Port of **Mackay**

Appendix A

Comparative Analysis of Dredge Material Placement Options

March 2022

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Executive summary

Background

North Queensland Bulk Ports (NQBP) commissioned Adaptive Strategies and Open Lines Consulting (the consulting team) to undertake a comparative analysis of the various alternatives for managing marine sediments and maintaining effective port operations at the Port of Mackay.

The comparative analysis was undertaken to inform maintenance dredging and in particular the development of a Long Term Maintenance Dredging Management Plan.

Approach to the comparative analysis

Undertaking a comparative analysis of the various options for managing marine sediments was a complex task. The analysis needed to consider:

- A series of questions about the actual need to manage sediment, the options for non-dredging management solutions, and the options for placement of dredge material.
- Management issues over both the short term (next 3 years) and long term (next 25 years).
- A wide range of detailed and comprehensive technical information developed to inform the various elements of the project.
- A significant number of possible alternatives for managing sediments. For example, a wide range of non-dredge solutions, as well as many alternatives for beneficial reuse or placement of dredge material.
- The diverse views of stakeholders about what was important to them in relation to the implications of managing sediment at the Port.
- A complex, dynamic environment comprising terrestrial, aquatic and marine areas.

To address these challenges, the consulting team adopted the principles of Structured Decision Making (Gregory *et al*, 2012) to help NQBP work through an organised and transparent approach for comparing alternatives. **This involved the following five steps:**

1. Understanding the decisions that needed to be made as part of the project.
2. Identifying what is important to stakeholders in the form of a clear set of objectives and performance measures.
3. Developing a range of alternative approaches for managing sediments.
4. Understanding the performance of the alternatives against the objectives.
5. Comparing alternatives and selecting a preferred option.

One of the key benefits of the structured decision making approach was the fact that the analysis was quantitative and was based on detailed technical information to measure the performance of each alternative. The quantitative nature of the analysis enabled direct comparisons between different management solutions in a clear and transparent way. It also enabled various weightings to be applied to understand how alternatives performed in different scenarios, and sensitivity analysis to be used to test the robustness of the results.

Sediment management options

Ports and Coastal Solutions (2021) examined the options to avoid or reduce sediment and found that many were simply not achievable in an enclosed harbour such as the Port of Mackay. **The options that were considered potentially achievable at the Port of Mackay included:**

- Traditional maintenance dredging.
- Diverting sediment loads.
- Constructed sediment traps.
- Using a drag bar for seabed levelling.
- Use of propeller wash agitation.

For each of these alternatives an estimate of the associated costs and greenhouse gas emissions (tonnes/$CO^2{}_{eq}$) was calculated. In addition, a constraints analysis for each of the alternatives has been developed to get an understanding of environment impacts, operational impacts, ongoing maintenance requirements, the confidence in achieving the desired outcomes and consideration of the regulatory pathways or approvals.

The constraints analysis led to three key findings:

1. Sediment at the Port of Mackay needs to be managed.
2. Dredging is required as part of the management solution.
3. There are a discrete set of feasible options that have the potential to provide a long term solution for use or placement of sediment that is captured as part of dredging.

Given that maintenance dredging is required as part of the solution, the comparative analysis focused in detail on how best to deal with the dredge material.

Alternatives for reuse or placement of sediment

As the avoid and reduce analysis showed eliminating the need to conduct maintenance dredging at the Port of Mackay is not a feasible option if port operations and safety are to be maintained at efficient levels. Accordingly, the comparative assessment then moved to determine the most suitable use or placement location for any dredged material.

The principal issue with beneficial reuse options for the Port of Mackay is the very high proportion of fines (silt/clay) in the volume of material to be managed and the absence of clear demand for that material. A beneficial reuse assessment conducted for the Port of Mackay (Advisian 2019) showed that whilst no beneficial reuse options are considered feasible at this stage, reusing material for shoreline protection and deepwater habitat creation ranked higher than other options.

Two beneficial reuse options were selected for further consideration when examining alternatives for reuse or placement. 'Habitat restoration/creation' (combining direct and indirect placement) and 'Land reclamation'. These options were previously investigated as part of the Port of Hay Point SSM and Port of Mackay stakeholders considered them important options to consider along with more traditional at-sea and onshore placement options.

Investigation of potential near-shore habitat 'restoration' opportunities for the nearby Port of Hay Point has been undertaken and is relevant to the Port of Mackay. Nearshore mapping along a coastal area of approximately 300km around the Port of Mackay showed there are very few opportunities for coastal habitat restoration and certain none of a scale that would warrant or accommodate volumes of dredged maintenance material. Nearshore mapping showed a number of small potential rehabilitation sites that could be restored by simply limiting human access (2Rog 2018a, 2018b). The use of dredged maintenance material was not considered beneficial to such small scale restoration options.

In considering creating a new type of coastal habitat using dredged maintenance material, where currently another habitat exists, it is important to note that as a general principle the placement of dredge material on tidal lands is not supported by the Department of Agriculture and Fisheries. Areas below the level of Highest Astronomical Tide are likely to contain marine plants and other fisheries resources of value, in these locations' development should be limited.

In addition, the Port of Hay Point SSM assessment examined land reclamation in detail. Similarly, to the Port of Mackay, the very high proportion of fines limited reclamation options and suitability. Any reclaims constructed with dredged maintenance material would have limited load bearing capacity and would only suit light or recreational uses. Reclamation options were also shown to perform very poorly with respect to most of the stakeholder values considered in the structured decision making process.

In addition to reuse analysis, a number of material placement alternatives and locations were identified.

Review of potential onshore placement sites was undertaken considering:

- Location of the site to minimise potential impacts on ecologically sensitive areas, both for the placement location and the pipeline route from dredge area to placement site.
- Proximity of the site to a watercourse for returning waters.
- Location of a sufficiently large area and generally level, yet as close as possible to deep water to allow a dredge to access within 1,500 m of the site to facilitate pumping.

As for the Mackay Harbour reclamation option it was considered logical to include the Port of Mackay onshore ponds option located in 'Bedford Paddocks', a parcel of port land west of Slade Point Road.

A number of offshore placement locations have been examined in the past, three were selected for consideration:

- An existing Mackay dredge material placement area (Mackay DMPA) that has been used at the Port for a number of years with success, monitoring has shown very low levels of environmental impact.
- The Port of Hay Point dredge material placement area (Hay Point DMPA) that has been used for both capital and maintenance dredge material placement.
- A mid shelf option in deeper water less influenced by tides and currents and well away from known inshore sensitive environments.

In total six (6) alternatives for sediment reuse or placement were identified and included in the comparative analysis (Table 1 and Figure 1).

Approach	Alternative	Summary description
Reuse	Alternative 1	**Land reclamation - Port of Mackay** – a 20 hectare land reclamation adjacent to the northern breakwall – in the area identified for future reclamation in the Port's Land Use Plan.
	Alternative 2	**Habitat (Mangrove) Creation** assumed a 60 hectare area adjacent to NQBP's Dudgeon Point land holding – Sandringham Bay. (This could service both the Ports of Hay Point and the Port of Mackay).
Onshore	Alternative 3	**Onshore pond at Port of Mackay** – a 32 hectare onshore bunded area on NQBP's Port of Mackay land holding - located in 'Bedford Paddocks', west of Slade Point Road.
Offshore	Alternative 4	**Existing Mackay dredge material placement area** – an at-sea relocation area approximately 4.6 km travel distance from the Harbour. Has been used for placement of dredge material from the Port of Mackay since 1960's.
	Alternative 5	**Existing Hay Point dredge material placement area** – an at-sea relocation area that has been used since 2006 Capital dredging at the Port of Hay Point – approximately 13.7 km travel distance from the Mackay Harbour.
	Alternative 6	**Mid-shelf offshore dredge material placement area** – a deeper water at-sea relocation area further offshore – approximately 30 km travel distance from the Harbour.

TABLE 1: MAINTENANCE DREDGE MATERIAL REUSE AND PLACEMENT OPTIONS

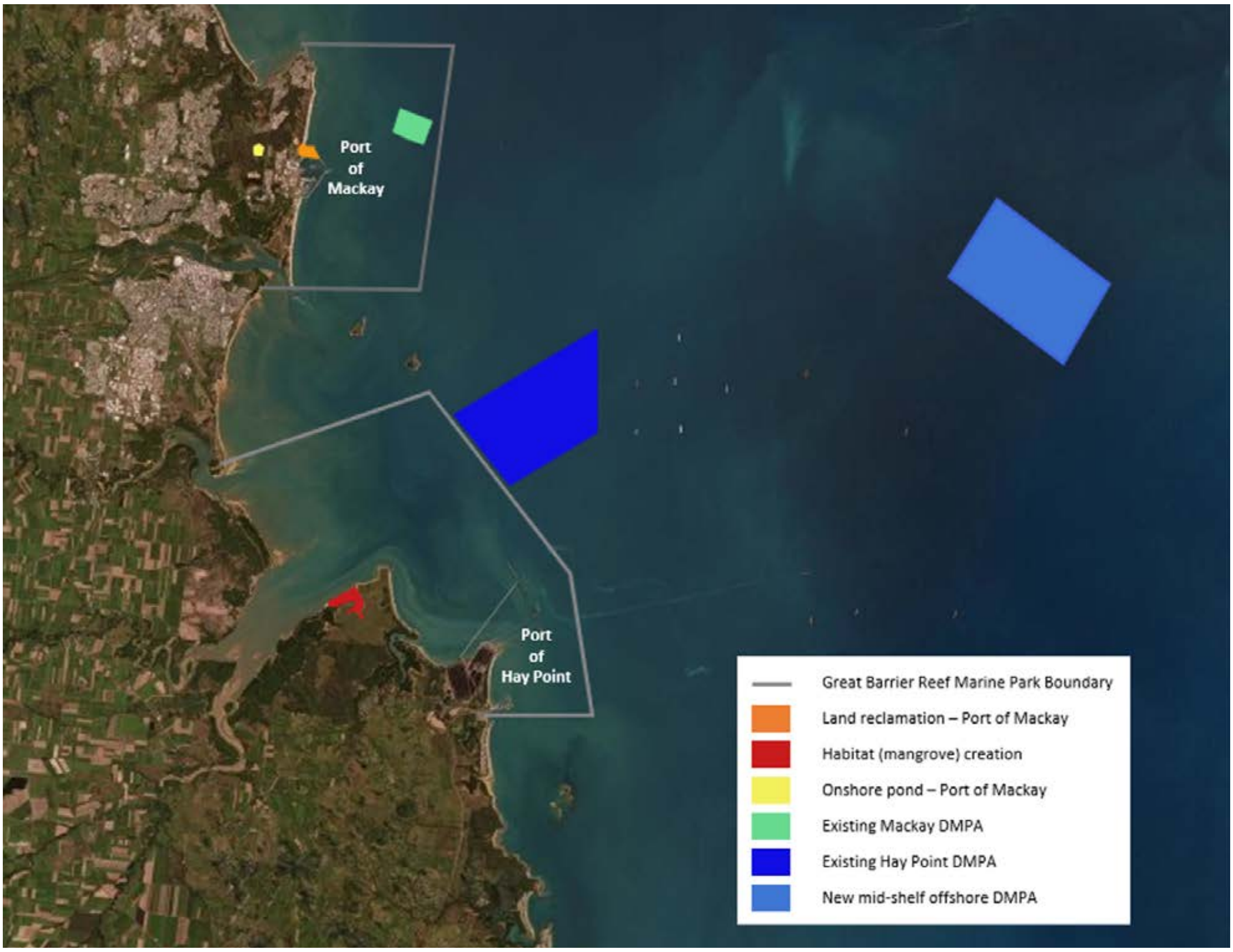


FIGURE 1. LOCATION OF MAINTENANCE DREDGE MATERIAL REUSE AND PLACEMENT OPTIONS.

Findings of the comparative analysis into options for reuse or placement of sediment

Preferred long term solution

Based on the detailed comparative analysis, offshore placement at the existing DMPA consistently performed the best. It was the strongest of the three best performers.

On balance, offshore placement at the existing DMPA was considered to be the option with the highest feasibility and therefore preferred solution. It provides both a short and long-term solution, is well understood and performs strongly in a range of scenarios.

It should be noted that mangrove restoration at Sandringham Bay was also considered to have merit as a result of the comparative analysis. Nearshore mapping has been completed since the initial consultation with stakeholders, the resulting identification of values and this initial comparative analysis. The mapping confirmed no suitable habitat restoration options exist within the extended Mackay region.

Introduction

North Queensland Bulk Ports (NQBP) are conducting a long term planning project for the ongoing management of marine sediments at the Port of Mackay.

The aim of the project is to develop long term solutions for the management of marine sediments at the Port by investigating:

- Where sediment at the Port comes from (e.g. onshore sources, marine sources).
- How it influences Port operations (e.g. by reducing depth within the Port navigational areas).
- Whether it can be eliminated or reduced before it influences Port operations (e.g. through mitigation and management measures).
- What options are available at the Port for the placement of sediments that might have accumulated and need to be dredged (e.g. beneficial reuse, onshore placement, offshore placement)?

To support the project, NQBP commissioned Adaptive Strategies and Open Lines Consulting (the consulting team) to undertake a comparative analysis of the various alternatives for managing marine sediments and maintaining effective port operations.

This report

This report documents the methods and results of the comparative analysis for the reuse or placement of dredged material.

In undertaking this comparative analysis significant information was used from a similar study undertaken for the Port of Hay Point *(Port of Hay Point – Sustainable Sediment Management (SSM) Assessment for Navigational Maintenance (Adaptive Strategies 2018))*. This study had previously considered the use of sediment placement options in and around the Port of Mackay that had direct relevance to this study.

Challenges to conducting the comparative analysis

There are a number of significant challenges to undertaking a comparative analysis of the various alternatives for managing marine sediments. **These include:**

- The analysis is complex and the range of possible approaches to managing marine sediments is extensive. The options range from non-dredging management measures, to various alternatives for the beneficial reuse of dredge material, to a multitude of scenarios for dredging and placement of material on land or at sea.
- There is a large amount of detailed, technical information available to inform decisions. In some instances this information has been generated using different methods and there is an inevitable level of uncertainty associated with all technical information.
- Stakeholders hold a variety of different and sometimes competing views about what is important to them across social, economic and environmental factors in relation to dredging.
- Decisions around the best approaches for the management of marine sediments at the Port are variously influenced by:
  - Technical, science based investigations and information.
  - Questions around engineering feasibility and design.
  - Detailed economic modelling and analysis.
  - Values based judgements around social, economic and environmental factors.

To address these challenges, the consulting team adopted the principles of Structured Decision Making (Gregory *et al*, 2012) to help NQBP work through an organised and transparent approach for comparing alternatives and making decisions.

Structured decision making

Structured Decision Making sets out a process for identifying alternatives and comparing them against a range of objectives. It provides a technical method for comparative analysis that is able to accommodate both science based and values based objectives and deal with uncertainty in information.

It is defined by Gregory *et al* (2012) as an:

> *"organized, inclusive and transparent approach to understanding complex problems and generating and evaluating creative alternatives. It's founded on the idea that good decisions are based on an in-depth understanding of both values (what's important) and consequences (what's likely to happen if an alternative is implemented)".*

It is important to note that the stakeholder driven structured decision making approach was successfully used by NQBP in recent years for the nearby Port of Hay Point. As the two ports operate within the same region, many of the studies, stakeholders, values and consequential outcomes are comparable between the two ports. All the technical documents for the Hay Point sustainable sediment management assessment can be accessed here.

For the Port of Mackay, the process:

- Helped to scope the questions and decisions relevant to sediment management at the Port.
- Helped define the things that are important to stakeholders within this context.
- Encouraged consideration of a broad set of options or alternatives for sediment management.
- Helped decision makers and stakeholders to think explicitly about how to measure performance of each sediment management option, including identifying the various impacts of each alternative, how they influence objectives and how they can be measured or predicted.
- Provided a set of results that can be queried according to differing stakeholder values and objectives in order to provide insight to decision makers and ultimately help inform their decisions.

The consulting team worked with NQBP to apply the following five steps of Structured Decision Making to the project (see Figure 2):

1. Understanding the decisions.
2. Identifying what is important.
3. Developing alternatives.
4. Understanding the performance of alternatives.
5. Comparing alternatives and selecting a preferred option.

The method and results for these five steps are presented in the subsequent sections of this report.

FIGURE 2: STEPS IN THE STRUCTURED DECISION MAKING PROCESS (ADAPTED FROM GREGORY *ET AL*, 2012)

Step 1: Understanding the decisions

It is critical in a comparative analysis process to understand the context about the nature of the decision or decisions being considered. This understanding ensures any analysis of options is focused towards the appropriate decision making process and that stakeholders are all on the same page.

Step 1 involved framing the decision to clarify:

- What decisions need to be made and what is the relationship between different decisions?
- What is the temporal and spatial scope of the decisions?
- Who are the decision makers?
- Who are the stakeholders in the decisions?
- What is the outcome or deliverable of the decision making process?

Framing the decisions

What decisions need to be made?

