Port of **Mackay**

Appendix H

Economic Impact of No Maintenance Dredging

Economic impact of no maintenance dredging at the Port of Mackay

Final Report to North Queensland Bulk Ports

August 2021

Synergies Economic Consulting Pty Ltd
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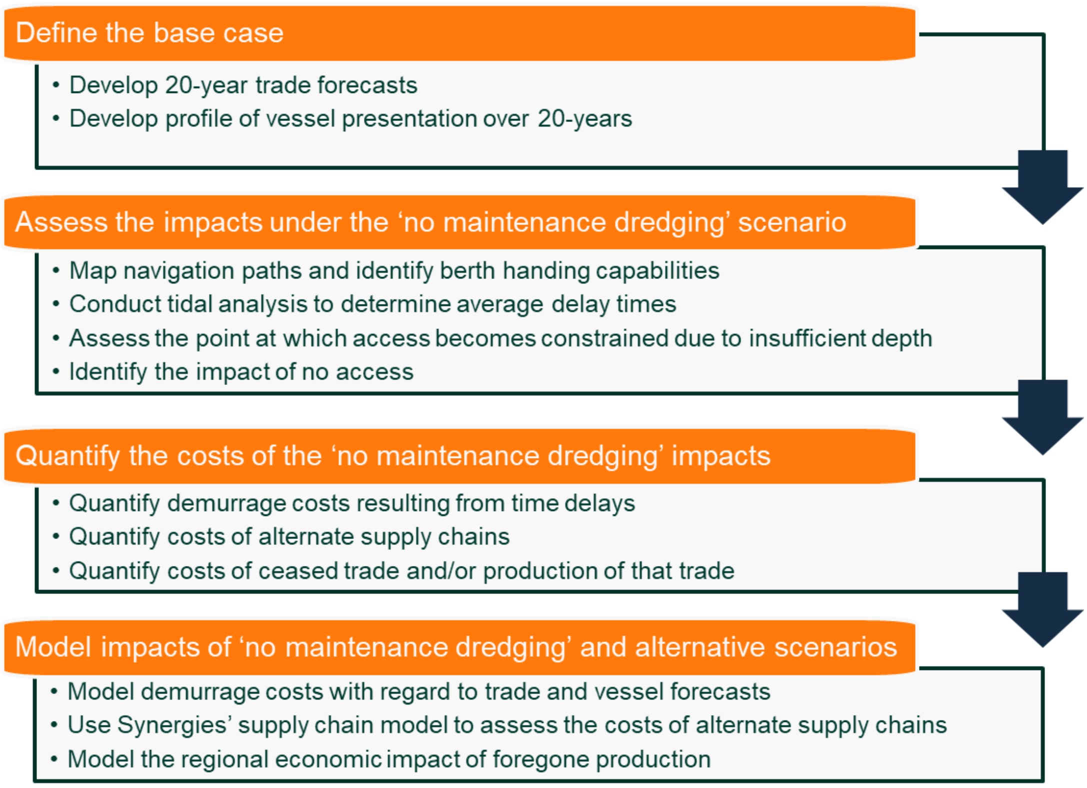
Executive Summary

North Queensland Bulk Ports (NQBP) is currently undertaking a Sustainable Sediment Management (SSM) assessment for the Port of Mackay. The purpose of the SSM assessment is to determine a preferred approach to long term sediment management within the Port to ensure safe and efficient operation into the future. The SSM assessment involves undertaking a series of studies or investigations to understand how and why sediment enters the port, the need for and best approach to manage that sediment. The SSM assessment also includes the use of a structured decision-making process focused on what is important to all stakeholders, not just the port authority and port customers. Synergies Economic Consulting (Synergies) was engaged as part of the SSM assessment to undertake an independent analysis of the economic impacts of not undertaking maintenance dredging at the Port. The approach applied to undertake this assessment is summarised in the figure below.

Assessing the economic costs of no maintenance dredging



Data source: Synergies.

The three key impacts[1] identified as occurring as a result of increasing sedimentation include:

- Increased vessel delays – Increasing sedimentation in the port areas impacts the window of accessibility for vessels to access berths. This constraint creates vessel delays, which has impacts on vessel and crew holding costs, manifesting in increased demurrage costs that are passed on to customers[2];
- Trade diversion – Where vessels are no longer able to be accepted at Port of Mackay due to depth constraints, the trades will be diverted to alternative supply chains, resulting in additional economic costs being incurred. These additional costs include land transport costs, port and port terminal costs, and externality costs (e.g., increased greenhouse gas emissions) resulting from the alternate supply chain movement.
- Loss of economic output – This economic impact arises where the production and trade of a commodity ceases due to constraints at the Port of Mackay and diverting to an alternative supply chain is not commercially viable.

The magnitude of the constraints on vessel access to the Port of Mackay and of the associated economic impacts was assessed based on trade volume and associated vessels forecasts for the 20-year analysis period. This incorporated analysis of tidal data provided by NQBP, and the depths identified in the Port & Coastal Solutions (PCS) future sedimentation analysis. Tidal data was assessed to determine the likely duration for which vessels with different draft requirements would be delayed in entering and exiting the port due to reduced port depth. Tidal tiers were identified, and an average wait time was calculated for each tier. The results of this analysis are presented in the figure below, showing the increasing delay times (indicated by tier 1 to tier 5) and the point at which total access is constrained.[3]

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[1] Reduced vessel loadings were also examined as a potential impact; however it was found that in no case was de-loading and adding additional vessels to move the same tonnages a commercially viable solution. Further, the vessels presenting at Port of Mackay are part of larger international supply chains therefore it is highly unlikely that shippers would change to smaller vessels to access the Port of Mackay.

[2] The modelling has shown that incurring the additional delay costs will be accepted by shippers until such time as the vessel is unable to be accommodated at the port due the insufficient depth.

[3] Average wait times for each tidal tiers are: T1 – 0.31 hrs, T2 – 2.28 hrs, T3 – 4.99 hrs, T4 – 7.48 hrs, T5 – 10.08 hrs, T6 – 11.66 hrs, T7 – 12.00 hrs.

Tidal and sedimentation impacts on vessel operations

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Petroleum																				
P-Shallow	T1	T1	T1	T2	T2	T2	T2	T3	T3	T3	T3	T3	T3	T4	T4	T4				
P-Medium	T2	T3	T3	T3	T3	T3	T3	T4	T4	T4	T4	T4								
P-Deep	T3	T4	T4	T4	T4	T4	T4	T5	T5											
Raw Sugar												T1	T1	T2	T2	T2	T2	T3	T3	T4
Refined Sugar								T1	T1											
Grain												T1	T1	T2	T2	T2	T2	T3	T3	T4
Magnetite	T1	T1	T1	T1	T1	T1	T2	T2	T2	T3	T3	T3	T3	T4	T4	T4				
Breakbulk					T1	T1	T1	T1	T1	T2	T2	T2	T2	T3	T3	T3	T4	T5	T5	T5
Fertiliser	T1	T1	T1	T1	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4	T4	T4				
Molasses	T2	T2	T2																	
Scrap Metal								T1	T1	T1	T1	T2	T1	T2	T3	T3	T3	T4	T4	T4
Ethanol	T1	T1	T1	T2	T2	T2	T2													
Cement								T1	T1	T1	T1	T2	T1	T2	T3	T3	T3	T4	T4	T4
Machinery								T1	T1	T1	T1	T2	T2	T3	T3	T3	T3	T4	T4	T4

No constraint | Tidal constraint | Total constraint

Note: 'T' denotes Tidal Tier and each tier represents an expected average waiting time. The higher the tier, the greater the wait time.
Data source: Synergies analysis.

The figure shows that there is no situation where delays exceed tidal tier 5 (10.08 hours). This is because where tidal impacts above Tier 5 occur for some commodities, the berth is constrained regardless due to increased sedimentation in the berth pocket. The majority of vessels experience a delay time of less than 4.99 hours (tidal tier 3). After the first three years, however, access to the port progressively becomes entirely restricted for various vessels, resulting in either trade diversion (where commercially viable) or loss of economic output.

Results

The total economic costs under the 'no maintenance dredging' scenario were estimated to be $224.0 million in Net Present Value (NPV)[4] terms over the 20-year analysis period. The following economic costs associated with the above impacts were modelled:

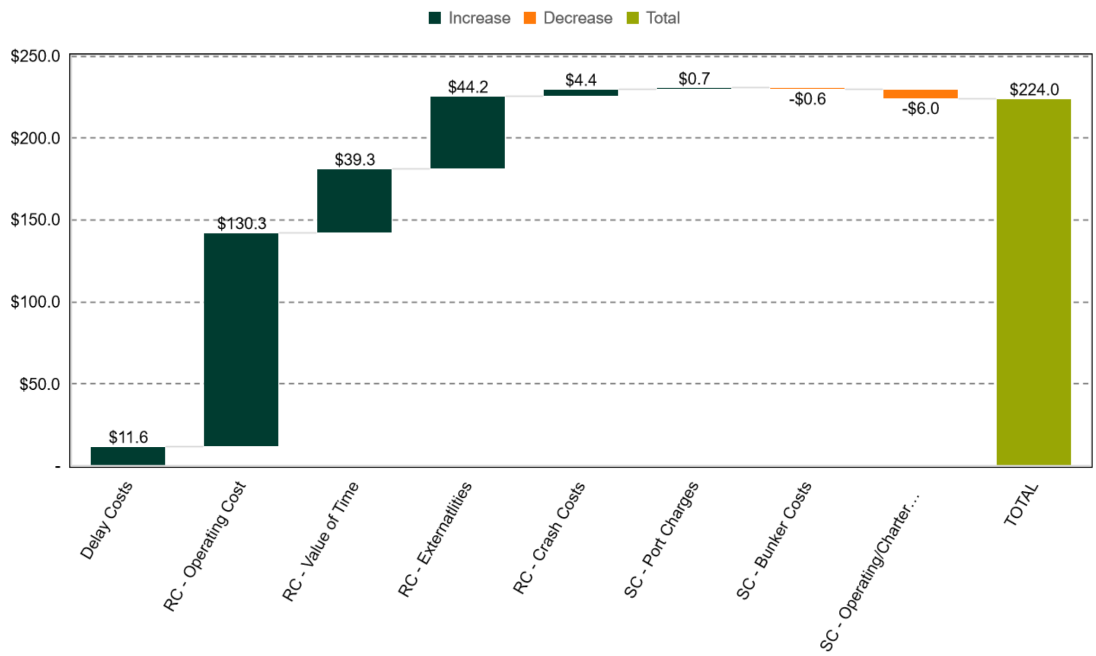
- Delay costs – bunker cost and charter cost
- Road costs – operating cost, value of time, externalities, and crash costs
- Shipping costs – port charges, bunker costs, and operating/charter costs.

As shown, the costs largely are attributable to road costs. This signifies that the impact of 'no maintenance dredging' at the Port of Mackay leads to not only increased costs for shippers but also unfavourable outcomes for the community in terms of increased

[4] Based on a real discount rate of 7 per cent, consistent with the Queensland Government's Project Assessment Framework.

environmental impact of heavy vehicle traffic and cost to government of increased road maintenance costs.

Economic costs attributable to 'no maintenance dredging' scenario (PV terms)



Note: RC = Road costs; SC = Shipping costs

In addition to the economic costs, there are also wider regional economic impacts attributable to the 'no maintenance dredging' scenario, resulting from the loss of trade and production of ethanol and refined sugar. It was identified through industry consultation that the production of these products would no longer be commercially viable without the capacity to export the commodities through the Port of Mackay.[5]

The annual regional economic impacts from loss of production of these commodities totalled a loss of $100.1 million in regional output, $24.4 million in gross regional product, and 119 jobs, as shown in the table below.

Regional economic impacts of loss of ethanol and refined sugar production

Impact	Unit	Ethanol total impacts	Refined sugar total impacts
Gross output	$	-$52.84	-$47.28
Gross regional product	$	-$13.84	-$10.59

[5] While bioethanol production would cease entirely, refined sugar would instead be exported as raw sugar, therefore not impacting the net production of sugar in the region. Instead, there will be a loss of the value-add activities the region undertakes in turning raw sugar into refined sugar.

