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Executive Summary

The proposed Oakajee port and rail network can play a key role in the development of potential mining opportunities throughout the Midwest and Northern Goldfields Regions. To achieve this, a transport system needs to be identified that will provide an economically viable network that will meet the current and future opportunities as well as the technical specifications necessary for connectivity with the wider Western Australian freight transport system.

The purpose of this report is to identify the range and location of freight transport demands that will underpin the development of the Oakajee port and transport network, and to provide a framework and recommendations that will assist achievement of an integrated 'best practice' long term system for the Midwest and Northern Goldfields.

Transporting bulk commodities above 1 million tonnes per annum (mtpa) over long distances cannot be cost effectively achieved using road haulage over the public road network. At this volume, road transport suffers from high costs of labour as well as significant wear and tear on road pavements. Even with modern multi-unit trucks, the labour costs remain high when compared with rail.

The alternative is to construct a freight railroad to meet these demands; however capital costs typically exceed $3 million per kilometre. The key benefit associated with the construction of a new mineral railroad designed to optimise efficiency and to provide third party access is an operating cost of around 2 cents per tonne kilometre of material transported. These low operating costs will result in significant costs savings compared to road, improving the commercial viability of isolated, highly transport dependent and otherwise marginal mineral deposits.

The Midwest and Northern Goldfields regions contain a wide range of mineral deposits but the predominant mass haul mineral is iron ore, both haematite and magnetite. There are three mineral clusters of significance that have been identified, and are depicted in Figure 1 at the back of this report:

- The northern group of resources and prospects covering Jack Hills, Weld Range, Wiluna, Robinson Range etc.
- The southern group of resources and prospects covering Koolanooka, Karara, Mount Gibson, Extension Hill etc.
- The Yilgarn group, including the resources and prospects that extend northwards from Koolyanobbing towards Sandstone.

The companies with iron ore resources in the northern group have generally been advocating the development of a direct, high quality standard gauge railroad from the northern area to the new Oakajee Port. Whereas companies with resources in the southern area are generally advocating the redevelopment and extension of the existing WestNet narrow gauge network from Karara to access Geraldton Port, and later Oakajee Port, with the aim of minimising initial capital costs. One company with substantial iron resources in the southern area proposes the construction of a 280 km slurry pipeline and associated water pipelines to transport its magnetite ore to Geraldton Port.

If two independent and different gauge railroads are built to service the northern and southern areas respectively, this will create compatibility issues between the two networks, and will result in inefficiencies and/or duplication of both rail infrastructure and materials handling facilities at the Port. It will in effect preclude achievement of the economies of scale that might be achieved through construction of one integrated shared railroad system. The construction of one integrated railroad and port infrastructure system has the potential to provide a range of benefits including:

- Integration of materials handling facilities within Port saving capital and operating costs;
• A single track approach reducing capital costs of rail construction; and
• Ability to operate rail cars to multiple mine sites thus reducing cost and increasing the flexibility of above rail operations.

In broader strategic terms, the selection of a preferred rail network option for accessing Oakajee Port cannot be based on servicing the needs of the northern and southern mining areas alone. Consideration must also be given to possible future rail extensions and connections that might be required to service other iron ore resource areas, such as the Yilgarn area, and/or the Northern Goldfields. These additional future tasks may assist to optimise the viability of the rail network and to facilitate further development.

Analysis of the Midwest and Northern Goldfields areas suggests that there is the potential for additional resource development given ready access to rail and port facilities. The following resources could also provide a secondary source of products for the rail and port:

- Nickel;
- Manganese;
- Copper/Lead/Zinc; and
- Uranium

The general location of the known resource and prospective areas for the above minerals are shown in Figure 5 at the back of the report.

Two basic railway network options have been considered in this report for connection of the northern, southern and Yilgarn iron ore areas to the proposed port at Oakajee. The first option comprises a central spine extending east-west from the coast to around Sandstone, with branches to the individual mines and mining areas to the north and south. The central spine could be extended further east and the Goldfields standard gauge network extended north of Leonora to achieve a connection of these two systems if required in the future. The conceptual alignment of the ‘spine’ network is shown in Figure 7.

The second option comprises a central spine extending east-west from the coast to around Mullewa, and two arms extending from Mullewa to the northeast and southeast respectively. The northern arm is to service the northern iron ore area (Weld Range and Jack Hills), with a possible extension further eastwards to the Wiluna area. The southern arm is to service the southern iron ore area (Koolanooka, Karara and Extension Hill), with a potential future extension to the Yilgarn iron ore area and the existing Goldfields standard gauge network. The conceptual alignment of the ‘two arm’ network is shown in Figure 8.

The two arm network has a number of significant advantages over the central spine network. These include:

- More direct rail service to all three major iron ore areas – Hence it offers a more cost effective solution in terms of operating costs for these major users.
- Less railway infrastructure - Hence lower overall capital cost and therefore less initial funding. This is important as the railroad will start with a small amount of traffic, and its presence then enabling other mines to be set up, catalysed by having an efficient transport network to an export port.
- Cost effective to build in stages - The arm going north does not need to be constructed at the same time as the one going south, and requires only a small length of central spine to be built.
- Greater flexibility for possible extensions to service other needs - The two arm network provides more cost effective opportunities to extend the railroad to areas of smaller resources, such as Wiluna West in the northern area, Mt Gibson/Extension Hill in the southern area, and also the Yilgarn area.
From a wider strategic perspective, both networks provide opportunities for connection of the existing Wheatbelt Narrow Gauge Network or the Pilbara rail systems should they offer sufficient benefits in the longer term. However, a more likely future requirement is to connect the Goldfields rail systems, either the Perth – Eastern Goldfields Rail (EGR) or the Leonora – Kalgoorlie Rail. Both networks provide the opportunity for such a connection, but a connection via the southern railroad of the two arm network would be the more direct option and also the more cost effective because it would also service the Yilgarn iron ore area.

Access to Oakajee is the priority, but the gauge and standards adopted for the southern railway line to Oakajee will be the key in determining the viability of future strategic extensions to the Yilgarn area and beyond. If the strategic option of a future rail connection between Oakajee and the Goldfields network is to be preserved, this requires that the rail network constructed to service Oakajee Port be compatible with the existing Goldfields standard gauge network.

The potential ultimate network extending from Oakajee to the Goldfields would provide a rail link distance from Leonora and Kalgoorlie to Oakajee that would be competitive with the rail link to Esperance and Fremantle Ports. The advantage of Oakajee is immense in that the blue water sailing distance to South East Asia is almost 2,000 nautical miles shorter than from Esperance, and the export logistics chain does not pass through any major population centres as Northern Goldfields required at Esperance and Fremantle Ports.

Rail gauge and standards are a significant issue for the proposed Oakajee railway system. The following technical requirements must be considered to achieve best practice cost rates of around 2 cents per net tonne kilometre:

- **Gauge** – Both standard and narrow gauge railways can achieve these cost rates however dual gauge will have a significantly higher capital cost and will also have higher operating costs. It should be noted that not all standard gauge railways are compatible, with different wheel profiles and cant varying depending on the technology employed.