The key decisions that need to be made were identified as follows:

Having determined that maintenance dredging was necessary to maintaining port operations the key questions were:

- What are the feasible options for use or placement of the dredged material?
- What is the best approach to provide for long term sustainable management of marine sediments at the Port of Mackay?

What is the temporal and spatial scope of the decisions?

It is recognised that the sediment management needs of the Port are different in the short term compared with the long term. Decision making in the context of maintaining port operations needs to accommodate both of these timeframes.
In this instance:

- Short term relates to the management of sediment over the next three (3) years.
- Long term relates to the management of sediment over the next 25 years.

The spatial scope of the decisions is defined by the port boundary and any onshore and offshore locations relating to the various sediment management options.

Who are the decision makers?

NQBP is the decision maker. The comparative analysis was used by NQBP as part of a process to develop a business case that defines (from their perspective) the best approaches to managing marine sediments at the Port of Mackay.

It is recognised in this process that the views and input of stakeholders are critical and that there will also be a range of future decisions (e.g. by regulators) in relation to any activity. Appropriate flow on decisions (e.g. relevant environmental approvals) must be addressed prior to commencement of any works.

Who are the stakeholders in the decisions?

Structured Decision Making is particularly useful for understanding and incorporating the views of stakeholders. There are a wide range of people with interests in any decisions around the management of marine sediments. They include Commonwealth, State and Local Government, port operators, conservation groups, local community including Indigenous and fishing groups, researchers, and tourism operators.

What is the outcome or deliverable of the decision making process?

The outcome of the decision making process is a business case that NQBP can take forward for the long term sustainable management of marine sediments at the Port of Mackay.

Initial analysis of the decisions

As described above, Structured Decision Making has provided a method for comparing alternatives for managing marine sediments against a range of objectives relevant to the Port. In order to arrive at a relevant set of alternatives and generally help to structure and clarify thinking, a number of technical studies were first needed to identify if dredging was necessary. That is, is it necessary to manage sediment at the Port in the short and/or long term, and if yes, what are the feasible ways to do this?

A summary of the work and analysis around the earlier studies is presented below.

Sustainable sediment management

From 2015 to 2018, NQBP undertook an extensive research project to investigate the most sustainable way to manage accumulated sediment in and around the Port of Hay Point.

The Port of Hay Point Sustainable Sediment Management Assessment for Navigational Maintenance (Port of Hay Point SSMA) was a comprehensive approach to examine all possible options and solutions to avoid, re-use, recycle and dispose of maintenance dredging material. Full details and data associated with the Port of Hay Point SSM assessment and supporting technical reports are available at https://nqbp.com.au/sustainability/research-and-reports/sustainable-sediment-management-research.

This innovative sediment management approach has been widely acknowledged and a similar framework is now applied in the Department of Transport and Main Road's Maintenance Dredging Strategy for Great Barrier Reef World Heritage Area Ports. This is applicable to all ports operating in the GBRWHA.

NQBP has also completed a similar process for the Port of Weipa (2020) with the same approach being applied at the Port of Mackay.

SSM assessment at Port of Mackay

Given the geographical, social and environmental proximity of the Port of Hay Point to the Port of Mackay and the currency of the studies undertaken it has been possible to leverage the Port of Hay Point SSMA in undertaking a comparative analysis at the Port of Mackay. **Additionally, a number of supporting studies have been undertaken specific to the Port of Mackay, these include:**

- Port of Mackay Avoid and Reduce Assessment (Port and Coastal Solutions 2021), including bathymetric analysis.
- Sediment characterisation and contaminant testing (Advisian 2018).
- Marine sediment properties (Advisian 2018).
- Beneficial reuse assessment (Advisian 2019).

The Mackay studies have investigated where specifically the sediment at the Port of Mackay comes from, what impact it has on Port operations, whether accumulation can be eliminated or reduced, and what alternatives are available to reuse or dispose of any sediment that might need to be dredged.

The studies have determined what is the best long-term approach to managing sediments within the Port. This includes investigation and consideration of:

- The source and nature of the particular sediment at the Port.
- The requirements for management of the sediment in the short and longer term.
- Whether sediment can be managed without dredging while maintaining port operations and meeting legal requirements.
- The feasible alternatives for use or placement of material if dredging is required. The assessment of alternative placement sites was undertaken as part of the Hay Point SSM assessment and considered both Hay Point and Mackay options. A selection of these same sites have been used for this assessment of the Port of Mackay options.
- The best package of measures to provide for long-term (25-year) sustainable management of marine sediments at the Port.

The work has provided valuable context for long-term management at the Port, including understanding the economic effects of sedimentation and development of a long-term sediment management strategy.

Source and volume of sediment requiring management

Studies undertaken to determine the source and nature of sedimentation within and around the Port of Mackay found that the dominant processes which result in the resuspension of sediment in the Mackay region are wave action and tidal currents. The waves have the potential to result in much higher resuspension, while the tidal currents (and wind-generated currents) will transport the suspended sediment (PCS, 2021).

The local currents around the Mackay Harbour result in a net import of sediment, and the low current speeds within the Harbour means that it retains much of the sediment and acts as a sediment sink. The sediments that are deposited within the Port are predominantly made up of fine-grained silt and clay (PCS, 2021).

Based on analysis of historic bathymetric data, the annual average sedimentation within the Port of Mackay is expected to be up to 50,000m^3/y taking into account the influence of increased sedimentation due to Tropical Cyclones.

Therefore, the sedimentation volume requiring management over 5 years is predicted to be 250,000m^3, over 10 years it is 500,000m^3 and over 20 years it is 1,000,000m^3. A 10 year sea dumping permit would allow for 15% contingency, totalling 575,000m^3 over the permit period.

Avoidance and reduction

The studies considered a range of possible alternatives to avoid or reduce the volumes or rates of sedimentation occurring within the navigational areas of the Port, as this would be the first and potentially ideal way to manage sediments in the Port area.

The studies undertaken have:

- Described the sediment and hydrodynamic environment at the Port of Mackay in the context of possible solutions to ‘keep sediment out’ of the harbour and navigational areas or ‘keep sediment moving’ within the harbour to keep navigational areas accessible.
- Identified both engineered and technological solutions to avoid or minimise future maintenance dredging and consider their feasibility based on the Port of Mackay environment, port layout and infrastructure design.
- Undertook a comparative analysis of the solutions for any feasible alternatives.
- Estimated the potential impact of any feasible solutions to existing and future maintenance dredging at the Port of Mackay.

Three broad strategies that can be implemented to reduce siltation at ports and harbours are to keep sediment out, keep sediment moving and/or keep sediment navigable. The potential applicability of approaches to reduce sedimentation must be considered on a case-by-case basis as the suitability is dependent on the port configuration, sediment type, natural environment and processes.

The range of possible approaches is provided in Table 2.

TABLE 2: OUTLINE OF APPROACHES TO AVOIDING OR REDUCING SEDIMENTATION

Strategy	Approach	Example
Keep Sediment Out	Control sediment sources	Reduce sediment inputs through better catchment management
	Divert sediment-laden flows	Divert river inputs away from port
	Trap sediments before entering port	Sediment traps and insurance trenches
	Blocking sediment entry	Pneumatic barriers, silt screens, barrier curtains
	Habitat creation	Seagrass, saltmarsh, mangroves to stabilise and promote accretion away from port areas
Keep Sediment Moving	Structural solutions to train natural flows	Training walls to divert flow and prevent local deposition of sediment.
	Devices to increase bed shear stresses	Hydraulic jets, mechanical agitators
	Methods to reduce sediment flocculation	Adopting designs that reduce turbulence and therefore flocculation (e.g. solid wharf walls instead of piling supported wharfs).
Keep Sediment Navigable	Adopt a 'nautical depth' navigation approach which includes fluid mud	Nautical depth is the distance from the water surface to a given wet density, typically in the range of 1,100 to 1,300 kg/m^3.

Ports and Coastal Solutions (2021) examined the options to avoid or reduce sedimentation and found that many were simply not achievable in an enclosed harbour such as the Port of Mackay. **The options that were considered potentially achievable based on the predicted sedimentation rates at the Port of Mackay included:**

- Traditional maintenance dredging – undertaken every three years including bed leveling in conjunction with or immediately following maintenance dredging program.
- Utilising the existing sedimentation trap in conjunction with maintenance dredging – maintenance dredging every five years with annual bed levelling in between to utilise the capacity of the sediment trap.
- Using a drag bar for seabed levelling – undertaken twice yearly and in the absence of any maintenance dredging.
- Use of propeller wash agitation – use of tug vessel over approximately 12hrs per week and in the absence of any maintenance dredging.

For each of these options an estimate of the associated costs and greenhouse gas emissions (tonnes/CO^2_{eq}) was calculated over a 20-year period. In addition, a constraints analysis for each of the options was developed to get an understanding of environmental impacts, operational impacts, ongoing maintenance requirements, the confidence in achieving the desired outcomes and consideration of the regulatory pathways or approvals.

A summary of the comparative constraints analysis for the potentially feasible solutions is provided in Table 3.

TABLE 3: SUMMARY OF THE CONSTRAINTS ANALYSIS.

Approach	Environmental impacts	Operational impacts	Ongoing maintenance	Effectiveness	Legal risk	Cost	GHG (CO^2e tonnes)
Maintenance Dredging (including bed levelling without use of sediment trap)	Low	Low	No	High	Low	$8.0M	7,950
Sediment Trap (utilising sediment trap with annual drag barring)	Low	Low	No	High	Low	$7.3M	9,380
Drag Barring (no maintenance dredging)	Low	Moderate	No	Medium	No	$9.2M	30,530
Propeller Wash Agitation (no maintenance dredging)	Low	Moderate	No	Low	No	$12.4M	26,160

The table shows the following:

- Maintenance dredging every three years with no drag barring between dredging programs results in the lowest GHG emissions over the 20-year period along with a high confidence in its effectiveness and low environmental and operational impacts and a low level of legal risk.
- Use of the existing sediment trap and annual bed levelling will reduce the frequency of maintenance dredging to every five years. This approach results in the lowest cost overall but slightly higher CHG emissions over the 20-year period compared to traditional maintenance dredging every three years. Use of the existing sediment trap as part of the overall strategy for managing sedimentation has been adopted at the Port and proven to be highly effective with low environmental and operational impacts and a low level of legal risk.
- Based on the constraints analysis, drag barring is not considered to be a realistic solution to manage all of the ongoing sedimentation in the Port of Mackay. The option is predicted to result in four times more GHG emissions than maintenance dredging and there is a risk that the approach might not be able to manage the sedimentation to maintain declared depths over the long term. However, this approach could continue to be adopted for assisting with the sediment management of small volumes of sedimentation between maintenance dredging programs to help maintain declared depths.
- As with drag barring, propeller wash agitation is not considered to be a realistic solution to manage all of the ongoing sedimentation in the Port of Mackay. The solution is predicted to be the most expensive and results in three times more GHG emissions than maintenance dredging. There is also a low confidence in the effectiveness of the approach.

The preferred approach to managing sedimentation within the Port of Mackay is the continued use of the sediment trap combined with ongoing maintenance dredging every five years and annual bed levelling/drag barring.

Although the approach doesn't specifically reduce the mass of sediment requiring management it will reduce the volume of sediment requiring maintenance dredging as the sediment in the trap will be more consolidated (reducing the in-situ volume), the bed levelling/drag barring will resuspend some of the sediment (based on bathymetry surveys approximately 1,000 m^3/day has been assumed) and the trap will also improve the efficiency of the maintenance dredging with more consolidated sediment located in a small area which will result in a reduction in the dredge duration.

The predicted dredge volumes and frequencies for maintenance dredging and use of existing sediment trap solution are as follows:

Maintenance Dredging: 1,000,000 m^3 relocated over 20 years, with maintenance dredging occurring every three years along with bed levelling.

- 150,000 m^3 removed every three years (assuming over/insurance dredging of 0.6 m this frequency should on average maintain design depths).
- Bed levelling undertaken immediately after maintenance dredging to level out the seabed and remove any high spots.

Sediment Trap: 800,000 m^3 relocated over 20 years, with maintenance dredging occurring every five years and bed levelling/drag barring annually.

- 220,000 m^3 removed by maintenance dredging every five years (assuming over/insurance dredging of 0.6 m this frequency will mean that some drag barring is required to maintain design depths in some berths).
- A total of six days per year of bed levelling and drag barring to move and resuspend recently deposited sediment into the trap (only from southeast region of swing basin) and resuspend sediment from the berths to help maintain depths.

The avoid and reduce analysis showed that eliminating the need to conduct maintenance dredging at the Port of Mackay is not a feasible option if port operations and safety are to be maintained at efficient levels. Irrespective of whether the sediment trap is utilised there will still be a need to dredge on a 3 or 5 yearly cycle. Accordingly, the next step was to determine the most suitable use or placement location for any dredged material.

Step 2: Identifying what is important

The second step in the comparative analysis process identified what is important to NQBP and stakeholders within the context of the decisions to be made - i.e.:

> *If dredging is required, what are the feasible options for use or placement of the material?*
>
> *What is the best approach to provide for long term sustainable management of marine sediments at the Port of Mackay?*

Step 2 encouraged values or outcomes focussed thinking, helping to define the things that really matter in relation to the consequences of sediment management at the Port and then setting up a process to assess the alternatives against those objectives.

Given the geographical, social and environmental proximity of the Port of Mackay to the Port of Hay Point and the currency of the studies undertaken it has been possible to leverage the Port of Hay Point SSMA in undertaking this step.

The Port of Hay Point SSMA provided two key inputs of the comparative analysis process:

1. **Objectives** to consider in the decision making process. In other words, the things that really matter to NQBP and stakeholders when trying to make comparisons between sediment management options.
2. **Performance measures** for each of the objectives that provide a clear and transparent way of measuring how each of the sediment management alternatives perform.

Approach

Objectives were defined across the seven themes. The objectives aimed to be (Gregory *et al*, 2012):

- Complete – objectives were designed to capture all of the things that matter at the Port in the context of the decisions being made.
- Concise – unnecessary or similar objectives were removed to avoid double counting.
- Sensitive – objectives were developed that distinguish between the alternatives, thereby helping to differentiate them to aid decision making.
- Independent – objectives were developed in a way that ensures that performance against an objective could be considered independently of any other objective.

Performance measures were then defined for each objective. These measures provided a mechanism for predicting how well each of the alternatives performed against the objectives. Similar to the objectives, the performance measures were developed with a set of principles in mind to ensure they were useful and appropriate. **The key issues considered when defining a performance measure were (Gregory *et al*, 2012):**

- Coverage - the measures addressed the range of relevant consequences of each alternative.
- Practicality – the measures needed to be predictable, which means the data required to assess them could be obtained or generated.
- Direct and specific – the measures reported directly on the relevant consequences and effectively highlight differences in the alternatives to allow informed value trade-offs.

Objectives and performance measures

Eleven objectives and fourteen performance measures were defined. These are shown in Table 4.

Further discussion of each of the performance measures, including a rationale for their use and how they have been calculated and analysed is provided at Step 4 and Appendix A.

Theme	Objective	Measure
Environment	1. Avoid and minimise impacts to coastal ecosystems	A) Predicted performance in relation to avoidance and minimisation of impacts to coastal ecosystems
		B) Predicted risk on dredge material placement plumes and/or tailwater discharge exceeding ambient variation (percentile above median ambient TSS)
	2. Minimise carbon emissions	C) Forecast Greenhouse gas emissions
Cultural heritage	3. Minimise impact on cultural heritage within the area	D) Nature and scale of any impact on cultural heritage
Port economics & operation	4. Maintain effective and efficient port operations	E) Number of days disruption to operations
		F) Predicted lead time to dredge material placement
		G) Capacity to provide a long term solution for the port
	5. Ensure solution is cost effective	H) Assessment of costs
	6. Avoid significant loss of future port expansion opportunities	I) Strategic Port Land (SPL) affected
Health & safety	7. Avoid or mitigate health and safety risks	J) Relative risk
Social	8. Minimise interference to social activities within the region	K) Scale and duration of any impacts on social activities
	9. Provide increased economic and social opportunities	L) Predicted number of FTE jobs created
Innovation	10. Promote innovation in port management	M) Ability of a solution to advance current dredging practice information, technology and techniques
World heritage	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) Scale and duration of activity within the Great Barrier Reef World Heritage Area

TABLE 4: OBJECTIVES AND PERFORMANCE MEASURES FOR THE SSM PROJECT

In consultation with the Port of Mackay Technical Advisory Consultative Committee, the objectives and performance measures developed as part of the Port of Hay Point SSMA were considered appropriate to adopt for the Port of Mackay SSM assessment. The committee considered the objectives and performance measures continued to be relevance and importance The TACC did not identify any new values or measures specific to the Port of Mackay assessment.

Step 3: Developing alternatives for reuse or placement of sediment

Following the analysis of sedimentation rates and options to avoid or reduce sedimentation in key port navigational areas (described under Step 1), it was concluded that maintenance dredging cannot be avoided and that it will be necessary to maintain effective port operations.