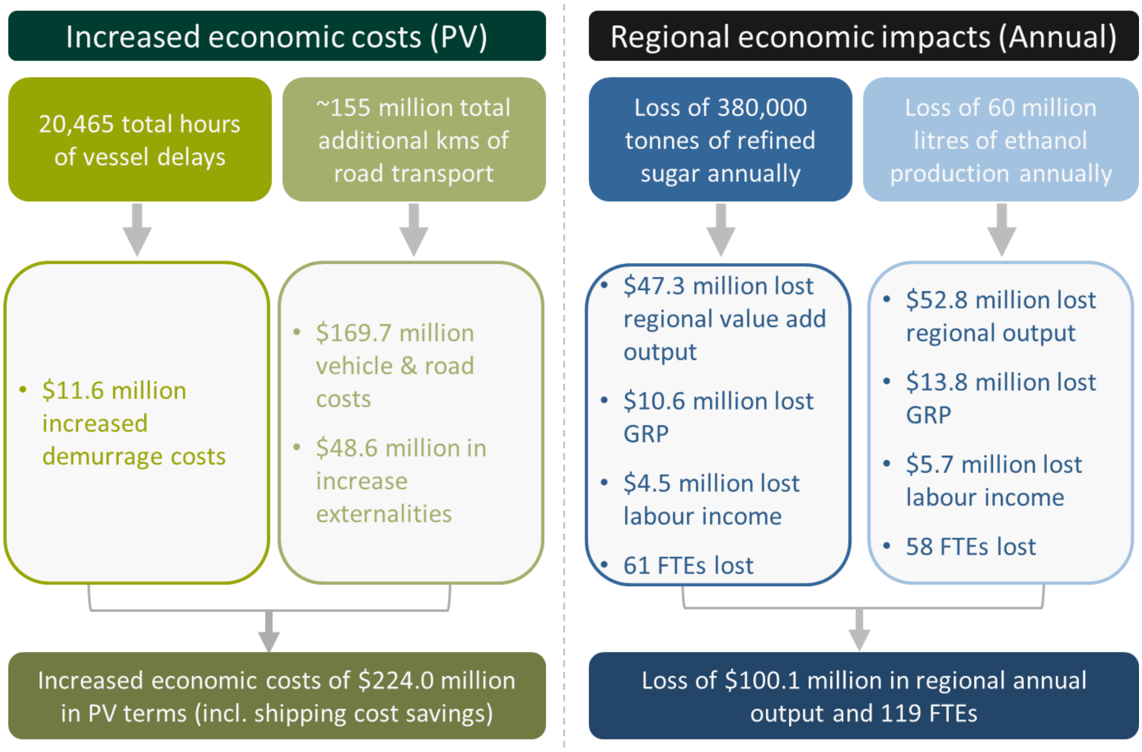
Impact		Unit	Ethanol total impacts	Refined sugar total impacts
	Labour income	$	-$5.67	-$4.53
	Employment	Full-time equivalent	-58	-61

Source: Synergies analysis.

Based on the above results, the key conclusions from the assessment of the economic impact of the 'no maintenance dredging' scenario for the Port of Mackay are as follows:

- Significant economic costs will be imposed on port customers, producers, and the regional economy, through increased transport costs, including negative externalities from increased heavy vehicle usage; and
- The loss of ethanol and refined sugar output will have a significant detrimental impact on the level of economic activity and employment in the regional economy.

The figure below presents total economic costs (present value) and annual economic regional impacts attributable to the 'no maintenance dredging' scenario for the Port of Mackay.



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1 Introduction

North Queensland Bulk Ports (NQBP) manages the Ports of Mackay, Hay Point, Abbot Point and Weipa. All are strategically significant connections between Queensland and the world, particularly in the food, energy, and metallurgical coal industries.

Maintaining safe and efficient port access is crucial to thousands of businesses and communities that depend on a seamless flow of goods through key port gateways in North Queensland. Critically, each of these ports are situated in highly sensitive environments, with three located in a World Heritage Area. Reflecting this, NQBP aims to take a leading approach to sustainable port management.

NQBP developed a Sustainable Sediment Management (SSM) assessment, which is an innovative approach to assessing sustainable approaches to the management of sediment. A SSM assessment has been completed for Port of Hay Point and Port of Weipa and is currently underway for Port of Mackay.

A central component of the SSM assessment is a structured decision-making process focused on what is important to all stakeholders, not just the port authority and port customers. This incorporates a detailed comparative analysis of the various alternatives that are available to manage sediment to determine the best long-term strategy.

Synergies Economic Consulting (Synergies) has been engaged to undertake an independent analysis of the economic impacts of not undertaking maintenance dredging at the Port, as part of the SSM assessment for Port of Mackay.

The remainder of the report is set out as follows:

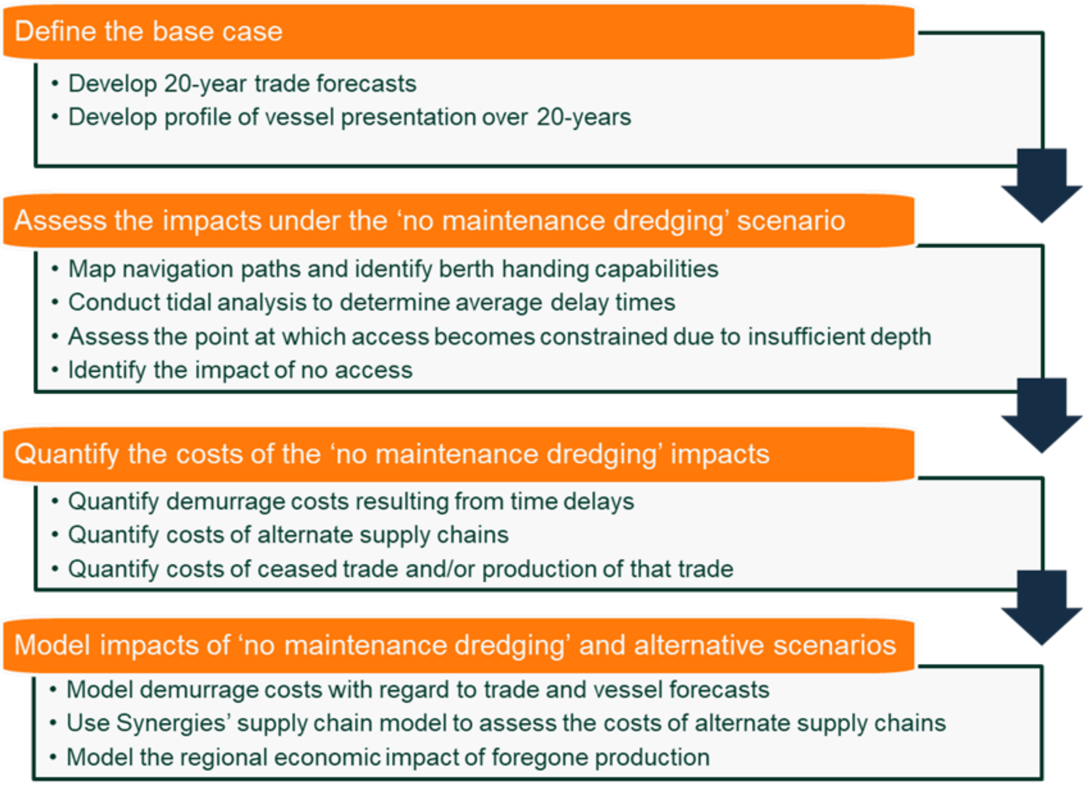
- section 2 provides a high-level summary of the approach taken;
- section 3 presents the base case analysis;
- section 4 presents the economic impacts and associated costs under the base case; and
- section 5 presents the results of the impact analysis, including results of modelling alternative scenarios.

The report also includes Appendix A, which provides an overview of Input-Output modelling.

2 Approach

The purpose of the assessment is to quantify the economic impact of the 'no maintenance dredging' scenario relative to the base case, being the scenario under which maintenance dredging is completed in accordance with the SSM assessment. Figure 1 provides a summary of the approach.

Figure 1 Overview of approach



Data source: Synergies.

2.1 Defining the base case

Assessing the economic impact of the 'no maintenance dredging' scenario requires the definition of the base case against which the changes to the port operations due to insufficient maintenance dredging are to be assessed. The base case represents the scenario under which the maintenance dredging is undertaken, and the depth of the harbour channels, swing basins and berth pockets are maintained at the level necessary to enable the safe navigation and loading/unloading of vessels.

The definition of the base case involved:

1) Development of trade projections for the Port of Mackay over the 20-year analysis period. This involved assessing the commodities handled at the port,

current and projected throughput levels, and consultation with NQBP to establish base trade projections for each commodity.

2) Development of a profile of vessel presentations at the Port of Mackay over the 20-year analysis period. This was based on data provided by NQBP on historic vessel presentations at the port and the trade projections developed for the analysis period. Typical vessel characteristics were developed for each commodity, including Gross Tonnage (GT); Deadweight Tonnage (DWT); draft (empty, fully laden, actual); cargo type; cargo volume, maximum loaded volume; cargo discharged/loaded; berth utilised; and time at berth.

2.2 Assessing impacts under 'no maintenance dredging' scenario

This step involved assessing the impact of the reductions in the depth of channels, swing basins and berth pockets under the 'no maintenance dredging' scenario for each commodity (and vessel type) handled at the port. This involved the following tasks:

- identifying the port areas through which the vessels are required to navigate to and from each berth and the capabilities of each berth in terms of handling each commodity type, recognising that some commodities are effectively 'tied' to a particular berth by reason of specific fixed equipment or infrastructure;
- identifying the depth required in each area of the harbour and berthing pockets to service each vessel type, using findings from the vessel analysis;
- with regard to the depths under 'no maintenance dredging' scenario for each year of the analysis, identifying the year at which the channels, berthing pockets and swing basins become constrained due to insufficient depth for each vessel/commodity type;
- determining the extent to which vessels are able to 'de-load' to mitigate insufficient depths and whether this is a commercially viable option;
- conducting tidal analysis to determine, for each year, the proportion of time during which vessels will be able to access berths and derive estimates for average delay time (upon arrival at and departure from port);
- determining the extent of delays for vessels that are tide restricted for each year of the analysis; and
- identifying alternative supply chains (e.g., diversion to another port, reduced production, or complete loss of trade) for those commodities that become

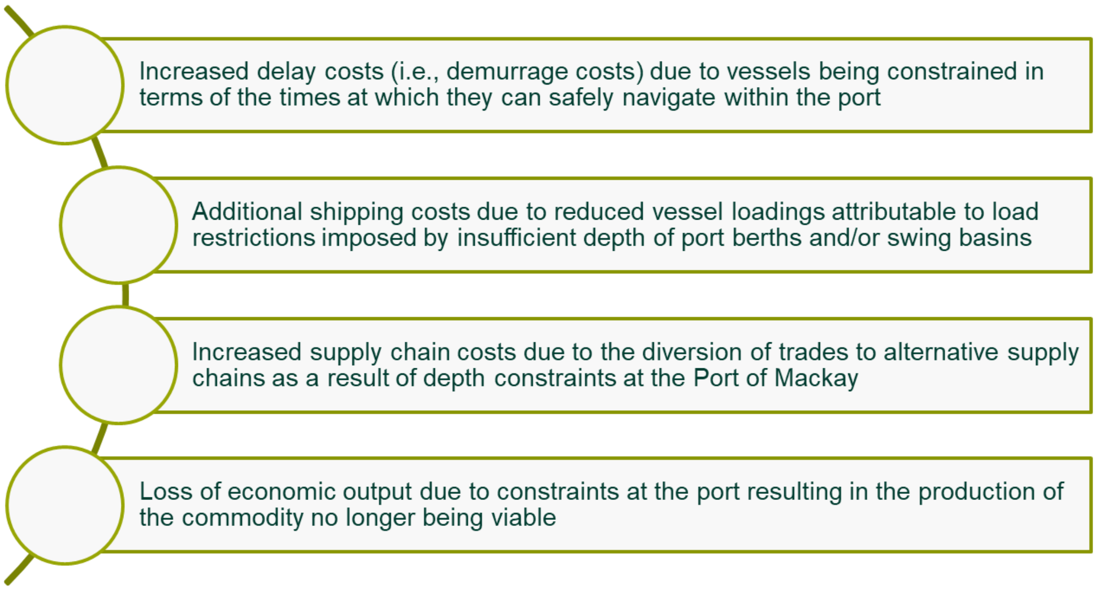
completely restricted from accessing the port areas due to tidal and depth constraints.

The analysis was conducted assuming current vessel characteristics remain constant over the analysis period.[6]

2.3 Modelling economic impacts

The four potential economic impacts under the 'no maintenance dredging' scenario are shown in Figure 2.

Figure 2 Potential economic impacts of no maintenance dredging



Data source: Synergies.

2.3.1 Assessing the economic cost of increased delays

Increasing sedimentation in the port areas impacts the window of accessibility for vessels to reach the berths, allowing for tides. This constraint creates vessel delays, as vessels must wait longer for tidal windows to arrive or depart the berth. The delays have impacts on vessel and crew holding costs, typically passed on to customers as demurrage costs.

6 The reasonableness of this assumption was confirmed with NQBP.

Box 1 Reduced vessel loadings as an alternative to increased demurrage costs

Where vessels are constrained, whether in the entrance channel, at the berth pocket, or in the swing basins, there is also the potential to reduce the vessel loading to ensure the vessel draft can be accommodated. The likelihood of this impact accruing is dependent on the magnitude of the cost of reducing vessel loadings relative to either incurring increased demurrage costs or diverting trades to other supply chains. This has been investigated, where appropriate, across the various commodities. The modelling showed that there was no situation where reducing vessel loads was more cost effective than either incurring increased demurrage costs or diverting trades to other supply chains. An example is presented in section 4.2.1.

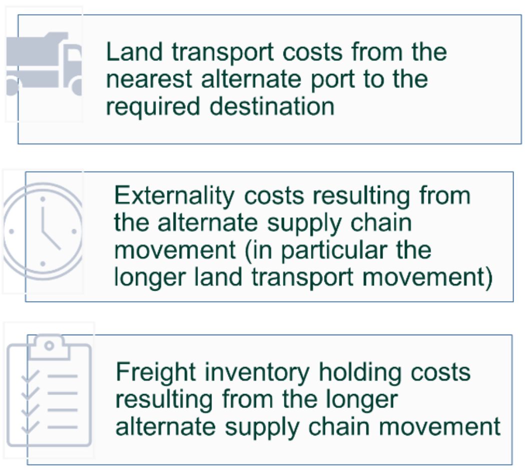
Data source: Synergies.