- **Axle Loads** – International Practice for standard gauge heavy haul railroads are for axle loads of around 32 tonnes, and 30 tonnes for narrow gauge. Higher axle loads are achievable on standard gauge railroads, with Fortescue Metals operating trains of 40 tonnes axle loads, and BHPB Iron Ore operating trains of 37.5 tonne axle loads on their respective Pilbara railways. However, heavier trains require much more technical engineering of track and rail cars to maintain the necessary safety and efficiency standards.

- **Vertical Alignment** – Not greater than 1/200 against loaded trains;

Consistent with the objectives of the brief, this report makes the following recommendations about the development of the rail network serving Oakajee:

- The new rail network should be standard gauge to facilitate a future connection to the standard gauge lines to the east or south of the Yilgarn area (and potentially also to the Pilbara standard gauge railways should that be required in the future).

- The rail network should be built to the best heavy haul standards but because of the multiple user access, it is suggested that the axle load be limited to 32 tonnes.

- The network should be constructed along the “Two Arm Network” model to minimise the upfront initial requirement for capital and develop the most efficient routes to port for the various geographically diverse iron ore deposits.

- A suitable operating model for the ownership and operation of the railway should be developed, that conforms to Western Australia’s Rail Access regime requirements.

- The optimum route to service the Jack Hills and Weld Range area is essentially the most direct route to Oakajee Port having regard for the various topographical, economic, social and environmental issues and constraints.
• The capital requirements, timescales and practical implications of upgrading the present narrow gauge line to the southern area should be compared to the cost of building a new standard gauge heavy haul line. The review must incorporate the Capex and ongoing Opex of both operations, and the benefits of full flexibility to achieve the desired longer term strategic outcomes.

• All future rail infrastructure development in the region should be undertaken in accordance with the strategic framework and principles outlined in this study, subject to consultation with key stakeholders, and endorsement by Government.

The networks illustrated in this document are conceptual in nature and do not take into account any of the physical features of the land through which they pass. Similarly no research has been done on environmental, native title and land ownership issues at this stage. However, while it is recognised that additional more detailed consideration of these aspects may influence the precise alignment of the various components of these networks, it is considered that they are in the main unlikely to alter the higher level strategic assessments and conclusions drawn in this report.

A future modern fast and heavy duty freight connection to Perth is another future option.
1 Introduction

Arup were appointed by the Department for Planning and Infrastructure (DPI) on 10 December 2008 for the Provision of Rail Engineering and Rail Operations Consultancy for the Selection of the Rail Corridor for the Oakajee Project. The consultancy is split into two separable parts, namely:

- Stage 1 – Strategic Rail Network Assessment
- Stage 2 – Detailed Operational Modelling and Assessment

This report is for Stage 1 – Strategic Rail Network Assessment. The purpose of the study is to identify the strategic rail network options for connecting of the Midwest and Northern Goldfields iron ore mineral areas to Oakajee, ensuring that the Oakajee rail line provides a strategic fit within the complete transport network in Western Australia.

1.1 Study Objectives

To define a strategic framework for a new railroad centred on Oakajee and Geraldton that will provide world class economic rail transport infrastructure from new and existing mines in the Midwest and Northern Goldfields of Western Australia for export from a suitable port. The specific focus of this study is on the mass haul of iron ore although other mineral deposits of significance have also been considered.

1.2 Proponent Proposals

Alignment options have been provided to DPI however the specific details of each proposal are not required for this analysis. The following key engineering standards, alignments and mine locations have been presented within the proponent’s proposals:

- Stand alone rail corridor to Jack Hills (via different routes) – North-east of Oakajee
- High standard rail corridor;
- Standard gauge; and
- Entry to the proposed deep water port at Oakajee via a cutting in the Moresby Ranges.

An additional railroad is proposed to the South East to the mine sites located at Koolanooka and Karara. Various proposals have been suggested, including proposals to upgrade and utilise the existing narrow gauge railroad, or to construct a new railroad from Oakajee to Karara via Mullewa.

1.3 Report Context

This report has drawn on freely available information from the Department of Mines and Petroleum (DMP)\(^1\), the mining companies and other publically available resources. It should be noted that due to the economic downturn, the viability of some of these mines, the proposed output and timeframes may now be different to those presented. Consideration should be given to the long term viability of the mining proposals.

1.4 Study Area

The area covered by this study is centred on the Midwest and Northern Goldfields regions as shown in Figure 1. For the purposes of this study three iron ore mineral clusters or areas of significance have been identified, and also depicted in Figure 1:

- The northern group of mines and prospects covering Jack Hills, Weld Range, Wiluna, Robinson Range etc.

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\(^1\) Previously Department of Industry and Resources (DOIR)
• The southern group of mines and prospects covering Koolanooka, Karara, Mount Gibson, Extension Hill etc.

• The Yilgarn group, including the mines and prospects that extend northwards from Koolyanobbing towards Sandstone.

The strategic framework for the new rail network in the Midwest and Northern Goldfields of Western Australia focuses on these areas and linkages back to Oakajee and Geraldton.

1.5 Estimates within this Report

The estimates in this report are quoted in Australian Dollars, January 2009.
2 Background

The proposed Oakajee Port has potential to play a key role in the development of the mining and resources sector in the Midwest and Northern Goldfields regions of Western Australia. There are many mineral deposits that have been found, with a number of mines already in production, and others that are being brought into production. Considerable exploration continues in the area. The Midwest and Northern Goldfields regions contain a wide range of mineral deposits but the predominant mass haul mineral is iron ore, both haematite and magnetite.

To date the development of mines in the area has been hampered by high cost land transport and less than efficient ports at both Geraldton and Esperance, both impeded by having the ports in the middle of growing urban communities.

Oakajee Port offers a new deep water port, remote from urban communities, in a strategic location that is closer to South East Asia when compared to Esperance, by some 2,000 nautical miles. It will provide an economic advantage to the mining community in the Midwest and Northern Goldfields regions of Western Australia.

This provides a unique opportunity for the Government of Western Australia to plan a strategic new mass haul transport network that will service the mines in the area, and provide a low cost economical solution for the overall transport task. It is critical that this is well considered and thought through.

Progressive development of a well designed, high standard railroad will be a catalyst for development and expansion of mining activity in the region. As transport costs measured in cents per tonne kilometre of land transport approach competitive world’s best practice rates, it is likely that more and more companies will prove their reserves and move into the production phase.

Initially the development of the Oakajee railroad will be dependent on iron ore, but the strategic framework set out in this report considers the needs of other minerals such as manganese, nickel and lead that also require efficient and cost competitive transport infrastructure and operations to develop. Low volume miners, such as gold producers are not expected to provide sufficient traffic levels to contribute to the viability of development of the strategic rail network, but once developed the rail network may provide an alternative to the road system for the transport of some mining inputs to these producers.

When the new network is reviewed from a future perspective, such as projecting back from say 2030, it is important to see that no long term problems were created or opportunities missed. Issues that have the potential to limit the effectiveness of the network and/or impose a high cost burden need to be identified and resolved so as not to inhibit development of the mining sector in the region, or the wider long term interests of the State.
3 Existing Transport Infrastructure

3.1 Introduction

Creating a strategic fit with the other infrastructure in the Midwest and Northern Goldfields, including complementary and competing infrastructure is critical in determining the optimal railroad solution for the study area. This section outlines the key infrastructure with some influence or interrelationship with Oakajee Port.