After establishing the need to dredge marine sediments, the subsequent decision that needed to be addressed was:

> *If dredging is required, what are the feasible options for use or placement of the material?*

The third step in the structured decision making process worked through this question in order to identify a set of relevant, feasible alternatives for consideration in the comparative analysis. This work aimed to consider as broad a range of options as possible and to not be limited by precedent or traditional thinking. The development of feasible alternatives was informed by detailed work to identify and describe the environmental, social and cultural values of the region (Jacobs 2016, and 2rog 2021).

Analysis to identify feasible alternatives for reuse or placement of sediment

A number of studies were undertaken to help identify the most appropriate solutions for reuse or placement of the maintenance dredge material. **This work involved:**

- Consideration of the sediment properties (Advisian, 2018).
- Identification and analysis of beneficial reuse options (Advisian, 2019).
- Identification and analysis of suitable material placement locations (a range of assessments, as identified below).

Sediment properties

One of the primary considerations for reuse is the physical and chemical properties of the sediment to be dredged. **The analysis of the geotechnical properties of the material to be dredged showed that the sediment is:**

- Mostly fine silt/clay material with just one sample being silty sand. Fines content ranges from 44% to 98%.
- Free of contamination.
- Highly mixed and thus impractical to separate during dredging for alternate use or placement options.
- Has high to very high plasticity.
- Has high moisture content, and therefore significant effort would be required to dry out the sediment.
- Has very low to medium compressibility and some potential to swell and shrink, making it unsuitable for heavy load bearing uses.
- Is likely to be potential acid sulfate soil (PASS); however, the sediment contains sufficient acid neutralising capacity to buffer inherent acidity to negligible concentrations and as such are unlikely to require ASS treatment.

Analysis of options for beneficial reuse of dredge material

Advisian (2019) identified ten potential options for the beneficial reuse of dredge material (see Table 5). These options were selected based on the sediment properties and the views of an expert team with local, international and specific dredging and materials use experience.

Reuse category	Option
Reuse of dredge material as an engineering material	• Land reclamation • Construction fill (low strength) • Road base • Lining material • Concrete products (low strength) • Shoreline protection • Beach nourishment
Recycle of dredge material as an environmental enhancement	• Deep water habitat creation
Reuse of dredge material as an agricultural application	• Aquaculture • Topsoil for agricultural use

TABLE 5: BENEFICIAL REUSE OPTIONS CONSIDERED FOR FEASIBILITY

The Port of Mackay beneficial reuse assessment also discussed reuse for coastal habitat restoration (direct and indirect placement) and habitat 'creation' that was considered as part of the Port of Hay Point SSMA and is currently being investigated further by NQBP.

The assessment undertook a comprehensive reuse assessment investigation of the most appropriate solutions for reuse of any maintenance dredging material. **Factors considered in examining reuse option were:**

- Opportunity - demand.
- Sediment suitability - reuse or reuse with treatment.
- Cost.
- Process - proposed process well understood.
- Duration - less than a year to proposed final use.
- Greenhouse gas emissions - tCO^2.
- Environmental implications - positive environmental outcomes.
- Social impacts - positive social opportunities.
- Economic implications - positive economic opportunities.
- Approvals and permits - approval pathway.
- Constraints - few constraints considered manageable.
- Knowledges gaps - few gaps, no further research.
- Future considerations - long term solution.

The analysis found that the majority of options were limited due to factors such as the suitability of the sediment (high plasticity, high moisture content, low compressibility), economic demand or cost.

Based on the analysis of feasibility, two options were selected for further consideration. These are habitat creation and land reclamation. These options were selected as they were generally amongst the higher-ranking options, they performed well against sediment suitability criteria and were also considered to have high or moderate demand/opportunity.

From these two beneficial reuses, three alternatives were developed based on likely suitable locations. **These are:**

- Habitat creation - Sandringham Bay.
- Land reclamation - Mackay Harbour.
- Onshore placement.

It is important to note that a number of the beneficial reuse options listed in Table 5 would require the material to be brought onshore for drying and processing. Although these options are not considered individually as feasible alternatives, onshore placement (as described below) is considered as part of the comparative analysis and essentially captures these options.

Analysis of options for placement of dredge material

Over time a number of studies have been undertaken to identify potential locations for the placement of dredge material from ports in the Mackay region. **These studies have included examination of options for both maintenance dredging material and material from capital dredging projects, including:**

- Spoil Ground Site Selection – Port of Hay Point (WBM 2004a).
- Assessment of Land Disposal Options for Dredge Spoil at the Port of Hay Point (WBM 2004b).
- Dredge Spoil Disposal Options Assessment Hay Point Coal Terminal Expansion BM Alliance Coal Operations Pty Ltd (Connell Hatch 2009).
- Literature Review and Cost Analysis of Land-based Dredge Material Re-use and Disposal Options, Revision 2.4, (SKM 2013 for GBRMPA Strategic Assessment).
- Dudgeon Point Coal Terminals Project: Dredge Material Relocation Options (Worley Parsons 2012).
- Maintenance Dredging Management Plan Port of Hay Point (Worley Parsons 2013a).
- Onshore Pond and Reclamation Engineering Design (Royal Haskoning DHV 2016).

Two beneficial reuse options were selected for further consideration: 'Nearshore habitat creation' and 'Land reclamation'. These options were selected as they ranked highly on the primary consideration of sediment suitability and also were considered to have high or moderate demand /opportunity.

Based on work done earlier for the Port of Hay Point two locations for these beneficial reuse options were identified, these are:

1. Land reclamation - Mackay Harbour.
2. Habitat (mangrove) creation - Sandringham Bay.

It is worth noting that as a general principle the placement of dredge material on tidal lands is generally not supported by the Department of Agriculture and Fisheries. Areas below the level of Highest Astronomical Tide are likely to contain marine plants and other fisheries resources of value, in these locations development should be limited.

In addition to reuse analysis, a number of material placement alternatives and locations were identified.

Review of potential onshore placement sites was undertaken considering:

- Location of the site to minimise potential impacts on ecologically sensitive areas, both for the placement location and the pipeline route from dredge area to placement site.
- Proximity of the site to a watercourse for returning waters.
- Location of a sufficiently large area and generally level, yet as close as possible to deep water to allow a dredge to access within 1,500 m of the site to facilitate pumping.

As for the Mackay Harbour reclamation option it was considered logical to include the Port of Mackay onshore ponds option located in 'Bedford Paddocks', west of Slade Point Road.

A number of at-sea placement locations have been examined in the past. The Port of Hay Point SSM assessment looked at the existing Hay Point DMPA, a mid-shelf option further seaward and an option in the outer-shelf some 200km from the coastline. The outer-shelf option was found to be one of the poorest performing relocation options and has been excluded from this analysis. **Consequently, three at-sea options were selected for consideration:**

- A existing Mackay dredge material placement area (Mackay DMPA) that has been used at the Port for a number of years with success, monitoring has shown very low levels of environmental impact.
- The existing Port of Hay Point dredge material placement area (Hay Point DMPA) that has been used for both capital and maintenance dredge material placement.
- A mid-shelf option in deeper water less influenced by tides and currents and well away from known inshore sensitive environments.

In total six (6) alternatives for sediment reuse or placement were identified and included in the comparative analysis (Table 6 and Figure 1).

Approach	Alternative	Summary description
Reuse	Alternative 1	**Land reclamation - Port of Mackay** – a 20 hectare land reclamation adjacent to the northern break wall – in the area identified for future reclamation in the Port's Land Use Plan.
	Alternative 2	**Habitat (Mangrove) Creation** – assumed a long term 60 hectare area adjacent to NQBP's Dudgeon Point land holding – Sandringham Bay.
Onshore	Alternative 3	**Onshore pond at Port of Mackay** – a 32 hectare onshore bunded area on NQBP's Port of Mackay land holding - located in 'Bedford Paddocks', west of Slade Point Road.
Offshore	Alternative 4	**Existing Mackay dredge material placement area** – an at-sea relocation area approximately 4.6 km travel distance from the Harbour. Has been used for placement of dredge material from the Port of Mackay since 1960s
	Alternative 5	**Existing Hay Point dredge material placement area** – an at-sea relocation area that has been used since 2006 Capital dredging at the Port of Hay Point – approximately 13.7 km travel distance from the Harbour.
	Alternative 6	**Mid-shelf offshore dredge material placement area** – a deeper water at-sea relocation area further offshore – approximately 30 km travel distance from the Harbour.

TABLE 6: MAINTENANCE DREDGE MATERIAL REUSE AND PLACEMENT OPTIONS

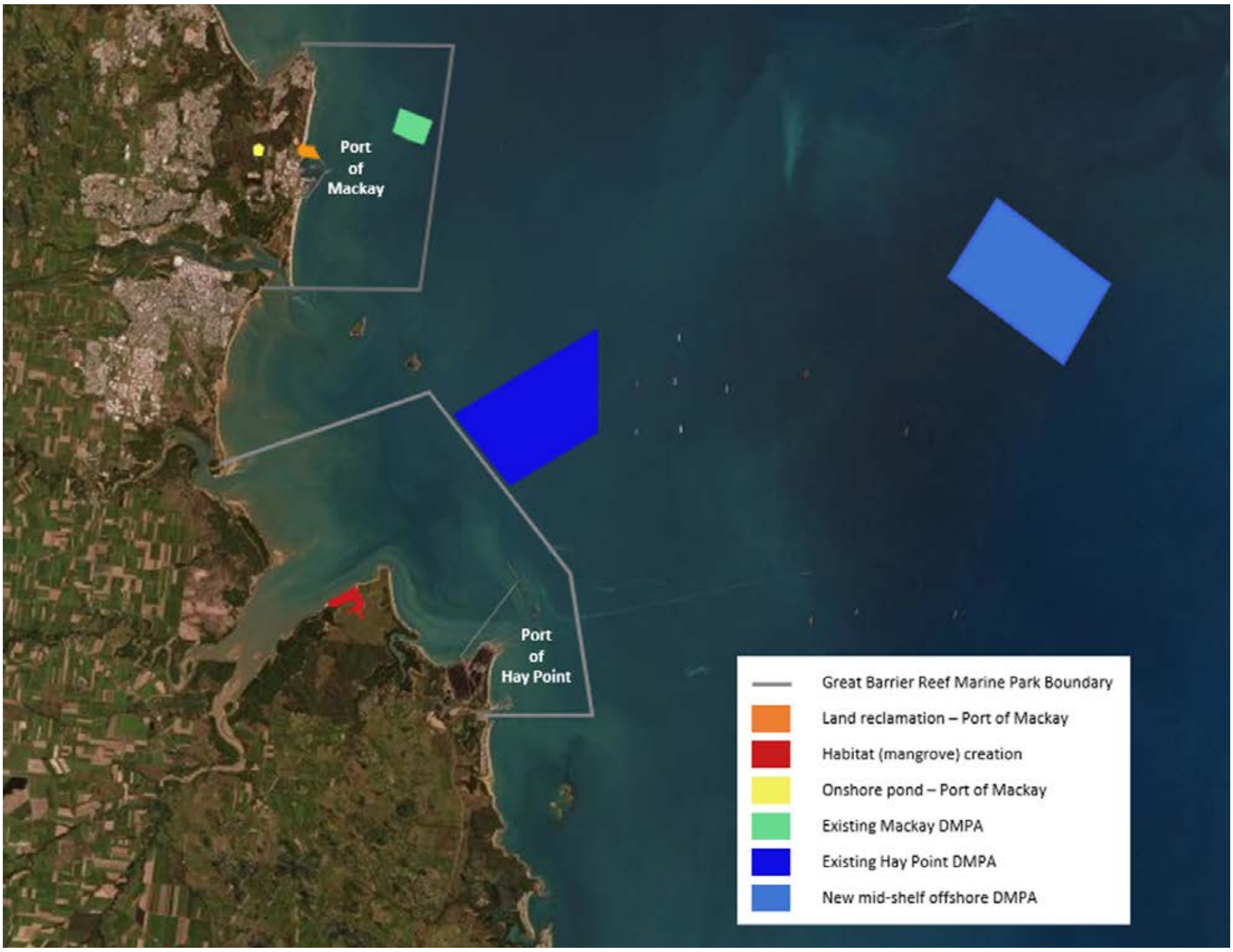


FIGURE 1. LOCATION OF MAINTENANCE DREDGE MATERIAL REUSE AND PLACEMENT OPTIONS.

Description of the alternatives for reuse or placement of sediment

As outlined above, the analysis of feasible options for the use or placement of dredge material arrived at six alternatives to be considered in the comparative analysis. Many of these options were originally identified for the Port of Hay Point SSM assessment and as such are transferable to the Port of Mackay due to the close proximity. It's worth noting the original Hay Point options where in consideration of approximately 200,000m^3 of material every 3-5 years, whereas the Port of Mackay options volumes are estimated 120,000m^3 to 150,000m^3 every 3-5 years.

We have not attempted to re-design the known options to cater for the specific change in expected volume, more so, it is recognised that any feasible options may have a longer viable life expectancy for the Port of Mackay.

Following is a short description of each alternative.

Reclamation at Mackay Harbour

Dredge material would be used to construct a reclamation area of approximately 20 ha adjacent to the existing north harbour wall. The reclamation area would be protected by a rock wall approximately 860 m in length.

The area has been identified for use as future strategic port lands. However, the reclaimed area at Mackay Harbour would have low load bearing strength due to the use of predominantly fine-grained sediments from the maintenance dredging. It would therefore be unsuitable for industrial use with heavy load bearing, although ground improvement measures could be undertaken to increase the strength partially.

Mangrove creation at Sandringham Bay

Dredge material would be used to create intertidal mudflats to support new areas of mangrove habitat. This option offers a unique opportunity to achieve environmental gains. Mangrove habitats provide an important ecological function including stabilizing shorelines, improving water quality and providing habitat and nutrients for a variety of fauna species. Mangroves also have a large capacity for absorbing substantial amounts of greenhouse gases.

The process would involve the use of coarser dredge material to create an underwater bund, with fine dredge material deposited behind the bund and retained to form new mudflats in which mangrove habitat can be created. For the purposes of this analysis, it is assumed that it could contain the volume from a single maintenance dredging campaign.

This process is generally well understood; however, there are few examples of it being undertaken using maintenance dredge material in Australia. Erftemeijer (2019) notes nine (9) examples of relevant beneficial reuse using maintenance material internationally, although application in the Mackay region would require significant investigation to fill knowledge gaps related to coastal dynamics, sediment material and potential impacts on foreshore dynamics, demand for habitat rehabilitation and detailed design, if this option is pursued. There are significant knowledge gaps around coastal dynamics, sediment material and potential impacts on foreshore dynamics, demand for habitat creation and detailed design that would need to be addressed if this option is pursued.

Onshore pond at Port of Mackay

Dredge material would be pumped into an onshore pond located to the west of Slade Road in the Port of Mackay. The pond would comprise an area of approximately 20 ha and would be contained within bund walls constructed using material from the site.

The site has capacity for one to two dredging campaigns. However, future campaigns could be accommodated by either removing the dried out dredge material from the pond to create sufficient capacity for any subsequent maintenance dredging campaign or by increasing the height of the bunds to increase the capacity of the pond.

Existing Mackay offshore dredge material placement area

Dredge material would be placed on the seabed within the existing offshore Dredge Material Placement Area (DMPA). The DMPA is located approximately 3km offshore. This location has previously been used to dispose of maintenance dredge material from the Port of Mackay and is approximately 130 ha.

Existing Hay Point offshore dredge material placement area

Dredge material would be placed on the seabed within an offshore Hay Point Dredge Material Placement Area (DMPA) located approximately 13 km to the south of the Port of Mackay. This location has previously been used to dispose of maintenance dredge material from the Port of Hay Point since 2006 and is approximately 1,800 ha.

Mid-shelf offshore dredge material placement area

Dredged material would be placed on the seabed at a mid-shelf DMPA. This area is located approximately 25 km east of the Port. Typical travel time to the mid-shelf placement location by a TSHD would be approximately 6 hours return.

Step 4: Understanding the performance of alternatives

As described under Step 2, objectives and performance measures were defined to allow the performance of each alternative to be measured and compared. A set of detailed, technical work was undertaken following identification of the alternatives to generate the data and scores against each performance measure.

Objective 1: Avoid and minimise impacts to coastal ecosystems

It is important to look for opportunities to avoid or minimise impacts on coastal ecosystems. **Two performance measures were generated in relation to this objective:**

A. Predicted performance in relation to avoidance and minimisation of impacts to coastal ecosystems.

B. Predicted risk on dredge material placement plumes and/or tailwater discharge exceeding ambient variation (percentile above median ambient TSS).

The coastal ecosystems performance measure examined potential impacts from each alternative in relation to the following coastal ecosystems:

- Land based ecosystems: threatened ecological communities (TECs), and other native vegetation.
- Freshwater and estuary ecosystems: wetlands, estuaries and mangroves.
- Coastal landforms: salt marsh, saline coastal flats / swamp, beaches, and rocky headlands.
- Marine ecosystems: coral reefs, seagrass and/or seabed.