Increased vessel delay/demurrage costs were calculated for each trade over the 20-year analysis period. The average delay time estimated for each vessel type was based on the vessel projections and results from the tidal modelling. The cost associated with the average delay times were then quantified by applying the unit rate costs for bunker and charter costs in Synergies' in-house shipping model to derive demurrage costs.

2.3.2 Assessing increased supply chain costs

Where vessels are no longer able to be accepted at the Port of Mackay due to depth constraints, further economic costs will be incurred as a result of trades being diverted to alternate ports and supply chains. The additional costs will generally fall into the broad categories shown in Figure 3.

Figure 3 Economic cost categories of vessel diversions



Data source: Synergies.

In addition to the above impacts, additional port and terminal costs will be incurred where a trade is diverted to an alternate supply chain, noting that this will also result in these costs being avoided at the Port of Mackay. The differential between these two costs represents the net cost attributable to the 'no maintenance dredging' scenario.

These impacts are assessed and quantified using Synergies' in-house shipping and road costing models. These models build a full cost of each transport movement from an analysis of each component of shipping costs, land transport costs, and externality costs.

2.3.3 Assessing loss of economic output

This economic impact arises where the production and trade of a commodity ceases due to constraints at the Port of Mackay. The likelihood of this occurring was assessed for each commodity identified as becoming constrained at the Port of Mackay over the 20-year analysis period.

It is most likely to be relevant for agricultural exports (e.g., ethanol, sugar, grain, molasses), as transport costs typically represent a more significant driver of feasibility relative to higher value commodities such as petroleum and machinery.

Where it is identified that the likely impact under the 'no maintenance dredging' scenario is the discontinuation of the trade, input-output modelling has been undertaken to assess the regional economic impacts from the loss of economic output. It is important to note that this differs from the other economic impacts (i.e., demurrage costs, increased supply chain costs) in that these impacts are not economic costs, but rather adverse economic impacts on the regional economy. This technique is discussed further in section 4.4 and Attachment A.

2.4 Alternate scenario analysis

Two alternate scenarios were chosen to assess the economic impacts under the scenario where:

- the forecasted growth in trade at the Port of Mackay is greater than under the base case over the next 20 years; and
- there is more rapid sedimentation of berthing pockets and swing basins than assessed under the base case over the next 20 years.

2.4.1 Optimistic trade forecast

The trade data and forecasts detailed in NQBP's 2020-21 Corporate Plan provide a base, worst, and best case scenarios. For the alternative scenario of optimistic growth in trade at the Port of Mackay, the best case scenario forecasts were applied.

Further, industry indicated that additional 10,000 tonnes of magnetite would be imported to support industrial activity from 2022.

2.4.2 More rapid sedimentation of berthing pockets and swing basins

To assess the scenario where more rapid sedimentation occurs and the associated impacts and costs, a 20 per cent increase was applied to the reduction in anticipated depths assessed under the base case.

3 Base case

This section sets out the base case trade forecasts and vessel projections against which the economic impact of the 'no maintenance dredging' scenario was assessed.

3.1 Trade forecast analysis

As the most recently available projections for trade throughput at Port of Mackay, the trade data and forecasts detailed in NQBP's 2020-21 Corporate Plan were adopted as the starting point for the analysis. The Plan details year-on-year forecasts for all commodities traded in material quantities, imports, and exports, at Port of Mackay to FY2050. The Plan also provides forecasts under three scenarios – worst, best, and base. The base scenario forecasts were adopted as the starting point for this analysis on the basis that these reflect the most likely projections.

Table 1 shows the average projections under the base scenario for trade through Port of Mackay based on five-year averages from FY22 to FY41. Forecasts are reported over a 20-year period to align with the study period for the economic impact assessment.

Table 1 Port of Mackay average trade forecasts (tonnes)

Commodity	FY22 – FY26	FY27 – FY31	FY32 – FY36	FY37 – FY41	20-year average
Petroleum	1,636,432	1,781,771	1,930,293	2,042,427	1,847,731
Ethanol	21,855	22,970	24,141	25,373	23,585
Raw Sugar	737,000	737,000	737,000	737,000	737,000
Refined Sugar	270,000	270,000	270,000	270,000	270,000
Fertiliser	54,117	56,877	59,779	62,828	58,400
Grain	220,000	220,000	220,000	220,000	220,000
Molasses	40,000	40,000	40,000	40,000	40,000
Cement	16,818	17,676	18,577	19,525	18,149
Magnetite	135,824	147,887	160,214	169,521	153,362
Scrap Metal	29,112	29,443	29,443	29,443	29,360
Breakbulk	76,515	80,418	84,520	88,832	82,571
Machinery	3,471	3,499	3,499	3,499	3,492

Note: It is noted that other commodities have been handled at Port of Mackay in recent years (e.g., ad hoc trades such as live cattle, logs, and meat) however the port is not currently handling sufficiently material quantities of these commodities to warrant inclusion in the trade forecasts for this analysis.

Data source: NQBP Corporate Plan 2020-21.

The throughput projections for the two key commodities – fuel and sugar – were further assessed to determine whether the forecasts above are reasonable, given the magnitude of throughput quantities and materiality for the analysis.

3.1.1 Fuel imports

As part of a cost-benefit analysis completed for NQBP in 2020[7], Synergies undertook a detailed fuel demand modelling exercise. This involved developing mine-by-mine coal production forecasts for those mines within Port of Mackay's catchment and estimating the fuel requirements associated with this production. For this analysis, we compared these forecasts with those contained within NQBP's Corporate Plan in addition to reviewing recent trade throughput to assess the currency of the forecasts.

Fuel demand is inherently driven by coal production forecasts, dependent on several factors including the size, type, and complexity of the mining operation necessary to extract the resource. In 2020, the global demand for both metallurgical and thermal coal fell due to the COVID-19 pandemic and the global containment measures imposed. However, according to the most recent update from the Office of the Chief Economist[8], late in 2020, with the gradual easing in COVID-19 measures and increased stimulus from countries, the outlook for metallurgical coal is expected to remain strong as steel and industrial production returns to normal levels, primarily driven by China's increased demand.

Similarly, demand for thermal coal, especially in Southeast Asia, remains strong though it faces a range of technological and policy challenges with an increasing number of countries substituting coal power with other sources such as gas and renewables. Figure 4 shows the Office of the Chief Economist's metallurgical and thermal coal export forecasts are likely to remain stable post FY2023.

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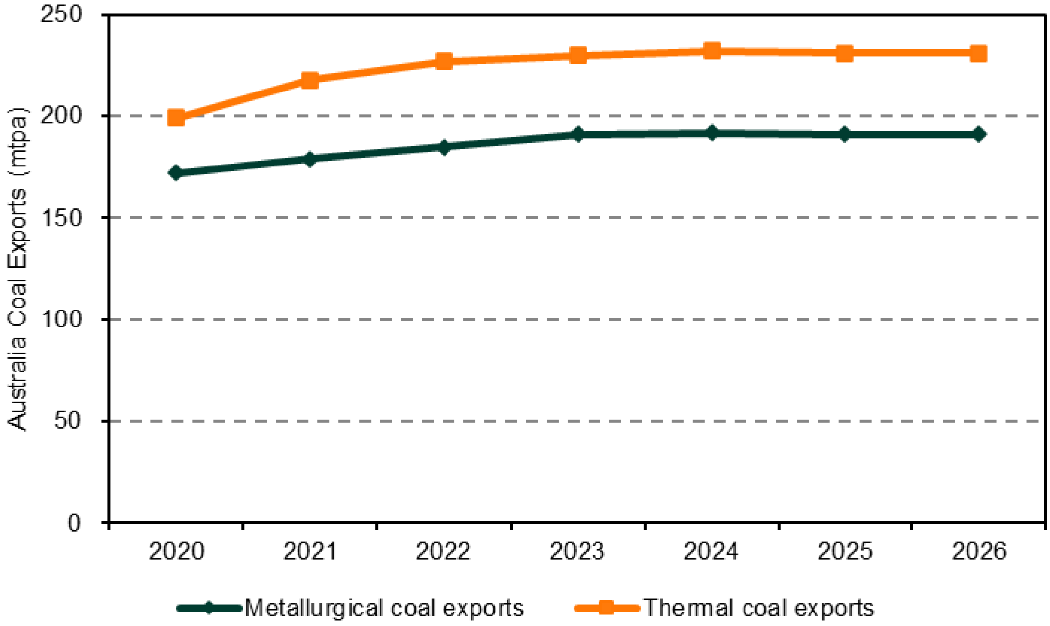
7 Cost-benefit analysis of ring road upgrade projects at Port of Mackay.

8 Office of the Chief Economist – resources and energy quarterly March 2021.

Figure 4 Australia Metallurgical and Thermal Coal Export Forecast



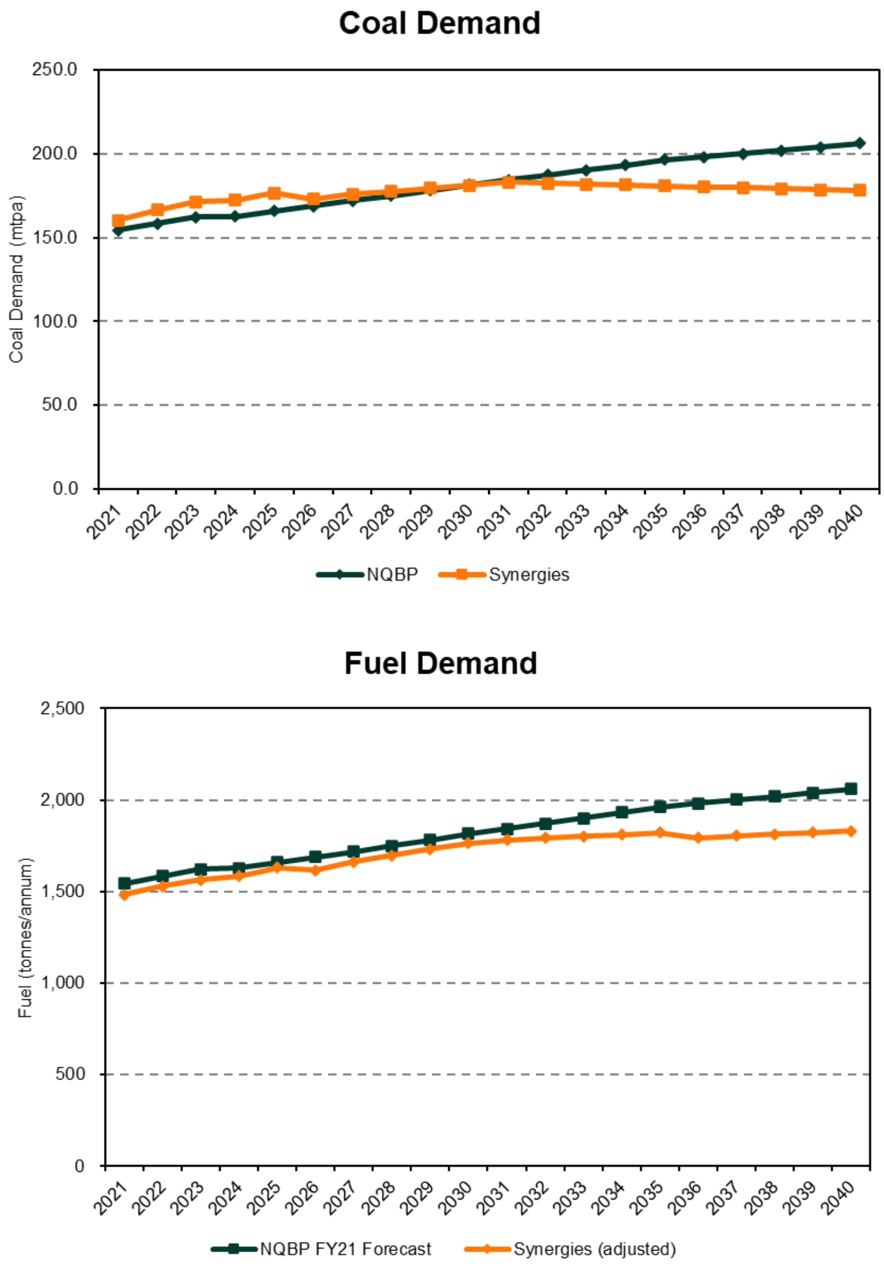
Data source: Office of the Chief Economist – resources and energy quarterly, March 2021.

In Australia, the outlook for coal demand is set to recover to pre-COVID levels in 2021[9], with coal demand remaining strong. Subsequently, Synergies has continued to use the coal forecasts adopted at the end of 2019 in forecasting future coal demand from 2021 onwards.

Figure 5 compares the base case coal production and fuel throughput projections developed by Synergies as part of the 2020 cost-benefit analysis with those detailed in NQBP's 2020-21 Corporate Plan.

[9] Office of the Chief Economist – resources and energy quarterly March 2021.

Figure 5 Comparison of Synergies and NQBP's coal production and fuel throughput forecasts



Data source: Synergies and NQBP Tonnage Projections 2021.