3.2 Port Infrastructure

3.2.1 Geraldton Port

Situated 424kms north of Perth, Geraldton Port is Australia’s second largest grain export facility, with exports of over 1.3 million tonnes of grain in 2006/07. Additionally, over 50% of the port’s cargo is from iron ore mining operations in the Midwest.

The port can accommodate fully laden Handymax and many Panamax vessels with a draft up to 12.8m (the largest Panamax vessels require 14m draft). Berth 5 has recently been upgraded to a dedicated iron ore berth to meet the increasing iron ore demands of the Midwest. The new berth will enable the Port to load up to 12 million tonnes per annum (mtpa) of iron ore, an increase of 7.3 mtpa of iron ore and other minerals. There are also facilities for fertiliser, livestock, fuels, and general cargo.

Geraldton’s cargo breakdown for 2006-2007 is set out in Table 1.

Table 1: Cargo Breakdown 2006-2007

<table>
<thead>
<tr>
<th>Cargo</th>
<th>Tonnes</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>1,314,678</td>
<td>20.4%</td>
</tr>
<tr>
<td>Mineral Sands</td>
<td>907,264</td>
<td>14.1%</td>
</tr>
<tr>
<td>Fuels and Oils</td>
<td>172,510</td>
<td>2.7%</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>28,361</td>
<td>0.4%</td>
</tr>
<tr>
<td>General Cargo</td>
<td>11,541</td>
<td>0.2%</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>3,470,666</td>
<td>53.9%</td>
</tr>
<tr>
<td>Talc</td>
<td>97,496</td>
<td>1.5%</td>
</tr>
<tr>
<td>Concentrates</td>
<td>420,442</td>
<td>6.5%</td>
</tr>
<tr>
<td>Livestock</td>
<td>12,041</td>
<td>0.2%</td>
</tr>
<tr>
<td>Bunker</td>
<td>2,996</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,437,995</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Geraldton Port is currently serviced by a primary roads network that covers the whole of the Midwest region and extends into the Northern Goldfields, and a narrow gauge rail network that covers only the southwest portion of the Midwest region. Some of Geraldton Port’s dry bulk mineral exports are transport to Geraldton from the Northern Goldfields by road.

3.2.2 Fremantle/Kwinana Port

Fremantle Port comprises the Inner Harbour at Fremantle which handles the state’s container trade and some bulk cargo; and the Outer Harbour at Naval Base/Kwinana that handles grain and dry bulk mineral cargo, including some dry bulk mineral products that are transported from the Goldfields, principally by rail.

3.2.3 Esperance Port

Esperance is a potential competitor for Oakajee, with standard gauge rail running from Esperance into the Goldfields to Leonora via Kalgoorlie. Esperance Port currently exports the following products from the Goldfields:

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2 Source Geraldton Port Authority
Iron ore is the major export from Esperance, accounting for 76% of all exports by weight, or around 7.5 million tonnes of ore. All of the iron ore currently exported from Esperance is from Cliffs Natural Resources Koolyanobbing mining operations in the southern portion of the Yilgarn mineral group.

3.3 Rail Infrastructure

3.3.1 Overview
The freight rail network in Western Australia comprises approximately 8000km of predominantly narrow gauge railroad. The network comprises the following three systems:

- Southern Narrow Gauge Network – Predominantly in the grain growing regions of Western Australia's Wheatbelt, (3,673 kms long with a further 314 kilometres not operational);

- Southern Standard Gauge Network – Key routes between the Eastern States and Perth (westwards from the WA/SA border) as well as between the Goldfields (Leonora) and Esperance Port (1192 km); and

- Pilbara Rail Networks – privately owned standard gauge rail networks (BHPB, Rio Tinto, Cliffs Natural Resources and Fortescue Metals) for transport of iron ore in the Pilbara Region (approximately 2700 km).

The southern narrow gauge network and the southern standard gauge network are both 'open access' networks operated by WestNet Rail, and the Australian Rail Track Corporation under lease from the Western Australian Government. The Pilbara Railroads are owner operated systems dedicated to the transport of iron ore, principally for their respective owners.

The existing rail network in the study area is shown in Figure 2, located at the back of this report.

3.3.2 Rail – Narrow Gauge Midwest Region
There are two narrow gauge rail lines through the wheat belt accessing Geraldton Port:

- Geraldton to Perth via Mingenew and Moora (Western Route, including the spur line from Dongara to Eneabba);

- Geraldton to Mayo via Mullewa and Morawa (Note: there is a non-operational section of railroad between Buntine and McLevie that may be reopened should it be required, providing alternative access to Perth and the Southwest via Avon).

Both of these WestNet Rail lines may provide rail access to developing and established mine sites in the Midwest region. Table 2 sets out rail operating characteristics for the various rail sections.
Table 2: Rail characteristics of existing narrow gauge rail in the Midwest Region\(^3\)

<table>
<thead>
<tr>
<th>Route</th>
<th>Gauge</th>
<th>Gross Tonnes per annum(^4)</th>
<th>Axle Load (tonnes)</th>
<th>Current Main Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narngulu to Mullewa</td>
<td>Narrow</td>
<td>5,102,000</td>
<td>16</td>
<td>Grain/ Iron Ore</td>
</tr>
<tr>
<td>Mullewa to Maya</td>
<td>Narrow</td>
<td>335,000</td>
<td>16</td>
<td>Grain</td>
</tr>
<tr>
<td>Narngulu to Moora</td>
<td>Narrow</td>
<td>1,081,000 – 2,806,000</td>
<td>16 - 19</td>
<td>Grain / Mineral Sands</td>
</tr>
</tbody>
</table>

As can be seen, the axle load for the 3 key sections is very low at 16 tonnes per axle. Low axle loads make it difficult to transport dense bulk products such as iron ore and are likely to require major upgrades to the network should iron ore be moved in large volumes via these lines.

3.3.3 Rail – Standard Gauge Goldfields Region

The East West Rail Corridor links Perth to Sydney/Melbourne/Adelaide and is the main land freight route into Western Australia, accounting for approximately 81% of all land freight transported between Western Australia and the East Coast. The rail line is standard gauge and carries over 26 million gross tonnes per annum\(^5\) (mtpa) on the most heavily used section.

The standard gauge line from Perth to Kalgoorlie, known as the Eastern Goldfields Railway was originally constructed by the private Midland Railway company and was subsequently incorporated into Westrail when the line was standardised in the late 1960’s. The line is owned by the Western Australian Government and access is granted by the Australian Track Corporation through agreements. The line west from Kalgoorlie to the South Australian Border (Interstate Line) was built in 1917 by the Commonwealth Railways and is now owned by the Australian Rail Track Corporation.

WestNet Rail also operates the standard gauge rail line between Leonora and Esperance via Kalgoorlie. These lines are converted narrow gauge lines, have steep grades and sharp curves and are of a lower standard than the other standard gauge lines in the area. The line is currently utilised by:

- **Nickel West** - to transport both Mt Keith and Leinster concentrate to the Kalgoorlie Nickel Smelter, where it is processed into nickel matte for export or further processing at the Kwinana Nickel Refinery;
- **Minara Resources Ltd.** - Minara Resources utilises the Leonora to Kalgoorlie line to transport reagents to their Murrin site and nickel to Kwinana for export;
- **The Shell Co of Australia Ltd** - Shell utilises the line to transport bulk diesel to various operations and communities in the region (Kalgoorlie to Leonora);
- **Jubilee Mines NL** - Jubilee Mines utilise the line to transport wet nickel concentrate from Leinster to the Esperance Port for export; and

---

\(^3\) Source: WestNet Rail

\(^4\) Figures relate to section tonnes (i.e. in both directions)

\(^5\) Source: WestNet Rail
• **Cliffs Natural Resources (Previously Portman Mining)** – Exports iron ore from the Koolyanobbing Mine through Esperance Port (NB: Initial movement is along Perth to Kalgoorlie Standard Gauge before turning off on the Kalgoorlie Esperance Line).