Changes or losses to these coastal ecosystems or landforms can lead to a variety of adverse environmental impacts, as well as serious implications for industries dependent on the Great Barrier Reef Marine Park. Rather than attempting to analyse potential impacts on individual species, the potential changes more broadly on coastal ecosystems and landforms (which provide the habitat for species) was an appropriate measure for understanding the potential impacts of each alternative. More detailed environmental impact assessment will form part of any future assessment and approval processes.

A performance score (higher score is better) was generated for each alternative based on a set of criteria that considered:

- Scale of change.
- Ecosystem status.
- Species habitat status.
- Duration of change.

A) Coastal ecosystems

Theme	Environment
Objective:	1. Avoid and minimise impacts to coastal ecosystems
Measure:	A) Predicted performance in relation to avoidance and minimisation of changes to coastal ecosystems
	Unit of measure: Performance score ranging from 4-16
	Which direction of the measure is better? Higher

Marine waters are the vector to disturbance of a range of receptors, including benthic communities (e.g. seagrass and coral), fishes, and a range of megafauna such as dolphins, turtles and whales. The potential impact on these waters is an important criteria to assess when considering the alternatives for long term sustainable sediment management at the Port of Mackay.

NQBP conduct an ambient water quality monitoring program that extends from Freshwater Point to the south of the Port, extending to Keswick Island to the north (approximately 55 km of the coastal strip). This program provides the background data for the performance measure.

A performance score (lower score is better) was generated for each alternative based on the predicted risk of dredge material placement plumes and/or tailwater discharge exceeding ambient variation (percentile above median ambient TSS).

B) Marine water quality

Theme	Environment
Objective:	1. Avoid and minimise impacts to coastal ecosystems
Measure:	B) Predicted risk of dredge material placement plumes and/or tailwater discharge exceeding ambient variation (percentile above median ambient TSS)
	Unit of measure: Performance score ranging from 0-21
	Which direction of the measure is better? Lower

Objective 2: Minimise carbon emissions

Consideration of the potential Greenhouse Gas (GHG) emissions from the construction and operational activities of each alternative is an important component of comparing the alternatives. Understanding how each alternative performed in relation to forecast GHG emissions should form part of the decision making process.

Calculating forecast GHG emissions was undertaken in accordance with the internationally recognised methodology outlined in the GHG Protocol. In accordance with the Protocol, the assessment considered the following emissions:

- Direct emissions – e.g. emissions associated with fossil fuel consumption by vessels/construction plant/vehicles during transport and construction. These are known as 'Scope 1' emissions in the GHG Protocol.
- Indirect emissions from supporting activities – e.g. emissions associated with the production of construction materials. These are known as 'Scope 3' emissions in the GHG Protocol. For this project high level estimates are used.

None of the alternatives were considered likely to result in significant indirect emissions due to the consumption of purchased electricity (known as 'Scope 2' emissions in the GHG Protocol). Scope 2 emissions were therefore not part of this assessment.

C) GHG emissions

Theme	Greenhouse Gas (GHG) emissions
Objective:	2. Minimise carbon emissions
Measure:	C) Forecast GHG emissions
	Unit of measure: Tonnes of CO^2 equivalent (tCO^2-e)
	Which direction of the measure is better? Lower

Objective 3: Minimise impact on cultural heritage within the area

Sustainable sediment management aims to further improve the management of port sediments while ensuring the continued operation of the port, ensuring social and cultural features are respected and that environmental and cultural heritage values are protected. The potential for impacts on cultural heritage arising from the various options was considered in the decision making process.

A cultural heritage performance score (lower score is better) was generated for each alternative based on a set of criteria that considered:

- The nature of any interaction with or disturbance to identified Indigenous cultural heritage or potential unknown sites and/or artefacts.
- The nature of any interaction with landscape/cultural connection of importance to Indigenous people.
- Impact on access for Indigenous people to culturally important places.

D) Cultural heritage

Theme	Cultural Heritage
Objective:	3. Minimise impact on cultural heritage within the area
Measure:	D) Nature and scale of any impact on cultural heritage
	Unit of measure: Performance score ranging from 3 - 9
	Which direction of the measure is better? Lower

Objective 4: Maintain effective and efficient port operations

It is important to examine alternatives that provided for effective and efficient port operations. **Three performance measures were generated in relation to this objective:**

A. Number of days disruption to port operations.
B. Predicted lead time to dredge material placement.
C. Capacity to provide a long term solution for the port.

A critical aspect to sustainable sediment management at the Port of Mackay is providing a solution that ensures ongoing port efficiency but also provides for minimal disruption to port operations during the actual dredging and placement activity.

Disruptions to port operations are most likely while the dredge is operating in the berth areas and swing basin of the Port. During these times other vessel movements may be limited and one or more berths may remain unoccupied for a longer period than usual. With some constraints on movement from other vessel traffic and tidal movements these disruptions can become extended and of some consequence.

E) Port disruption

Theme	Port Economics & Operation
Objective:	4. Maintain effective and efficient port economics and operation
Measure:	E) Number of days disruption to operations
	Unit of measure: Days
	Which direction of the measure is better? Lower

Finding appropriate solutions that could be implemented within required timeframes is important (i.e. how long it will take to plan, get approval, and prepare works).

The lead time for each alternative was calculated based on industry experience in relation to the following key preparatory stages:

- Research/studies.
- Engineering design.
- Planning and approval.
- Construction.

F) Lead time

Theme	Port Economics & Operation
Objective:	4. Maintain effective and efficient port economics and operation
Measure:	F) Predicted lead time to dredge material placement
	Unit of measure: Years
	Which direction of the measure is better? Lower

A critical aspect to the project is providing a long term solution that can address the requirements of multiple dredging campaigns. A well designed and implemented long term solution will provide certainty for all stakeholders and the best outcomes across the various project themes (environment, cultural heritage, port economics and operation, health and safety, social, innovation, and World Heritage).

The capacity of each alternative was calculated based on the need for 200,000 m^3 of maintenance dredging every five years to maintain effective and safe operation of the Port, noting that at the Port of Mackay estimates are closer to 150,000m^3.

G) Long term solution

Theme	Port Economics & Operation
Objective:	4. Maintain effective and efficient port economics and operation
Measure:	G) Capacity to provide a long term solution for the port
	Unit of measure: Years
	Which direction of the measure is better? Higher

Objective 5: Ensure solution is cost effective

Cost is an important criteria to assess when considering the alternatives and ensuring that solutions are cost effective is critical.

It is important to note that the assessment of cost did not attempt to provide a full, detailed costing of each option. Rather it took a high level approach to determine the rough order of magnitude costs for each alternative using present dollar values.

H) Cost

Theme	Port Economics
Objective:	5. Ensure solution is cost effective
Measure:	H) Assessment of costs
	Unit of measure: AUD and Present Value
	Which direction of the measure is better? Lower

Objective 6: Avoid significant loss of future port expansion opportunities

Maintaining effective port operations and future port development opportunities is a critical component of the decision making process.

One of the factors to consider around this objective is the impact of each of the alternatives on the statutory designated port land in the Port of Mackay. Strategic Port Land (SPL) is set aside through the planning system to facilitate the operation and future development of port related activities.

Any loss of available port land (SPL) and thus restrictions on future opportunities for growth should be considered.

The area that would be potentially impacted was calculated based on the location and land area needed to deliver each alternative. Calculations include maritime port area that may also be used to facilitate port activities in the future.

I) SPL affected

Theme	Port Economics & Operation
Objective:	6. Avoid significant loss of future port expansion opportunities
Measure:	I) Strategic Port Land (SPL) affected
	Unit of measure: Hectares
	Which direction of the measure is better? Lower

Objective 7: Avoid or mitigate health and safety risks

The impacts on human health and safety is an important criteria to assess when considering the alternatives for long term sustainable sediment management at the Port of Mackay.

To assess this component, a range of human health and safety measures were developed along with some simple performance criteria to rank them.

It is important to note the process was not intended to replicate a full risk assessment (based on unmitigated and mitigated risks derived from likelihood and consequences of various activities). Rather it took a high level approach around potential risk pathways and complexity. More detailed assessment will be considered for the preferred alternative as part of any future project planning and management. **A performance score (lower score is better) was generated for each alternative based on a set of criteria that considered:**

- Interaction with public areas.
- Dust and emissions.
- Duration of activity (influences likelihood of occurrence).
- Spills and contaminants.
- Heavy vessel / machinery interaction.
- Isolated areas – proximity to medical support.
- Weather exposure.
- Personnel requirements.

J) Human health and safety

Theme	Human Health and Safety
Objective:	7. Avoid or mitigate health and safety risks
Measure:	J) Relative risk
	Unit of measure: Performance score ranging from 8-24
	Which direction of the measure is better? Lower

Objective 8: Minimise interference to social activities within the region

The coastal areas and inner waters of the GBR around Mackay support a range of social and commercial activities, including: farming, commercial fishing, recreational fishing, boating, informal recreation (swimming, surfing, walking).

A performance score (lower score is better) was generated for each alternative based on a set of criteria that considered:

- The nature of any interaction with social features or activities.
- The length of time any interaction or disturbance will occur for.
- Number of people affected.

K) Social

Theme	Social
Objective:	8. Minimise interference to social activities within the region
Measure:	K) Scale and duration of any impacts on social activities
	Unit of measure: Performance score ranging from 3 - 9
	Which direction of the measure is better? Lower

Objective 9: Provide increased economic and social opportunities

As part of the broader social theme, it is recognised that a positive consideration would be to measure and compare the jobs created by each option. In particular, local job creation is seen as important as it will contribute to the regional economy and enhance the social fabric of the region. Jobs created at a broader level are also of value but for the purposes of comparison have been weighted at a lower factor.

For each alternative the forecast number of part-time and full time jobs (if any) was determined to create an overall jobs score.

L) Employment

Theme	Social
Objective:	9. Provide increased economic and social opportunities
Measure:	L) Predicted number of FTE jobs created
	Unit of measure: Full Time Equivalent (FTE) jobs created
	Which direction of the measure is better? Higher

Objective 10: Promote innovation in port management

In line with the 'net benefits concept' promoted in the Reef 2050 Plan and various findings from the Independent Review of the Port of Gladstone it is desirable to seek and examine new port and environmental management options that promote best practice and deliver improved sustainable solutions.

A performance score (higher score is better) was generated for each alternative based on a set of criteria that considered:

- Application of information.
- Application of technology/techniques.
- Use of ingenuity.

M) Innovation

Theme	Innovation
Objective:	10. Promote innovation in port management
Measure:	M) Ability of a solution to advance current dredging practice information, technology and techniques
	Unit of measure: Performance score ranging from 3-9
	Which direction of the measure is better? Higher

Objective 11: Avoid and minimise impacts to the Great Barrier Reef World Heritage Area

NQBP operates three ports within the Great Barrier Reef World Heritage Area (GBRWHA), including the Port of Mackay. NQBP undertakes a number of water quality management and monitoring initiatives to ensure that impacts to the WHA are avoided and minimised as far as practicable. These initiatives actively ensure that the Port is operating in accordance with the objectives and actions of the Reef 2050 Plan.

A World Heritage performance score (higher score is better) was generated for each alternative based on a set of criteria that considered:

- The size of the seabed area within the WHA directly altered by the sediment management alternative.
- The length of time the alteration to the seabed within the WHA would occur.
- The time it takes to complete the dredger operational activities associated with a single dredge campaign within the WHA.

N) World Heritage

Theme	World Heritage
Objective:	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area
Measure:	N) Scale and duration of activity within the Great Barrier Reef World Heritage Area
	Unit of measure: Performance score ranging from 3 - 9
	Which direction of the measure is better? Higher

Step 5: Comparing alternatives and selecting a preferred option

The final step in the comparative analysis was the application of a process to compare the alternatives against the objectives and performance measures using the results of the analysis in Step 4.

The process was extensive and involved:

- Comparing alternatives against the objectives and performance measures identified in Step 2.
- Ranking alternatives using various methods (e.g. different weightings, sensitivity analysis).
- Refining alternatives as needed to reach an optimal long term solution.
- Recommending a preferred solution based on the outcomes of the analysis.

5a. Comparison of alternatives

The comparison of alternatives examined the six possible options for reuse or placement of sediment identified in Step 3:

- Land reclamation - Mackay Harbour (Rec – M).
- Habitat (mangrove) creation - Sandringham Bay (Rehab).
- Onshore pond at Mackay Harbour (Onshore – M).
- Existing Mackay offshore Dredge Material Placement Area (Existing DMPA - M).
- Existing Hay Point offshore Dredge Material Placement Area (Existing DMPA – HP).
- Mid-shelf offshore Dredge Material Placement Area (Mid-shelf).

Raw scores consequence table

The raw scores from each performance measure (see Step 4 and Appendix A) were used to generate a consequence table. A consequence table is a matrix that illustrates and compares the performance of each alternative with respect to the objectives. **Key elements of Table 7 include:**

- All of the objectives and performance measures identified in Step 2.
- Indicates which direction is better for each performance measure in the “Dir” column. “H” is higher, and “L” is lower.
- The best (or equal best) scores for a performance measure are highlighted in green.
- The worst (or equal worst) scores for a performance measure are highlighted in orange.

TABLE 7: RAW SCORES FOR ALTERNATIVES

Theme	Objectives	Performance measure	Units	Dir	Rec - M	Habitat	Onshore - M	Existing DMPA - M	Existing DMPA - HP	Mid-shelf
ENV	1. Avoid and minimise impacts to coastal ecosystems	A) Coastal ecosystems performance	4-16	H	4	16	6	6	6	8
		B) Water quality performance	0-21	L	0	0	0	2	6	1
	2. Minimise carbon emissions	C) GHG emissions	tCO^2-e	L	18,904	887	4,305	419	572	853
CULTURE	3. Minimise impact on cultural heritage within the area	D) Cultural heritage performance	3-9	L	4	3	5	3	3	3
ECON	4. Maintain effective and efficient port operations	E) Port disruption	Days	L	11.6	19.4	11.6	6.4	9.3	14.6
		F) Lead time	Years	L	4	5.5	4.25	0	0	1./5
		G) Long term solution	Years	H	25	10	25	25	25	25
	5. Ensure solution is cost effective	H) Cost	$ million	L	$29.86	$2.19	$16.46	$0.82	$1.13	$1.68
	6. Avoid significant loss of future port expansion opportunities	I) SPL area affected	ha	L	40	20	50	0	0	0
H&S	7. Avoid or mitigate health and safety risks	J) Relative risk	8-24	L	16	10	16	8	8	11
SOCIAL	8. Minimise interference to social activities within the region	K) Social performance	3-9	L	7	3	7	3	3	3
	9. Provide increased economic and social opportunities	L) Employment	FTE	H	5.46	1.58	2.73	0.25	0.25	0.5
INNO	10. Promote innovation in port management	M) Innovation	3-9	H	3	8	3	3	3	5
WH	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) World Heritage performance	4-12	H	6	11	9	10	9	8

Analysis

The above analysis of the six alternatives shows how they each perform against the objectives and measures.

Further analysis of the individual alternatives was undertaken in order to better compare how each alternative performs in comparison to the others. **This further analysis involved:**

- Normalising the scores so that a quantitative comparison could be made between performance measures with different units.
- Applying weightings to performance measures to arrive at an overall performance score for each alternative.

Normalised scores

Because many of the performance measures were reported in different units, the raw scores were normalised in order to enable further analysis and comparison. Various approaches were used depending on the nature of the performance measure to normalise the scores as unitless numbers between 0 and 1, where 0 is the worst value and 1 is the best.

The calculation used to normalise scores is as follows:

$$\textit{Normalised score} = \frac{\textit{score} - \textit{worst score}}{\textit{best score} - \textit{worst score}}$$

Water quality example

A useful example to consider in relation to normalisation is the water quality performance measure. The raw scores were calculated based on a performance score ranging from 0-21 (where 0 is the best raw score for water quality). The normalisation process distributed the raw scores between 0-1 (where 1 is the best normalised score for water quality).

The formula that was used was:

$$\textit{Normalised water quality score} = \frac{21 - \textit{raw score}}{21}$$

The results of this work are shown in Table 8. **In this example:**

- Three of the alternatives have the best possible raw score for water quality and consequently received a normalised score of 1.
- Two alternatives have slightly poorer raw scores. For example, the existing offshore DMPA has a raw score of 2 and consequently received a normalised score of 0.90. It is worth noting that this still represents a good overall performance score.

TABLE 8: RAW AND NORMALISED SCORES FOR WATER QUALITY (PERFORMANCE MEASURE B)

Water quality (B)	Rec - M	Habitat	Onshore - M	Existing DMPA - M	Existing DMPA - HP	Mid-shelf
Raw scores (range from 0-21)	0	0	0	2	6	1
Normalised scores (range 0-1)	1.00	1.00	1.00	0.90	0.71	0.95

The full set of normalised scores are shown in Table 9.