The key observations from the comparison are:

- the two forecasts are similar for the period FY2021 to FY2030; and
- beyond FY2030, Synergies' projections are slightly more conservative, largely driven by a more conservative coal demand forecast and adjustments made for future technological changes in the mining sector to account for advancements and

changes in energy sources for machinery which would affect the fuel demand forecast[10].

To ensure robustness of fuel trade forecasts, Synergies' fuel throughput forecasts were adopted for the base case.

3.1.2 Sugar exports

NQBP's 2020-21 Corporate Plan projects total raw and refined sugar exports for FY2021 of 737,000 tonnes and 270,000 tonnes, respectively. Sugar throughput is expected to remain relatively constant out to FY2041, primarily due to the limited growth outlook for the world sugar price due to increased international competition and a lack of growth in global sugar demand.

While these projections are considered appropriate for use in this analysis, it is noted that current trends (i.e., increasing concerns over long-term health outcomes from sugar consumption, implementation of sugar taxes in developed countries,[11] and increased substitution for alternatives) indicate reasonable potential for further downward pressure on the world sugar price.

Given the annual growth rates from both ABARES of -0.03%[12] and -0.08% for OECD[13], NQBP's refined and raw sugar forecasts were applied in the analysis.

3.1.3 Other commodities

With regard to the other commodities, the base projections as detailed in NQBP's 2020-21 Corporate Plan forecasts were applied in assessing the economic impacts. While it is noted that Covid-19 has caused significant disruption to the operation of trade routes since these forecasts were largely developed, these impacts are not expected to persist beyond the short term in relation to the commodities handled at Port of Mackay.

3.1.4 Base case trade forecasts

Based on our assessment above, the base case forecasts adopted for the economic impact modelling are shown in Table 2.

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10 Synergies has applied a one percent reduction in fuel demand from FY2031-35 and a three percent reduction thereafter up to FY2040.

11 In the past 2 years, Sugar taxes have been legislated in a number of countries including the United Kingdom, India, Ireland, the Philippines, Portugal, Sri Lanka, Thailand and the United Arab Emirates, constraining the sugar demand growth and incentivising a reduction in sugar content in foods and beverages.

12 ABARES Agricultural Commodities: March Quarter 2021, annual growth rate from 2018-19 to 2025-26.

13 OECD-FAO Agricultural Outlook 2020-2029, Section 5.6.

Table 2 Base case forecasts over a 20-year study period ('000 tonnes)

Commodity	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Petroleum	1,530	1,563	1,585	1,631	1,629	1,681	1,721	1,762	1,802	1,822	1,836	1,849	1,863	1,876	1,851	1,865	1,878	1,891	1,904	1,917
Ethanol	21	22	22	22	22	23	23	23	23	23	24	24	24	24	25	25	25	25	26	26
Raw Sugar	737	737	737	737	737	737	737	737	737	737	737	737	737	737	737	737	737	737	737	737
Refined Sugar	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270
Fertiliser	53	54	54	55	55	56	56	57	57	58	59	59	60	60	61	62	62	63	63	64
Grain	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Molasses	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Cement	16	17	17	17	17	17	17	18	18	18	18	18	19	19	19	19	19	20	20	20
Magnetite	132	135	135	138	140	143	145	148	151	153	155	158	160	163	164	166	168	169	171	173
Scrap Metal	28	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Breakbulk	75	76	77	77	78	79	80	80	81	82	83	84	85	85	86	87	88	89	90	91
Machinery	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Source: Synergies analysis; NQBP 2020-21 Corporate Plan.

3.2 Vessel forecast analysis

The following key assumptions underpinning the vessel forecasts over the 20-year analysis period were as follows[14]:

- one 'typical vessel' has been defined for all commodities other than petroleum. That is, it has been assumed that each defined vessel represents a reasonable representation of all vessels carrying the respective commodity;
- for petroleum, given the significance of the trade to the Port of Mackay and the large number of vessels, three vessel types have been defined (shallow, medium, and deep draft vessels) to forecast the different types of petroleum vessels entering the port (discussed further below);
- for petroleum, it has been assumed that the proportion of the total tonnage of petroleum handled by the three vessel types (i.e., shallow, medium, and deep draft) remain the same throughout the study period; and
- it has been assumed that the average number of vessels per year between 2018 to 2021 provides a reasonable proxy for vessels in FY2022.

3.2.1 Typical Vessels

Based on historical data from NQBP, the typical vessel characteristics for each commodity are shown in Table 3, noting that three vessel types have been modelled for petroleum, as mentioned above.

Table 3 Typical vessel characteristics for each commodity for 2022

Commodity	Vessels per year	Average Draft (m)	Average DWT	Ave. Cargo per Vessel (tonnes)	Average Time at Berth (days)
Petroleum	84	9.55	50,932	22,044	0.82
Shallow (Average draft 8.51m)	28	8.51	53,148	17,820	0.74
Medium (Average draft 9.63m)	27	9.63	50,645	20,599	0.88
Deep (Average draft 10.46)	29	10.46	49,086	20,122	0.84
Raw Sugar	20	6.26	43,126	33,923	1.63
Refined Sugar	15	6.71	22,140	17,819	2.07
Grain	8	6.31	31,983	18,989	2.71

[14] Further, we note that there is an expectation that vessel sizes are increasing, however we expect this to be more relevant for large cargo shipping vessels rather than the types of vessels accessing the Port of Mackay. As such, the vessel sizes assumed for this analysis are conservative and should increasingly larger vessels need to access the Port of Mackay, the impacts will be greater.

Commodity	Vessels per year	Average Draft (m)	Average DWT	Ave. Cargo per Vessel (tonnes)	Average Time at Berth (days)
Magnetite	8	8.26	35,067	18,986	2.63
Breakbulk	11	7.37	19,574	2,824	0.95
Fertiliser	9	8.27	38,127	5,219	1.67
Molasses	2	8.95	14,396	8,149	1.32
Scrap Metal	7	7.00	31,609	7,679	2.43
Ethanol	8	8.45	13,277	2,027	0.36
Cement	3	6.94	24,134	6,002	1.07
Machinery	21	7.07	17,611	3,034	0.73
TOTAL	**196**				
AVERAGE		**8.28**	**177**	**17,619**	**1.21**

Note 1 Machinery includes RORO, Motor Vehicles, and other Mobile Equipment.

Note 2 Draft excludes under keel clearance and trimming.

Source: Synergies analysis of NQBP data.

Between January 2018 and May 2021, an average of 185 vessels visited the Port of Mackay annually, with petroleum the most common commodity, followed by sugar (raw and refined), and fertiliser. Regarding historical forecasts, as shown in Table 4, we note there has been a noticeable increase in vessel visits in FY2021, compared to other years. Following discussions with NQBP, the increase in vessels was due to a recently added RoRo vessel service per month which, based on the regional coal mining demand, is likely to be continued in the future. As a result, the vessel numbers used for FY2022 vessel number forecast of 196 vessels per year was used, which is closely aligned with FY2021 vessel numbers.

Table 4 Historical Vessel Forecast

	FY2018[a]	FY2019	FY2020	FY2021[b]	Average
No. of Vessels	182	178	182	193	185

a NQBP provide data from Jan to Jun 2018 of 91 vessels, which has been extrapolated to estimate the FY2018 number of vessels.

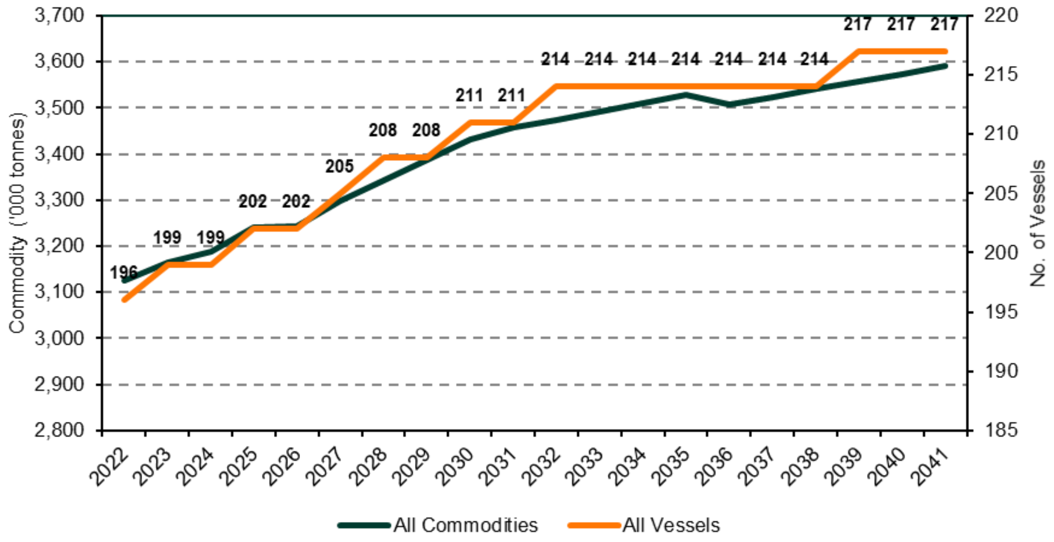
b NQBP provided data up to May 2021, with the number of vessels of 177 for FY2021. This has been extrapolated to estimate the FY2021 number of vessels.

Source: Synergies analysis of NQBP data.

3.2.2 Vessel Forecasts

Figure 6 below shows a comparison of the total commodity and vessel forecasts for Mackay Port from FY2022 to FY2041.

Figure 6 Comparison of total commodity and vessel forecasts from 2022-2041



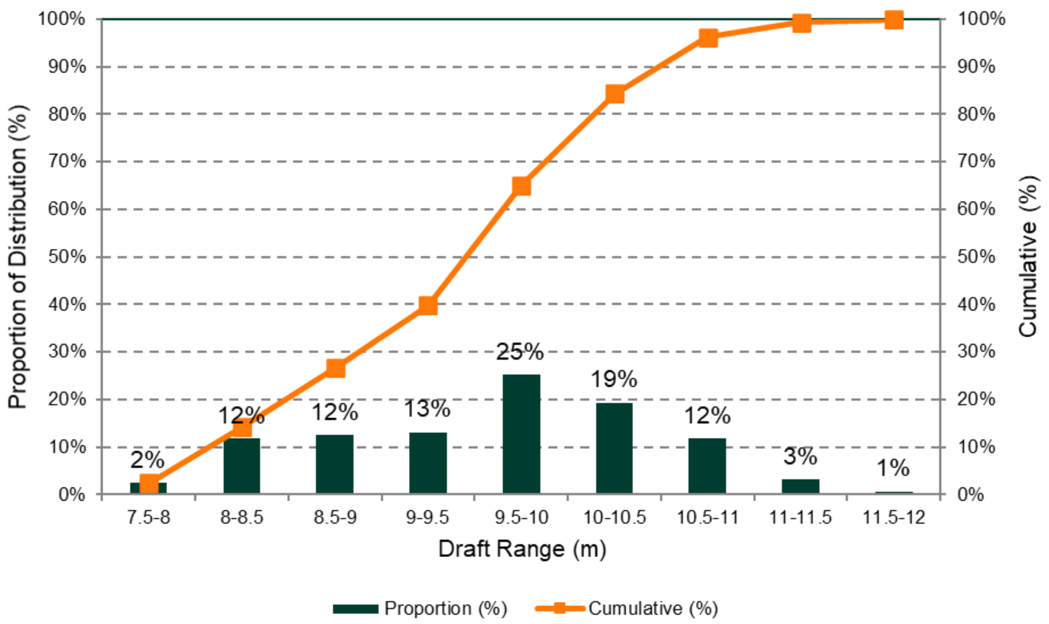
Data source: Synergies.

Details on the vessel forecasts for each commodity are presented below.

Petroleum

There were 289 petroleum vessels that visited the Port from January 2018 to May 2021, averaging approximately 84 vessels per year. The vessel loaded drafts on arrival ranged from a minimum of 7.5 meters to a maximum of 11.54 meters, with an average of 9.55 meters. Figure 7 shows the distribution of vessels based on different draft size groups.

Figure 7 Distribution of Petroleum Vessels by Draft



Data source: NQBP data.

The figure shows that the largest proportion of vessels are within the 9.5 to 10 meters draft group, though the distribution is fairly dispersed. As mentioned above, given the large range of distribution of vessels and the significance of petroleum imports to the Port, three vessel categories have been defined and reflected in the forecasts for the number of petroleum vessels entering the Port.

The cut-off ranges for the draft range groups are based on the 33rd and 66th percentile as follows:

- shallow for vessel drafts below 9.30 meters
- medium for vessel drafts ranging from 9.30 to 10.00 meters
- deep for vessel drafts above 10.00 meters.

Table 5 shows a summary of the typical vessel characteristics based on the proposed draft groups.

Table 5 Vessel characteristics by draft group based on historical data from 2018 to 2021

Petroleum Draft Category	Draft Range (m)	Average no. of vessels per year	Average Draft (m)	Average GT	Average DWT	LOA (m)	Average cargo (tonnes)	Average Time at Berth (days)	Yearly Tonnage Proportion (%)
Shallow	<9.30m	28	8.51	31,664	53,148	191	17,820	0.74	30%
Medium	9.30-10.00m	27	9.63	30,254	50,645	186	20,599	0.88	35%

Petroleum Draft Category	Draft Range (m)	Average no. of vessels per year	Average Draft (m)	Average GT	Average DWT	LOA (m)	Average cargo (tonnes)	Average Time at Berth (days)	Yearly Tonnage Proportion (%)
Deep	>10.00m	30	10.46	29,633	49,086	183	20,122	0.84	34%

Note 1 Averages are derived by taking the averages of all the vessels within each draft range.