The rail lines from Kalgoorlie to Leonora and Kalgoorlie to Esperance have been converted to standard gauge but are largely on the old narrow gauge alignments and formations, with steep grades, up to 1 in 40 and tight curves. The line to Esperance has subsequently been upgraded as it has been carrying increasing amounts of mineral traffic, principally iron ore, for export through Esperance. The line to Leonora remains in a poor condition with low axle loads, and can only handle short trains because of short passing loops and the steep grades.

Table 3 sets out rail operating characteristics for the various rail sections.

**Table 3: Rail characteristics of existing standard gauge rail in the Goldfields Region**

<table>
<thead>
<tr>
<th>Route</th>
<th>Gauge</th>
<th>Gross Tonnes per annum</th>
<th>Axle Load (tonnes)</th>
<th>Main Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leonora to Kalgoorlie</td>
<td>Standard</td>
<td>2,519,000</td>
<td>23</td>
<td>Nickel/ Diesel/ Lead Carbonate</td>
</tr>
<tr>
<td>Kalgoorlie to Esperance</td>
<td>Standard</td>
<td>13,563,000</td>
<td>20.5 - 24</td>
<td>Grain/Nickel/ Iron Ore / Fuels</td>
</tr>
</tbody>
</table>

It is noteworthy that BHP, the operator of Nickel West considers the Leonora to Kalgoorlie line as “a constraint to development due to the line suffering from steep inclines, poor track condition, short crossing stations and a vulnerability to flooding, resulting in load, speed and reliability constraints. These combined constraints create logistical and cost impacts for businesses utilising the line.” Provision of an alternative rail route or major upgrading of the existing Kalgoorlie-Leonora line may result in additional mine viability and expansion of nickel production in the Northern Goldfields area.

### 3.3.4 Standard Gauge – Pilbara

There are three separately operated railroad networks in the Pilbara. The two largest networks are those owned and operated by BHPB Iron Ore and Rio Tinto Rail, both around 1200 route kilometres in length. The Rio Tinto Rail operations are a combination of the lines formerly built by Hamersley Iron, owned by Rio Tinto, and those built by Robe River, owned by Rio Tinto and Cliffs’s Natural Resources. Although operated as one entity they are in effect two separate systems with different ore cars that require separate and specialised loading and unloading facilities. The third and newest operation is that of Fortescue Metals Group (FMG) and comprises a 240 km long line from Port Hedland to Cloud Break.

Each of the Pilbara networks has been developed into a highly specialised railroad that gains significant efficiencies through using high axle loads, and other advanced techniques. Pilbara Rail (Rio Tinto/Cliffs’s Natural Resources) operates at 32.5 tonne axle loads, BHPBIO 37.5 tonne and FMG 40 tonne axle loads, the highest in the world, on a main line railway.

To achieve this level of operation the owners have developed sophisticated ways of managing the wheel rail interface and each have variations on the shape of rails, the precise gauge between the rails and the wheel profiles. For example the gauge of a standard gauge railway is 1435mm, but this frequently varies by a few millimetres and can and does vary from around 1432 mm to 1440 mm even on the defined interstate network in Australia.

---

6 Source: WestNet Rail  
7 Figures relate to section tonnes (ie in both directions)  
8 Source: BHP Billiton, Submission to the Western Australian State Infrastructure Strategy, February 2006
When coupled to high axle loads, the matching of the wheel to the rail has to be accurate to avoid exceeding the yield point of the steel in either the rail or the wheel. Each of the Pilbara railways has adopted different approaches resulting in risk of rail or rolling stock failure should “foreign” rolling stock be operated on the line. The resultant delays in production could be substantial.

### 3.4 Road

The network comprises four groupings based on road function, namely:

- **National Highway** - Great Northern Highway, the north-south strategic freight route that passes through the eastern parts of the study area;
- **Coastal Route** - Brand Highway and North West Coastal Highway, the coastal north-south strategic freight route;
- **East West Route** - Geraldton-Mt Magnet Road and Mt Magnet-Sandstone Roads, linking Geraldton to the eastern Murchison and Northern Goldfields; and
- **Wheat Belt Access Roads** - links to Wheat belt towns and grain receival points.

Roads in the Midwest Region carry a large number of heavy vehicles, mainly serving the mining areas. Table 4 provides examples of the percentage of heavy vehicles operating on a selection of Midwest roads.

#### Table 4: Midwest Roads Heavy Vehicle Usage

<table>
<thead>
<tr>
<th>Road</th>
<th>Average Annual Daily Traffic</th>
<th>% Heavy Vehicles</th>
<th>Number of Heavy Vehicles per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geraldton-Mt Magnet Rd</td>
<td>963</td>
<td>17%</td>
<td>161</td>
</tr>
<tr>
<td>Great Northern Highway</td>
<td>512</td>
<td>51%</td>
<td>261</td>
</tr>
<tr>
<td>Brand Highway</td>
<td>1797</td>
<td>17%</td>
<td>309</td>
</tr>
<tr>
<td>North West Coastal Highway</td>
<td>1750</td>
<td>24%</td>
<td>420</td>
</tr>
<tr>
<td>Goldfields Highway</td>
<td>71</td>
<td>45%</td>
<td>32</td>
</tr>
</tbody>
</table>

### 3.5 Road Maintenance

A key benefit of a new freight rail network into the Midwest is the transfer of heavy vehicles from the road network to rail and this will in turn reduce significantly the road maintenance requirements, through the transfer of large volumes of bulk freight from road to rail. There are already considerable levels of heavy transport over the roads carrying iron ore and other minerals to Geraldton for export. Once the present economic climate improves it is likely that the level of trucks on the highways will increase, and that their transfer to rail would be of considerable benefit.

Of equal importance is the reduction of heavy road transport will improve the safety of other users of these roads and improve the liveability of the communities through which the roads pass.

---

9 Source: Main Roads Western Australia
4 Other Factors Impacting on Rail Alignments

The transport demand for freight rail transport in the study area is the key to determining the preferred shape of the strategic long term rail network for the study area. Nevertheless, there are several other significant features that impact on the development of suitable alignments for the long term freight rail network.

4.1 Square Kilometre Array

The Australian Square Kilometre Array Pathfinder (ASKAP) is a next-generation radio telescope. It will be a key demonstrator for new technologies required by the Square Kilometre Array (SKA) – an international project now under consideration by a consortium of 19 countries.

The SKA will be built either in South Africa or Australia with construction of the SKA scheduled to begin in 2012 for initial observations by 2016 and full operation by 2020. If built in Australia, the central core of ASKAP will be located at the Murchison Radio Observatory in inland Western Australia, one of the most radio-quiet locations on the Earth, and this site is one of the two short listed potential locations for this facility, along with the site in South Africa.