Theme	Objectives	Performance measure	Units	Dir	Rec - M	Habitat	Onshore - M	Existing DMPA - M	Existing DMPA - HP	Mid-shelf
ENV	1. Avoid and minimise impacts to coastal ecosystems	A) Coastal ecosystems performance	4-16	H	0.00	1.00	0.17	0.17	0.17	0.33
		B) Water quality performance	0-21	L	1.00	1.00	1.00	0.90	0.71	0.95
	2. Minimise carbon emissions	C) GHG emissions	tCO^2-e	L	0.00	0.97	0.79	1.00	0.99	0.98
CULTURE	3. Minimise impact on cultural heritage within the area	D) Cultural heritage performance	3-9	L	0.83	1.00	0.67	1.00	1.00	1.00
ECON	4. Maintain effective and efficient port operations	E) Port disruption	Days	L	0.60	0.00	0.60	1.00	0.78	0.37
		F) Lead time	Years	L	0.27	0.00	0.23	1.00	1.00	0.73
		G) Long term solution	Years	H	1.00	0.00	1.00	1.00	1.00	1.00
	5. Ensure solution is cost effective	H) Cost	$ million	L	0.00	0.95	0.46	1.00	0.99	0.97
	6. Avoid significant loss of future port expansion opportunities	I) SPL area affected	ha	L	0.20	0.60	0.00	1.00	1.00	1.00
H&S	7. Avoid or mitigate health and safety risks	J) Relative risk	8-24	L	0.50	0.88	0.50	1.00	1.00	0.81
SOCIAL	8. Minimise interference to social activities within the region	K) Social performance	3-9	L	0.33	1.00	0.33	1.00	1.00	1.00
	9. Provide increased economic and social opportunities	L) Employment	FTE	H	1.00	0.26	0.48	0.00	0.00	0.05
INNO	10. Promote innovation in port management	M) Innovation	3-9	H	0.00	0.83	0.00	0.00	0.00	0.33
WH	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) World Heritage performance	4-12	H	0.25	0.88	0.63	0.75	0.63	0.50

TABLE 9: RAW SCORES FOR ALTERNATIVES

Weightings

The second step involved weighting the normalised scores for each performance measure and calculating an overall performance score for each alternative out of 100. A score of 100 would mean that an alternative performs perfectly against every performance measure.

Weighting is an important step in the decision making process. It is a process that people often undertake subconsciously by placing more value on some objectives over others when trying to make a decision between options. The structured decision making process provides a transparent way of applying and testing weightings. It is recognised that stakeholders value objectives differently and will therefore apply different weightings. Given this, no attempt was made to reach a consensus on how to apply weightings. Rather a number of different weighting scenarios were generated to see how each alternative would perform. **The weighting scenarios (see Table 10) were:**

- **Equal weights** - all performance measures were weighted equally.
- **Environment focus** - performance measures relating to the environment theme were attributed with 75% of the weightings.
- **Social focus** – performance measures relating to the social theme were attributed with 75% of the weightings.
- **Economic focus** - performance measures relating to the port economics and operation, and health and safety themes were attributed with 75% of the weightings.
- **Cultural focus** – the performance measure relating to the cultural heritage theme was attributed with 75% of the weightings.
- **World Heritage** – the performance measure relating to the World Heritage theme weighted was attributed with 75% of the weightings.

TABLE 10: WEIGHTING SCENARIOS

Objectives	Performance measure	Equal weights	Enviro focus	Social focus	Economic focus	Cultural focus	WHA
1. Avoid and minimise impacts to coastal ecosystems	A) Coastal ecosystems performance	8.3	25.0	2.5	3.1	2.3	2.3
	B) Water quality performance	8.3	25.0	2.5	3.1	2.3	2.3
2. Minimise carbon emissions	C) GHG emissions	8.3	25.0	2.5	3.1	2.3	2.3
3. Minimise impact on cultural heritage within the area	D) Cultural heritage performance	8.3	2.8	2.5	3.1	75.0	2.3
4. Maintain effective and efficient port operations	E) Port disruption	8.3	2.8	2.5	18.8	2.3	2.3
5. Ensure solution is cost effective	H) Cost	8.3	2.8	2.5	18.8	2.3	2.3
6. Avoid significant loss of future port expansion opportunities	I) SPL area affected	8.3	2.8	2.5	18.8	2.3	2.3
7. Avoid or mitigate health and safety risks	J) Relative risk	8.3	2.8	2.5	18.8	2.3	2.3
8. Minimise interference to social activities within the region	K) Social performance	8.3	2.8	37.5	3.1	2.3	2.3
9. Provide increased economic and social opportunities	L) Employment	8.3	2.8	37.5	3.1	2.3	2.3
10. Promote innovation in port management	M) Innovation	8.3	2.8	2.5	3.1	2.3	2.3
11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) World Heritage performance	8.3	2.8	2.5	3.1	2.3	75.0
	Total	**100**	**100**	**100**	**100**	**100**	**100**

Weighted scores

A summary of the overall performance of each option under the six weighting scenarios is provided in Table 11. The best performing option under each scenario is highlighted in green and the worst performing is highlighted in orange.

TABLE 11: SUMMARY OF WEIGHTED SCORES (MAX 100) FOR EACH ALTERNATIVE ACROSS THE SIX WEIGHTING SCENARIOS

	Rec - M	Habitat	Onshore - M	Existing DMPA - M	Existing DMPA - HP	Mid-shelf
Equal weights	43	67	49	77	73	72
Environment focus	36	89	60	72	66	74
Social focus	60	64	43	58	57	58
Economic focus	43	52	48	90	86	77
Cultural focus	72	91	62	94	93	92
WHA	30	82	59	76	65	56

Best score for an option under a particular weighting scenario

Second best score for an option under a particular weighting scenario

Worst score for an option under a particular weighting scenario

Observations

Review of the analysis led to the following observations:

- The three offshore options all perform relatively well across a range of measures. The existing offshore alternative generally out performs both the Hay Point DMPA and the mid-shelf alternative.
- The reclamation option is by far the worst performed option, followed by the onshore pond at the Port of Mackay.
- The habitat creation project generally scores well except for lead in time.
- All of the alternatives perform well in relation to the marine water quality performance score.
- Under an equal weights scenario, the two existing offshore DMPAs and, mid-shelf DMPA ranked as the three highest performing alternatives.
- Two alternatives occupied the top spot in all six performance themes. This result implies that these alternatives can be expected to respond well to a broader range of stakeholder values and factors that might influence decision makers. These were:
  - Habitat creation, which ranked highly under the four scenarios of Environment, Social and World Heritage.
  - Existing DMPA - Mackay which ranked highly under the three scenarios of Equal, Economic, Cultural and second under World Heritage.

Addressing uncertainty

Uncertainty is an inherent component to the complex type of analysis and decision making being undertaken. **There is a level of uncertainty in:**

- The scores against each performance measure (e.g. the cost calculations for each option).
- The weightings that may be applied and how influential those weightings are to the selection of a preferred solution.

To respond to these challenges, sensitivity analysis was undertaken at two levels:

- Analysis to understand how influential changes to the performance measure scores would be to overall performance.
- Analysis to understand how overall performance scores may change under different weighting scenarios.

Sensitivity analysis around performance measure scores

An analysis was undertaken to understand how influential changes to individual performance measure scores would be to overall performance scores (Figure 3). This was done for all measures under the six weighting scenarios. The process involved examining how much the overall performance score would change for every one unit of change in a performance measure. The method provides confidence in the performance measures by testing their sensitivity and it addresses any outliers.

The results indicate that small changes to the performance measures will generally lead to very small changes in the overall performance of an alternative. This suggests that there is some margin for error in the scores assigned to each performance measure, which helps to address concerns around uncertainty in this aspect of the analysis.

A useful example to consider is the water quality performance measure. A decrease in the performance score of one unit will lead to a maximum reduction in the overall performance of an alternative by 0.2 (this occurs under the environment weighting scenario).

The exception to this is where a performance measure is highly influential under a particular weighting scenario (e.g. the cultural heritage measure under the cultural focus weighting scenario). In this instance, small changes to the key performance measure(s) will have a much greater effect on the overall score. This result is to be expected given the method used in deriving the weighted scores.

The sensitivity of how scores alter should be taken into account when examining the results of the weighted scores, however, it does not greatly alter the results of the analysis.

FIGURE 3: HOW CHANGES IN PERFORMANCE MEASURE SCORES INFLUENCE OVERALL PERFORMANCE SCORES UNDER EACH WEIGHTING SCENARIO

Sensitivity analysis around weightings

The second important component to the sensitivity analysis was understanding how performance varied as the weighting scenarios varied.

An indicative 75% weighting was used to derive the initial scenarios (e.g. 75% of the weights applied to economic measures to create the economic focus scenario). To understand how that might change, weights were varied for each scenario between 5% and 95% and the overall performance scores for each option plotted to provide a comparison. These are illustrated in the graphs below (Figures 4-8).

The following conclusions were reached from results of this analysis:

- Changes to the weights applied to the environment focus would have minimal impact on the overall outcome. Two of the three highest performing options maintain their top performance rankings regardless of changes in the weighting used.
- Increasing the weighting applied to the social focus led to a steady decline in the three highest performing options. Based on this result, you could expect to see a different set of highest performing options once the weighting exceeded 75%. This suggests that stakeholders with an almost exclusive focus on social outcomes might arrive at a preferred option, which is different to those that performed well under other weightings.
- Changes to the weights applied to the economic focus would have no impact on the overall outcome. Increasing the weighting under this scenario only improved the scores of the three highest performers, further strengthening their rankings compared with the other options.
- Similarly, changes to the weights applied to the cultural heritage focus would have no impact on the overall outcome, with an increase in the weighting leading to an increase in the scores of the three highest performers.
- The World Heritage focus is the most responsive to changes in the weightings used. The ranked performances of the different options begin to change when World Heritage is given a weighting of around 40%. Up until this point, the options that perform well under all other scenarios continue to remain the same.

FIGURE 4: ENVIRONMENTAL FOCUS ANALYSIS

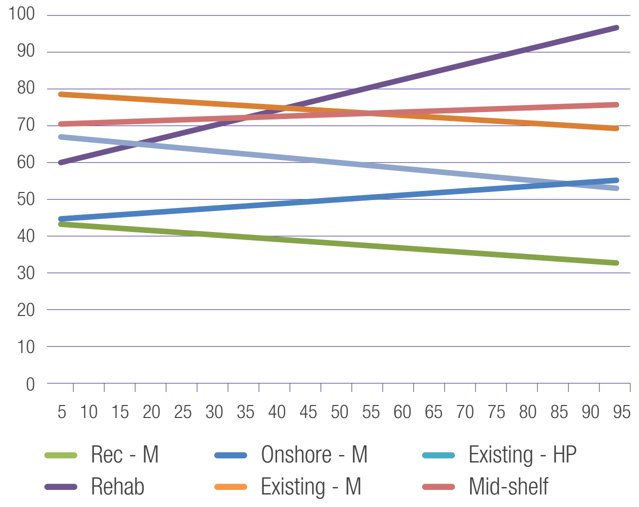


FIGURE 7: WORLD HERITAGE FOCUS SENSITIVITY ANALYSIS

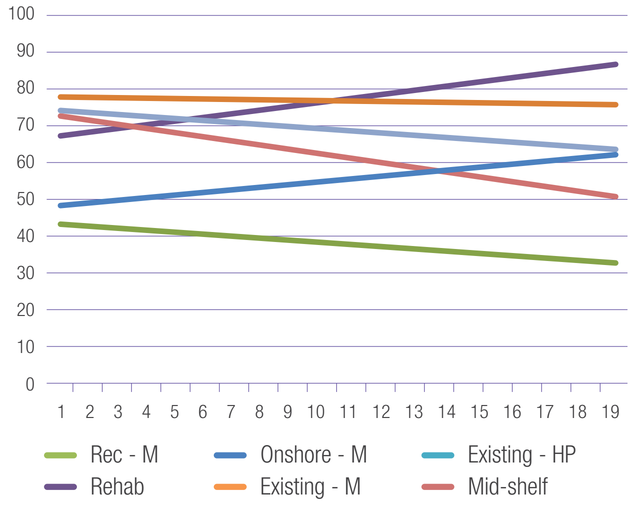


FIGURE 5: ECONOMIC FOCUS SENSITIVITY ANALYSIS

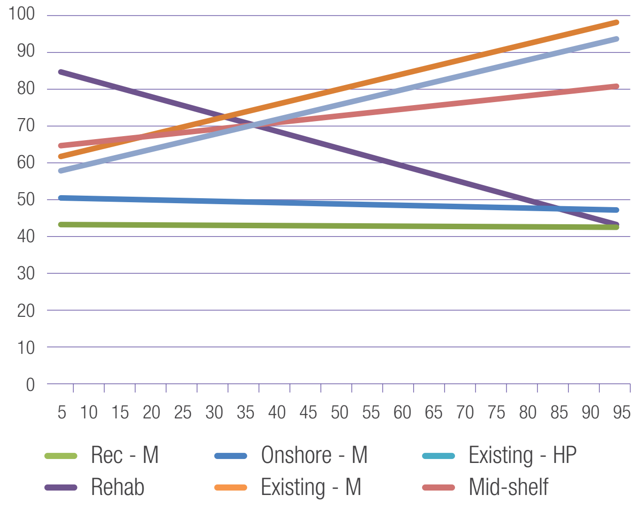


FIGURE 8: CULTURAL FOCUS SENSITIVITY ANALYSIS

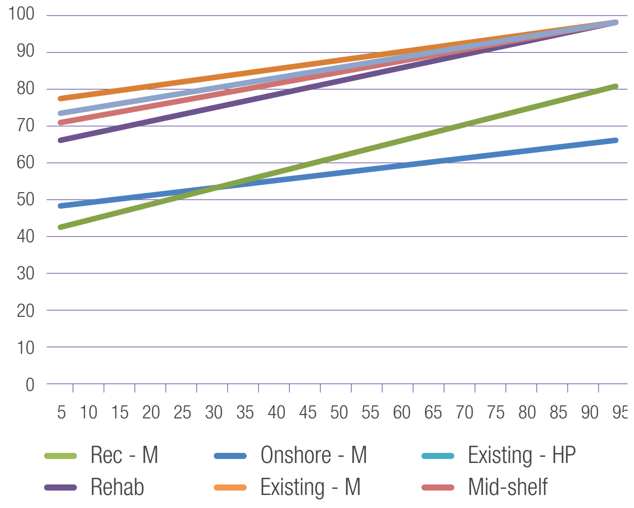
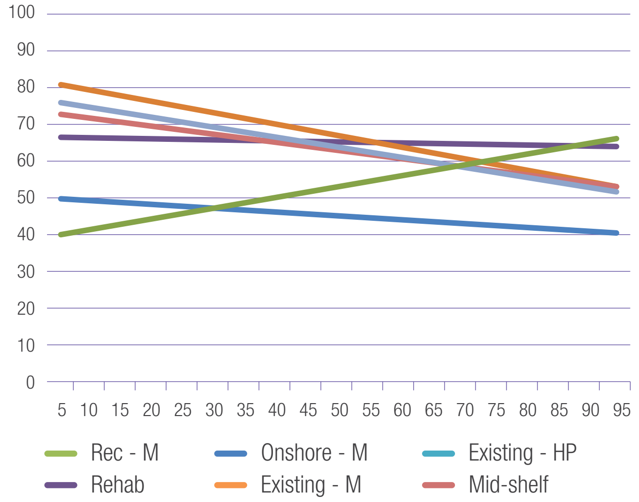


FIGURE 6: SOCIAL FOCUS SENSITIVITY ANALYSIS



Overall analysis and conclusion

The comparative analysis has led to three key findings:

- Sediment at the Port of Mackay needs to be managed.
- Dredging is required as part of the management solution.
- There are a discrete set of feasible options that have the potential to provide a long term solution for the placement of sediment.

Analysis of long term options

Of the six options that were tested in the comparative analysis, two stood out as the best performers under a range of scenarios against the objectives of the project. **They were:**

- At-sea placement at the existing Port of Mackay DMPA
- Habitat creation at Sandringham Bay.

These two options scored well[1] against a number of performance measures including coastal ecosystems, water quality, GHG emissions, cultural heritage, cost, affected SPL area, relative risk to health and safety and social performance. These performance measures largely represent the range of measures influencing the different weighting scenarios. As a result, these two high performing options were also found to perform well under most scenarios used to represent the different values or focus that might be applied by a range of stakeholders.

The exception to this was the World Heritage scenario. The two highest performing options generally began to shift once a weighting of around 40-65% or greater was applied. This suggests that a stakeholder with a very strong focus on World Heritage outcomes might select a different preferred option to the two best performers identified here.

The options that generally performed poorly were those that included onshore placement or reclamation at Mackay Harbour.

Preferred long term solution

Based on the detailed comparative analysis, offshore placement at the existing DMPA consistently performed the best. On balance, offshore placement at the existing DMPA is considered to be the preferred solution. It provides both a short and long-term solution, is well understood, and performs strongly in a range of scenarios.