Note 2 Draft excludes under keel clearance and trimming.

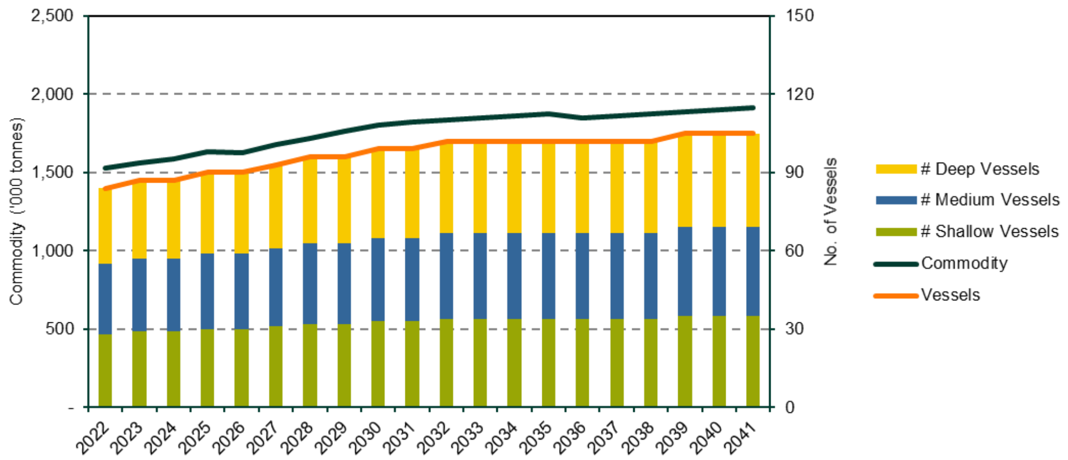
Source: NQBP data, Synergies analysis.

The table shows that the average cargo of the vessels (17,820 to 20,122 tonnes) does not vary significantly with changes in average draft (8.51 to 10.36 meters). In addition, the utilisation of most vessels (tonnes/DWT) visiting the Port are less than 50 percent. This is likely attributable to petroleum vessels making calls to multiple Australian ports.[15]

For this analysis, Synergies has kept the proportion of vessel capacity attributable to petroleum unloaded at the Port of Mackay constant over the study period. This results in an assumed maximum volume for shallow, medium, and deep vessels to Mackay of 17,820 tonnes (30 per cent), 20,599 tonnes (35 per cent), and 20,122 tonnes (34 per cent) respectively.

These proportions are subsequently applied to the total fuel forecast to derive the volume attributable to the three draft estimates. A comparison of the commodity and vessel forecasts is shown in Figure 8.

Figure 8 Comparison of commodity and vessel forecast for petroleum



Data source: Synergies analysis.

15 That is, petroleum vessels are full upon arrival in Australia and the cargo is unloaded at multiple ports.

Raw Sugar, Refined Sugar, Grain, Molasses, Scrap Metal and Machinery

Based on the forecast demand, raw sugar, refined sugar, grain, molasses, scrap metal, and machinery, growth for these commodities remain limited throughout the study period. As a result, Synergies has kept the same vessel forecast as the FY2022 vessel numbers throughout:

- Raw Sugar – 20 vessels per year
- Refined Sugar – 15 vessels per year
- Grain – 8 vessels per year
- Molasses – 2 vessels per year
- Scrap Metal – 7 vessels per year
- Machinery – 21 vessels per year.

Magnetite, Breakbulk, Fertiliser, Ethanol and Cement

Based on the demand projections, the following commodities are expected to exhibit steady growth over the analysis period – magnetite, breakbulk, fertiliser, ethanol, and cement. However, as shown in the Table 6, the average utilisation of the vessel load capacity is very low, ranging from approximately 14 per cent to 54 per cent. As such, it is assumed there is significant additional capacity able to accommodate growth in tonnages and rather than requiring additional vessels to handle the increased tonnage.

Table 6 Vessel utilisation and characteristics for various commodities

Commodity	Average number of vessels per year	Average Vessel DWT	Average Volume per Vessel (tonnes)	Average utilisation	Additional Capacity (tonnes)
Magnetite	8	35,067	18,986	54.83%	70,616
Breakbulk	11	19,574	2,824	15.51%	138,852
Fertiliser	9	38,127	5,219	13.74%	227,377
Ethanol	8	13,277	2,027	16.44%	67,505
Cement	3	24,134	6,002	26.48%	38,747

Note: Additional capacity is calculated by deducting the assumed maximum utilisation of 80% to the current average utilisation and applying this to the Vessel DWT and number of vessels per year.

Source: Synergies analysis.

Table 7 below sets out the base case vessel forecasts for each commodity.

3.2.3 Base case vessel forecasts

Table 7 Base case forecasts over a 20-year study period ('000 tonnes)

Commodity	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Petroleum	84	87	87	90	90	93	96	96	99	99	102	102	102	102	102	102	102	105	105	105
Shallow (Average draft 8.51m)	28	29	29	30	30	31	32	32	33	33	34	34	34	34	34	34	34	35	35	35
Medium (Average draft 9.63m)	27	28	28	29	29	30	31	31	32	32	33	33	33	33	33	33	33	34	34	34
Deep (Average draft 10.46m)	29	30	30	31	31	32	33	33	34	34	35	35	35	35	35	35	35	36	36	36
Raw Sugar	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Refined Sugar	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Grain	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Magnetite	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Breakbulk	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Fertiliser	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Molasses	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scrap Metal	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Ethanol	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Cement	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Machinery	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
TOTALS	**196**	**199**	**199**	**202**	**202**	**205**	**208**	**208**	**211**	**211**	**214**	**214**	**214**	**214**	**214**	**214**	**214**	**217**	**217**	**217**

Note: The analysis commences in 2022 (Y1).

Source: Synergies analysis; NQBP 2020-21 Corporate Plan.

4 Impacts of no maintenance dredging

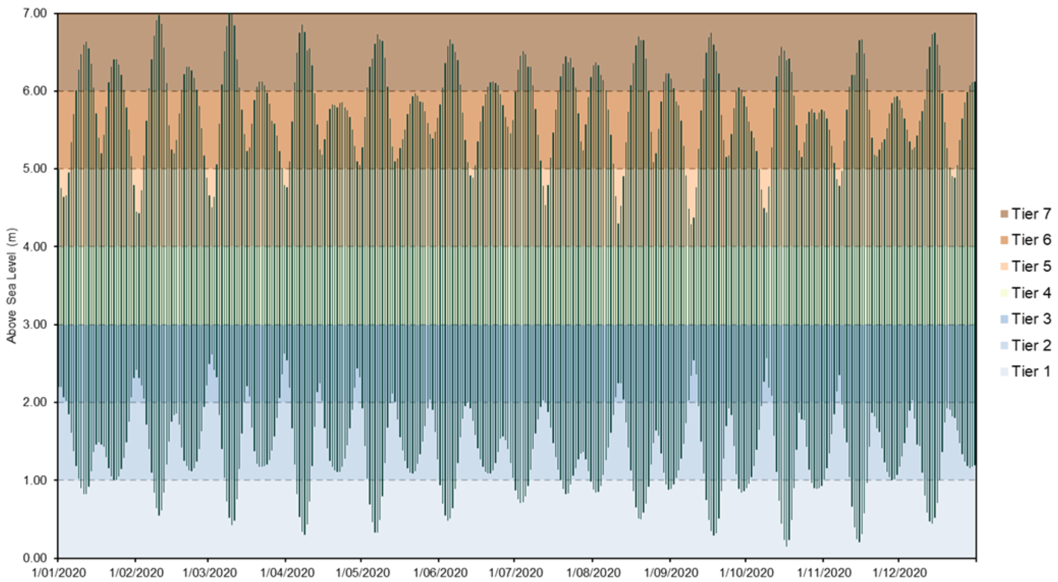
This section sets out our assessment of the impacts under the 'no maintenance dredging' scenario on vessel presentations at the port, including increased delay (demurrage) costs, and the constraints on vessels accessing the port berths.

4.1 Increased demurrage costs

4.1.1 Estimating duration of vessel delays

As discussed in section 2, the increased demurrage costs incurred under the 'no maintenance dredging' scenario required an analysis of tidal data for Mackay. The tidal data for 2020 was assessed to determine the likely duration for which vessels with different draft requirements would be delayed in entering and exiting the port due to reduced port depth. As shown in Figure 9, this involved categorising tide levels into seven tiers based on metres above sea level at Lowest Astronomical Tide (LAT).

Figure 9 Tidal data for Port of Mackay (2020)



Data source: Queensland Open Data Portal, Transport and Main Roads – 2020 Mackay Outer Harbour Storm Surge tide gauge archived interval recordings.

An average wait time was calculated for each tier, based on maximum and minimum wait times and on the probability of occurrences for each tier. The average wait times derived are applicable to vessels that require the relevant tier to safely navigate and berth at the port. Each vessel type is allocated a tier for each year of the 20-year analysis period. The assessment of which tier is required for each vessel type involved an analysis of the required draft for each vessel and the depth of each port area through which the vessel is required to navigate to reach the relevant berth. Allowance for Underkeel Clearance (UKC) was made for each vessel type as advised by the Harbour Master. The average wait time for each tier is shown in Table 8.

Table 8 Average wait time based on 2020 tidal data

Tidal Group	Tide Range	Counts	Probability of occurrence	Max Potential Wait[a]	Average Wait Time[b]
Tier 1	0 - 1m	1,347	3%	3%	0.31hrs
Tier 2	1 - 2m	8,663	16%	19%	2.28hrs
Tier 3	2 - 3m	11,918	23%	42%	4.99hrs
Tier 4	3 - 4m	10,928	21%	62%	7.48hrs
Tier 5	4 - 5m	11,422	22%	84%	10.08hrs
Tier 6	5 - 6m	6,910	13%	97%	11.66hrs
Tier 7	6 - 7m	1,509	3%	100%	12.00hrs

a Sum of previous tiers.

b Calculated by taking the average of the minimum potential wait time of zero and the maximum potential wait time of 24 hours multiplied by the cumulative max potential delay time probability.

Source: Synergies analysis.

A comparison of required draft for each vessel and the depth of the relevant port areas through which the vessel is required to navigate to reach the relevant berth was undertaken to enable a tier to be assigned to each vessel type for each year of the analysis. Based on this, an estimate for the average delay time (upon arrival at and departure from the port) can be derived for each vessel type for each year of the analysis period.

It is also noted that the NQBP Port Procedures Manual includes requirements for vessels entering the port during slack water in addition to vessels also being able to enter safely during the 0.25 knot window (being the period during which knots are between 0.25 and -0.25). These restrictions were not considered to result in delay times sufficiently material to be incorporated into the analysis.

As shown in Figure 10, there is no situation where delays exceed 10.08 hours (tidal tier 5). This is because where tidal impacts above Tier 5 occur, for some commodities, the berth is constrained regardless due to increased sedimentation. For some commodities, regardless of tide, at a certain point they will no longer be able to access the port due to insufficient depth. The majority of vessels experience a delay time of less than 4.99 hours (tidal tier 3).

Figure 10 Tidal and sedimentation impact on vessel operations

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Petroleum																				
P-Shallow	T1	T1	T1	T2	T2	T2	T2	T3	T3	T3	T3	T3	T3	T4	T4	T4				
P-Medium	T2	T3	T3	T3	T3	T3	T3	T4	T4	T4	T4	T4								
P-Deep	T3	T4	T4	T4	T4	T4	T4	T5	T5											
Raw Sugar												T1	T1	T2	T2	T2	T2	T3	T3	T4
Refined Sugar								T1	T1											
Grain												T1	T1	T2	T2	T2	T2	T3	T3	T4
Magnetite	T1	T1	T1	T1	T1	T1	T2	T2	T2	T3	T3	T3	T3	T4	T4	T4				
Breakbulk					T1	T1	T1	T1	T1	T2	T2	T2	T2	T3	T3	T3	T4	T5	T5	T5
Fertiliser	T1	T1	T1	T1	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4	T4	T4				
Molasses	T2	T2	T2																	
Scrap Metal								T1	T1	T1	T1	T2	T1	T2	T3	T3	T3	T4	T4	T4
Ethanol	T1	T1	T1	T2	T2	T2	T2													
Cement								T1	T1	T1	T1	T2	T1	T2	T3	T3	T3	T4	T4	T4
Machinery								T1	T1	T1	T1	T2	T2	T3	T3	T3	T3	T4	T4	T4

No constraint **Tidal constraint** **Total constraint**

Note: 'T' denotes Tier.
Data source: Synergies analysis.

When vessels are no longer able to access the berths, they will re-direct to an alternative supply chain or the producer/user of that commodity will cease production/consumption (discussed in the following sections).

4.1.2 Quantifying delay costs

The demurrage costs associated with the estimated delay times were quantified by applying the unit rate costs for bunker and charter costs in Synergies' in-house shipping model. These costs were informed by publicly available information and industry knowledge.