For Australia to be awarded the SKA project, it is necessary for the government to maintain a strict radio quiet zone around the proposed SKA site. To achieve this objective, several concentric buffer zones have been specified that radiate out from the proposed SKA site. Varying levels of restrictions apply to the type of development and radio frequencies permitted within these zones. The most stringent restrictions apply within the central 70 kilometre radius buffer zone scribed around the SKA site. In addition the Western Australian Government has implemented a Section 19 Exemptions Zone to the mining act primarily to ensure that mining activities around the SKA site do not compromise the site’s radio quiet requirements. The 70km radius central buffer zone and Section 19 Exemptions Zone are shown in Figure 3.

The following details the Section 19 Exemption Zone requirements of the Mining Act (1978) of Western Australia

19. Power to set aside land for mining or exempt it therefore

   (1) The Minister may from time to time by instrument in writing under his hand —

   (a) exempt any land, not being private land or land that is the subject of a mining tenement or of an application therefore, from —

      (i) mining;

      (ii) a specified mining purpose;

      (iii) this Act; or

      (iv) a specified provision of this Act;

   or

   (b) vary or cancel an exemption referred to in paragraph (a), and shall cause any such instrument to be published in the Government Gazette as soon as is practicable after its execution by him.

The SKA buffer requirements therefore represent a significant constraint in terms of possible alignments for development of a heavy freight railroad to connect the Northern Group iron ore deposits with port facilities on the Geraldton coast.
4.2 Track Access Regime - Westnet

The present narrow gauge rail operations around Geraldton are operated under a track access regime overseen by the Government of Western Australia. The track is owned by the State Government but is leased to and maintained by WestNet Rail.

Presently some iron ore moves on the narrow gauge network from Mullewa to Geraldton. The narrow gauge line from Geraldton to Mayo via Mullewa and Morawa also interfaces with and services grain silos along the line.

Parts of the existing narrow gauge railroad corridor from Nangulu to Morawa via Mullewa may be able to be adapted for development of a higher standard or narrow gauge freight railway to meet the transport needs of a new railroad linking to the proposed Oakajee Port.

WestNet Rail have considered various options to cater for increased iron ore volumes, including upgrading the present narrow gauge line to carry higher axle loads (up to 25 tonne axle loads), and an option to build a parallel standard gauge line within their existing corridor.

4.3 Geraldton Northeast Goldfields Infrastructure Corridor

An easement is being established by the Department for State Development[^10] for development of an infrastructure corridor that extends from the Geraldton area eastwards to the Northern Goldfields. This corridor is known as the Geraldton to Northeast Goldfields Infrastructure Corridor (GNEGIC) and is shown in Figure 3. The easement being established for this corridor may provide an opportunity for part of the Oakajee railway to be located within this easement. The cross sectional concepts for the GNEGIC are set out in Figure 4 below.

**Figure 4: Infrastructure Corridor Concepts[^11]**

[^10]: previously the Department of Industry and Resources
[^11]: Source: Figure 4 from Bowman Bishaw Gorham, 2002
However, while the GNEGIC easement may have sufficient width to accommodate development of a freight railway there are several factors which may mitigate against the use of this corridor for the Oakajee railway. The alignment standards for railways, roads, pipe lines and overhead transmission cables vary considerably, and the ability to cost effectively group all such services in such a way is not easily achieved. Furthermore the GNEGIC does not extend westwards to the coast; it terminates at the DBNGP. Also, at this point the rail design standards that can be cost effectively achieved along this easement are unknown, and the location of the easement may not provide a sufficiently direct route between the Oakajee Port and the iron ore areas that the railway is required to service.

4.4 Disused Rail - Mullewa to Wiluna

The Mullewa to Wiluna rail line is a disused narrow gauge railway dating from the early gold rush years (Geraldton to Meekatharra). The route of the disused railway is shown indicatively in Figure 3.

The branch from Meekatharra to Wiluna opened on 2 November 1932. The line operated east to Meekatharra until the 1970’s with an intermodal terminal to supply the Pilbara region. The line to Wiluna was closed on 5 August, 1957. The track and the majority of the structures with the exception of the small piece between Mullewa and Pindar, have been removed.
5 Potential Rail Transport Demand Drivers

5.1 Introduction

To assess the optimal rail solution, it is critical to understand what products will be imported and exported through the Oakajee Port and associated rail network. For consistency in reporting, Arup have used JORC compliant data from the Department of Mines and Petroleum (DMP). JORC compliant data includes Indicated and Measured Mineral Resources as defined by the JORC code. These definitions can be found in Appendix A of this report.

5.2 Resources in the Midwest and Goldfields Regions

The most prolifically found minerals by value in the study area as defined by Region (see Figure 1 for regional boundaries) are as follows:

Table 5 Midwest Region Mining – Values by Mineral Type ($)\(^{12}\)

<table>
<thead>
<tr>
<th>Mineral Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>707,873,638</td>
</tr>
<tr>
<td>Copper, lead and zinc</td>
<td>522,248,327</td>
</tr>
<tr>
<td>Crude Oil, Condensate</td>
<td>122,038,865</td>
</tr>
<tr>
<td>Heavy Mineral Sands, Chromite</td>
<td>403,493,370</td>
</tr>
<tr>
<td>Nickel and Cobalt</td>
<td>226,211,088</td>
</tr>
<tr>
<td>Iron ore</td>
<td>190,302,604</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>31,700,904</td>
</tr>
<tr>
<td>Silver</td>
<td>30,763,654</td>
</tr>
<tr>
<td>Construction Materials, Talc and Other</td>
<td>15,206,968</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,249,839,418</strong></td>
</tr>
</tbody>
</table>

Table 6 Goldfields-Esperance Region – Values by Mineral Type ($)

<table>
<thead>
<tr>
<th>Mineral Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>4,699,227,208</td>
</tr>
<tr>
<td>Gold</td>
<td>2,594,779,564</td>
</tr>
<tr>
<td>Cobalt</td>
<td>401,223,468</td>
</tr>
<tr>
<td>Copper and Zinc</td>
<td>98,698,757</td>
</tr>
<tr>
<td>Silver</td>
<td>15,013,768</td>
</tr>
<tr>
<td>Construction Materials</td>
<td>5,689,372</td>
</tr>
<tr>
<td>Gypsum and Limesand</td>
<td>5,358,678</td>
</tr>
<tr>
<td>Other</td>
<td>14,810,071</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7,835,651,100</strong></td>
</tr>
</tbody>
</table>

5.3 Optimal Minerals for Rail Transport

Several of the minerals detailed above are precious metals that are produced in relatively low volumes, with less than 1 million tonnes combined total per year being mined in Australia. These minerals are not seen as primary drivers for expansion of the rail system in the study area as low tonnages tends to lend itself to the lower capital cost transport option of road. The following minerals are not considered to be key drivers of the rail system for this reason:

12 Source: Western Australian Mineral and Petroleum Statistical Digest 2007-08
• Gold;
• Vanadium;
• Silver;
• Manganese; and
• Magnesite.

Although these minerals are not key drivers, if the rail network is extended to serve other primary needs then rail may provide an alternative to road transport for the transport of both the mining inputs and outputs associated with some of these mining operations.

Others such as Crude Oil and Natural Gas are mined offshore and have therefore been excluded from the analysis.