Habitat creation at Sandringham Bay is also considered to have merit. It is an alternative that can provide a positive environmental benefit and it is recommended that it should be examined in more detail as part of an integrated solution with at-sea placement at the existing DMPA. Habitat creation is not proposed as an immediate solution as there is a need to first understand the feasibility, value and legislative constraints in essentially replacing one coastal habitat with another (habitat creation).

1. It should be noted that even though some scenarios scored the lowest for a performance measure (i.e. water quality) across the range of scenarios considered, the scenario still scored well for the performance measure.

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SKM (2013). *Literature Review and Cost Analysis of Land-based Dredge Material Re-use and Disposal Options*. Report prepared for the GBRMPA (Great Barrier Reef Strategic Assessment – Marine Zone).

Port and Coastal Solutions (2021) *Port of Mackay Avoid and Reduce Assessment*. Report No. P012 R02v01.

Appendix A – Performance measures

The following performance measures are described in this appendix:

A. Predicted performance in relation to avoidance and minimisation of impacts to coastal ecosystems.

B. Predicted risk on dredge material placement plumes and/or tailwater discharge exceeding ambient variation (percentile above median ambient TSS).

C. Forecast Greenhouse gas emissions.

D. Nature and scale of any impact on cultural heritage.

E. Number of days disruption to operations.

F. Predicted lead time to dredge material placement.

G. Capacity to provide a long term solution for the port.

H. Assessment of costs.

I. Strategic Port Land (SPL) affected.

J. Relative risk.

K. Scale and duration of any impacts on social activities.

L. Predicted number of FTE jobs created.

M. Ability of a solution to advance current dredging practice information, technology and techniques.

N. Scale and duration of activity within the Great Barrier Reef World Heritage Area.

A) Coastal ecosystems performance

Theme:	Environment
Objective:	1. Avoid and minimise impacts to coastal ecosystems
Measure:	A) Predicted performance in relation to avoidance and minimisation of changes to coastal ecosystems
	Unit of measure: Performance score ranging from 4-16
	Which direction of the measure is better? Higher

Coastal ecosystems and landforms are areas where the land and water meet in a distinct environment of high diversity, connectivity and flow. They provide a range of ecological services including water distribution, food and habitat, nutrient and chemical cycling, as well as important links between land, freshwater and marine environments and breeding grounds for many coastal species. There are a range of coastal ecosystems and landforms that are relevant to the assessment of alternatives for long term sustainable sediment management at the Port of Mackay.

They include:

- Land based ecosystems: threatened ecological communities (TECs), and other native vegetation.
- Freshwater and estuary ecosystems: wetlands, estuaries, and mangroves.
- Coastal landforms: salt marsh, saline coastal flats / swamp, beaches, and rocky headlands.
- Marine ecosystems: coral reefs, seagrass and/or seabed.

Changes or losses to these coastal ecosystems or landforms can lead to a variety of adverse environmental impacts, as well as serious implications for industries dependent on the Great Barrier Reef Marine Park. More detailed environmental impact assessment will form part of any future assessment and approval processes.

Method of calculation

The performance of each alternative in relation to avoiding and minimising changes to coastal ecosystems and landforms was determined through the application of a set of criteria that considered:

- The scale of predicted direct changes to coastal ecosystems and landforms.
- Relative significance of effects to ecosystems in terms of listing status and condition (as recorded in the GBR Outlook Report).
- Relative significance of changes in terms of species habitat.
- Duration of changes.
- Any positive contributions to coastal ecosystems and landforms.

The process involved:

- Defining a coastal ecosystem and landform spatial layer.
- Intersecting the spatial footprint of each alternative with the coastal ecosystem and landform data to determine the potential scale and relative significance of predicted changes to coastal ecosystems.
- Applying the performance criteria (see Table 12) to arrive at a performance score for each alternative.

TABLE 12: COASTAL ECOSYSTEM AND LANDFORM PERFORMANCE CRITERIA

Performance criteria				
Measure	**Very High** (Score = 4)	**High** (Score = 3)	**Medium** (Score = 2)	**Low** (Score = 1)
Scale of change	Increase in extent of ecosystem	Small or no area affected (<5 ha)	Moderate area affected (5-15 ha)	Large area affected (> 15 ha)
Ecosystem status	Positive contribution to ecosystem	No changes OR Changes to least concern or unlisted ecosystem OR Changes to ecosystem in very good condition	Changes to of concern or vulnerable ecosystem OR Changes to ecosystem in good condition	Changes to critically endangered or endangered ecosystem OR Changes to ecosystem in poor or very poor condition
Species habitat status	Positive contribution to species habitat	No changes OR Changes to habitat used by unlisted or near threatened species	Changes to 'general habitat' used by vulnerable species	Changes to 'important habitat' or habitat used by critically endangered or endangered species

Duration of change	No changes	Short term changes (recovery within natural/ seasonal variations 1-2 years)	Medium term changes (recovery expected within 5-10 years)	Permanent changes

Results

	Reclamation Mackay	Habitat creation	Onshore Mackay	At sea existing – Mackay	At sea existing – Hay Point	At sea mid-shelf
Land based ecosystems						
TECs (ha)	0.7	0.0	0.0	0.0	0.0	0.0
Other native vegetation (ha)	0.7	0.0	17.1	0.0	0.0	0.0
Freshwater and estuary ecosystems						
Wetlands (ha)	0.0	1.9	0.7	0.0	0.0	0.0
Estuaries (ha)	0.0	41.6	0.0	0.0	0.0	0.0
Mangroves (ha)	0.0	0.0	0.0	0.0	0.0	0.0
Marine ecosystems						
Coral reefs (ha)	0.0	0.0	0.0	0.0	0.0	0.0
Seagrass and/or seabed (ha)	26.46	14.94	0.0	130	1840	2009
Coastal landforms						
Salt marsh (ha)	0.0	0.0	19.0	0.0	0.0	0.0
Saline coastal flats / Swamp (ha)	0.0	21.8	0.2	0.0	0.0	0.0
Beaches (ha)	1.8	5.5	0.0	0.0	0.0	0.0
Rocky headlands (ha)	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 13: PREDICTED AREA* OF DIRECT EFFECTS TO COASTAL ECOSYSTEMS AND LANDFORMS

Alternative	Commentary
Reclamation Mackay	• Small scale permanent impacts to: - Littoral Rainforest and Coastal Vine Thickets of Eastern Australia TEC (~0.7 ha) - Other native vegetation (~0.7 ha) - Beach (~1.8 ha) which: › Has been identified as suitable (low density) habitat for nesting turtles › Is recorded as being in good condition with a stable trend in the GBR Outlook Report • Large scale (~26.46 ha) permanent impacts to the seabed of the inshore marine area
Habitat Creation Area	• Positive benefit to the estuary ecosystem through the regeneration of mangrove habitat (~70 ha). Mangrove forests are recorded as being in good condition with a stable trend in the GBR Outlook Report • No permanent changes to other ecosystems or landforms
Onshore Mackay	• Small scale permanent changes to: - Wetlands (~0.7 ha) which are recorded as being in poor condition (no trend) in the GBR Outlook Report - Saline coastal flats / swamps (~0.2 ha) • Large scale permanent changes to: - Other native vegetation (~17.1 ha) including REs that are potentially of concern or endangered - Salt marsh (~19 ha) which is recorded as being in good condition (no trend) in the GBR Outlook Report • No marine area changes
At Sea Existing – Mackay	• Small scale short term changes to previously disturbed areas of the seabed (~130 ha) within the existing dredge material placement area. • No changes to coral • No land based changes • No changes to known important habitat for species. However, site likely to provide variable foraging value for a number of species (e.g. turtles and dugong)
At Sea Existing – Hay Point	• Moderate scale short term changes (monitoring indicates recovery within 1-2 years) to previously disturbed areas of the seabed (~1840 ha) • No changes to coral • No land based changes • No changes to known important habitat for species. However, site likely to provide variable foraging value for a number of species (e.g. turtles and dugong)
At Sea Mid–shelf Area	• Moderate scale short term changes to the seabed environment (~2009 ha) • No changes to mapped seagrass • Unknown species changes • No land based changes

TABLE 14: COMMENTARY ON THE PERFORMANCE OF EACH ALTERNATIVE

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At sea existing – Mackay	At sea existing – Hay Point	At sea mid-shelf
Scale of change	1	4	1	2	2	2
Ecosystem status	1	4	1	3	2	2
Species habitat status	1	4	3	2	2	2
Duration of change	1	4	1	3	3	3
Total score	**4**	**16**	**6**	**10**	**9**	**9**

Very high performance

High performance

Medium performance

Low performance

TABLE 15: COASTAL ECOSYSTEM AND LANDFORM PERFORMANCE SCORES FOR EACH ALTERNATIVE FOR A DREDGING CAMPAIGN (HIGHER SCORE IS BETTER)

B) Marine water quality performance

Theme:	Environment
Objective:	1. Avoid and minimise impacts to coastal ecosystems
Measure:	B) Predicted risk of dredge material placement plumes and/or tailwater discharge exceeding ambient variation (percentile above median ambient TSS)
	Unit of measure: Performance score ranging from 0-21
	Which direction of the measure is better? Lower

Marine waters are the vector to disturbance of a range of receptors, including benthic communities, nekton (fishes), and a range of megafauna such as dolphins, turtles and whales. Changes in water quality in the nearshore environment have been well documented in the area around the Port of Mackay. NQBP have implemented an ambient monitoring program that extended from Freshwater Point to Keswick Island, approximately 55 km of the coastal strip (Figure 9). Since implementation in 2014 the program has been reviewed and rationalised annually with some monitoring locations removed due to data replication between sites.

FIGURE 9: COASTAL TRANSECT OF WATER QUALITY MONITORING LOCATIONS

Changes in total suspended solids (TSS) concentrations is a water quality variable for which a healthy dataset of natural conditions exists in the coastal area of Mackay. TSS concentration not only provide a good indicator of water quality but also provide a useful surrogate for potential impacts on receptors such as fringing corals and seagrasses, particularly in the context of differentiating between alternatives for dredge material relocation. Using hydrodynamic modelling techniques, sedimentation deposition rates can also be derived from TSS data, coupled with information related to coastal hydrology and processes.

Elevated TSS can reduce the amount of light reaching the seafloor and impact on photosynthesising organisms such as hard corals and seagrasses (Erftemeijer and Lewis 2006; Erftemeijer et al 2012). Extended period of greater than 15mg/l TSS may lead to sub-lethal biota, depending on the sensitivity of individual organisms1, whereas extended periods of greater than 100mg/l has been shown to reduce the Surface Irradiation (SI) reaching the seafloor to below 1% in some environments1, which can lead to mortality of some species. **TSS data from NQBP's ambient monitoring program is shown in Figure 10 at number of sensitive receiving locations from the coastal transect of monitoring sites, where:**

- Bottom whisker - 5th percentile (TSS concentration occur 95% of the time).
- Bottom box - 20th percentile (TSS concentration occur 80% of the time).
- Line - Median (midpoint of the observed/predicted TSS concentrations).
- Top box - 80th percentile (TSS concentrations occur 20% of the time).
- Top whisker - 95th percentile (TSS concentrations occur 5% of the time).

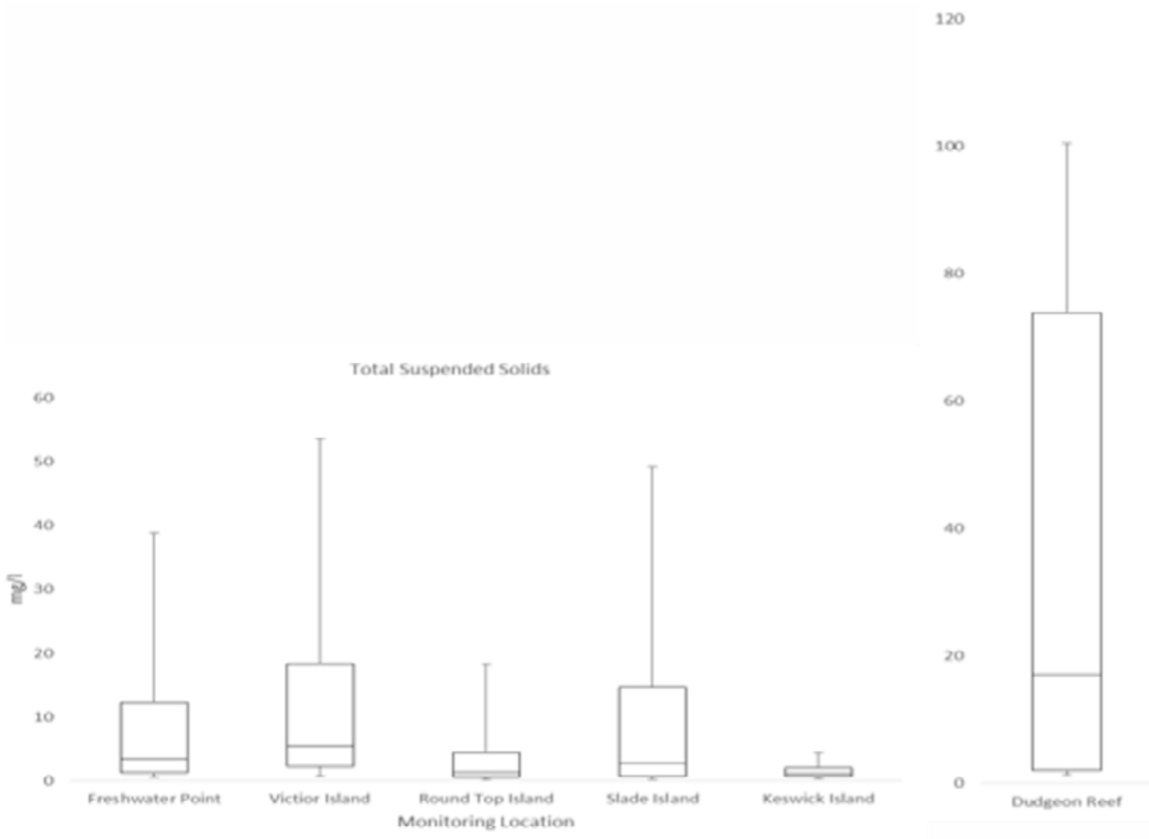

FIGURE 10: TSS DATA FROM NQBP'S AMBIENT MONITORING PROGRAM

Hydrodynamic modelling has been undertaken for each of the placement alternatives and similarly percentile data has been generated for each (Hay Point SSM Appendix K – section 5.3). This modelling was derived for the Port of Hay Point SSM assessment, but as discussed applies directly to the shared Port of Mackay placement alternatives. The results indicated no predicted concentrations in excess of 15mg/l at any of the sensitive receiving locations from the coastal transect of monitoring sites.

Method of calculations

To assess the performance of each alternative a number of performance criteria were developed to compare the modelled TSS data associated with potential plumes from each of the alternatives, which compares the summary statistics against natural median TSS concentrations:

- Onshore alternatives – a tailwater outflow of 50mg/l at the proposed tailwater discharge site has been assumed.
- Reclamation alternatives – a failure event has been modelled and assumes a significant tear in the filter lining.
- At-sea alternatives – have used modelled outputs from original plume modelling undertaken by Worley Parsons for 207,000m^3 which overestimates the proposed volume of 120,000m^3 to 150,000m^3 proposed for the Port of Hay Mackay.
- Habitat Creation alternative – has used the same failure criteria as for the reclamation alternatives.

Performance criteria

For each alternative a water quality performance score was determined by comparing predicted changes in TSS against natural variability at seven sensitive receiver locations along the coast from Freshwater Point in the south, to Keswick Island to the north. See Table 16 for the performance criteria.

