
  - Improvement of land after major weather events including erosion that may have resulted from extreme rainfall.
- Land improvement:
  - Improvement of current land surfaces as a mitigation for flood impacts or in climate resilience (including increased storm surge and frequency / severity of weather events)
  - General method of land management, or to enable future use of the land, this is related to Option 17 where dredged material may be suitable to prepare sites for urban or industrial development through earthworks, however dredged material is not intended to inform final landform.
- Construction fill:
  - Where the site does not have adequate volumes available, or the material on site is not of suitable quality construction fill is required for new developments (industry, commercial, public) or expansion to current developments.

– Construction fill is an addition to land improvement, where fill is required to have certain properties to meet the end use. An option is the addition of other products, such as ash by-products to enhance the dredged sediments properties.

Process Description

To enable use of dredge material for land rehabilitation, improvement or construction fill, significant onshore placement and processing (screening, desalinisation, etc.) would be required.

Pumping ashore comprises the fluidising of material in the hopper and pumping of material from the hopper to the processing area via pipelines and pumps (if required). Typically the solids concentration of the slurry would be in the order of 10 percent to 15 percent by volume. The pump ashore operation would normally involve the vessel berthed at a suitable / dedicated pump out berth (or anchoring in a mooring area that is located within the safe operational limits of its navigable depth (as outlined in Section 2) and the coupling of its pump ashore discharge outlet to a discharge pipeline intake manifold attached to a floating buoy anchored to the seabed). The discharge pipeline would comprise sections of floating, submerged and onshore pipeline. A discharge outlet would be located onshore from which deposited material would be reworked in the processing area by crew using land based plant and equipment (such as bulldozers and front-end loaders), scrolling or machine passes to drain water, and / or wick or horizontal drains.

To enable dewatering of the material, an onshore dewatering area would be required to be established comprising a series of subdivided basins separated by adjustable weirs and or pipelines. This provides control over water retention times and velocities to separate varying materials according to size, density and settling velocity. It should be noted that the dewatering process typically results in the segregation of fines from coarser materials. In the case of land improvement such a narrow grading of material would be considered poor material.

Once dewatered and desalinated, a complex process of mixing, treatment, extraction, processing by screening, stockpiling and then potential blending and batching with imported material would be required in order to manufacture a suitable land rehabilitation, improvement or fill material.

The level of screening required would depend upon the site to be rehabilitated or improved, or the construction fill needed. If general fill was required where it is not necessary to meet any specific standards, such as in void infilling, then screening is not required as fine or coarse material would be suitable. Alternatively, where material is proposed in instances where revegetation is undertaken (e.g. the top 0.5 m to 1.0 m of soil surface), or where erosion is a potential consequence, screening of material will be required. It is also considered that soil improvement will be required, such as nutrients / fertilizer for vegetation growth or rock armouring for erosion protection.

During the processing and screening phase there is opportunity to add other materials that would improve the overall properties of the material. Using different by-products from other processes/industries creates an added benefit whereby the by-products are then beneficially reused rather than being disposed of to landfill.

One by-product that is known to be used to alter soil properties (whether it be for concrete or other fill needs) is the ash by-product from burning coal. In Gladstone there are a number of potential sources of ash by-product including Cement Australia, QAL and the NRG Gladstone Powerstation. Ash by-product could be added to the dredged material during processing by suitable plant at a defined ratio to improve sediment properties and enable greater potential for end uses.

7.9.2 Opportunity

Land Rehabilitation

With regard to the potential for mining or quarry infill / rehabilitation the following is noted:

- Within approximately 20 km of the PoG DNRME (2019) identify the following mining leases within 20 km:
  - Queensland Energy Resources oil shale project located west of Fishermans Landing (Queensland Energy (No. 1) (Stuart) Pty Limited) which is currently on hold following a successful Stage 1 trial project until economic conditions are favourable, one rehabilitation process on site is to utilise spent material as backfill, however other opportunities may be present for different material
  - South west of Mount Larcom (Cement Australia (Exploration) Pty Ltd)
  - Adjacent to Awoonga Dam (Frost Enterprises Pty Ltd).
- Within 50 km and east of Bajool / Marmor are mining permits (Cheetham Salt Limited) (DNRME, 2019).
- Within 80 km to 150 km is extensive mining associated with areas about Biloela and Moura, and the historical Mount Morgan mine.
- Other quarries are potentially operated in the region under Environmental Authorities and not mining leases, there are three quarries within 5 km and one within 10 km.

At this stage of the Beneficial Reuse Assessment process detailed information regarding the mines and their rehabilitation plans is unknown. Typically mine and quarry rehabilitation is progressively undertaken, therefore there are likely ongoing needs for fill on a planned basis. The volumes and site specific details are unable to be quantified at this stage.

As per Option 20/21 (refer to Section 7.7), there a number of industrial land uses within the region that have the potential to cause land contamination, as a result rehabilitation is required either during rehabilitation or upon closure. The requirements for rehabilitation during operation are unquantifiable as works would be in response to incidents or specific maintenance / improvement projects.

In additional to known land uses, there is the potential for other contamination events, such as road or rail spills to occur and require clean-up. As safety and management of Queensland's transport network improves and transport measures are upgraded the risk of spills occurring is reduced. It is considered that spill clean-up is not a reliable option to rely on for material use.

Land Improvement

The GRC have Q100 mapping within their Planning Scheme overlays (GRC, 2017). It shows flood risk at a number of locations, including the Port and land associated with the Boyne River (including downstream from Awoonga Dam) and Calliope River (including Police Creek). The flooding impact are likely to be exacerbated by climate change. Dredge material can be utilised at these sites to mitigate the effects of flooding. The use of dredge material could be:

- Filling areas of inundation to allow a future land use
- Construction of levees to protect areas or direct flow to other areas
- Construction of dams or increasing the capacity of current dams (such as Awoonga Dam or the current Rockhampton Fitzroy River project).

The certainty with regards to fill requirements for flood mitigation projects is uncertain as the works are project specific. The Gladstone Area Water Board (GAWB) regularly assess water supply and demand for the region. An augmentation project that was identified in 2000 and reassessed in 2012 was raising the dam wall height from 40 m to 45 m (GAWB, 2013). The undertaking of a dam wall raise would involve a number of resources, including fill. The fill requirements for dam walls are stringent and in accordance with Australian Standards, but there is potential that dredged material could form part of the fill in combination with other materials. The certainty of the project proceeding and the timeframe is unknown, therefore potential volumes are unquantifiable at this stage.

Other land improvement activities are in relation to preparing land for future development, whether that be urban / residential or industrial. GRC have approved a number of urban developments in the region of the last 10 years. Some of these developments have been on hold over the last five years due to the economic slow-down in Gladstone and it is unclear when they will be reinstated.

Fill

The opportunities for construction fill relate to development within the region. Fill is required for a number of projects including:

- Infrastructure such as pipelines, reservoirs, roads (embankments)
- As cover material for landfill cells
- Private uses including large and small scale urbane development
- Commercial uses which are expected to require very small volumes of fill
- Industrial land uses.

With regards to industrial development, the State government have set aside the Gladstone State Development Area to grow the economy and potential of the region. In the past, key development has been around the Yarwun and Fishermans Landing area, where land is flat to undulating and the requirements for imported fill for landform works are relatively low, but construction fill is required for foundation support, internal road and infrastructure, and other uses. Although there are potential projects in the process of feasibility assessments, such as Australian Future Energy and the potential CSIRO hydrogen facility, the requirements for offsite fill are unknown at this stage (consultation will be required if the option is progressed further). Furthermore, other future industrial land use is unknown and unable to be quantified for this Assessment.

The Gladstone State Development Area does not preclude industrial areas being developed in other areas of Gladstone. As above, the future industrial land use is unknown and unable to be quantified for this Assessment.

In addition to new industrial land use is expansions or upgrades to existing facilities, where construction fill may be required if new land is used. Based on the current knowledge of the Gladstone region, the construction fill requirements are typically minor in comparison to volumes required for new development, but may be an ongoing use.

7.9.3 Suitability of Sediments

For land rehabilitation the suitability of sediments depends upon the project. For the infilling of voids there is unlikely to be specific physical parameters that are required to be met and as such sediment that is fine to course would be suitable. However, where rehabilitation works are required to restore a site due to damage or contamination there are likely to be site specific requirements (similar to construction fill) that would stipulate the sediment type suitable for use. In these instances it is likely that sediment could be combined with other material, such as gravel, ash by-product or ameliorants / nutrients, to meet the required properties.

Similar to land rehabilitation, the suitably of sediments for land improvement depend upon the project. For larger projects it is likely that the majority of the fill / material requirements would for be general fill with no set physical parameters, however for surfaces that are either subject to erosion or where vegetation is proposed to grow parameters, physical and chemical, will be set. As per above, in these instances it is likely that sediment could be combined with other material, such as gravel, ash by-product or ameliorants / nutrients, to meet the required properties.

As above, the sediment suitability for construction requirements depends upon the project. Section 3.2.1 provided a review of the engineering characteristics of the sediments. Typically fines are required to enable the use of material for construction fill, therefore Fishermans, Jacobs or the Marina may be suitable following processing, or sediment may be mixed from different portions of the other Inner and Middle Channels. The suitability of sediment would depend upon the level of processing undertaken.

The addition of an ash by-product to later the properties of the dredge material has been previously researched. It has been found that ash can decrease the plasticity index and decrease the moisture content and increase the compound strength (for example Beeghly and Schrock, 2009).

7.9.4 Environment

The negative environmental impact associated with onshore placement, processing and transport of materials is to be considered (as outlined in section 7.2.4).

After processing has been undertaken, the use of dredged material in land rehabilitation / improvement works or as fill minimises the requirements for sourcing such material elsewhere (such as further quarries) and the environmental impacts associated with that. Onsite use of dredge material land rehabilitation works would result in the same environmental impacts as if other material was used (e.g. site storage until use, erosion risk of exposed surfaces).

The potential for ASS and contamination are as per the discussion in Section 7.2.4. Where based on current data the risk is low, however ASS will require additional confirmation on an as needs basis.

Each potential rehabilitation, improvement or fill project has different and site specific environmental impacts and / or benefits. Due to the number of different sub-options and potential projects it is unfeasible at this stage to undertake an assessment of the environmental impacts for each one. It is assumed that as per regulatory requirements each project will be assessed as necessary.