5.4 Iron Ore

Significant iron ore deposits have been identified in the Midwest Region, with several mine sites proposed to be developed or currently in operation. Iron ore is the most significant mineral in the study area in terms of potential transport demand and is therefore the primary driver for the proposed rail network. The location, density and bulk nature of iron ore has presented a challenging transport task for the State, with demand set to exceed Geraldton Port’s current capacity. As a result, the state is progressing options for the development of a deep water port at Oakajee to meet anticipated demands.

Due to the remote location of many of the more significant iron ore deposits (see Figure 5), rail to port is the preferred method of iron ore transportation because it offers the following potential advantages over road transport:

• Reduce whole of life costs of infrastructure;
• Less social impact; and
• Less environmental impact.

There are two types of iron ore in the Midwest, namely, haematite and magnetite. The key difference in the transport task is that haematite can be directly exported whereas magnetite, as a lower grade iron ore, generally needs to be partially processed (frequently referred to as “beneficiation”) to meet an acceptable grade for shipping, in terms of the percentage of iron ore in the exported material.

The more significant known iron ore deposits in the study area are located in three broad areas as shown in Figure 5, and as described below. Each of these areas contains varying volumes of proven Joint Ore Reserves Committee (JORC)13 compliant haematite and magnetite resources and reserves. Each area also contains other highly prospective tenements where ongoing exploration could lead to the discovery of additional iron ore resources.

5.4.1 Northern Group - Jack Hills/ Weld Range

Iron Ore can be found in four key areas of the northern group, including:

• Jack Hills;
• Weld Range;
• Robinson Range; and
• Wiluna.

Jack Hills and Weld Range are the two major resource areas initially targeted by the Oakajee Rail proponents. Jack Hills is currently in operation.
These key areas are shown in Figure 5, and the known proven reserves and resources in each area are shown in Table 7.

Table 7 – JORC Compliant Resources (Northern Group)

<table>
<thead>
<tr>
<th>Project Title</th>
<th>DSO</th>
<th>Magnetite</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld Range Iron Ore</td>
<td>199.4</td>
<td>199.4</td>
<td></td>
</tr>
<tr>
<td>Beebyn / Giralia</td>
<td>7.2</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>Wiluna West Iron</td>
<td>123.8</td>
<td>123.8</td>
<td></td>
</tr>
<tr>
<td>Jack Hills / Midwest Metals</td>
<td>15.4</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td>Jack Hills / Murchison Metals</td>
<td>176.8</td>
<td>354.6</td>
<td>531.4</td>
</tr>
<tr>
<td>Three Rivers Iron</td>
<td>2.8</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>525.4</td>
<td>354.6</td>
<td>880.0</td>
</tr>
</tbody>
</table>

The combined known JORC compliant iron ore reserves and resources in the northern group total approximately 880 million tonnes, of which 525 million tonnes is haematite ore and 355 million tonnes is magnetite.

5.4.2 Southern Group – Karara / Koolanooka/Extension Hill

The area south-east of Oakajee contains major iron ore deposits at Koolanooka, Mt Karara, Blue Hills, Koolanooka South, Extension Hill and Mt Gibson, as shown in Table 8.

Table 8 – JORC Compliant Resources (Southern Group)

<table>
<thead>
<tr>
<th>Project Title</th>
<th>DSO</th>
<th>Magnetite</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Gibson Iron Ore</td>
<td>19.5</td>
<td>254.8</td>
<td>274.3</td>
</tr>
<tr>
<td>Midwest Iron</td>
<td>22.9</td>
<td>547.0</td>
<td>569.9</td>
</tr>
<tr>
<td>Karara - Blue Hills / Gindalbie</td>
<td>23.8</td>
<td>2,487.0</td>
<td>2,510.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>66.2</td>
<td>3,288.8</td>
<td>3,355.0</td>
</tr>
</tbody>
</table>

The combined known JORC compliant iron ore reserves and resources in the southern group total approximately 3360 million tonnes, of which 66 million tonnes is haematite ore and 3289 million tonnes is magnetite.

5.4.3 Yilgarn Group – Koolyanobbing/Lake Barlee

Yilgarn is located over 200 km east, south east of Mt Gibson. The Yilgarn Area is currently serviced by existing rail infrastructure to Esperance Port, as shown in Table 9.

Table 9 – JORC Compliant Resources (Yilgarn Group)

<table>
<thead>
<tr>
<th>Project Title</th>
<th>DSO</th>
<th>Magnetite</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Caudan Iron</td>
<td>19.0</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>Koolyanobbing</td>
<td>149.6</td>
<td>149.6</td>
<td></td>
</tr>
<tr>
<td>Bullfinch North - Mayfield</td>
<td>8.0</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Carina Yilgarn / Polaris</td>
<td>96.1</td>
<td>96.1</td>
<td></td>
</tr>
<tr>
<td>Mt Manning Range Iron</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Pigeon Rocks Iron</td>
<td>8.5</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Mt Mason</td>
<td>2.2</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Lake Giles Magnetite</td>
<td>167.2</td>
<td>167.2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>288.4</td>
<td>167.2</td>
<td>455.6</td>
</tr>
</tbody>
</table>
The combined known JORC compliant iron ore reserves and resources in the Yilgarn group total approximately 460 million tonnes, of which 290 million tonnes is haematite ore and 170 million tonnes is magnetite.

### 5.4.4 Other Iron Ore

There are several other known proven iron ore deposits and prospects in the study area that are not located within the three general groupings described above. These deposits are:

- **Yogi (operated by Yalgoo/Ferrowest)** – located due east of Oakajee, Yogi is being considered for development with proven deposits of 113 million tonnes of magnetite ore. Also in the area are the prospects at Minga Well, Warriedar and Plateau.

- **Tallering Peak (Mt Gibson Iron)** – located 75km north east of Geraldton, represents 38 million tonnes of haematite ore. The mine is operational and is expected to remain operational until 2013.

<table>
<thead>
<tr>
<th>Table 10 – JORC Compliant Resources (Other Midwest Areas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProjectTitle</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Tallering Peak</td>
</tr>
<tr>
<td>Yalgoo Iron / Ferrowest</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

### 5.5 Nickel

Nickel is a potential secondary driver of transport demand in the study area. The majority of known nickel deposits and prospects are located in the eastern parts of the study area as shown in Figure 5. Some minor nickel deposits also exist at Weld Range.

Nickel is typically processed before being exported in the form of nickel in concentrate or nickel matte, therefore it is required that the ore be transported to a local concentrator or smelter before being exported. The following extracts are taken from Geoscience Australia’s – Australia’s Identified Mineral Resources 2007 publication:

> “Western Australia also has a nickel smelter at Kalgoorlie and a nickel refinery at Kwinana as well as BHP Billiton's nickel concentrators at Kambalda, Leinster and Mt Keith which process ores from third party operators.”

> “Most of the nickel ore treated at the Kambalda, Leinster and Mt Keith concentrators is smelted into nickel matte containing about 68% nickel at the Kalgoorlie nickel smelter. The mill and concentrator at Kambalda are supplied with third party ore and produce concentrate containing about 13% nickel.”