The average bunker cost per day for an idle vessel was calculated as $1,929 per day, based on published IFO380 costs[16], and which is applied to the average idle fuel consumption per day based on Synergies' Industry knowledge. The charter rates are calculated from Synergies' in-house shipping model based on ship operating costs from Drewy[17], cross checked with publicly available sources[18], which ranges from $21,000 to $28,167 per day, depending on the vessel type used.

A summary of estimated demurrage costs for each commodity/vessel type is shown in Figure 11.

[16] Bunker prices based on Bunker Port News, converted to AUD. Idled vessel consumption assumed to be 15% of average vessel fuel consumption.

[17] Ship Operating Costs Annual Review and Forecast 2020/21

[18] Charter prices based on Alibra Shipping and Simpson Spence Young data

Figure 11 Estimated average delay (hrs) and the demurrage costs by commodity ($m)

	NPV	Y1	…	Y5	…	Y10	…	Y15	…	Y20
Delay (hrs)										
Petroleum										
P-Shallow		17.2		136.8		329.6		508.8		
P-Medium		123.1		289.6		478.8				
P-Deep		289.6		463.9						
Raw Sugar								91.2		299.3
Refined Sugar										
Grain								36.5		119.7
Magnetite		4.9		4.9		79.9		119.7		
Breakbulk				6.7		50.1		109.9		221.8
Fertiliser		5.5		41.0		89.9		134.7		
Molasses		9.1								
Scrap Metal						4.3		69.9		104.7
Ethanol		4.9		36.5						
Cement						1.8		30.0		44.9
Machinery						12.9		209.7		314.2
Total Delay		**454.3**		**979.4**		**1,047.3**		**1,310.2**		**1,104.7**
Demurrage Costs ($m)										
Petroleum										
P-Shallow	$2.0	$0.0		$0.1		$0.3		$0.5		-
P-Medium	$2.7	$0.1		$0.3		$0.5		-		-
P-Deep	$3.2	$0.3		$0.4		-		-		-
Raw Sugar	$0.4	-		-		-		$0.1		$0.4
Refined Sugar	$0.0	-		-		-		-		-
Grain	$0.2	-		-		-		$0.0		$0.1
Magnetite	$0.5	$0.0		$0.0		$0.1		$0.1		-
Breakbulk	$0.6	-		$0.0		$0.1		$0.1		$0.3
Fertiliser	$0.6	$0.0		$0.1		$0.1		$0.2		-
Molasses	$0.0	$0.0		-		-		-		-
Scrap Metal	$0.3	-		-		$0.0		$0.1		$0.1
Ethanol	$0.1	$0.0		$0.0		-		-		-
Cement	$0.1	-		-		$0.0		$0.0		$0.1
Machinery	$0.9	-		-		$0.0		$0.3		$0.4
Total Demurrage	**$11.6**	**$0.4**		**$1.0**		**$1.1**		**$1.5**		**$1.4**

No constraint **Tidal constraint** **Total constraint**

Data source: Synergies analysis

4.2 Reduced vessel loadings

One way to mitigate the decreasing depths of the swing basins and berth pockets would be for shippers to reduce the tonnages carried in the vessels to reduce their required draft. This would subsequently involve either a reduction in the tonnages carried, or additional vessels being required to carry the same tonnages.

Consultation with NQBP indicated that this was unlikely to be adopted by shippers as a response to port depth constraints, as the cost impacts would likely exceed the additional demurrage costs incurred. This trade-off was assessed as part of the economic impact assessment, with the results revealing that it is never cost-effective for shippers to respond to depth constraints by reducing vessel loading.

An example of assessing the costs of adding an additional petroleum vessel is shown in the box below, demonstrating that it will be more cost-effective to incur delay costs than to reduce vessel loads to accommodate port depth constraints.

Box 2 Example of the cost of reducing vessel loadings

Reducing vessel loading was found not to be a commercially viable response to constrained port depths relative to increased demurrage costs. This was demonstrated by comparing the vessel costs, estimating the time required for a whole trip versus the time required to wait for the tide and applying this to a $/day vessel charter rate. In this example, we assume that the petroleum vessel be required to wait an average of 5 hours (or a total of 10 hours both ways), with the alternative scenario being the reduced loading which would require the vessel to take one round trip, estimated to take around 2 to 4 weeks or 336 to 672 hours. When a $/day charter rate is applied the additional time for both scenarios, it is evident that it would be much more cost effective to incur the increased demurrage costs, with the additional shipping costs incurred from reducing vessel loading far outweighing the delay costs. This result is consistent with those observed across other commodities and vessel types.

Data source: Synergies.

4.3 Increased supply chain costs

Figure 10 above shows that after the first three years of the analysis period, vessels begin to become entirely constrained from accessing port berths. This is demonstrated where the box for the relevant year is shaded in red for the commodity and vessel type.

When a vessel is completely constrained from accessing the Port of Mackay to load or discharge, even allowing for tidal assistance, the trade will either divert to an alternative supply chain, where export/import via an alternative supply chain is commercially feasible or will be discontinued. Alternative supply chains were assessed under the 'no maintenance dredging' scenario for the six commodities for which trade will be constrained due to insufficient depth of the berths capable of handling these commodities (see Figure 10).

Table 9 below lists the assumptions adopted regarding the alternative supply chain that would accommodate the trade.

Table 9 Alternative supply chains for constrained commodities

Commodity	Import/ Export	Alternative supply chain	Rationale
Petroleum	Import	Port of Gladstone/Townsville Port (to coal mines in Bowen Basin)	Gladstone is the nearest port with existing petroleum exports. Townsville Port may also be an option for some mines in the northern Bowen Basin. Our previous cost-benefit analysis indicates that these ports possess the necessary capacity to accommodate a significant increase in petroleum imports. We drew upon the results from our previous modelling to identify the volumes of petroleum imports that would be diverted to Gladstone and Townsville and the economic impact under the 'no maintenance dredging' scenario was modelled accordingly.

Commodity	Import/ Export	Alternative supply chain	Rationale
Refined sugar	Export	Nil	The inability to export refined sugar via the Port of Mackay would have significant implications for the commercial viability of the Racecourse Refinery, which is Australia's largest sugar refinery. While it may be possible to continue the operation of the refinery and transport refined sugar to domestic markets (i.e. Brisbane, Sydney, Melbourne, other major cities) via road and/or rail, due to the narrow margins involved in sugar refining, the economic impact of the constraint has been modelled under the assumption that the Racecourse Refinery would likely cease operations, with additional tonnages of raw sugar being transported to Victoria for refining, assuming this refinery has capacity to handle increased throughput viably otherwise the raw sugar would be expected to be exported to overseas markets. While export tonnages from the port would remain largely unchanged in net terms, the regional economy will be adversely impacted by the loss of activity from the sugar refinery. This loss of activity was modelled using Synergies' input-output at a high level (i.e., assumptions being made where necessary).
Magnetite	Import	Port of Gladstone	Gladstone currently trades in magnetite and given the relatively small volumes to be exported, it is assumed this trade can be accommodated at Gladstone.
Fertiliser	Import	Port of Townsville	Both ports can accommodate fertiliser imports (98,000 tonnes of fertilisers imported through Port of Townsville per annum and similar tonnages through Gladstone. The Port of Townsville was chosen as it was the most cost effective route as shown by economic cost modelling.
Ethanol	Export	Nil	Based on industry advice[19], if the export of ethanol (to Asia or Melbourne) cannot be accommodated at the Port of Mackay, the processing plant will no longer be viable and the bioethanol plant will shut down. The economic impact of the loss of ethanol production and plant shutdown was modelled using Synergies' input-output model.
Molasses	Export	Nil	Molasses is a waste by-product from sugar milling and refining. Given the low margins derived from the export of molasses, it will not be commercially feasible to export the tonnages currently handled at the Port of Mackay through an alternative facility under the 'no maintenance dredging' scenario. Hence, it is assumed the molasses will be sold into the domestic market at a slightly lower net return. Noting this, it is not proposed to model the economic impact of this loss of trade, as any impact is unlikely to be material.

Source: Synergies analysis, NQBP, and industry insight.

4.3.1 Quantifying supply chain costs

Supply chain costs were assessed using Synergies' in-house shipping cost model, which analyses each component of shipping costs, land transport costs, and externality costs:

- shipping costs – port charges, bunker costs, and operating/charter costs based on Synergies' in-house port price benchmarking and shipping model, together with other publicly available sources.

19 The ethanol trade at the Port of Mackay comes from Wilmar's Bioethanol plant at Sarina.

- road costs – operating cost, value of time, and crash costs and externality costs primarily sourced from DTMR's Cost Benefit Analysis Manual, Freight Metrics, BITRE and other publicly available sources.

Figure 12 Road supply chain costs and relevant parameters by constrained commodities

	NPV	Y1	…	Y5	…	Y10	…	Y15	…	Y20
Incremental Road Distance (000' kms)										
Petroleum - Shallow		-		-		-		-		5,901.7
Petroleum - Medium		-		-		-		6,588.1		6,822.3
Petroleum - Deep		-		-		6,334.6		6,435.4		6,664.2
Refined Sugar		N/A		N/A		N/A		N/A		N/A
Magnetite		-		-		-		-		1,167.2
Fertiliser		-		-		-		-		438.2
Total Incremental Distance	**-**	**-**		**-**		**6,334.6**		**13,023.4**		**20,993.5**
Incremental Road Time (000' hrs)										
Petroleum - Shallow		-		-		-		-		61.7
Petroleum - Medium		-		-		-		68.9		71.4
Petroleum - Deep		-		-		66.3		67.3		69.7
Refined Sugar		N/A		N/A		N/A		N/A		N/A
Magnetite		-		-		-		-		12.4
Fertiliser		-		-		-		-		4.8
Total Incremental Road Time	**-**	**-**		**-**		**66.3**		**136.2**		**220.0**
Incremental Road Operating Cost ($m)										
Petroleum - Shallow	$16.6	-		-		-		-		$13.7
Petroleum - Medium	$43.9	-		-		-		$15.2		$15.8
Petroleum - Deep	$65.4	-		-		$14.7		$14.9		$15.4
Refined Sugar		N/A		N/A		N/A		N/A		N/A
Magnetite	$3.3	-		-		-		-		$2.7
Fertiliser	$1.2	-		-		-		-		$1.0
Total Incremental Road Cost	**$130.3**	**-**		**-**		**$14.7**		**$30.1**		**$48.6**
Incremental Road External Costs ($m)										
Petroleum - Shallow	$11.2	-		-		-		-		$9.2
Petroleum - Medium	$29.6	-		-		-		$10.3		$10.6
Petroleum - Deep	$44.1	-		-		$9.9		$10.0		$10.4
Refined Sugar		N/A		N/A		N/A		N/A		N/A
Magnetite	$2.2	-		-		-		-		$1.8
Fertiliser	$0.8	-		-		-		-		$0.7
Total Incremental Road Cost	**$87.9**	**-**		**-**		**$9.9**		**$20.3**		**$32.8**
Road Cost ($m)										
Petroleum - Shallow	$27.8	-		-		-		-		$22.9
Petroleum - Medium	$73.4	-		-		-		$25.5		$26.4
Petroleum - Deep	$109.5	-		-		$24.5		$24.9		$25.8
Refined Sugar		N/A		N/A		N/A		N/A		N/A
Magnetite	$5.5	-		-		-		-		$4.5
Fertiliser	$2.1	-		-		-		-		$1.7
Total Incremental Road Cost	**$218.2**	**-**		**-**		**$24.5**		**$50.5**		**$81.4**

Data source: Synergies modelling.

Figure 13 Shipping supply chain costs (savings) and relevant parameters by constrained commodities

	NPV	Y1	…	Y5	…	Y10	…	Y15	…	Y20
Diverted Vessels										
Petroleum - Shallow		-		-		-		-		35.0
Petroleum - Medium		-		-		-		33.0		34.0
Petroleum - Deep		-		-		34.0		35.0		36.0
Refined Sugar (Diverted to Raw Sugar)		-		-		-		14.0		14.0
Refined Sugar (Raw Sugar Vessels)		-		-		-		-7.0		-7.0
Magnetite		-		-		-		-		8.0
Fertiliser		-		-		-		-		9.0
Total Diverted Vessels	**-**	**-**		**-**		**34.0**		**75.0**		**129.0**
Incremental Time Added (Saved) - Days										
Petroleum - Shallow		-		-		-		-		-35.0
Petroleum - Medium		-		-		-		-33.0		-34.0
Petroleum - Deep		-		-		-34.0		-35.0		-36.0
Refined Sugar		N/A		N/A		N/A		N/A		N/A
Magnetite		-		-		-		-		-8.0
Fertiliser		-		-		-		-		-9.0
Total Incremental Time Added (Saved)	**-**	**-**		**-**		**-34.0**		**-68.0**		**-122.0**
Incremental Charter/Bunker Cost (Saving) - $m										
Petroleum - Shallow	-$1.0	-		-		-		-		-$0.8
Petroleum - Medium	-$2.2	-		-		-		-$0.8		-$0.8
Petroleum - Deep	-$3.5	-		-		-$0.8		-$0.8		-$0.8
Refined Sugar	$0.2	-		-		-		$0.0		$0.1
Magnetite	-$0.0	-		-		-		-		-$0.0
Fertiliser	-$0.0	-		-		-		-		-$0.0
Total Incremental Cost	**-$6.6**	**-**		**-**		**-$0.8**		**-$1.5**		**-$2.3**
Incremental Port Cost (Saving) - $m										
Petroleum - Shallow	$0.3	-		-		-		-		$0.2
Petroleum - Medium	$0.7	-		-		-		$0.2		$0.2
Petroleum - Deep	$0.4	-		-		$0.1		$0.1		$0.1
Refined Sugar		-		-		-		-		-
Magnetite	-$0.6	-		-		-		-		-$0.5
Fertiliser	-$0.0	-		-		-		-		-$0.0
Total Incremental Cost	**$0.7**	**-**		**-**		**$0.1**		**$0.3**		**$0.0**
Total Incremental Cost (Saving) - $m										
Petroleum - Shallow	-$0.7	-		-		-		-		-$0.6
Petroleum - Medium	-$1.5	-		-		-		-$0.5		-$0.5
Petroleum - Deep	-$3.1	-		-		-$0.7		-$0.7		-$0.7
Refined Sugar	$0.2	-		-		-		$0.0		$0.1
Magnetite	-$0.6	-		-		-		-		-$0.5
Fertiliser	-$0.1	-		-		-		-		-$0.0
Total Incremental Cost	**-$5.9**	**-**		**-**		**-$0.7**		**-$1.2**		**-$2.3**

Data source: Synergies modelling.