Under historical legislation the owners/operators of mines / quarries were not regulated with regards to site rehabilitation at the completion of works. As a result the State has been left with the rehabilitation of historical mine sites, such as Mount Morgan. Where rehabilitation may entail filling, the availability of material from dredging, rather than sourcing from another open pit quarry, would provide a net environmental benefit. Filling of voids may also reduce the risk of contaminated water creation (for example where sulphides are present in waste rock, or rock faces), entrapment of fauna and visual amenity.

There are likely many steps involved in such a project, for example if Mount Morgan was to be infilled, the wastewater that has pooled would need management prior to filling works.

7.9.5 Resource Use

The resources required for this option include:

- Onshore placement which will segregate a portion of land
- Screening and washing to separate the desired sized particle and salts will utilise plant and equipment (use of fuel and water)
- Potential waste products from the screened material (i.e. larger sediment) and requirement to manage that separately (either a use or dispose of)
- Transport of the material to the facility (fuel).

A positive resource use impact is a reduction in the volume of resources from quarries (and the associated processing) in the region.

The GHG assessment calculated an estimated 38,140 t CO_2 over five Marina dredging events. The option considered appropriate infrastructure and sites would be available that do not require establishment, as transport distances are unknown a low base rate was adopted.

Green carbon impacts directly related to the options are neutral (i.e. the dredge material itself does not create vegetation). However, the end land use could result in increased green carbon reserves such as in the event of rehabilitation of a disturbed site to a park.

7.9.6 Legislative Requirement

Provided the appropriate Australian Standards, Queensland guidelines, and requirements of the site are met the legislative requirements are considered standard (as per section 6) with approvals to include workable conditions.

As previously mentioned, the range of end project uses are broad. Each project would have its own approval pathway to follow with some considered standard, and others requiring Commonwealth, State and Local approvals. At this stage it is not possible to quantify such legislative requirements.

7.9.7 Health and Safety

Health and safety risks are associated with the placement and processing of materials, similar to Option 3 (refer to Section 7.2.7).

Additional health and safety risks arise from:

- Transport of the material to site via the truck and road network, which could be over 20 km for some sites
- Facility / site worker use of material (risks will be specific to the project)
- Public access to sites where material is being used (risks will be specific to the project).

With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.

7.9.8 Cultural

The potential for impacts upon Aboriginal cultural values is neutral as the only new impact is associated with placement / processing, and a suitable site that minimises cultural impact is likely available. Similarly, potential impact upon historical heritage are considered neutral as a suitable site with no direct historical heritage is likely available.

As mentioned previously, each sub-option or project will have site specific cultural values and at this stage such values are unable to be quantified.

7.9.9 Social

Social benefits generally arise from the increase in the availability of suitable land from old mining, quarry or industrial site, and land improvement works in relation to preservation / revival of coastal land, parks, buildings (commercial and residential) that are significant for the local community from the effects of flooding. The specific benefits / impacts will be dependent upon the project.

7.9.10 Port Operations

Dredging will be completed in accordance to previous campaigns with operations to be conducted to minimise disruptions with Port operations. Option 3 provided an assessment of the impact on port operations for onshore placement / processing, these would apply to this option (refer to Section 7.2.10).

However, if material from the PoG Channel was to be used, modifying the transport and placement methodology has the potential to reduce dredge production rates and extend the duration of dredging works (for example over an hour per load to discharge via pumping / pipeline compared to ten minutes for bottom dumping). Provided the dredged works are planned accordingly, an extended program is not expected to impact upon port operations since shipping movements have right of way over dredging works. The actual program impact would depend upon the final method of transporting material and additional plant and equipment committed to the project.

7.9.11 Cost

Table 7-4 details the approximate unit costs for reuse Option 23 (Australasian Marine Associates 2016).

Table 7-4 Approximate costs for Option 23

Cost Item	Cost
Site clearance	$3,200 to 4,800/ha
Pump / pipeline transport to on-land disposal site[8]	$4.4 to $8/cum
On-road transport by truck	$0.0085 to $0.35/cum/km
Dewatering (land farming, evaporation, natural / artificial compaction, geobags etc.)	$7 to $112/cum
Stabilisation of PASS[9]	$33 to $169/cum
Separation (setting ponds, sieves, hydrocylones etc.)	$7 to $27/cum
On-land containment area	$9.3/cum
Total	$60.7 to $325.3/cum[10]

Production of material suitable for land rehabilitation from maintenance dredged material requires a number of interim steps including transport, pump ashore, dewatering, washing, blending, onshore transport and final placement. As a result, this option is considered one of the most expensive beneficial reuse option, equating to an annual maintenance dredging cost of approximately $12.5 million for processing of 260,000 m^3.

[8] Unite rate are for transport / disposal only and exclude dredging costs
[9] If required
[10] Excludes prices rates for site clearance and on-road transport by truck.

7.9.12 Economics

Potential negative economic impacts will occur as a result of land based quarries not required to supply materials for land rehabilitation / improvement / fill (where material is not available onsite). It is noted though that for some projects where dredge material is proposed to be used, other material will likely be required as well (such as addition of gravel or ash by-product), addition may be a new stream of work for local contractors.

There will be little job creation from dredging and placement at the processing site, which will likely be conducted by a non-local contractor.

Minor job creation from processing the dredge material, which will likely be conducted by a local contractor.

As per other factors, the specific economic impacts or benefits will depend upon the project and will likely be assessed as part of the specific projects. Economic benefits may arise from creation of suitable land, the protection of land / asset from flooding, or for project proponents with respect to commercial savings via using dredged material.

7.9.13 Methodology

The dredging, onshore placement and processing, and final placement is a relatively tried and tested technique. Uncertainties and challenges are as per those outlined for liner / bund material in Section 7.8.13. Overall there is a moderate certainty of the approach being successful.

Addition of other material to dredge material, and soils in general, is a known process. The uncertainties arise from potential interactions between materials (such as ash) and the dredge material as the end product is highly dependent upon the materials, mixing method and mixing ratio. An example of where ash has been combined with dredge material is in Pennsylvania where the end product was utilised as structural fill in mine pit backfilling (as reported in Beeghly, and Schrock, 2009).

7.9.14 Innovation

The onshore placement and processing of dredged materials as fill and construction materials is common practice. However, it is important to note that under such practices the ultimate destination for such materials is typically relatively close to the dredge site (minimising transport and associated risks). There exists potential to optimise the dewatering and material blending process however this would require an investment into research and development by either GPC or the contractor.

7.9.15 Longevity

The requirements for this option are project based and as such definitive volumes, frequency and duration is unable to be quantified. For flood mitigation works, materials are typically required post flood event, but proactive works can be enacted to lessen the effect of flood events, detailed consultation with council or other proponents would be required. Construction fill is required frequently in the region.

8. Conclusions

A detailed assessment of each shortlisted beneficial reuse option has been undertaken against the agreed evaluation objectives to identify any fatal flaws and provide recommendations for the options warranting further consideration during subsequent stakeholder engagement to be undertaken by GPC.

It has been agreed with GPC that following completion of GHD's option development work, the final scoring of preferred option(s) will be undertaken by GPC in consultation with relevant stakeholders.

Key observations stemming from this phase of the investigations are summarised below and should be considered and discussed during the subsequent stakeholder engagement phase:

- The PoG has high rates of sedimentation and is one of the few ports in the region in which sands and gravels accumulate within dredged areas. As a result, the PoG is well positioned to investigate the beneficial reuse of maintenance dredge sediments. However, upon review of the conceptual sediment budgets and historical dredge volumes, relatively little gravel requires removal.
- Physical property results of PSD analysis reported that sediments in the outer and middle channel locations (Wild Cattle, Golding, Auckland, Clinton) consisted of a higher percentage of coarse sand and gravel materials than those sediments found in the upper channel reaches (Fishermans and Jacobs) and in the Marina. Current and wave action are considered the main drivers of sediment movement. Finer silty sediment was reported in the locations of lower current flow (upper channel and Marina) along with a higher TOC concentration.
- Maintenance dredge material requires removal from ten main wharf centres and over 50km of channels. As a result, distances to disposal or beneficial reuse locations are highly variable which generally restricts the suitable dredging equipment to TSHD, CSD or barging operations.
- Draft restrictions prevent large dredging plant from discharging dredged material in close proximity to onshore areas as required for beach nourishment or land reclamation. Similarly, even large plant is generally limited to an unaided pumping distance of around 1,500 m. The relatively wide, gently sloping intertidal areas of the Gladstone region necessitate the dredging of access channels or acceptance of long pumping distances and the use of booster stations which significantly increase the cost of dredging works and decrease the efficiency.
- Although maintenance dredging is undertaken on an annual basis, sedimentation rates and associated maintenance dredging volumes are variable from year to year and are influenced by a variety of factors beyond GPC's control. As a result, multiple dredge campaigns (over a number of years) may be required in order to provide sufficient suitable materials for beneficial reuse options.
- An initial high level review identified a long list of potential options involving the beneficial recycling or reuse of maintenance dredge sediments. The majority of these options were discounted following a preliminary feasibility review. However, it is noted that technology or Gladstone region land uses may alter in the medium to long term resulting in other options potentially coming to the forefront. As part of the Maintenance Dredging Strategy (Queensland Government, 2018) proponents are required to review regularly and as such the options list may be altered as part of future projects.