> “Some of the nickel matte was sold to overseas customers but most of it was refined at BHP Billiton’s Kwinana nickel refinery to produce LME accredited nickel briquettes, nickel powder and other intermediate products such as cobalt-nickel-sulphide. The Kwinana nickel refinery has a capacity of 70,000 tpa of nickel metal.”

Some of the major miners and processors of nickel in the Goldfields Area include:

- BHP Billiton;
- Norilsk Nickel;
- Xstrata; and
- Western Areas.

Nickel exports from Western Australian ports are shown in Table 11 below.
Table 11: Nickel exports (tonnes) from Western Australia

<table>
<thead>
<tr>
<th>Port</th>
<th>2007/08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esperance</td>
<td>229,130</td>
</tr>
<tr>
<td>Fremantle</td>
<td>58,144</td>
</tr>
</tbody>
</table>

The potential for export of nickel through either Geraldton or Oakajee Port, in either a processed or non-processed form, is not known. However, the construction of a rail line for transport of iron ore across the study area, coupled with development of the proposed heavy industries estate at Oakajee, may open up future opportunities for nickel exports through Oakajee Port, using the new railroad.

5.6 Base Metals - Copper / Lead / Zinc (Concentrates)

Copper, lead and zinc base metal ores are mined in the Midwest, predominantly from the Golden Grove mine in the Southern Group, operated by Newmont Mining. At present, the Golden Grove mine produces 100,000 tonnes of copper concentrate and 150,000 tonnes of zinc concentrate for shipment out of Geraldton Port.

The potential for greater exports of copper, lead and zinc can be found in the Northern Group, further east of Weld Range, near Wiluna where several companies have been exploring the area. The area has a large concentration of base metal deposits and prospects that are currently undeveloped. Lower transport costs may result in mine development.

There is also the potential for base metals mined near Leonora and presently exported through Esperance to be exported from Oakajee in the future, avoiding transport through a populated area, and therefore having a better outcome.

5.7 Mineral Sands

Mineral sands product exports account for 14%, just over 900,000 tonnes per annum of all exports from Geraldton Port. Iluka currently mines mineral sands at its Eneabba Mine site, located south of Geraldton near the coast. The sands are transported to the processing plant at Narngulu near Geraldton on the existing Eneabba-Geraldton narrow gauge railway, and the products, Zircon, Rutile and Ilmenite are then transported by road for export through Geraldton Port.

As the mineral sands deposits in the Perth-Geraldton coastal plain become depleted the owners of the Narngulu processing plant are considering importing mineral sands from other mines, located on the eastern edge of the Nullabor plain through the Geraldton Port for processing at Narngulu. A heavy haul rail link to the standard gauge railway from Perth to South Australia could see consideration of these mineral sands being transported by rail, as the mine is located near Ooldea siding on that railroad.

5.8 Uranium

The Barnett lead Liberal-National Government lifted a ban on uranium mining in Western Australia on 17th November 2008.

Currently in Australia, uranium, in the form of uranium concentrate is transported to ports via trucks and/or rail. It is shipped overseas for further treatment at enrichment plants, in a number of countries.

There are several large, high quality uranium deposits in the Midwest, located mainly around Mt Keith and Wiluna within the Northern Group. With the lifting of the ban on uranium mining it is now likely that a number of companies will seek to mine these deposits.

14 Source: Ports Australia
BHP Billiton has already decided to shelve expansion of its Olympic Dam uranium and copper mine in South Australia in favour of reopening its uranium mine in Western Australia at Yeelirri. However, the limited quantity of uranium concentrate that is likely to be produced annually of the product mean uranium is unlikely to be a significant driver for motivating the extensions to the rail system in the study area, although rail extensions driven by other users would provide an alternative to road for transport of uranium to port.

Generally, the preferred mode for uranium transport is rail, where available, because of the perceived safety issues associated with the transport of the concentrated ore.

### 5.9 Grain

The southern areas of the Geraldton grain belt catchment are currently serviced by road and rail and the northern areas exclusively by road.

Co-operative Bulk Handling Limited (CBH) is the major grain exporter in the region and the predominant user of the WestNet Rail narrow gauge rail network to the Geraldton Port. There are 7 primary grain receival sites in the region, with 5 operating on the rail network at Mullewa, Morawa, Perenjori, Carnamah and Minganew. Another 8 secondary receival sites are in the region with 7 on rail lines, primarily along the Geraldton to Marchagee line. An additional 6 surge receival sites are located on the Mullewa to Buntine line.

A large proportion of grain is currently delivered to port via road.

It is likely that in the future grain receival sites will be consolidated rather than expanded, and grain will continue to be transported to Geraldton Port via the existing rail and road system, rather than on any new freight railways that may be built within the study area for transport of bulk mineral products.

### 5.10 Imported Products

Major imports through Geraldton Port in 2007-2008 are listed below in Table 12.

<table>
<thead>
<tr>
<th>Product</th>
<th>Tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertiliser DAP (Di-ammonium Phosphate)</td>
<td>7,218</td>
</tr>
<tr>
<td>Fertiliser MAP (Mono-ammonium Phosphate)</td>
<td>1,579</td>
</tr>
<tr>
<td>New Phosphate</td>
<td>4,610</td>
</tr>
<tr>
<td>Urea</td>
<td>23,126</td>
</tr>
<tr>
<td>Petroleum Products</td>
<td>177,449</td>
</tr>
<tr>
<td>Mineral Sands</td>
<td>13,502</td>
</tr>
<tr>
<td>General</td>
<td>39,596</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>267,038</strong></td>
</tr>
</tbody>
</table>

The total tonnage of imports is presently small at 267,000 tonnes per annum when compared to the port’s total throughput and the potential future growth of the bulk commodities exports. There is likely to be a significant increase in the imports of mineral sands for processing at Narngulu to supplement the declining reserves at Eneabba.

The distribution of other imported products is likely to remain via road based services.

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15 Source: Geraldton Port Authority
5.11 Future Mining Importation Demands

The mining industry requires the import of many commodities ranging from diesel fuel and ammonium nitrate in large and consistent quantities for mining operations to the import of the large and heavy machinery such as shovels, bulldozers and haulpaks. The heavy machinery is not suitable for rail transport. Recent investigations for other studies completed by Arup show that it is more cost effective to assemble the heavy machinery at a location as close to the importing port as possible and then transport by heavy road transport equipment. An example of this is similar to the transport of locomotives from Perth to the Pilbara along the Great Northern Highway.

The transport of diesel by rail on the proposed network is an option, if the diesel is imported at one of the local ports. If it is imported by road to the area, it would be more efficient to take it to the mine by road. Because there are so many mines, and each would have a relatively small diesel requirement, it is likely that diesel would remain on road.

Ammonium nitrate is currently transported to the Pilbara by road from Perth and with the new security requirements as set by the DMP\(^{16}\) it is preferable to retain the status quo. All Australian States have passed new legislation that increases the security against theft of ammonium nitrate as a precaution against terrorist attacks as many terrorist bombs have used ammonium nitrate as one of the key ingredients. The new requirements cover all aspects of the distribution form the manufacturing facility to the final storages on a mine site.

Shipments of ammonium nitrate must be guarded at all times when stationary in transit and must not be left unattended at any time. The new requirements are comprehensive and make the movement of small amounts of the commodity by rail expensive and uneconomic. For the movement of large quantities, such as to a major mine site, rail is a viable alternative to road.