From the figures above, we see that increases in supply chain costs is dominated by the increased road freight, which is largely driven by the large distances between the alternative ports and the mines for petroleum. The analysis also shows minor cost savings for shipping costs for the alternative supply chains, explained by the assumption that most of the vessels would stop at multiple stops under the base case, and that approximately 1 day would be avoided (primarily berth loading times) when Mackay becomes constrained.

4.4 Loss of economic output

As noted above, there are some trades for which the import/export of the trade will not be commercially feasible if the trade cannot be accommodated at the Port of Mackay. This results in either the commodity being supplied through domestic supply chains or the production of the commodity itself no longer being commercially feasible, leading to a loss of economic activity and employment for the regional economy.

There are three commodities that are identified as being constrained from accessing the Port of Mackay during the 20-year analysis period that would not be diverted to an alternative supply chain:

- Refined sugar – constrained in Year 10
- Ethanol – constrained in Year 8
- Molasses – constrained in Year 4

As shown in Table 9, it is assumed that molasses, as a waste by-product from sugar production, will be supplied to domestic users rather than being exported via the Port of Mackay. While this may result in a slight reduction in net return to molasses producers, the economic impact of this will be negligible.

For refined sugar and ethanol, industry consultation indicates that the production of these commodities would not be commercially feasible under the 'no maintenance dredging' scenario.

4.4.1 Quantifying loss of economic output

The non-linear input-output (I-O) modelling technique was applied to assess the impact of the loss of refined sugar and ethanol production on the regional economy. Synergies' I-O model captures the manner in which an initial 'shock' – in this case loss of production – flows through the various sectors of the regional economy, generating wider impacts. Generally, I-O models can be understood as a summary of all supply chains in a region. A brief summary of economic impact modelling using I-O is provided in the box below and further described in Appendix A.

Box 3 Brief overview of Input-Output modelling

At the heart of the model is a static representation of the regional economy called an I-O table, which reflects the interdependencies between 21 industry sectors. Synergies has created an I-O table representing the industries within the SA4 Mackay-Isaac-Whitsunday region.

There are three components of economic impacts that are measured in economic impact modelling:

- Direct impacts – these relate to activities directly attributable to the change in activity;

- Indirect impacts – these relate to production activities downstream of the change in activity by industries that supply into the sector directly supplying the final product or service; and
- Induced impacts – these relate to activities generated by the spending of additional income directly or indirectly related to the activity for which impacts are being assessed.

The overall economic impact of any expenditure or loss of activity will be the sum of all three. The results of these impacts are presented in four measures:

Gross Output (turnover) measures the gross value of transactions generated or facilitated by the stimulus. Within this gross value is included the value of raw materials that, in most cases, have already been counted as part of gross output from earlier production. As a result, there is a tendency for gross output figures to include some double counting. Nevertheless, it is a useful measure of the total level of economic activity in gross terms (before netting off input costs).

Gross Regional Product (GRP) measures the money value of final goods and services generated or facilitated by the stimulus. When assessed at State level, the measure becomes Gross State Product (GSP). Similarly, at national level, the measure is referred to as Gross Domestic Product (GDP).

GRP differs from Gross Output because only the value added at each step of the production chain is considered (as opposed to the entire transactional value of each step as is the case for turnover). That is, GRP is the sum of value added across all industries, not the value of industry output or sales. Accordingly, the economic contribution of an industry, as measured by GRP, is distinguished from its gross value of output and total exports, which do not discount inputs supplied by other industries or economies.

Labour income (wages paid) relates to the share of value added (and gross output) which is directly paid to individuals in the form of salaries or wages. It is a percentage of value added and cannot exceed value added.

Employment measures the total number of full-time equivalent (FTE) jobs generated or facilitated by the stimulus.

Data source: Synergies.

Ethanol

Quantification of the regional economic impact from the loss of ethanol production firstly required estimation of the annual quantity of ethanol produced at Wilmar's bioethanol plant and the expected market price (value) of the ethanol.

Wilmar's bioethanol plant produces around 60 million litres per annum.[20] The average market price of ethanol over the past five years is around $1.50 USD[21] per gallon, or $0.53 AUD per litre.[22] Based on this, the loss of annual production value to be assessed by the I-O model is $32.1 million.

The process of shocking a sector is summarised Appendix A (Box A.1). The model captures the manner in which an initial "shock" (e.g., decrease in the export of ethanol from the port) impacts businesses along the ethanol production supply chain (e.g.,

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[20] Wilmar, Ethanol for fuel. Available at: https://www.wilmarsugar-anz.com/what-we-do/ethanol-for-fuel

[21] While in the past six months ethanol prices have increased to $2.35 USD per gallon, we based our assessment on more consistent market pricing of an average $1.50 over the last five years.

[22] Market price as of 08 July 2021 Nasdaq, converted from USD to AUD at 1.35 and converting gallons to litres.

sugarcane field, transport, refining/crushing, transport, export). This, in turn, impacts further economic activity through the associated businesses' own supply chains (e.g., fuel, labour, specialised machinery).

As the inputs to the secondary supply chains require inputs in their own right, those supply chains are also impacted. Importantly, as some of the value is typically paid as wages (labour), kept as profits, or used to purchase imports, the payment flows to the sub-supply chains become smaller and smaller and eventually become (close to) zero. This conceptual framework also holds true with respect to a decrease in the export of a commodity and resultant losses in economic activity along all associated supply chains.

Refined sugar

While the net production of raw sugar in the region will not be impacted by the closure of Wilmar's Racecourse Refinery, there will be a loss of the value-add activities the region undertakes in turning raw sugar into refined sugar.

As with lost ethanol production, quantification of the regional economic impact from the loss of sugar refining activity requires estimation of the annual quantity of refined sugar produced at the Racecourse Refinery and the net value add attributable to the refining activity.[23]

The Racecourse Refinery has an annual production of 380,000 tonnes.[24] Current and recent historical market prices for raw and refined sugar were assessed and the average differential between the prices was found to be around $0.03 per pound ($66.14 per tonne).[25] With the net market price of $0.03 per pound, the loss of annual production value to be assessed by the I-O model is $25.1 million.

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23 Noting that the production of the raw sugar used in the refining process will still occur within the region, it is only the refining activity that will be lost under the 'no maintenance dredging' scenario.

24 Wilmar, Refineries. Available at: https://www.wilmarsugar-anz.com/what-we-do/refineries

25 International Sugar Organization, Daily Sugar Prices.

5 Results

This section summarises the results from the economic impact assessment of the 'no maintenance dredging' scenario, including the increased economic costs attributable to the import/export of trades currently handled at the Port of Mackay and the negative impacts on the regional economy as a result of the loss of refined sugar and ethanol production.

5.1 Economic cost of no maintenance dredging

The total economic costs under the 'no maintenance dredging' scenario were estimated to be $223.7 million in Net Present Value (NPV) terms over the 20-year analysis period. Largely, the costs are attributable to road costs, which includes operating costs, value of time, negative environmental externalities, and crash costs.

This signifies that the impact of no maintenance dredging at the Port of Mackay leads to not only increased costs for shippers but also unfavourable outcomes for the community in terms of increased environmental impact of heavy vehicle traffic and cost to government of increased road maintenance costs. As such, it is evident that the proximate access to sectors exporting or importing goods provided by the Port of Mackay is of strategic significance.

Figure 14 Economic cost of no maintenance dredging by commodity & cost type

	NPV ($m)			
($m)	Delay Cost	Road Costs	Shipping Costs	Total
Petroleum	$7.9			**$7.9**
Shallow	$2.0	$27.8	-$0.7	**$29.1**
Medium	$2.7	$73.4	-$1.5	**$74.7**
Deep	$3.2	$109.5	-$3.1	**$109.5**
Raw Sugar	$0.4		$0.2	**$0.6**
Refined Sugar	$0.0			**$0.0**
Grain	$0.2			**$0.2**
Magnetite	$0.5	$5.5	-$0.6	**$5.3**
Breakbulk	$0.6			**$0.6**
Fertiliser	$0.6	$2.1	-$0.1	**$2.6**
Molasses	$0.0			**$0.0**
Scrap Metal	$0.3			**$0.3**
Ethanol	$0.1			**$0.1**
Cement	$0.1			**$0.1**
Machinery	$0.9			**$0.9**
TOTAL	**$11.6**	**$218.2**	**-$5.9**	**$224.0**
Proportion (%)	**5%**	**97%**	**-3%**	**100%**

Data source: Synergies

Figure 15 Economic cost of no maintenance dredging by cost type

Economic Costs	NPV	Y1	…	Y5	…	Y10	…	Y15	…	Y20
Delay Costs	$11.6	$0.4		$1.0		$1.1		$1.5		$1.4
RC - Operating Cost	$130.3	-		-		$14.7		$30.1		$48.6
RC - Value of Time	$39.3	-		-		$4.4		$9.1		$14.7
RC - Externatlities	$44.2	-		-		$5.0		$10.2		$16.5
RC - Crash Costs	$4.4	-		-		$0.5		$1.0		$1.6
SC - Port Charges	$0.7	-		-		$0.1		$0.3		$0.0
SC - Bunker Costs	-$0.6	-		-		-$0.1		-$0.1		-$0.2
SC - Operating/Charter Costs	-$6.0	-		-		-$0.7		-$1.4		-$2.1
Total	**$224.0**	**$0.4**		**$1.0**		**$24.9**		**$50.7**		**$80.4**

Note: RC = Road costs; SC = Shipping costs

Data source: Synergies.

5.2 Regional economic impacts from foregone production

The regional impacts from loss of production of refined sugar and ethanol totalled a loss of $100.1 million in regional output, $24.4 million in gross regional product (GRP), $10.2 million in labour income, and 119 FTEs. It is important to note that unlike the economic cost impacts presented above, these are not PV estimates but are annual impacts. That is, these estimates represent the level of economic activity foregone each year following the cessation of sugar refining and ethanol production, Year 10, and Year 8, respectively.

Table 10 and Table 11 present the regional economic impacts for both ethanol and refined sugar, respectively.

Table 10 Annual regional economic impacts of loss of ethanol production

Impact	Unit	Direct Impacts	Indirect Impacts	Total Impacts
Gross output	$	-$32.06	-$20.78	**-$52.84**
Gross regional product	$	-$5.27	-$8.57	**-$13.84**
Labour income	$	-$2.82	-$2.85	**-$5.67**
Employment	Full-time equivalent	-24	-34	**-58**

Source: Synergies analysis.

Table 11 Annual regional economic impacts of loss of refined sugar production

Impact	Unit	Direct Impacts	Indirect Impacts	Total Impacts
Gross output	$	-$25.13	-$22.15	**-$47.28**
Gross regional product	$	-$3.73	-$6.85	**-$10.59**
Labour income	$	-$2.18	-$2.35	**-$4.53**
Employment	Full-time equivalent	-29	-32	**-61**

Source: Synergies analysis.

5.3 Alternative scenarios

The economic impact under the 'no maintenance dredging' scenario was also assessed under two alternative scenarios – an optimistic trade forecast scenario and a scenario under which the sedimentation of the port occurs more rapidly than estimated by the modelling undertaken by PCS.

5.3.1 Optimistic trade forecast

For the alternative scenario of optimistic growth in trade at the Port of Mackay, the best case scenario forecasts were applied from NQBP's 2020-21 Corporate Plan. Further, based on industry advice, it is expected that 10,000 additional tonnes of magnetite per annum will be imported through the Port of Mackay to support mining activity. The trade forecasts under the optimistic scenario are detailed in Table 12.

Table 12 Optimistic trade forecasts over a 20 year study period ('000 tonnes)

Commodity	Year 1	Year 5	Year 10	Year 15	Year 20
Petroleum	1,589	1,765	2,059	2,337	2,528
Ethanol	21	22	23	25	26
Raw Sugar	752	782	822	864	908
Refined Sugar	275	287	301	317	333
Fertiliser	53	55	58	61	64
Grain	222	231	243	256	269
Molasses	41	43	45	47	50
Cement	16	17	18	19	20
Magnetite	142	157	181	204	220
Scrap Metal	28	28	28	28	28
Breakbulk	80	80	80	80	80
Machinery	3	3	3	3	3

Source: NQBP 2020-21 Corporate Plan; industry discussions.