- Land Reclamation – either at the existing Fishermans Landing facility or at a new reclamation site was considered. The availability of coarse sediments suggests that a long term reclamation area (similar to that adopted by Port of Brisbane) would be feasible. Nevertheless a key constraint will be the availability of suitably low lying portside land. Investigations have revealed that there is land designated for environmental protection or future development which limits available land for reclamation. In order to progress this option, a suitable reclamation area must be identified and agreed upon.
- Shoreline Protection – Coastal Erosion Mitigation was considered. The availability of coarse sands and gravels allows direct placement of dredged materials on eroding foreshores comprised on finer, less stable sediments. Alternatively, dredged materials could be used to fill geotextile bags or tubes for use as a variety of shoreline protection structures. Although there are a number of sites potentially suitable for shoreline protection, the high additional costs associated with such works mean that feasibility will be determined by the need for shoreline protection measures at these locations and the availability of lower cost, alternative, non-dredging related solutions. In addition, significantly altering the composition of these areas and associated coastal processes requires detailed investigations and careful planning.
- Beach Nourishment – Onshore or Offshore Placement was considered. Unlike many ports of the region, maintenance dredging within some areas of the PoG requires removal of sand, which would be potentially suitable for beach nourishment. Beach nourishment is the preferred policy approach to dealing with coastal erosion in Queensland and there are a number of local sites which would benefit from placement of dredged material. Whilst beach nourishment using dredged sands is technically feasible, progressing this option would require consultation with key stakeholders, a comprehensive cost benefit analysis and environmental assessment and approvals. It should also be noted that the quantities of material required for beach nourishment are relatively small in comparison to the overall maintenance dredging volumes.
- Habitat Restoration / Creation – Seagrass was considered. This option would have significant environmental benefits and potentially suitable locations are located within Port Curtis, however negative environmental impacts are anticipated from construction works. Uncertainties for this option relate to whether placement of dredge material would increase seagrass meadows, or if other factors play critical roles. Research into Port Curtis seagrasses is ongoing by JCU CQUniversity.
- Coastal Habitat Restoration / Creation – Direct and Indirect Placement Options have been considered. This option would have significant benefits such as supporting migratory and resident birds, land fauna such as reptiles, insects and small mammals (like the vulnerable water mouse), promotion of the growth of seagrass and indirect benefits such as improved long-term water quality and green and blue carbon benefits. The primary drawback with such options relates to the additional cost of delivering the works and negative environmental impacts from construction works. As such, progressing such as option would require consultation with key stakeholders, a comprehensive cost benefit analysis and environmental assessment and approvals.
- Lining / Bunding Material has been considered. Physical properties of the maintenance dredge sediments are such that a suitable lining / bunding material could be produced. A number of industries within the Gladstone region use environmental bunds. The primary challenges associated with this option relate to the high cost of establishing an onshore area and the extensive works required to produce a suitable product. It is also recognised that there is relatively little demand for such material locally.

- Land Rehabilitation / Land Improvement / Fill has been considered. The variety of material types requiring dredging means that a viable land rehabilitation / improvement or construction fill material could be produced. Similarly to bund material, the challenges associated with this option relate to the low demand and high costs associated with producing such a material. Once dewatered, a complex process of mixing, treatment, extraction, processing by screening, stockpiling and then potential blending and batching with imported material would be required which may render this option uncompetitive when compared to other potential sources of material. An aspect that increases its viability is the addition of by-products, such as ash, which are readily available to improve the sediments properties.
- Given the variation in stakeholder’s perceptions of relative importance for evaluation criteria and the subjective nature of options assessments in general, it is recommended that GPC consult with key stakeholders on the findings of this options assessment. The aim of this consultation should be to agree upon any potentially feasible beneficial reuse options, triggers for when these options should be progressed and timeframes for review of available options.

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Appendices

Appendix A - Option Synopses

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BENEFICIAL REUSE OPTION 1 and 2: Land Reclamation – Fishermans Landing and New Reclamation Sites

Land reclamation works involve the use of the maintenance dredge material as fill to raise a low-lying or submerged area such that it may be used as commercial or public land. This beneficial reuse option assessed the potential for use of the current reclamation sites (Fishermans Landing and Western Basin) for maintenance material in addition to capital material, and the establishment of new reclamation sites for maintenance dredge material only.

The process involves the construction of perimeter bunds by direct placement with land based plant. The material to be used as infill would be dredged, transported and placed at the disposal site via a combination of overland and submerged or floating pipeline. Onsite dewatering and processing occurs on an as needs basis. The sediment type that is most suited is sandy / coarse material as finer material requires longer consolidation periods. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	The potential new reclamation areas contain sensitive marine and land flora and fauna which will be heavily impacted by these works. Nearby areas contain sensitive marine environments including seagrass, mangroves, coastal wetlands and associated benthic communities.
Resource use	Fuel will be used in the transportation, placement and processing of the dredge infill material at the deposition site. Construction of the perimeter bund will require armour rock material from other deposits, such as land based quarries. The associated GHG emissions are estimated to be 16,400 t CO_2 over 5 years.
Legislative requirement	Reclamation of land is considered achievable under the current legislation, but may be complex pending detailed assessments and location. Works will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Reclamation areas would be closed to the public. With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.
Cultural	Land reclamation can sterilise or restrict access to land with Aboriginal or European cultural significance.. Therefore, liaison with the local Aboriginal party and review of heritage registers (Queensland, GRC and Aboriginal) are required as a minimum prior to final site selection.
Social	Social concerns may arise regarding potential impacts to fish resources, sterilisation of land and access to coastal areas. A social benefit from land reclamation works includes the creation of land (depending on ultimate end land use).
Port operations	The reclaimed land can be used to expand Port operations or industrial/commercial activities that will benefit the Port. New sites would need to consider proximity to the current PoG channel to reduce the risk of impacts. There will be an increase in maintenance dredging time due to the alternate disposal method.
Cost	Placement of dredged material into reclamation areas is significantly more costly than offshore placement. Placement of the full annual maintenance dredge volume within an existing reclamation area is expected to cost approximately $9.2 million. In the event that a new reclamation area is required, annual costs would equate to approximately $17.7 where the cost of establishment is spread over 20 years.
Economics	Local quarries will be utilised for the supply of material for the perimeter bunds, however relatively little job creation would result from the dredging reuse option. The expansion of Port, industrial or other commercial activities is likely to have significant impact on job creation and income on Gladstone region.
Methodology	High certainty of the approach being successful. Land reclamation is currently undertaken in Gladstone and Australia.
Innovation	The reuse of locally dredged materials for land reclamation is a well-practised solution and is therefore not considered to be new or innovative.
Longevity	Given the regular frequency of maintenance dredging operations and the volume of material generated by each campaign, land reclamation works should be considered a finite placement Option.

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BENEFICIAL REUSE OPTION 3: Shoreline Protection – Coastal Erosion Mitigation

Coastal erosion typically occurs as a result of natural processes and can be exacerbated by extreme weather events. As a result of climate change predictions, coastal erosion may be further exacerbated by an increased frequency/severity of weather events, worsening storm tide inundations and/or sea level risk.

Dredge material can be placed directly onshore to protect exposed areas. Material would typically be removed and transported as close as possible to the proposed shoreline protection site via TSHD before being pumped ashore, dewatered (at a small dedicated bunded area on the shore if required) and transported/reworked at the coastal protection site. Alternatively, dredge material can be placed in geotextile bags (for example) to form structures that protect the coast from erosion. Material would require transport to an onshore disposal site, processing, dewatering, placement in geotextile bags (for example) and transport to the coastal protection site. The direct placement requires sand/coarse material for stability, whereas a range of materials are suitable for the placement within geotextile bags. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	Shoreline protection works aim to improve the long term viability of foreshore coastal environments and may improve protection of coastal fauna habitats. However potential impacts may arise where extensive modification and armouring is required to stabilise the foreshore where there are environmental values in the placement area.
Resource use	Direct placement requires use of fuel for transport (TSHD) and profiling of the placement (plant/bulldozers). Placement in geotextile bags may be direct (fuel and geotextile use) or placement onshore for processing (additional fuel and geotextile use). The associated GHG emissions are estimated to be between 10,900 and 24,900 t CO_2 over 5 years.
Legislative requirement	Shoreline protection is considered achievable under the current legislation. Works within the foreshore environment will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Greater interaction with the general public during placement operations, though risks are considered manageable with appropriate planning and management during construction.
Cultural	Coastal protection projects can be selected with the goal of protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers.
Social	Social benefits from coastal protection works include the preservation of coastal land, parks, buildings (commercial and residential) that are significant for the local community.
Port operations	There will be an increase in maintenance dredging time due to the alternate disposal method and potential placement work.
Cost	Direct placement of coarser materials would attract a moderate increase of offshore placement, equating to approximately $9.2 million. Filling and placement of geotextile sand containers would first require the establishment of an onshore dewatering area comparable to the existing reclamation areas and would therefore be significantly more expensive than direct placement.
Economics	Relatively little job creation would result from the dredging and placement activities. Preservation and enhancement of eroded shorelines would be of value to the region.
Methodology	High certainty of the approach being successful. Use of dredge material for shoreline protection is currently undertaken in Australia.
Innovation	Shoreline protection and the reuse of locally dredged materials is a well-practised solution in Australia and is therefore not considered to be new or innovative.
Longevity	If designed correctly, these shoreline protection options can provide a long-term solution to migrating the risks of erosion. However, there are a finite number of foreshores sites requiring shoreline protection in the Gladstone region. Given the regular frequency of maintenance dredging operations and the volume of material generated by each campaign, shoreline protection works cannot be considered a long term placement option.