Table 17 summarises the modelling outputs from simulated sediment plumes from the various placement scenarios (as described in Hay Point SSM Appendix K – section 5.3. The score at each receiver location is summed to give an overall performance score (Table 18)

Performance Criteria				
Measures	Very High (Score 0)	High (Score = 1)	Medium (Score = 2)	Low (Score = 3)
Total Suspended Solids (TSS)	95th percentile TSS concentrations not shown to occur above natural median concentration	TSS concentrations occur above natural median concentrations between 5% and 20% of the time	TSS concentrations occur above natural median concentrations for 20% to 80% of the time	TSS concentrations occur above natural median concentrations greater than 80% of the time

TABLE 16: MARINE WATER QUALITY PERFORMANCE CRITERIA

Results

Location	Ambient monitoring	Reclamation Mackay			Habitat Creation			Onshore Mackay		
SSC	Natural Median^	95th ‰	80th ‰	95th ‰	80th ‰	20th ‰	20th ‰	95th ‰	80th ‰	20th ‰
Victor Island	5.41	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.00
Round Top Island	1.28	0.10	0.10	0.00	0.00	0.00	0.00	0.10	0.10	0.00
Slade Island	2.72	1.10	0.90	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Slade Point	2.00	0.90	0.70	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Keswick Island	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		At-sea existing – Mackay			At-sea existing – Hay Point			At-sea Mid-shelf		
SSC	Natural Median^	95th ‰	80th ‰	95th ‰	80th ‰	20th ‰	20th ‰	95th ‰	80th ‰	20th ‰
Victor Island	5.41	0.10	0.02	0.00	0.16	0.05	0.00	0.05	0.02	0.00
Round Top Island	1.28	0.37	0.19	0.00	2.90	1.74	0.01	0.32	0.15	0.00
Slade Island	2.72	4.26	3.47	0.86	1.78	1.59	0.12	1.21	0.59	0.13
Slade Point	2.00	5.33	3.84	0.73	1.25	0.43	0.00	0.10	0.05	0.00
Keswick Island	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 17: SUMMARY RESULTS FOR TOTAL SUSPENDED SOLIDS

Sensitive receiver locations	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Freshwater Point	0	0	0	0	0	0
Victor Island	0	0	0	0	0	0
Hay Reef	0	0	0	0	2	1
Dudgeon Reef	0	0	0	0	0	0
Round Top Island	0	0	0	0	2	0
Slade Island	0	0	0	1	2	0
Slade Point	0	0	0	1	0	
Keswick Island	0	0	0	0	0	0
Total score	**0**	**0**	**0**	**2**	**6**	**1**

Very high performance
High performance
Medium performance
Low performance

TABLE 18: OVERALL PERFORMANCE SCORE FOR MARINE WATER QUALITY (LOWER SCORE IS BETTER)

C) GHG emissions

Theme:	Greenhouse Gas (GHG) emissions
Objective:	2. Minimise carbon emissions
Measure:	C) Forecast GHG emissions
	Unit of measure: Tonnes of CO2 equivalent (tCO_2-e)
	Which direction of the measure is better? Lower

Consideration of the potential Greenhouse Gas (GHG) emissions from the construction and operational activities of each alternative is an important component of comparing the long term sustainable sediment management alternatives at the Port of Mackay. Understanding how each alternative performed in relation to forecast GHG emissions forms part of the decision making process.

Method of calculation

Calculating forecast GHG emissions was undertaken in accordance with the internationally recognised methodology outlined in the GHG Protocol. In accordance with the Protocol, the assessment considered the following emissions:

- Direct emissions – e.g. emissions associated with fossil fuel consumption by vessels/construction plant/vehicles during transport and construction. These are known as 'Scope 1' emissions in the GHG Protocol.
- Indirect emissions from supporting activities – e.g. emissions associated with the production of construction materials. These are known as 'Scope 3' emissions in the GHG Protocol. For this project high level estimates are used.

None of the alternatives were considered likely to result in significant indirect emissions due to the consumption of purchased electricity (known as 'Scope 2' emissions in the GHG Protocol). Scope 2 emissions were therefore not part of this assessment.

Calculations of the forecast GHG emissions for each alternative for an initial dredge campaign were based on:

- Calculations of the direct GHG emissions from the consumption of bunker fuel during the operation of the Trailer Suction Hopper Dredger (TSHD) Brisbane (dredging, pumping and transport to the mooring areas) for each option were calculated using guidance from USEPA (2009). The emission parameters and rates used in the assessment were derived using the USEPA methodology and the TSHD Brisbane specification.
- Direct GHG emissions associated with diesel fuel consumption from construction plant were calculated using emission factors from the Australian National Greenhouse Accounts (2015).
- Construction material GHG emissions were calculated from the volume of construction materials used for each alternative.

Results

TABLE 19: SUMMARY OF GHG EMISSION ESTIMATES FOR A DREDGE CAMPAIGN FOR EACH ALTERNATIVE (CO_2-e TONNES) (LOWER IS BETTER)

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Dredge campaign estimate (Scope 1 and Scope 3)	18,904	887	4,305	419	572	853

D) Cultural heritage performance

Theme:	Cultural Heritage
Objective:	3. Minimise impact on cultural heritage within the area
Measure:	D) Nature and scale of any impact on cultural heritage
	Unit of measure: Performance score ranging from 3 - 9
	Which direction of the measure is better? Lower

Mackay was first settled by Europeans in 1862 and developed into a large city in the 1870s and 1880s with a booming sugar industry. The process of European settlement had a significant impact on the Aboriginal people of the region. In the 1930s Mackay became Queensland's first regional city to have a town plan when the outer harbour was constructed.

The sustainable sediment management project aims to further improve the management of port sediments while ensuring the continued operation of the port, social and cultural features are respected and that environmental and cultural heritage values are protected.

Method of calculation

The performance for each alternative was calculated based on a set of criteria (see Table 20) that consider:

- The nature of any interaction with or disturbance to identified Indigenous cultural heritage or potential unknown sites and/or artefacts.
- The nature of any interaction with landscape/cultural connection of importance to Indigenous people.
- Impact on access for Indigenous people to culturally important places.

TABLE 20: CULTURAL HERITAGE PERFORMANCE CRITERIA

Performance Criteria			
Measures	High (Score = 1)	Medium (Score = 2)	Low (Score = 3)
Nature of interaction or disturbance – site/artefact	None	Potential risk to identified site but can be mitigated or avoided, or Potential risk to unknown site/artefact but can be adequately managed	Destruction, loss of identified or unknown site or artefact
Nature of interaction or disturbance - landscape/ cultural connection	None or positive	Connection and identified value lost due to change in environment on site specific scale	Connection and identified value lost due to change in environment on regional scale
Impact on access to culturally important places	None or positive	Access lost or disrupted temporarily	Access lost permanently

Results

Alternative	Commentary
Habitat Creation Area	• An area of 70 ha will be altered as dredge material is placed within a bund to create the habitat creation area. • No known cultural heritage. Activity will restore the natural vegetation, improving connection with landscape.
Onshore Mackay	• An area of 50 ha will be altered as dredge material is placed within a bund system. • No identified cultural sites but the area may contain artefacts and has recognised connection for the traditional owners.
At Sea Existing – Mackay	• No identified cultural heritage and no connection to landscape or island importance.
At Sea Existing – Hay Point	• No identified cultural heritage and no connection to landscape or island importance.
At Sea Mid – shelf Area	• No identified cultural heritage and no connection to landscape or island importance.

TABLE 21: COMMENTARY ON THE PERFORMANCE CRITERIA FOR EACH ALTERNATIVE

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Nature of interaction or disturbance – identified site	1	1	2	1	1	1
Nature of interaction or disturbance - landscape/ cultural connection	2	1	2	1	1	1
Impact on access to culturally important places	1	1	1	1	1	1
Total performance score	4	3	5	3	3	3

High performance
Medium performance
Low performance

TABLE 22: CULTURAL HERITAGE PERFORMANCE SCORES FOR EACH ALTERNATIVE (LOWER SCORE IS BETTER)

E) Port disruption

Theme:	Port Economics & Operation
Objective:	4. Maintain effective and efficient port operations
Measure:	E) Number of days disruption to port operations
	Unit of measure: Days
	Which direction of the measure is better? Lower

A critical aspect to sustainable sediment management at the Port of Mackay is providing a solution that ensures ongoing port efficiency but also provides for minimal disruption to port operations during the actual dredging and placement activity.

Disruptions to port operations are most likely while the dredge is operating in the berth and swing basin areas of the port. During these times other vessel movements may be limited and one or more berths may remain unoccupied for a longer period than usual. With some constraints on movement from other vessel traffic and tidal movements these disruptions can become extended and of some consequence.

Method of calculation

The maximum potential disruption has been calculated in days lost.

The timeframe for dredging campaign varies by option given the time taken to travel to the placement location and to deposit the material from the hopper either by opening the hopper doors or pumping to certain locations. Disruptions to port operations will only occur during the time the dredger is in the port area. **Based on this the following assumptions have been applied:**

- Approximately 120,000m^3 of maintenance dredging is required every five years to maintain effective and safe operation of the port.
- Disruption is counted as a whole day during the dredging campaign.

Results

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Days	11.6	19.4	11.6	6.4	9.3	14.6

TABLE 23: MAXIMUM DISRUPTION TIME FOR EACH ALTERNATIVE FOR (LOWER IS BETTER)

F) Lead time

Theme:	Port Economics & Operation
Objective:	4. Maintain effective and efficient port operations
Measure:	F) Predicted lead time to dredge material placement
	Unit of measure: Years
	Which direction of the measure is better? Lower

Maintaining effective port operations is a critical component of the decision making process for sustainable sediment management at the Port of Mackay. One of the factors to consider around this objective is the implementation time for each of the alternatives (e.g. how long it will take to plan, get approval, and prepare works).

Method of calculation

The lead time for each alternative was calculated based on industry experience in relation to the following key preparatory stages:

- **Research/studies:** prior to commencing or planning an action it may be necessary to gather additional information, scientific data, knowhow or develop technology. This may include background research, field/ocean studies, feasibility, environmental constraints and management, and design.
- **Engineering design:** Detailed design work.
- **Planning and approval:** For example, work required to prepare management plans (e.g. environment, health and safety) and apply for regulatory approvals (applications, assessment processes).
- **Construction:** Construction works required to prepare each alternative for dredge material placement (e.g. site preparation, construction of bunds, etc).

The following assumptions were made in calculating lead times:

- Where time periods might overlap subsequent time estimates are based on the additional time period required to complete the stage. Accordingly, time periods are cumulative not overlapping.
- Alternatives that involve new approaches, have significant environmental risks or involve locations where little environmental information is available will require considerable time to work through the earlier three stages (research, design, planning and approval).

Results

Alternative	Commentary
Reclamation Mackay	• Reclamation activities are well understood; short term investigations on coastal process and environmental impacts would be required, followed by engineering and management design. • A number of approvals would be necessary at National, State and local level. • Construction estimated at 1 year.
Habitat Creation Area	• Significant investigation is needed into the techniques to be applied, location and logistics of this activity. Mangrove rehabilitation is well practised and proved but good local planning is required to ensure success. • A number of approvals would be necessary possibly at National, State and local level. • Minimal construction time is anticipated.
Onshore Mackay	• Onshore placement activities are well understood; short term investigations on local topography, avoidance of adjacent activities and environmental impacts would be required, followed by engineering and management design. • A number of approvals would be necessary possibly at National, State and local level. • Construction estimated at approximately 9 months.
At Sea Existing – Mackay	• Extensive knowledge and data already exists for this location and the likely impacts that may result. No engineering design or construction is required. • Statutory approval times are moderate.
At Sea Existing – Hay Point	• Extensive knowledge and data already exists for this location and the likely impacts that may result. No engineering design or construction is required. • Statutory approval times are moderate.
At Sea Mid–shelf Area	• Some knowledge and data already exists for this location further oceanographic modelling and environmental studies will be necessary. • No engineering design or construction is required. • Statutory approval times are moderate.

TABLE 24: COMMENTARY ON THE LEAD TIMES FOR EACH ALTERNATIVE

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Research/studies	0.5	3	1	-	-	0.5
Engineering design	0.5	0.5	0.5	-	-	-
Planning and approval	2	1.5	2	-	-	1
Construction	1	0.5	0.75	-	-	-
Total # of years	**4**	**5.5**	**4.25**	**0**	**0**	**1.5**

TABLE 25: LEAD TIME FOR EACH ALTERNATIVE

G) Long term solution

Theme:	Port Economics & Operation
Objective:	4. Maintain effective and efficient port operations
Measure:	G) Capacity to provide a long term solution for the port
	Unit of measure: Years
	Which direction of the measure is better? Higher

A critical aspect to sustainable sediment management at the Port of Mackay is providing a long term solution that can address the requirements of multiple dredging campaigns. A well designed and implemented long term solution will provide certainty for all stakeholders and the best outcomes across the various project themes (environment, cultural heritage, port economics and operation, health and safety, social, innovation, and World Heritage).

Method of calculation

The maximum potential timeframe that each alternative could operate was determined by:

- Assuming:
  - **A.** 120,000m^3 - 150,000m^3 of maintenance dredging is required every five years to maintain effective and safe operation of the port.
  - **B.** The first dredge campaign starts in year 0. Therefore, a maximum capacity of 1 dredge campaign would have a timeframe of five years, two campaigns would be ten years, and so on.
  - **C.** A total timeframe of 25 years.
  - **D.** No lead time for any of the alternatives (e.g. related to planning and approvals). Lead time is addressed specifically in performance measure F.
- Considering the maximum capacity of each alternative to receive dredge material over that time.

Results

Alternative	Commentary
Reclamation Mackay	• Due to the large tidal range in the area and the relatively high cost for construction, this alternative has been configured to contain the volume from five maintenance dredging campaigns.
Habitat Creation Area	• The habitat creation area has been designed to contain the volume from a single maintenance dredge campaign. • However, it has the potential to be expanded and for the purposes of this analysis it is assumed that it could contain the volume from two maintenance dredging campaigns.
Onshore Mackay	• Both of the onshore pond concept designs have been initially configured to contain the volume from a single maintenance dredging campaign. • Two options are considered realistic for the ponds to enable them to contain additional volumes of material from future campaigns: - Remove the dry material from the pond to create sufficient capacity for the subsequent maintenance dredging campaign. A suitable site for disposing of the dry material, or a reuse option for the material would be required. - Increase the height of the bunds to increase the capacity of the pond. It is possible that some of the dry material could be used to increase the bund heights, although additional imported material would be expected to be required to improve the quality of the sediment. • It is assumed for the purposes of this analysis that the capacity of the onshore ponds could be increased to contain the volume from five maintenance dredging campaigns. The additional costs associated with this are addressed in the cost performance measure.
At Sea Existing – Mackay	• All of the at sea dredge material placement areas have the capacity to contain significant volumes. For the purposes of this analysis it is assumed they can contain the maximum required volume from five maintenance dredging campaigns.
At Sea Existing – Hay Point	
At Sea Mid – shelf Area	

TABLE 26: COMMENTARY ON THE CAPACITY OF EACH ALTERNATIVE TO RECEIVE DREDGE MATERIAL

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Maximum capacity (campaigns)	5	2	5	5	5	5
Maximum capacity (years)	**25**	**10**	**25**	**25**	**25**	**25**

TABLE 27: MAXIMUM CAPACITY OF EACH ALTERNATIVE TO RECEIVE DREDGE MATERIAL

H) Cost

Theme:	Port Economics
Objective:	5. Ensure solution is cost effective
Measure:	H) Assessment of costs
	Unit of measure: AUD millions and Present Value
	Which direction of the measure is better? Lower

All stakeholders recognised that cost was an important criteria to assess when considering the alternatives for long term sustainable sediment management at the Port of Mackay. Ensuring that solutions are cost effective is critical.

Method of calculation

It is important to note that the assessment of cost used here does not attempt to provide a full, detailed costing of each option. Rather it takes a high level approach to determine the rough order of magnitude (ROM) costs for each alternative using present dollar values.

Cost estimates are provided for each alternative in relation to an initial single dredge campaign, noting that the habitat creation option assumes no supporting engineered wall, bunds or structures are required.

Results

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Site preparation & land based access		$0.50	$0.1			
Earthworks & bund formation			$5.3			
Rockwall construction	$18.0					
Weir boxes			$0.02			
Geotextiles	$0.18	$0.4	$3.4			
Perimeter drainage			$0.9			
Monitoring		$0.3				
Miscellaneous		$0.2	$0.5			
Dredging (Inc. Transport and pumping/placement)	$3.5	$1.0	$3.5	$0.81	$1.12	$1.53
Cost estimate	$21.7	$1.69	$13.72		$1.12	$1.53
Contingencies	20%	30%	20%	10%	10%	10%
Total (excl GST)	**$29.86**	**$2.19**	**$16.46**	**$0.82**	**$1.13**	**$1.68**

TABLE 28: COST ESTIMATES FOR OPTIONS FOR A SINGLE DREDGE CAMPAIGN - $ MILLION

I) SPL affected

Theme:	Port Economics & Operation
Objective:	6. Avoid significant loss of future port expansion opportunities
Measure:	I) Strategic Port Land (SPL) affected
	Unit of measure: Hectares
	Which direction of the measure is better? Lower

Maintaining effective port operations and future port development opportunities is a critical component of the decision making process. One of the factors to consider around this objective is the impact of each of the alternatives on the statutory designated port land in the Port of Mackay. Strategic Port Land (SPL) is set aside through the planning system to facilitate the operation and development of port related activities.

Method of calculation

The area potentially affected by each alternative was calculated based on the location and land area needed to deliver each alternative. Calculations include maritime port area that may also be used to facilitate port activities in the future.

Results

Alternative	Commentary
Reclamation Mackay	• Reclamation activities will occur on both land and maritime area within the port boundary. The poor load bearing nature of the reclamation will make this area unsuitable for primary port operations. There will be a loss of SPL of 40 ha.
Habitat Creation Area	• Habitat creation will primarily be in tidal areas away from existing port infrastructure. A small loss of 20 ha of SPL is expected as a result of the immediate onshore areas that will be included as part of this option and the areas for staging ponds that would be lost to any future port development.
Onshore Mackay	• Onshore placement will occur on port land within the port boundary. This will result in a loss of SPL of 50 ha
At Sea Existing – Mackay	• Placement is outside of SPL but within port limits.
At Sea Existing – Hay Point	• Placement is outside of SPL but within port limits.
At Sea Mid – shelf Area	• Placement is outside of port limits.