These forecasts were then applied to determine the forecast vessel movements over the 20-year analysis period. These are detailed in Table 13.

Table 13 Optimistic vessel forecasts over a 20 year study period ('000 tonnes)

Commodity	Year 1	Year 5	Year 10	Year 15	Year 20
Petroleum	84	96	111	123	135
Shallow (Average draft 8.51m)	28	32	37	41	45
Medium (Average draft 9.63m)	27	31	36	40	44
Deep (Average draft 10.46m)	29	33	38	42	46
Raw Sugar	20	21	23	24	25
Refined Sugar	15	16	17	18	19

Commodity	Year 1	Year 5	Year 10	Year 15	Year 20
Grain	8	9	10	10	11
Magnetite	8	8	8	8	8
Breakbulk	11	11	11	11	11
Fertiliser	9	9	9	9	9
Molasses	2	3	3	3	4
Scrap Metal	7	7	7	7	7
Ethanol	8	8	8	8	8
Cement	3	3	3	3	3
Machinery	21	21	21	21	21
TOTAL	**196**	**212**	**231**	**245**	**261**

Source: Synergies.

The optimistic trade scenario results in the following impacts on swing basin and berth access on the 20-year analysis period.

Figure 16 Tidal and sedimentation impacts under the rapid sedimentation scenario

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Petroleum																				
P-Shallow	T1	T1	T1	T2	T2	T2	T2	T3	T3	T3	T3	T3	T3	T4	T4	T4				
P-Medium	T2	T3	T3	T3	T3	T3	T3	T4	T4	T4	T4	T4								
P-Deep	T3	T4	T4	T4	T4	T4	T4	T5	T5											
Raw Sugar												T1	T1	T2	T2	T2	T2	T3	T3	T4
Refined Sugar								T1	T1											
Grain												T1	T1	T2	T2	T2	T2	T3	T3	T4
Magnetite	T1	T1	T1	T1	T1	T1	T2	T2	T2	T3	T3	T3	T3	T4	T4	T4				
Breakbulk					T1	T1	T1	T1	T1	T2	T2	T2	T2	T3	T3	T3	T4	T5	T5	T5
Fertiliser	T1	T1	T1	T1	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4	T4	T4				
Molasses	T2	T2	T2																	
Scrap Metal								T1	T1	T1	T1	T2	T1	T2	T3	T3	T3	T4	T4	T4
Ethanol	T1	T1	T1	T2	T2	T2	T2													
Cement								T1	T1	T1	T1	T2	T1	T2	T3	T3	T3	T4	T4	T4
Machinery								T1	T1	T1	T1	T2	T2	T3	T3	T3	T3	T4	T4	T4

No constraint | Tidal constraint | Total constraint

Note: 'T' denotes Tier.

Data source: Synergies analysis.

Results

The increased volumes did not have any major impact to the results, estimated that $224.4 million, an increase of only $0.4 million compared to base case volumes, primarily consisting of road cost savings of $219.0 million, delay costs of $12.3 million and shipping cost savings of -$6.9 million.

The regional economic impacts do not change under this scenario, noting that these impacts occur as a result of the loss of sugar refining and ethanol production from the region under the 'no maintenance dredging' scenario. As the year in which refined sugar and ethanol vessels become constrained from accessing the Port of Mackay is the same under this scenario as under the central modelling scenario, the annual economic impacts from this loss of production remain unchanged.

5.3.2 More rapid sedimentation of berthing pockets and swing basins

We applied a 20 per cent increase on the rate of sedimentation to assess a greater reduction in berth and swing basin depths each year over the 20-year analysis period. The impact on port access is shown below.

Figure 17 Tidal and sedimentation impacts – rapid sedimentation scenario

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Petroleum																				
P-Shallow	T3	T3	T3	T3	T3	T3	T3	T4												
P-Medium	T4	T4	T4																	
P-Deep																				
Raw Sugar	T1	T1	T1	T1	T1	T1	T1	T2	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4		
Refined Sugar	T1	T1	T1	T1																
Grain	T1	T1	T1	T1	T1	T1	T1	T2	T2	T2	T2	T2	T2	T3	T3	T3	T3			
Magnetite	T3	T3	T3	T3	T3	T3	T3													
Breakbulk	T2	T2	T2	T2	T2	T2	T2	T3	T3	T3	T3	T3	T3							
Fertiliser	T3	T3	T3	T3	T3	T3	T3													
Molasses																				
Scrap Metal	T1	T1	T1	T2	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4						
Ethanol																				
Cement	T1	T1	T1	T2	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4						
Machinery	T1	T1	T1	T2	T2	T2	T2	T2	T2	T3	T3	T3	T3	T4						

No constraint | Tidal constraint | Total constraint

Note: 'T' denotes Tier.

Data source: Synergies analysis.

Results

These added tidal and access constraints due to more rapid sedimentation is estimated to result in an increase of $378.3 million in costs to $602.3 million, primarily driven by the requirement to shift supply chains much earlier, resulting in large road economic costs. The economic cost consists of $611.7 million in additional road costs, $8.1 million in delay costs and -$17.5 million shipping cost savings.

In terms of the regional economic impacts from the loss of refined sugar and ethanol production, while the annual impacts remain unchanged, they commence earlier in the assessment period (year 1 for ethanol and year 5 for refined sugar). This is due to these trades becoming constrained from accessing the Port of Mackay several years earlier under the rapid sedimentation scenario relative to the central scenario for the economic impact assessment.

A. Input-Output modelling

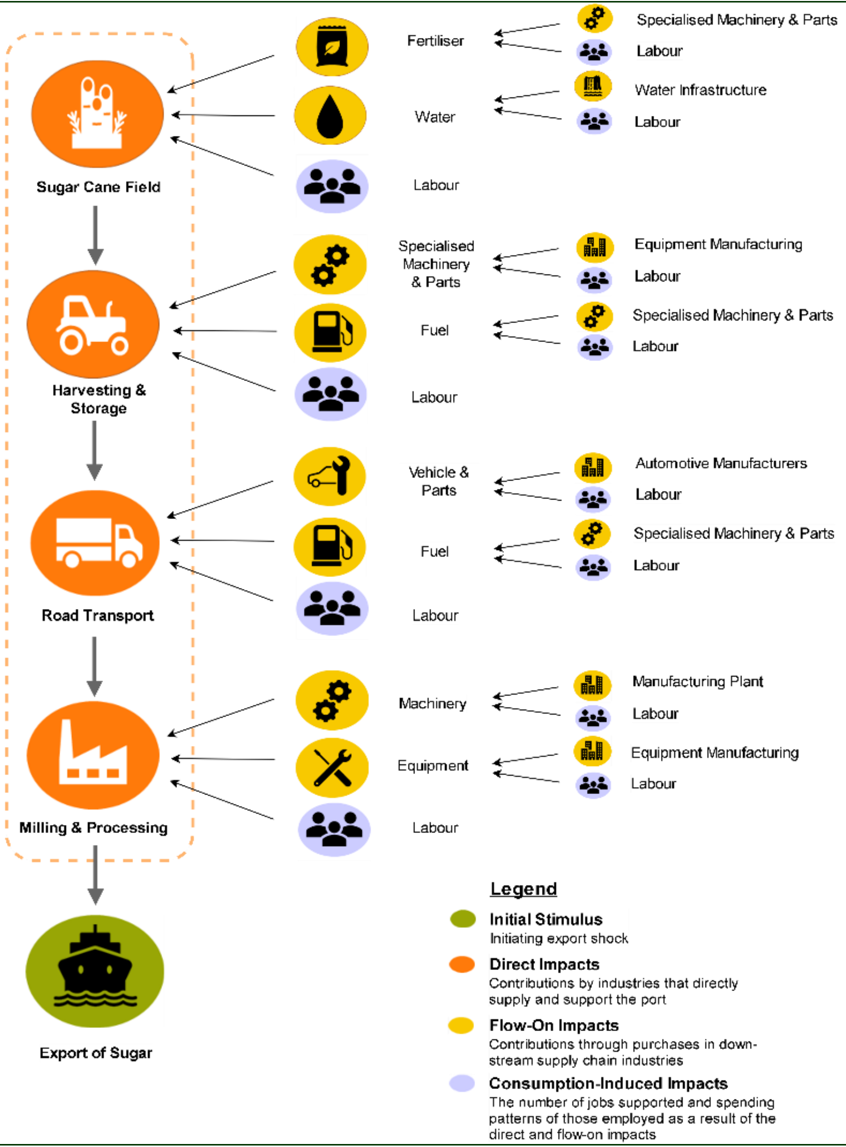
An I-O model captures the manner in which an initial "shock" – such as a new expenditure on goods or services – flows out through the various sectors of the economy, generating further economic activity. Generally, I-O models can be understood as a summary of all supply chains in a region, as shown in Box A.1 below.

Box A.1 Example of IO Model Function

The sugarcane production supply chain, as shown to the right, provides an example of how economic modelling is undertaken. The I-O model can, in general, be understood as a summary of all supply chains in a region.

Each of the steps along the primary supply chain requires inputs which are sourced through the associated businesses' own supply chains. For example, canegrowers require fertiliser and water; harvest and storage facilities require machinery and energy; and road transport requires vehicle parts and fuel.

As the inputs to the secondary supply chains require inputs in their own process, the supply chains fan out to the right on the diagram. Importantly, as some of the value is (typically) paid as wages, kept as profits or used to purchase imports, the payment flows to the sub-supply chains become smaller and smaller and eventually become (close to) zero.



Data source: Synergies.

At the heart of the model is a static representation of the regional economy called an I-O table, which reflects the interdependencies between 21 industry sectors. Synergies creates I-O tables for Queensland as a whole and for each development region of interest following the method of regionalisation. We derive these tables by starting with the latest (2016-17) national I-O table published by the Australian Bureau of Statistics (ABS)[26] and adjusting it using other more granular data. Various sources of granular secondary data are used in the process of developing regional I-O tables which allows us to mechanically and appropriately inspect and scale the host (i.e., national) I-O table, ensuring state and sub-state tables derived reflect the economic structure of each region as accurately as possible. Our approach is consistent with other well-accepted and widely used hybrid[27] regional I-O approaches, such as the Distributive Commodity Balance (DCB)[28] and the Generation of Regional Input-Output Tables (GRIT) [29].

Non-linear I-O models (the type used by Synergies) largely overcome potential weaknesses of the conventional, linear form. It does this by relaxing the constraining assumption that all factors of production shift in proportion to each other. The non-linear version also accounts for inter-regional trade more accurately and includes economic supply constraints. Synergies' I-O model has been developed 'in-house' using best practice standards for non-linear I-O modelling.[30] The model has been peer reviewed by John Mangan, Professor of Economics within the UQ Business School at the University of Queensland.[31]

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[26] Australian Bureau of Statistics (2019). Australian National Accounts: Input-Output Tables, 2016-17. Cat. No. 5209.0.55.001, Commonwealth of Australia, Canberra.

[27] The hybrid approach combines the use of non-survey techniques with superior data (i.e. statistical information obtained through surveys, experts or other reliable sources).

[28] Christie, J. and Varua, E., M. (2010). Application of the Distributive Commodity Balance Method Approach to Regional Disaggregation: the Case of Penrith LGA. University of Western Sydney.

Johnson, P. (2001). An Input-Output Table for the Kimberly Region of Western Australia. Economic Research Centre, University of Western Australia.

[29] Jensen, R., C., Mandeville, T., D. and Karunarante, N., D. (1977). Generation of Regional Input-Output Tables for Queensland. Report to Coordinator General's Department and Department of Commercial and Industrial Development, Department of Economics, University of Queensland.

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West, G., R. (1980). Generation of Regional Input-Output Tables (GRIT): An Introspection. Economic Analysis and Policy, 10, pp. 71-86.

West, G., R., Morison J., B. and Jensen, R., C. (1984). A Method for the Estimation of Hybrid Interregional Input-Output Tables. Regional Studies, 18(5), pp. 413–422.

[30] The method adopted by Synergies for preparing the regional I-O tables is consistent with the GRIT method, as documented in West, G., R. (1980). *Generation of Regional Input-Output Tables (GRIT): An Introspection. Economic Analysis and Policy*, 10, pp. 71-86; and West, G., R., Morison J., B. and Jensen, R., C. (1984). *A Method for the Estimation of Hybrid Interregional Input-Output Tables*. Regional Studies, 18(5), pp. 413–422.

[31] Professor Mangan is one of Australia's leading authorities on economic impact assessment and has published widely in the academic literature.

A CGE model is considerably more complex again as it allows for more sophisticated economic and behavioural assumptions that are not addressed in I-O models. These include the explicit incorporation of prices, the capture of behavioural responses by consumers, investors, and businesses due to price changes, and the possibility of changes in the combination of inputs used in production due to change in relative prices or technology.

The drawback of CGE models is the cost of implementation and the need to specify large numbers of parameters and coefficients, data for which are often unavailable. Hence, 'best guess' values must be used which leads to a large unknown and questionable element in the model. There is evidence to suggest that this can have a significant impact on empirical results.[32]

32 Wang, J and Charles. B, M. 2010, *I-O Based Analysis: A Method for Estimating the Economic Impacts by Different Transport Infrastructure Investments in Australia*