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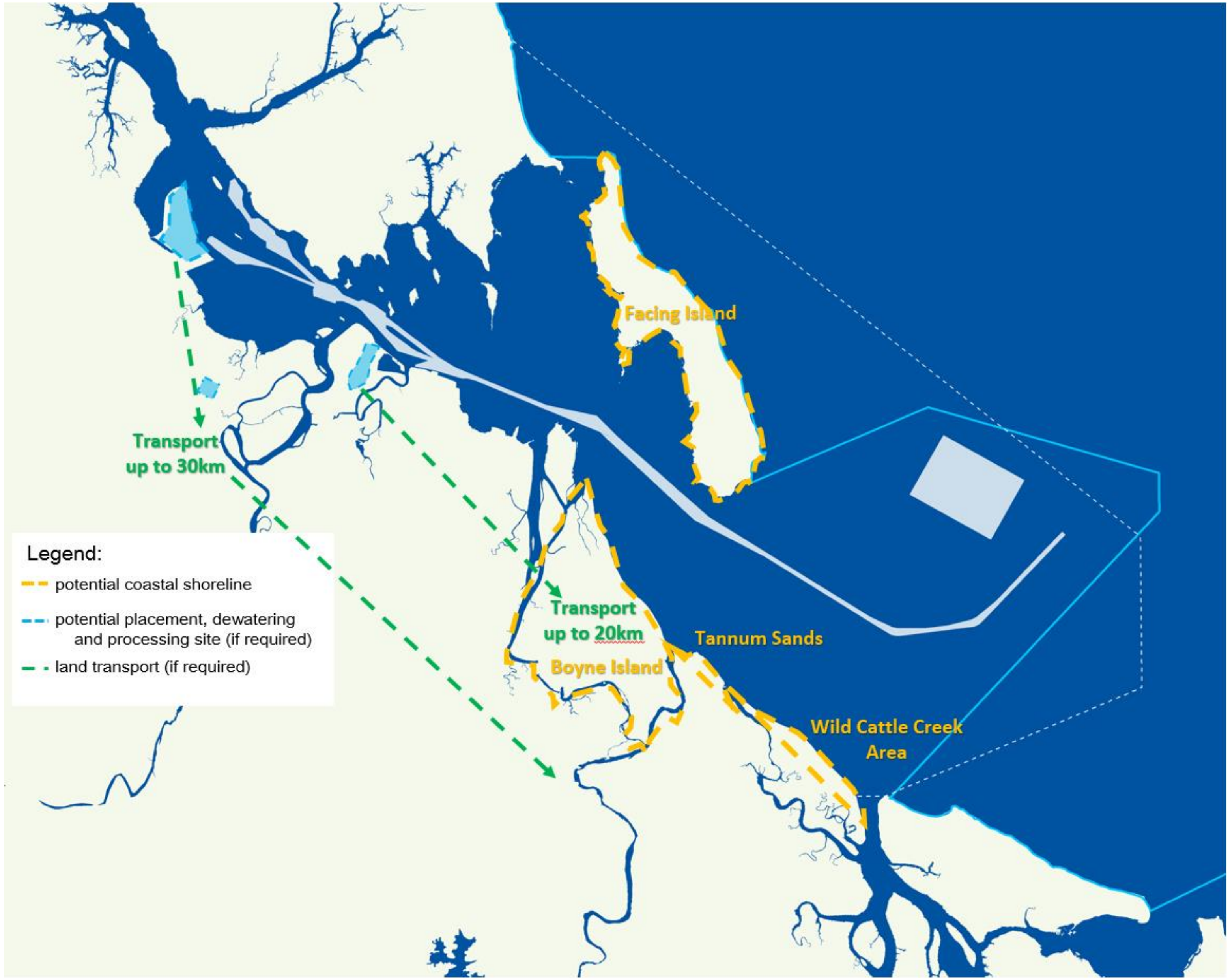

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BENEFICIAL REUSE OPTION 5: Beach Nourishment – Onshore Placement

Beach nourishment is the replacement of sand/sediment that has been lost to erosion. It is typically ongoing as the coastal processes that drive erosion are not mitigated by nourishment and continue to cause sand loss.

The nourishment material would typically be dredged and transported as close as possible to the proposed nourishment location using a TSHD. Material would then be transferred to the nearshore zone and upper portion of the beach profile via pipeline and dewatering may be undertaken (at a small dedicated bunded area on the shore if required). Land based equipment such as trucks and dozers are typically used to relocate the discharge pipe outlet at regular intervals and to profile the nourishment material once placed.

The dredge material suitable is sand which is available from the Golding and Wild Cattle Channels. Both channels are in proximity to beaches. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	Beaches in the region provide habitat for a range of species, specifically turtle nesting. Turtle nesting can be adversely affected where beaches have been effected by erosion resulting in steep banks or narrow strips of sand above high tide. If appropriately timed, beach nourishment would replenish sand at the beach and restore more favourable beach profiles for turtle nesting.
Resource use	Fuel will be used in the transportation of nourishment material to the nearshore zone and in the profiling of the upper portion of the beach. The associated GHG emissions are estimated to be 10,900 t CO_2 over 5 years.
Legislative requirement	Beach nourishment is considered achievable under the current legislation. Works within the foreshore environment will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Greater interaction with general public during placement operations. Nevertheless, risks to the public and project personnel are considered manageable with appropriate planning and management during construction.
Cultural	Beach nourishment projects can be selected with the goal of protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers.
Social	Beaches in the region are important for recreational use. Where beaches are steep or have a narrow strip of sand above high tide, recreational use can be adversely affected due to excessive erosion. Beach nourishment would temporarily replenish sand at the beach and restore more favourable beach profiles for recreational use.
Port operations	There will be an increase in maintenance dredging time due to the alternate disposal method and potential placement work.
Cost	Steaming distances to beach nourishment sites would be comparable those of the existing EBSDS, however onshore dewatering and profiling requirements would attract significant additional costs beyond those required for bottom dumping operations, equating to approximately $9.2 million.
Economics	Beaches in the region are an important assets for the local tourism industry. Beaches are also important for the local tourism industry and would benefit from beach nourishment.
Methodology	High certainty of the approach being successful. Use of dredge material for nourishment material is currently undertaken in Australia.
Innovation	The dredging and placement of locally sourced nourishment material is a well-practised solution in Queensland and Australia and is therefore not considered to be new or innovative.
Longevity	As a coastal protection practise, beach nourishment is a short to medium-term solution and is typically repetitive to ensure its long-term success. It does not address the physical forces that cause beach loss, but replaces the lost sand. The nourishment material will eventually be lost through longshore drift or erosion and will need to be replenished. Nourishment can be considered a long term reuse option but only for relatively small quantities of dredged material.

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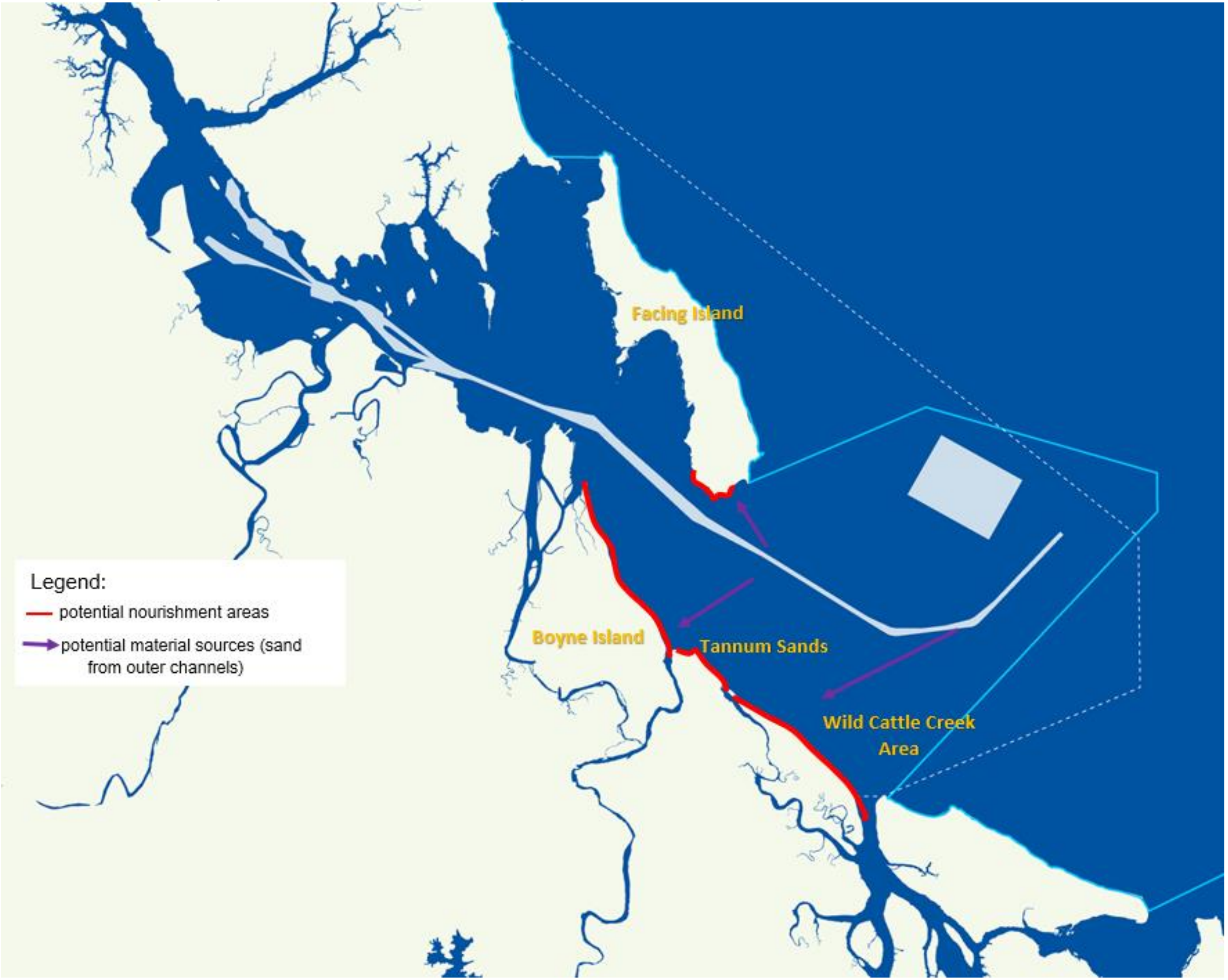

BENEFICIAL REUSE OPTION 6: Beach Nourishment – Offshore Placement

Offshore placement enables the dredge to place material on the seabed directly via the hopper doors on the hull of the vessel. Offshore placement then relies on natural coastal processes to move the sediment to suitable locations, including beaches. Sand is the preferred sediment type.