TABLE 29: COMMENTARY ON THE LEAD TIMES FOR EACH ALTERNATIVE

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
SPL impacted (ha)	40	20	50	0	0	0

TABLE 30: SPL POTENTIALLY AFFECTED BY EACH ALTERNATIVE (LOWER IS BETTER)

J) Human health and safety

Theme:	Human Health and Safety
Objective:	7. Avoid or mitigate health and safety risks
Measure:	J) Relative risk
	Unit of measure: Performance score ranging from 8-24
	Which direction of the measure is better? Lower

The potential impacts on human health and safety was an important criteria to assess when considering the alternatives for long term sustainable sediment management. To assess this component, a range of human health and safety measures were developed along with some simple performance criteria to rank them.

Method of calculations

It is important to note the process is not intended to replicate a full risk assessment (based on unmitigated and mitigated risks derived from likelihood and consequences of various activities). Rather it takes a high level approach around potential risk pathways and complexity. More detailed assessment will be considered for the preferred alternative as part of any future project planning and management.

For each alternative, each measure is assessed against the performance criteria and graded (see Table 31). A total performance score for each alternative is then derived from the sum of performance criteria.

The performance scores for the long term options were taken from the worst performing component of that option.

Performance Criteria			
Measures	High (Score = 1)	Medium (Score = 2)	Low (Score = 3)
Interaction with public areas	Remote from public areas or is in an area of low public usage	Regular interaction with public areas but is able to be easily managed	High use public area requiring ongoing management
Dust and emissions	No dust or emissions expected above natural air quality variants	Dust or emissions expected but is able to be managed easily	Dust or emissions requiring ongoing management
Duration of activity (influences likelihood of occurrence)	0 - 2 weeks	2 weeks – 8 weeks	> 8 weeks
Spills and contaminants	Limited sources of spills or contamination in easily contained environment	Multiple sources of spill or contamination over single onsite area	Multiple sources of spill or contamination extending to multiple offsite areas
Heavy vessel / machinery interaction	Single vessel or machinery only	Multiple vessels or machinery with limited interaction with each other	Multiple vessels or machinery with regular interaction with each other
Isolated areas – proximity to medical support	Access to medical support similar to normal regional services	Short delays (hrs) in obtaining normal regional medical support	Long delays (days) in obtaining normal regional medical support
Weather exposure	Able to easily retreat in adverse weather	Short delays (hrs) in seeking retreat in adverse weather	Long delays (days) in seeking retreat from adverse weather
Personnel requirements	Small (<10) workforce in single location	Small to medium (up to 20) workforce working across multiple locations	Medium to large (>20) workforce operation across multiple locations

TABLE 31: HUMAN HEALTH AND SAFETY MEASURES AND PERFORMANCE CRITERIA

Results

Alternative	Commentary
Reclamation Mackay	• Location will require access restrictions and fencing • Long term (>8 weeks) construction period • Increase in dust is possible • Import of construction material by heavy vehicle and multiple traffic movements • Multiple ongoing machinery interactions • Ongoing management during operational phase will be required
Habitat Creation Area	• Remote location on boundary of Strategic Port Land • Short term (4 weeks) construction of retaining walls and material handling facilities • Multiple machinery requirements with limited direct interaction with each other • Short-term management of small workforce
Onshore Mackay	• Location will require access restrictions and fencing • Medium term (<8 weeks) construction of retaining walls and material handling facilities • Increase in dust possible • Multiple machinery requirements with direct interaction with each other • Medium-term management of medium workforce
At Sea Existing – Mackay	• Maritime location with limited public activity • Single dredger with limited interaction with other machinery • Small to medium workforce, on single vessel
At Sea Existing – Hay Point	• Maritime location with limited public activity • Single dredger with limited interaction with other machinery • Small to medium workforce, on single vessel
At Sea Mid – shelf Area	• Maritime location with limited public activity • Single dredger with limited interaction with other machinery • Small to medium workforce, on single vessel

TABLE 32: COMMENTARY ON THE HUMAN HEALTH AND SAFETY PERFORMANCE OF EACH ALTERNATIVE

Sensitive receiver locations	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Public Interaction	3	1	2	1	1	1
Dust and Emissions	2	1	2	1	1	1
Duration	3	1	3	1	1	2
Spills and Contamination	2	2	2	1	1	1
Machinery Interaction	3	2	3	1	1	1
Isolation - medical	1	1	1	1	1	2
Retreat	1	1	1	1	1	2
Personnel	1	1	2	1	1	1
Total score	**16**	**10**	**16**	**8**	**8**	**11**

- High performance
- Medium performance
- Low performance

TABLE 33: HUMAN HEALTH AND SAFETY PERFORMANCE SCORES FOR EACH ALTERNATIVE (LOWER IS BETTER)

K) Social performance

Theme:	Social
Objective:	8. Minimise interference to social activities within the region
Measure:	K) Scale and duration of any impacts on social activities
	Unit of measure: Performance score ranging from 3 - 9
	Which direction of the measure is better? Lower

The Mackay region supports a population of 200,000 people. Of these 14.4% are aged 65 years and above, 7.3% are born overseas and 4.1% identify as being Indigenous. In the area, 46.8% of households are couples with children. The top three employment sectors in the area are transport, postal and warehousing, agriculture, forestry and fishing, and construction. People holding a non-school qualification make up 47.6% of the population.

The coastal areas and inner waters of the GBR around Mackay support a range of social and commercial activities, including: farming, commercial fishing, recreational fishing, boating, informal recreation (swimming, surfing, walking). People living in the area need to access a wide range of services from Mackay.

The sustainable sediment management project aims to further improve the management of port sediments while ensuring the continued operation of the port, social and cultural features are respected and that environmental values are protected.

Method of calculation

The performance criteria for each alternative was calculated based on:

- The nature of any interaction with social features or activities.
- The length of time any interaction or disturbance will occur for.
- Number of people affected.

Performance Criteria			
Measures	High (Score = 1)	Medium (Score = 2)	Low (Score = 3)
Nature of interaction or disturbance	None or positive	Results in a need for alteration or relocation of an area or activity	Activity must cease.
Duration of interaction	None	Short to medium term – life of the dredging campaign.	Permanent or long-term
Number of people affected	None	Small numbers of participants, single interest group (1 to 30 people)	Larger numbers (+30) or multiple interest groups, whole community.

TABLE 34: SOCIAL PERFORMANCE CRITERIA

Results

Alternative	Commentary
Reclamation Mackay	• Direct removal and permanent alteration of an area of 26 ha of inshore marine area adjacent to the northern breakwall. This area is known to be used by surfers and suitable wave action in this location may be lost.
Habitat Creation Area	• An area of 70 ha will be altered as dredge material is placed within a bund to create the habitat area • No known social activities are know from the site, the area is on and adjacent to port land.
Onshore Mackay	• An area of 50 ha will be altered as dredge material is placed within a bund system. • No known social activities are know from the site, the area is on port land. However, some disturbance to adjacent industrial activities, road ways etc can be anticipated.
At Sea Existing – Mackay	• No specific activities are known for the location, some minor disruption to fishing and boating activity may result.
At Sea Existing – Hay Point	• No specific activities are known for the location, some minor disruption to fishing and boating activity may result.
At Sea Mid –shelf Area	• No specific activities are known for the location.

TABLE 35: COMMENTARY ON THE PERFORMANCE CRITERIA FOR EACH ALTERNATIVE

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Nature of interaction	3	1	2	1	1	1
Duration	2	1	2	1	1	1
Number of people affected	2	1	3	1	1	1
Total performance score	**7**	**3**	**7**	**3**	**3**	**3**

High performance

Medium performance

Low performance

TABLE 36: SOCIAL PERFORMANCE SCORE FOR EACH ALTERNATIVE (LOWER SCORE IS BETTER)

L) Employment

Theme:	Social
Objective:	9. Provide increased economic and social opportunities
Measure:	L) Predicted number of FTE jobs created
	Unit of measure: Full Time Equivalent (FTE) jobs created
	Which direction of the measure is better? Higher

As part of the broader social theme, a positive consideration would be to measure and compare the jobs created by each option. In particular local job creation is seen as important as it will contribute to the regional economy and enhance the social fabric of the region. Jobs created at a broader level are also of value but for the purposes of comparison have been weighted at a lower factor.

Method of calculation

For each management option the forecast number of part-time and full time jobs (if any) has been determined to create an overall jobs score. All jobs created have been included in the comparative analysis, however the calculations below for the 25 year time frame have applied a different multiplier to the jobs in the local (Mackay) region (x1) at a national level (x 0.5) and internationally (x 0.25). Indirect jobs supported or created beyond the region (such as work for regulatory agencies, consultants etc.) are not included as they are too intangible for inclusion.

Full-time Equivalent (FTE) is a unit equivalent of a full-time employee's workload. It represents a business's total number of full-time equivalent employees by summing the total hours worked by employees, both full and part-time, then dividing by the number of working hours available in a given period (days, week or year). In this way, it is used to determine the number of full-time equivalents regardless of the number of actual employees and variations in the number of hours worked during a period.

The formula used is:

$$\text{Number of employees X } \frac{\text{number of hours worked}}{\text{number of available working hours}}$$

$$\text{e.g. } \frac{3 \times 20}{(3 \times 40)} = 0.5$$

In this instance the formula has been based on a yearly period to account for full time, part time and contract personnel who may work full time for a period of weeks rather than a full year. A worked example is shown in the table below.

Employment profile	# of personnel	FTE
Full time all year	1 person	1
Part time all year	2 people x 2 days a week (2 x 2/5 = 0.8)	0.8
Full time part year (e.g. 3 months)	20 personnel x 12 weeks (20 x 12/52 = 4.6)	4.6
Totals	**23 individuals**	**6.4 FTE**

The calculations for the mixed alternatives over the 25 year period are based on an annual FTE multiplied by the weightings as follows.

- Local by 1.0
- National by 0.5
- International by 0.10

Results

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Local (FTE)	4.96	1.08	2.23	0	0	0
National (FTE)	1	1	1	0.5	0.5	1
International (FTE)	-	-	-	-	-	-
Adjusted (FTE)	**5.46**	**1.58**	**2.73**	**0.25**	**0.25**	**0.5**

TABLE 37: FTE PERFORMANCE SCORES FOR EACH ALTERNATIVE BASED ON A SINGLE CAMPAIGN (HIGHER SCORE IS BETTER)

M) Innovation

Theme:	Innovation
Objective:	10. Promote innovation in port management
Measure:	M) Ability of a solution to advance current dredging practice information, technology and techniques
	Unit of measure: Performance score ranging from 3-9
	Which direction of the measure is better? Higher

In line with the 'net benefits concept' promoted in the Reef 2050 Plan and various findings from the Independent Review of the Port of Gladstone it is desirable to seek and examine new port and environmental management options that promote best practice and deliver improved sustainable solutions.

Innovation can be defined as the deliberate application of information, technology and ingenuity in deriving greater or different values from a process. Within the broader comparative analysis a consideration of the innovative status of an option may make that option more attractive or worthy of greater consideration if it demonstrates usefulness beyond the Port of Mackay. Accordingly, stakeholders were of the opinion that the innovative nature of alternatives should inform the decision making process.

Throughout Australia and internationally a variety of approaches and solutions are already used to maintain navigational infrastructure areas, these approaches include:

- Upstream controls of sediment sources (erosion reduction, sediment traps etc).
- Sediment bypass systems.
- Sediment agitation to move sediment from port areas.
- Recycling of sediment back into the originating marine or land environment.
- Reuse of sediment for beach nourishment, reclamation, construction, habitat rehabilitation/creation.
- Dredging and material placement.

Method of calculation

An assessment of the innovative nature of possible options has been undertaken using a small set of performance criteria as a means of examining if the options offer solutions to advancing current dredging practice information, technology and techniques.

For each alternative an innovation performance score is determined through an analysis against the criteria.

Performance Criteria			
Measures	High (Score = 3)	Medium (Score = 2)	Low (Score = 1)
Application of information	Provides an opportunity to trial new approaches and enhance current knowledge base	Provides an opportunity to apply recent knowledge advances in a practical manner	Is well understood and offers limited opportunities for new learning
Application of technology/techniques	Requires the imaginative use and development of new technology or techniques	Requires the application of recently developed technology or techniques	Uses known and existing technology or techniques
Use of ingenuity	Offers a new solution that could enhance environmental or business outcomes	Is a rarely used option that if effective could reduce adverse environmental or business outcomes	Is a well established option that produces known and expected results

TABLE 38: INNOVATION MEASURES AND PERFORMANCE CRITERIA

Results

It is important to note that few ports have exactly the same scenario in terms of material type, volumes, land/sea availability. This analysis has assumed that circumstances are favourable for a wider application of options. Each port and each scenario would need to be assessed taking into account the needs and situation at an individual port.

Alternative	Commentary
Reclamation Mackay	• Reclamation is a well established and understood activity based around existing techniques
Habitat Creation Area	• Habitat creation offers significant opportunities to trial new approaches and enhance the current knowledge base • The activity has been done before in a limited number of cases and will be based on the application of recently developed techniques • It potentially offers a new solution to other ports that could enhance environmental and business outcomes
Onshore Mackay	• Onshore placement is a well established and understood activity based around existing techniques
At Sea Existing – Mackay	• Placement of dredge material at the existing placement area is a well established and understood activity based around existing techniques
At Sea Existing – Hay Point	• Placement of dredge material at the existing placement area is a well established and understood activity based around existing techniques
At Sea Mid – shelf Area	• Placement of dredge material at sea is a well established and understood activity based around existing techniques • Mid-shelf placement has not been undertaken frequently, modelling and monitoring results would be informative to other ports and future activities.

TABLE 39: COMMENTARY ON THE INNOVATION PERFORMANCE OF EACH ALTERNATIVE

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Information	1	3	1	1	1	2
Technology	1	2	1	1	1	1
Ingenuity	1	3	1	1	1	2
Total score	**3**	**8**	**3**	**3**	**3**	**5**

High performance

Medium performance

Low performance

TABLE 40: INNOVATION PERFORMANCE SCORES FOR EACH ALTERNATIVE (HIGHER SCORE IS BETTER)

N) World Heritage performance

Theme:	World Heritage
Objective:	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area
Measure:	N) Scale and duration of activity within the Great Barrier Reef World Heritage Area
	Unit of measure: Performance score ranging from 4 - 12
	Which direction of the measure is better? Higher

North Queensland Bulk Ports (NQBP) operates three ports within the Great Barrier Reef World Heritage Area (GBRWHA). Ensuring that the potential for direct impacts and increased operational activities from different alternatives within the GBRWHA was important to capture in the decision making process.

Method of calculation

The performance criteria for each alternative was calculated based on:

- The size of the seabed area within the WHA directly altered by the sediment management alternative.
- The length of time the alteration to the seabed within the WHA will occur.
- The time it takes to complete the dredger operational activities associated with a single dredge campaign within the WHA.
- The potential risk to adjacent values that contribute to the WHA.

The following assumptions have been made when calculating the performance criteria for each alternative:

- Scale of change has been calculated by intersecting the spatial footprint of each alternative with the most current GBRWHA spatial layer.
- Analysis of the duration of change to the GBRWHA represents a worst-case scenario of possible direct impacts. It is therefore assumed that the maximum direct changes would occur during the initial dredge campaign.
- All alternatives assume the use of the TSHD Brisbane that has a maximum hopper capacity of 2,900 m3.

Performance Criteria			
Measures	High (Score = 3)	Medium (Score = 2)	Low (Score = 1)
Scale of change within GBRWHA	Small or no change to GBRWHA (<5 ha)	Moderate change to GBRWHA (5-15 ha)	Large change to GBRWHA (> 15 ha)
Duration of change within GBRWHA	Positive or no change to GBRWHA	Short to medium term change to GBRWHA (recovery within 1-10 years)	Permanent or long-term change to GBRWHA
Duration of operational activities within GBRWHA	Short term operational activities within the GBRWHA (≤20 days)	Medium term operational activities within the GBRWHA (20-30 days)	Long term operational activities within the GBRWHA (>31 days)
Potential risk to values that contribute to GBR World Heritage	No identified risk	Low level risks, temporary or minor	Confirmed risk and potential impact to values

TABLE 41: GREAT BARRIER REEF WORLD HERITAGE PERFORMANCE CRITERIA

Results

	Reclamation Mackay	Habitat Creation	Onshore Mackay	At Sea Existing – Mackay	At Sea Existing – Hay Point	At sea Mid-shelf
Scale of change	1	2	3	1	1	1
Duration of change	1	3	3	2	2	2
Duration of operational activities	3	3	3	3	3	3
Risk to adjacent values	3	3	2	3	3	3
Total performance score	8	11	11	9	9	9

High performance

Medium performance

Low performance

TABLE 42: WORLD HERITAGE PERFORMANCE SCORE FOR EACH ALTERNATIVE (HIGHER SCORE IS BETTER

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