The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	Lower risk of impact with regards to turtle nesting and hatching as the material is gradually moved onshore by natural processes. However, placement of nourish material offshore risks burying/smothering existing benthic environments or seagrass meadows which provide habitat, food resources, and promote biodiversity values. Site selection would need to consider such factors.
Resource use	Minor differences when compared to existing placement EBSDS operations depending on the distance to the nourishment site. The associated GHG emissions are estimated to be 7,400 t CO_2 over 5 years.
Legislative requirement	Beach nourishment is considered achievable under the current legislation, however, consideration of site specific impacts is required.
Health & Safety	No appreciable difference in risks when compared to existing EBSDS operations.
Cultural	Beach nourishment projects can be selected with the goal of protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers.
Social	Beaches in the region are important for recreational use. Where beaches are steep or have a narrow strip of sand above high tide, recreational use can be adversely affected due to excessive erosion. Beach nourishment would temporarily replenish sand at the beach and restore more favourable beach profiles for recreational use.
Port operations	There will be negligible impact upon maintenance dredging time as disposal methods and locations are similar to the EBSDS.
Cost	Provided that no additional management controls are required then minimal additional direct dredging costs would be incurred and in some cases, a cost saving may be achieved. Additional coastal modelling, design and approvals considerations and ongoing monitoring would be required, equating to an additional $1 million.
Economics	Beaches in the region are an important assets for the local tourism industry. Beaches are also important for the local tourism industry and would benefit from beach nourishment.
Methodology	Moderate certainty of the approach being successful. Use of dredge material for nourishment material is currently undertaken in Australia, the successfulness in the PoG region will depend upon detailed modelling.
Innovation	The dredging and offshore placement of locally sourced nourishment material is a well-practised solution in Australia. If undertaken, there is potential for continual improvement as modelling and coastal data of the Gladstone region increases.
Longevity	As a coastal protection practise, beach nourishment is a short to medium-term solution and is typically repetitive to ensure its long-term success. It does not address the physical forces that cause beach loss, but replaces the lost sand. The nourishment material will eventually be lost through longshore drift or erosion and will need to be replenished. Nourishment can be considered a long term reuse option but only for relatively small quantities of dredged material.

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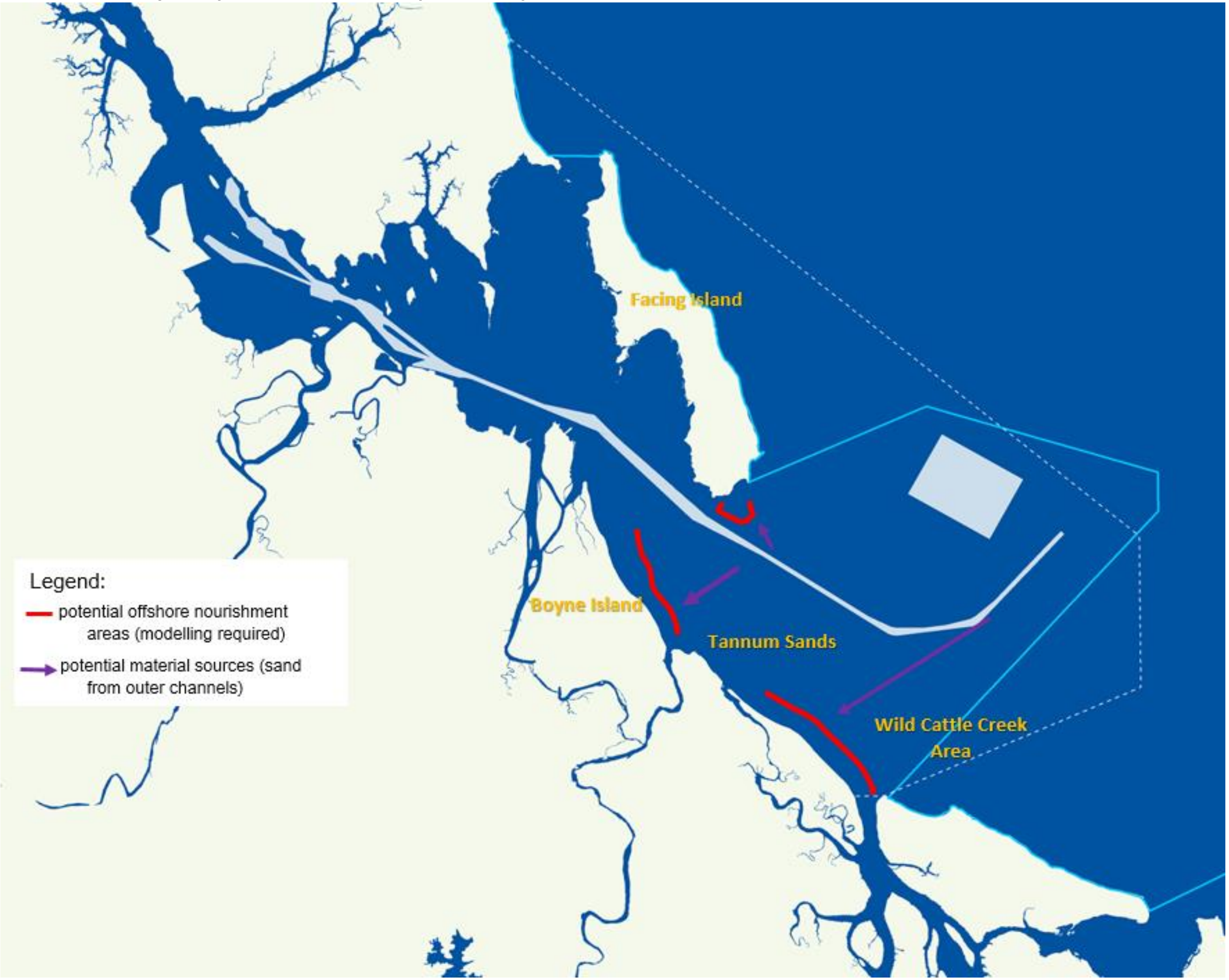

BENEFICIAL REUSE OPTION 7: Habitat Restoration / Creation – Seagrass

Seagrasses are marine plants that form meadows in estuaries and shallow coastal waters with sandy or muddy bottoms. They provide a range of critically important and economically valuable ecosystem services. Strategic placement of dredge material could potentially increase the area available that is suitable for seagrass growth.

Material would be dredged, transported and placed directly at the disposal site. Initial placement could be undertaken via bottom dumping as per current placement at the EBSDS. Final placement of material to achieve shallow depths suitable for colonisation by seagrass will require placement via rainbowing / bow casting or the use of pipelines. The use of material for some sites (such as areas of Shoal Bay) will not be suitable for bottom dumping. The sediment material suitable is considered to be finer material (clay, silts). The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	Restoration or creation of seagrass meadows will have a number of environmental benefits which include; the promotion of biodiversity values through supporting unique fish assemblages, provision of food resources, provision of habitat, maintaining food webs that support important fisheries, stabilise sediments and sediment nutrient cycle. Placement of dredge material for seagrass habitat will require the consideration and management of negative environmental impacts such as turbidity impacts and the existing environment (such as benthic conditions).
Resource use	Minor differences in fuel usage when compared to existing placement EBSDS operations depending on the distance to the placement area. The associated GHG emissions are estimated to be 9,200 t CO_2 over 5 years.
Legislative requirement	Habitat creation is considered achievable under the current legislation. Nevertheless, works will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	No appreciable difference in risks when compared to existing EBSDS operations.
Cultural	It is considered that placement of material for seagrass habitat, such as at Shoal Bay can be undertaken with the goal of avoiding or protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers.
Social	Recreational fishing (including crabbing and other crustaceans) can potentially benefit from the restoration / creation of seagrass habitats, by supporting fish communities. Additionally, pending location, aesthetic values of the coast may be enhanced.
Port operations	There will be an increase in maintenance dredging time due to the alternate disposal method when pumping is required to achieve the final depths.
Cost	The cost of dredging works to create habitat restoration areas will be heavily dependant on the distance material is required to be transported from the dredge site to the placement location. Placement of material into shallow areas is expected to require extensive bunding and complex pumping or rainbowing operations equating to a cost of approximately $13 million.
Economics	Commercial fishing can potentially benefit indirectly from the restoration / creation of seagrass habitats, by supporting fish communities.
Methodology	Moderate certainty of the approach being successful as the reuse option has occurred internationally but within Australia it is a relatively new solution. Research may be required.
Innovation	Creation of seagrass habitat on this scale has not been undertaken in Australia. There is potential that studies by Universities and ongoing GPC surveys in the port will improve methods and outcomes for this option.
Longevity	If proven to be successful, sites could be expanded over time, providing additional capacity for beneficial reuse of dredged materials. However opportunity is considered finite.

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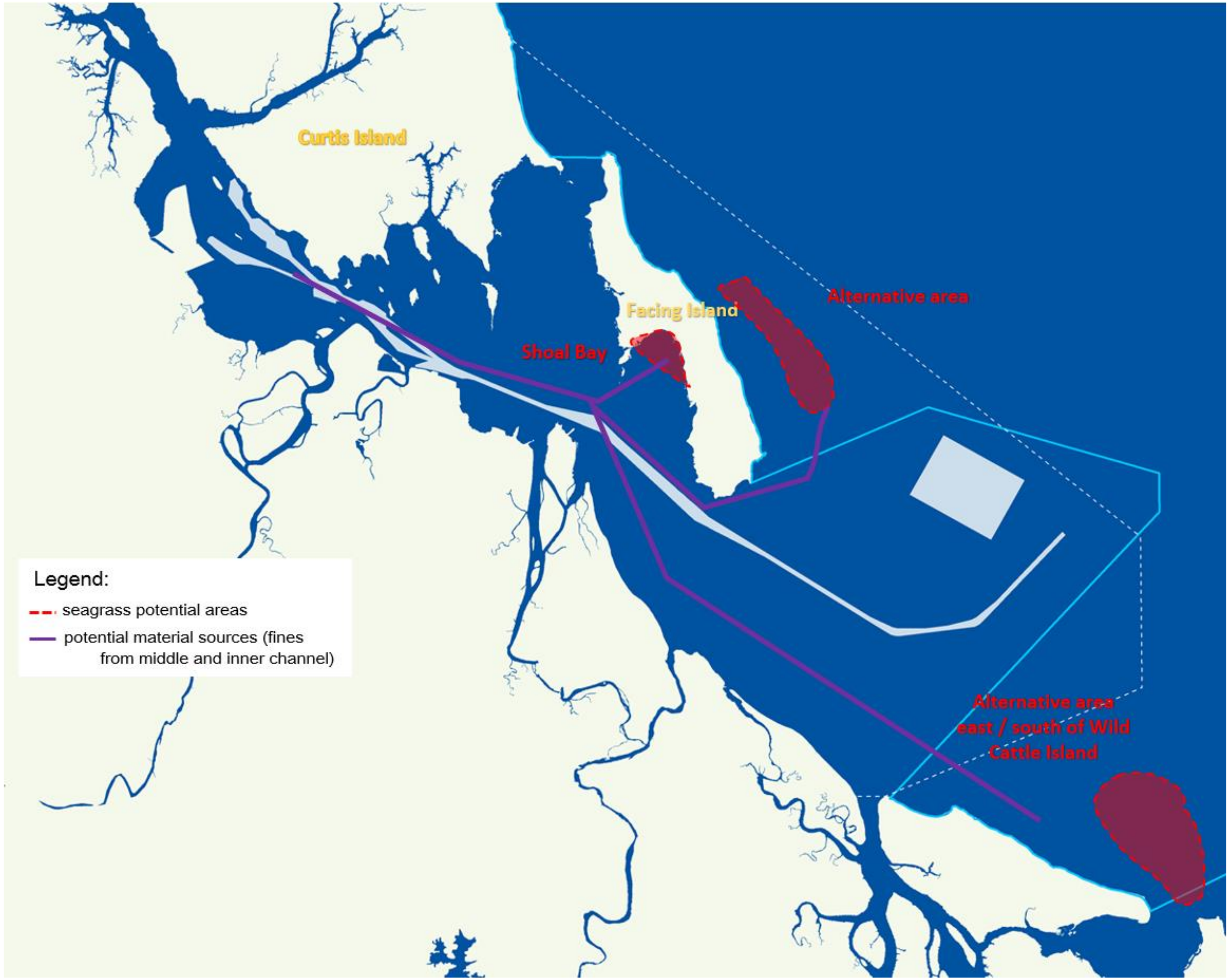

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BENEFICIAL REUSE OPTION 8 and 9: Coastal Habitat Restoration / Creation – Direct and Indirect Placement

The placement of dredge material can restore or create new coastal habitats by promoting the growth of mudflats. Dredge material can be places directly into purposely constructed bunds and backfilled with dredge material via rainbowing / bow casting or the use of pipelines (where bunds are either partly parallel to the shoreline or in a circular/island formation). An alternate option is placement of material indirectly via the concept of a 'mud-motor' where siltation/sedimentation rates along the portion of coast are enhanced, but the process is gradual. Silts and clays would be the preferred sediment type for backfilling and indirect placement. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	Coastal habitats like mudflats and mangroves provide a range of functions similar to seagrass communities, in addition to supporting migratory and resident birds, land fauna such as reptiles, insects and small mammals, and improving water quality though sediment capture. Further, mudflats and mangroves promote the growth of seagrass by providing essential nutrients into the ecosystem. Potential impacts need consideration pending site and placement methodology. The direct placement may affect local benthic environments and turbidity. Indirect placement via the 'mud-motor' concept has a high turbidity risk and risks for smothering of benthic environments.
Resource use	Minor differences in fuel usage when compared to existing placement EBSDS operations depending on the distance to the placement area. The associated GHG emissions are estimated to be between 9,200 and 17,600 t CO_2 over 5 years.
Legislative requirement	Habitat creation is considered achievable under the current legislation. Nevertheless, works will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Greater interaction with general public during placement operations depending on the site selected. Nevertheless, risks to the public and project personnel are considered manageable with appropriate planning and management during construction.
Cultural	Placement sites can be selected with the goal of protecting sites with Aboriginal or European cultural significance. This will require liaison with the local Aboriginal party and review of heritage registers.
Social	Recreational fishing (including crabbing and other crustaceans) can potentially benefit from the restoration / creation of coastal habitats, by supporting fish communities. Additionally, pending location, aesthetic values of the coast will be enhanced
Port operations	There will be an increase in maintenance dredging time due to the alternate disposal method when pumping or alternate equipment (interacting with the TSHD) is required. .
Cost	The cost of dredging works to create habitat restoration areas will be heavily dependent on the distance material is required to be transported. Where placement locations are in close proximity to the dredge sites, this option may be progressed with moderate additional costs, equating to approximately $9.2 million. Location would determine whether perimeter bunding and armouring would be necessary to ensure the long term stability of the placement area. If required this would significantly increase the costs associated with this option.
Economics	Commercial fishing can potentially benefit from the restoration / creation of coastal habitats, by supporting fish communities.
Methodology	Moderate certainty of the approach being successful as the reuse option has occurred internationally but within Australia it is a relatively new solution. Research may be required.
Innovation	There have been a number of successful deployments in the Netherlands, Ijssel Delta for direct and Port of Harlingen for indirect placement, the option is subject to innovation.
Longevity	It is considered that direct placement options may require a few dredging programs to establish, with indirect placement potentially requiring longer due to the slower process (i.e. natural processes). If proven to be successful, sites could be expanded over time, providing additional capacity for beneficial reuse of dredged materials.

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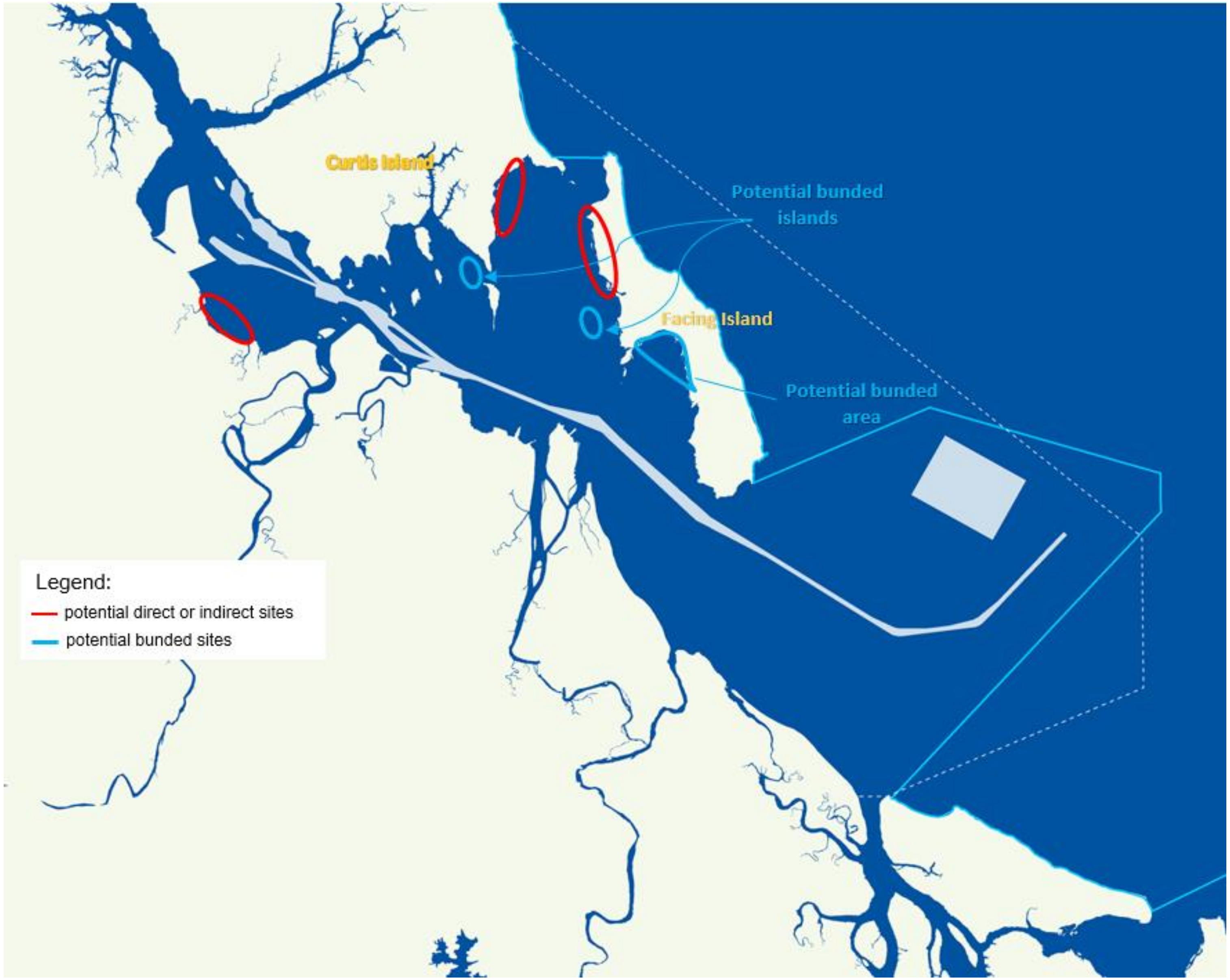

BENEFICIAL REUSE OPTION 11 and 14: Deep Water Habitat / Scallop Beds

Dredged material could be strategically placed to enhance deep water habitats (e.g. changing bedform) and promote scallop bed distribution. Recent studies by James Cook University indicate that there is a correlation between scallops (Queensland saucer scallop (*Ylistrum balloti*)) abundance and concentrations of mud. The dredged material would be dredged, transported and placed at the disposal site. The sediment material types suitable depend upon the use, high sand content would be suitable for deep water habitat, whereas high clay/silt content would be suitable for scallop beds. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	The aim of deep water habitat would be a net improvement to environmental conditions at the location relating to increases in biodiversity values of benthic, coral, marine mammals and fish.
Resource use	Additional fuel will be used in the transportation and placement of the dredge infill material to the deposition site due to minimum transport distances of approximately 20 nM. The associated GHG emissions are estimated to be 17,600 t CO_2 over 5 years.
Legislative requirement	It is anticipated that any deep water habitat or scallop beds would be located within the GBRWHA and GBRMP. The location adds a layer to the approval process in triggering EPBC referral and marine park permits. The process is considered complex but obtainable under the current legislation. Works will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Public interaction risk is low as per the EBSDS. Additional health and safety risks to dredge operators is apparent due to additional steaming distances (up to 20 nm offshore).
Cultural	There are no cultural/historical values associated with deep water areas provided shipwreck sites are avoided.
Social	The enhancement of deep water habitat and scallop beds has the potential to support fish communities for recreational activities, and may support recreational diving (in the long-term). It also has the potential to restore its commercial scallop fishing industry.
Port operations	There will be a significant increase in maintenance dredging time due to steaming distance required for disposal via the TSHD. This is likely to negatively impact the schedule and port operations (for example within the set timeframe only half of the dredging may be possible).
Cost	Whilst the dredging and placement methodology would be identical to that currently employed, the steaming distance and cycle time would be greatly increased and would therefore attract a significant cost penalty. Increasing the minimum steaming distances to around 20 nM could be expected to increase current dredging and disposal costs by a factor of two to three, equating to a cost of approximately $5.5 million for disposal of finer sediments from the upper portion of the maintenance dredge areas only.
Economics	Commercial fishing can potentially benefit from improved deep water habitats.
Methodology	Moderate certainty of the approach for deep water habitat being successful as the reuse option (deep water habitat) has occurred internationally but within Australia it is relatively new. Low certainty of the approach for scallop beds being successful as research regarding the Queensland saucer scallop and interactions with fine material is currently underway.
Innovation	The option in its current form is innovative as it relates to newer and upcoming research (scallop beds). As a result the feasibility of this option, if advanced, will require additional research and potential innovation (for example alterations in placement methods to having the TSHD travel large distances).
Longevity	If proven to be successful, sites could be expanded over time, providing additional capacity for beneficial reuse of dredged materials, thereby making this a long term solution if material and sites prove favourable.

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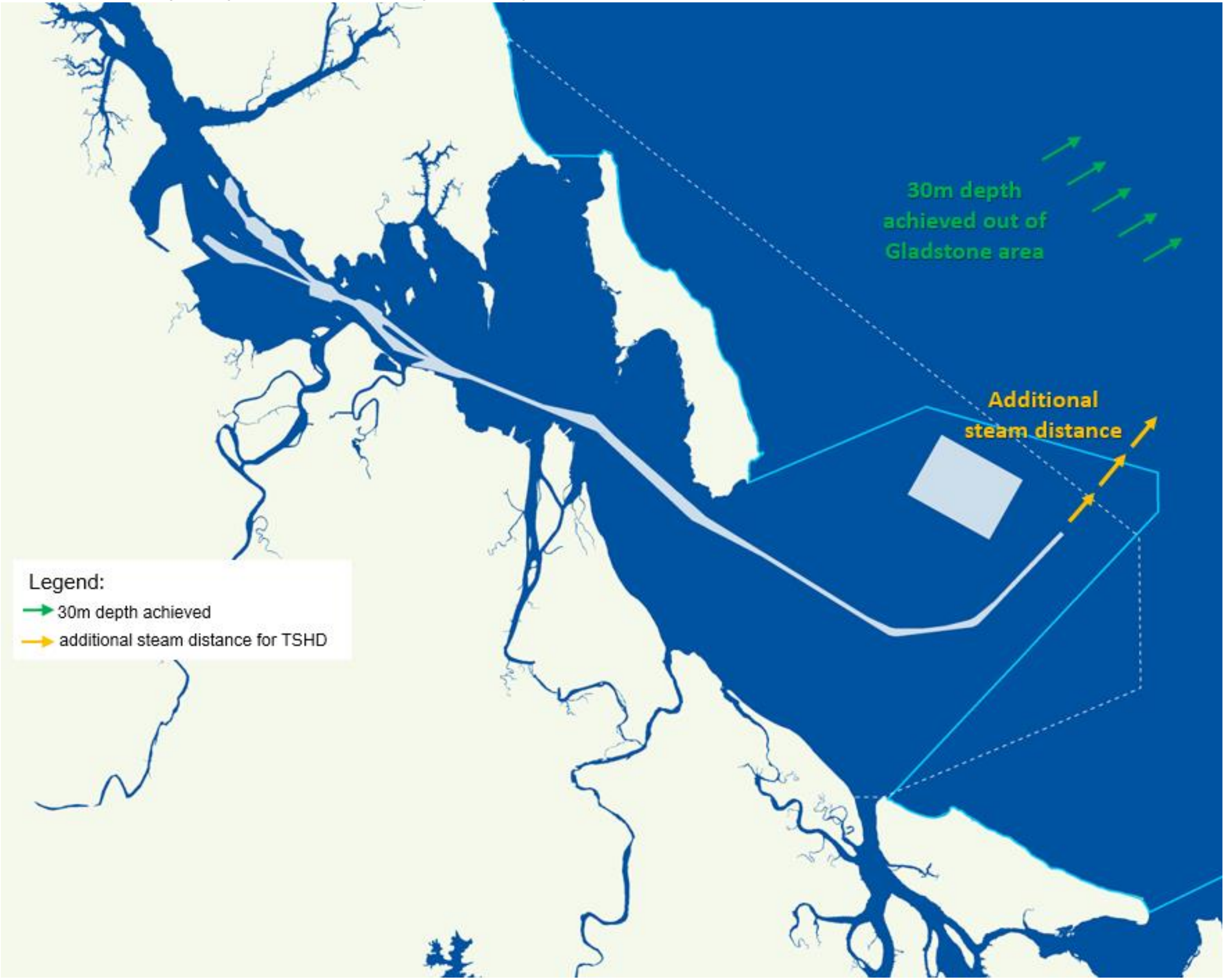

BENEFICIAL REUSE OPTION 20 and 21: Lining / Bunding Material

Maintenance dredge material can be used to form environmental bunds or liners. A number of industrial land uses require the construction of bunds to contain potential contaminants. Liners are required for confined disposal facilities where leachate has the potential to enter the environment.

A discharge pipeline would transfer the materials dredged via TSHD or CSD to the temporary onshore disposal site. Once dewatered and blended appropriately, the processed material would be stockpiled, before being transported via road for use as either a liner or bund material. The fine clay/silt sediments are best suited. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	The use of dredged material as a liner or bunding material minimises the requirements for sourcing such material elsewhere (such as from land based quarries). However, consideration must also be given to the nearshore dewatering areas and potential impacts of discharge of reclamation return waters.
Resource use	A positive resource use impact is a reduction in the volume of resources from quarries (and the associated processing) in the region. Nevertheless additional fuel will be used in the transportation, placement and processing of the dredge infill material at the deposition site. The associated GHG emissions are estimated to be up to 38,140 t CO_2 over 5 events.
Legislative requirement	Beneficial reuse of dredged materials for onshore purposes is considered achievable under the current legislation. Nevertheless, works will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Reclamation areas would be closed to the public, thereby limited potential interactions. Transport of dewatered sediments via roads would increase the numbers of truck movements on local roads. With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.
Cultural	Material dewatered and processed using existing reclamation areas would not be expected to have an impact upon sites of Aboriginal or European cultural significance. Similarly, it is envisaged that the material would be destined for projects which had been assessed in consultation with the local Aboriginal party and following review of heritage registers.
Social	Similarly to any options requiring the onshore dewatering of dredged materials, social concerns may arise regarding potential impacts to fish resources, sterilisation and access to coastal areas. Additional truck movements are considered manageable.
Port operations	There will be an increase in maintenance dredging time due to the alternate disposal method. If the marina sediment is used there will be no impact (as sediment is currently bought to land).
Cost	Production of lining or bunding material from maintenance dredged material requires a number of interim steps including transport, pump ashore, dewatering, washing, blending, onshore transport and final placement. As a result, this option is considered one of the most expensive beneficial reuse option, equating to an annual maintenance dredging cost of approximately $12.5 million.
Economics	Potential negative economic impacts will occur as a result of land based quarries no longer needing to supply materials for liners or bunding.
Methodology	Moderate certainty of the approach as liner and bund properties are known and dredged sediment properties can be improved by addition of other material. It is uncommon in Australia.
Innovation	The option is relatively uncommon in Australia outside of port adjacent reclamation areas. The process is relatively innovative.
Longevity	The requirements for liners and bund material are project/opportunistically based and as such definitive volumes, frequency and duration is unable to be quantified. However, it should be assumed that there are a finite number of projects requiring liners or bunds and as such this option cannot be considered a long term solution.

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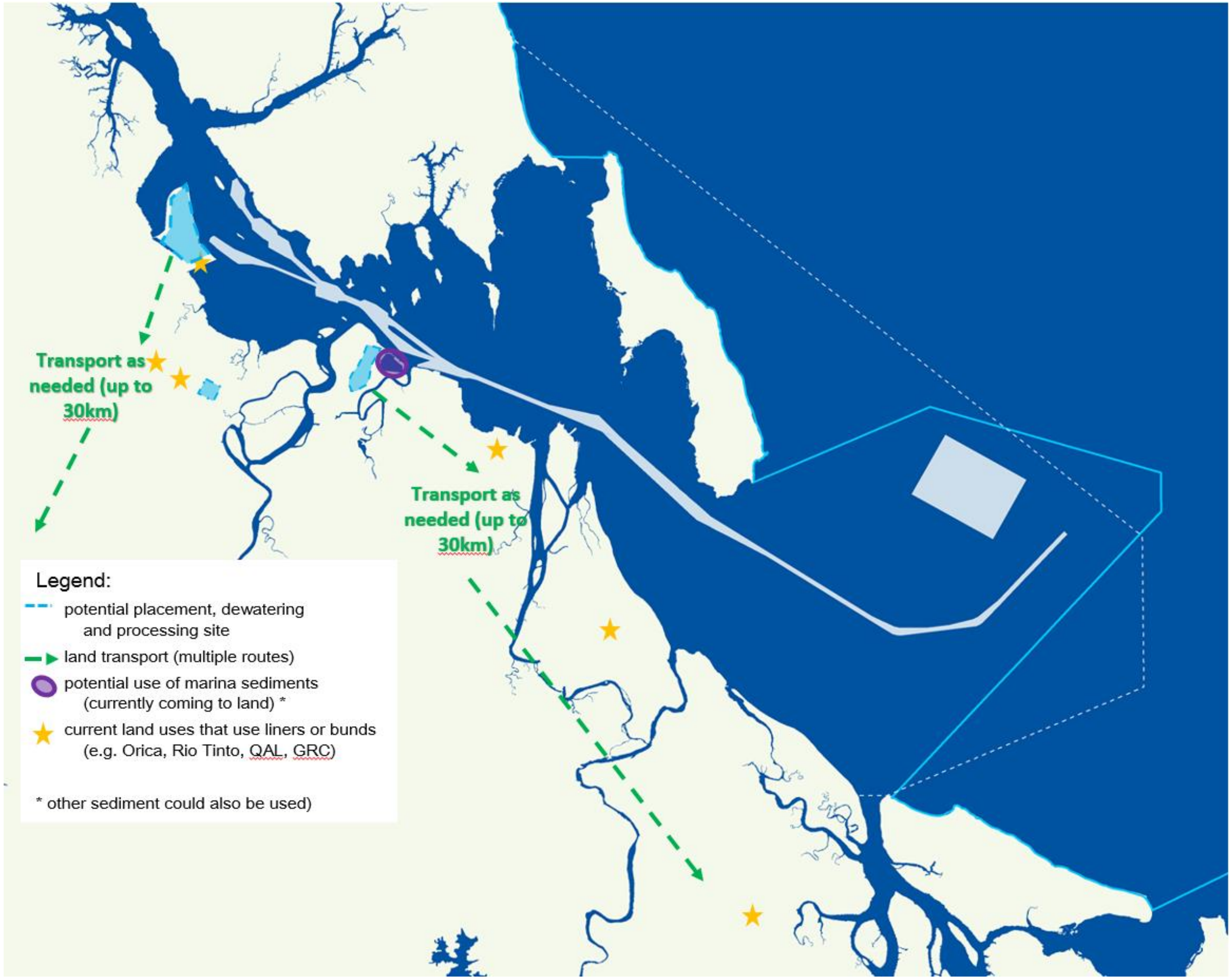

BENEFICIAL REUSE OPTION 23: Land Rehabilitation / Land Improvement / Fill

Dredged material can be utilised in land rehabilitation works (such as old mines/quarries), land improvement works (for example flood mitigation), or as construction fill (such as urban development earthworks).

A discharge pipeline would transfer the materials dredged via TSHD or CSD to the temporary onshore disposal site. Once dewatered and blended appropriately, the processed material would be stockpiled, before being transported via road to be used at the desired site. The sediment type is dependent upon the site requirements. The Objectives Assessment for this approach is detailed in the table below, and a schematic representation is shown overleaf.

ASPECT	SUMMARY
Environment	This option is focused on improving the environmental condition of previously disturbed or degraded sites. Whilst significant biodiversity benefits may be achieved, consideration must also be given to the impacts upon nearshore dewatering areas and potential impacts of discharge of reclamation return waters.
Resource use	A positive resource use impact is a reduction in the volume of resources from quarries (and the associated processing) in the region. Nevertheless additional fuel will be used in the transportation, placement and processing of the dredge infill material at the deposition site. The associated GHG emissions are estimated to be up to 38,140 t CO_2 over 5 events.
Legislative requirement	Beneficial reuse of dredged materials for onshore purposes is considered achievable under the current legislation. Nevertheless, works will require detailed assessment and a number of approvals as outlined in the Beneficial Reuse Report.
Health & Safety	Reclamation areas would be closed to the public, thereby limited potential interactions. Transport of dewatered sediments via roads would increase the numbers of truck movements on local roads. With appropriate planning and management during construction, risks to the public and project personnel are considered manageable.
Cultural	Material dewatered and processed using existing reclamation areas would not be expected to have an impact upon sites of Aboriginal or European cultural significance. Similarly, it is envisaged that the material would be destined for projects which had been assessed in consultation with the local Aboriginal party and following review of heritage registers.
Social	Social benefits generally arise from the improvements made to land degraded by historical mining, quarrying or industrial operations. Similarly benefits may be associated with preservation / revival of coastal land, parks, buildings (commercial and residential) that are significant for the local community from the effects of flooding.
Port operations	There will be an increase in maintenance dredging time due to the alternate disposal method. If the marina sediment is used there will be no impact (as sediment is currently bought to land).
Cost	Production of material suitable for land rehabilitation from maintenance dredged material requires a number of interim steps including transport, pump ashore, dewatering, desalinisation, blending, onshore transport and final placement. As a result, this option is considered one of the most expensive beneficial reuse options, equating to an annual maintenance dredging cost of approximately $12.5 million.
Economics	Potential negative economic impacts will occur as a result of land based quarries not required to supply materials for land rehabilitation/improvement/fill. Conversely, economic benefits may arise from creation of suitable land, the protection of land/asset from flooding, or for project proponents with respect to commercial savings via using dredged material.
Methodology	Moderate certainty of the approach as sediment properties can be improved by addition of other material. Similar uses (such as land reclamation) occur in Australia.
Innovation	In general the options is not considered to be new or innovative. Innovative aspects may apply with regards to addition of other material which could be ash byproducts (e.g.).
Longevity	The requirements for this option are project based and as such definitive volumes, frequency and duration is unable to be quantified. However, it should be assumed that there are a finite number of projects requiring fill or rehabilitation and as such this option cannot be considered a long term solution.

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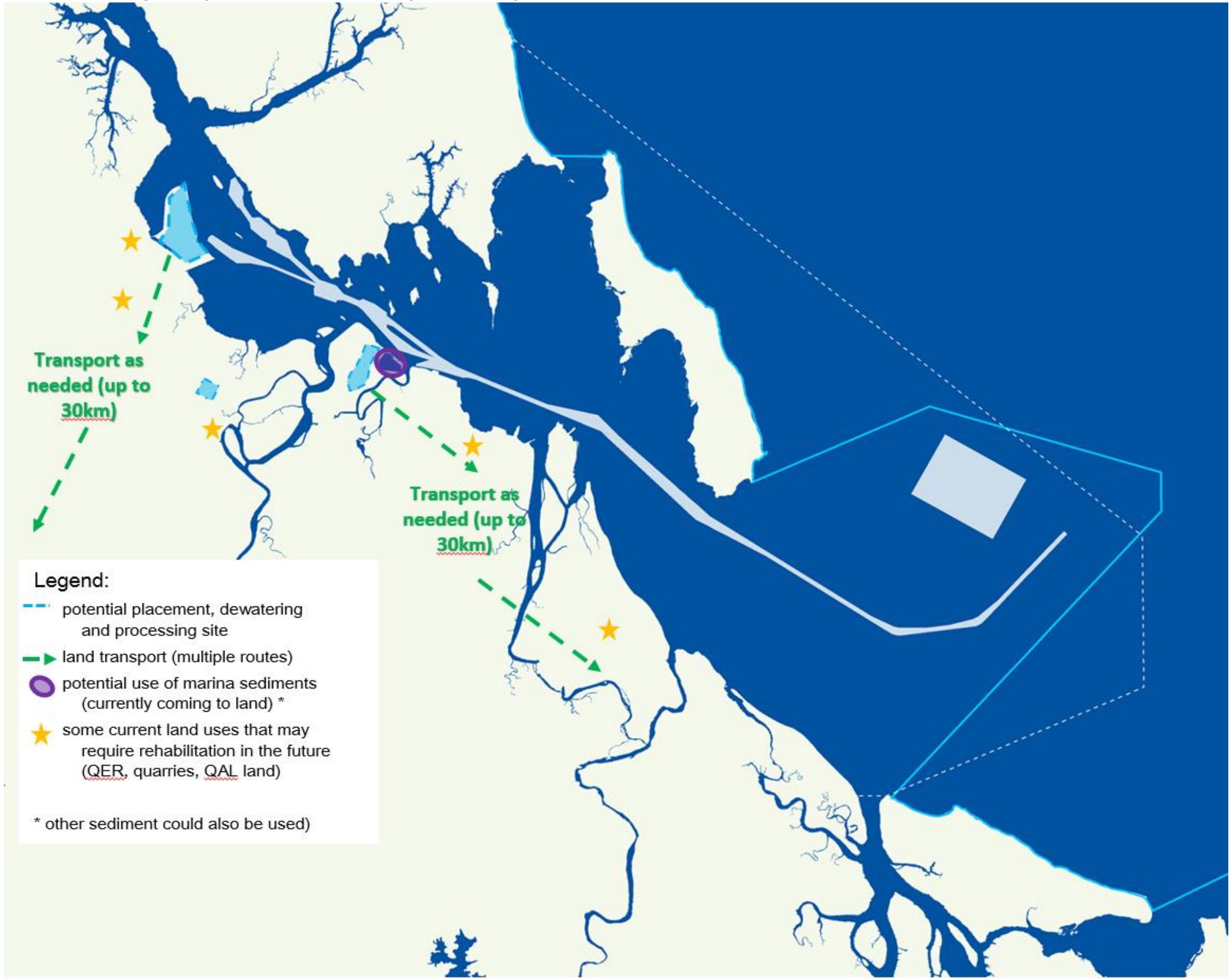

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Appendix B - GHG Assessment

B 1 GHG Assessment Approach

The aim of the GHG assessment is to allow a comparative assessment between the options presented. The assessment has been undertaken in accordance with the GHG Protocol

Emissions are defined Scopes 1, 2 and 3, in accordance with the GHG Protocol:

- Scope 1 emissions are GHG emissions created directly by a person or business from sources that are owned or controlled by that person or business.
- Scope 2 emissions are GHG emissions created as a result of the generation of electricity, heating, cooling or steam that is purchased and consumed by a person or business. These are indirect emissions as they arise from sources that are not owned or controlled by the person or business who consumes the electricity.
- Scope 3 emissions are GHG emissions that are generated in the wider economy as a consequence of a person or business's activities. These are indirect emissions as they arise from sources that are not owned or controlled by that person or business but they exclude Scope 2.

The assessment relates to the option itself only (for example beach nourishment relates to dredging of suitable material for a set quantity) and has used timing and equipment from the cost estimates.

B 1.1 Exclusions from the Assessment

The following were excluded from the assessment:

- Emissions associated with the mobilisation and demobilisation of vessels and other equipment.
- Emissions associated with the leakage of hydrofluorocarbons. The options may use negligible quantities of hydrofluorocarbons for refrigeration and air conditioning during construction and operation. However, the associated emissions are likely to be negligible compared with other emissions from the options and therefore were excluded from the assessment.
- Emissions associated with the manufacture of minor consumables and the transportation of these consumables to site. These emissions were considered negligible compared to the overall emissions.
- Emissions associated with employees commuting between home and the site. These emissions were considered negligible compared to the overall emissions.
- Scope 3 emissions.

B 1.2 Assumptions

Assumptions used in estimating the activity levels and associated greenhouse gas emissions for the options are outlined in

Table B-1 Assumptions for the GHG Assessment

Parameter Measured	Assumptions
Diesel	Low sulphur diesel is used in all vessels and plant Fuel for the vessels and plant is considered supplied by PoG as they are commissioning the vessels and as such are Scope 1 emissions
Timeframe	To align the options assessment a 10 year timeframe has been

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Document Status

Revision	Author	Reviewer		Approved for Issue		
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