Overall there is likely to be limited opportunity to import mining materials and then transport them on the new proposed rail network, unless underground mining is undertaken in a way that will require back filling with materials like cement and fly ash.

5.12 Conclusions

The development of the proposed rail lines to link the Weld Range/Jack Hills mineral tenements in the Northern Group and to the Karara tenements in the Southern Group to the new Oakajee Port will be driven primarily by the economically viable iron ore deposits in these areas, with limited opportunity to increase volumes through the transport of other minerals.

In the longer term the possible future extension of the Weld Range/Jack Hills line to the Wiluna area, and possible extension of the Karara line to Extension Hill (and perhaps ultimately further east to connect with the Goldfields’ rail system), will allow the proposed Oakajee port and rail infrastructure to capitalise on increased iron ore volumes as well as haulage of inputs and outputs for other minerals including:

- Copper/Lead/Zinc (in concentrate);
- Nickel; and
- Uranium

The development of an efficient Oakajee port and rail system extending into the Northern Goldfields area may stimulate the future growth and development of these and other minerals to a greater extent than the existing transport systems centred on the Esperance and Fremantle Ports. However, with respect to nickel, the export of nickel product via the

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\(^{16}\) NB: Security requirements are set on a case by case basis
Oakajee system may require establishment of nickel processing plants somewhere in the logistics chain between the deposits and Oakajee Port.

6 Oakajee Port

The location and key roles of the proposed deep water port at Oakajee and the likely future interrelationship between the new port and alternative ports are also factors likely to influence the strategic form and development of the freight rail network. These factors are briefly discussed in this Section.

6.1 Description

Oakajee Port is proposed to be a major open access rail and port installation for the transportation of iron ore, other bulk resources and cargo. The planning for the proposed Oakajee Port includes provision for 3 iron ore berths plus 7 other berths for other resources and cargo. When built the port will provide deepwater anchorage and will have the capacity to cater for fully laden Panamax and smaller Cape Size vessels, up to 180,000 dead weight tonnes. The port could potentially handle up to 100 mtpa of iron ore exports once fully constructed.

The port will be constructed in phases; the first will provide a breakwater to the south, allowing Panamax and Cape Size vessels capable of shipping 180,000 tonnes of ore per ship and 35 million tonnes of iron ore per annum.

The rail routes planned to service Oakajee Port include provision for both narrow and standard gauge rail access through a cutting in the Moresby Ranges at the Wokatherra Gap. The rail planning includes provision for grade separation of the rail and road systems on the approaches to the Port. In the first phase of the port development, iron ore trains will operate to a car dumper capable of handling 50 million tonnes of iron ore per annum, which will then be transported by conveyers to stockpiles or directly loaded onto ships.

The construction of the northern breakwater in phase two of the port development will provide a calmer maritime environment for general cargo. Panamax berths planned for the export and import of other general bulk cargoes, as well as the possibility of handling container vessels.

Current proposals indicate that the port and rail will have the capacity to cater for 20 trains per day.

6.2 Relationship between Oakajee and Geraldton Ports

Due to location, Oakajee Port has the potential to compete directly with Geraldton Port and has several key advantages over Geraldton including location, deep water capability and larger storage capacity which will make it more attractive for bulk goods such as iron ore that are typically transported by the larger Panamax and Cape Sized Vessels, up to 200,000 tonnes.

The location of Oakajee outside a major town centre is another key advantage of Oakajee Port, allowing bulk transport of minerals that are considered to be an environmentally sensitive, or that may represent a potential safety risk to local communities (e.g. lead and nickel concentrates) to bypass these communities.

The existing Geraldton Port has expanded its bulk materials handling facilities and is now estimated to have a potential 12 mtpa capability. The bulk handling facilities are primarily intended for iron ore exports, but other minerals are also able to be loaded using the same...
equipment. It is envisaged that total minerals exports from the Midwest and Northern Goldfields regions may exceed 100 mtpa in the long term. At this level of production, it is expected that the vast majority of exports above present levels will be exported through Oakajee Port which will become the major bulk exporting facility in the Midwest area.

However, it is envisaged that grain, some iron ore and other bulk mineral exports will continue to be handled through Geraldton for the foreseeable future. It is also envisaged that import of most bulk products, including existing product imports and possibly import of mineral sands (at a level of around 0.5 mtpa), will also be handled through Geraldton.

6.3 Relationship between Oakajee and Esperance Ports

The relationship between Oakajee and Esperance Ports is not as clear as between Oakajee and Geraldton however it may have major implications to the way ore is exported from Western Australia. Currently, the majority of minerals from the Goldfields Esperance Region is exported through Esperance (as described in Section 3.2.3). The construction of a heavy haul railroad to the Goldfields area will therefore allow direct completion between these ports.

It should be noted that the distance from the Goldfields to Oakajee or to Esperance Port is roughly the same, however exporting through Oakajee presents some significant advantages once an efficient modern heavy haul railroad is constructed. The advantages that favour Oakajee are as follows:

- There is no town close to the port, therefore dust and other environmental problems will be easier to manage;
- The blue water distance to south east Asia is roughly 2000 nautical miles shorter, for the same rail transport distance;
- The Esperance to Leonora railway that links Esperance to the Goldfields was originally developed as a low cost grain and general cargo narrow gauge railway, with steep grades and tight curves. Although it has been converted to standard gauge, and parts of the Kalgoorlie to Esperance section of the line have been upgraded to cater for transport of iron ore from Koolyanobbing to Esperance, its likely that operating costs on this railway will always be higher than a modern purpose built rail line, such as is proposed to link the study area iron ore deposits to Oakajee.

6.4 Relationship between Oakajee and Other Ports

The other ports that service the southern parts of Western Australia have different impediments to them becoming major export ports for iron ore. For completeness these are briefly discussed in this report.

Albany is not directly linked to the Goldfields and other mining areas, and the rail line to Albany is the original narrow gauge network. The port is surrounded by the town, and is primarily used for grain exports. It is not suitable for development into a major mineral export facility, despite being a deep water port.

Bunbury is too far away from the Goldfields and is not directly linked by a suitable rail route. Bunbury is not a deep water port.

Kwinana would require the use of the standard gauge interstate network that is already heavily used, including the operation of passenger trains. The route passes through the suburbs of Perth, and the axle load is limited to 25 tonnes. It is unlikely that this route would be able to offer the low operating rates that a purpose built railway could deliver, and the iron ore and mineral traffic would have to intermingle with all the existing traffic on the line. This will lead to poor cycle times and inefficient use of rail rolling stock, further increasing the land transport cost. Kwinana is also the states premier heavy industry estate and is restricted in land availability. Although this is outside the scope of the study, it is likely that the allocation of space at Kwinana would be better allocated elsewhere.
7 Key Requirements for a Strategic Rail Network

The key task for the new freight rail network is to provide a low cost, efficient and fast transport system to the ports from existing and proposed mines in the study area.

Low cost transport systems for bulk commodities above around 1 mtpa cannot be effectively developed using road haulage over the public road network. At this volume, road transport suffers from high costs of labour as well as significant wear and tear on the road pavements. Even with modern multi-unit trucks, the labour costs remain high when compared with rail.

Relatively, rail can provide extremely cost effective transport when there are large quantities being hauled. When quantities exceed 20 mtpa, the operational costs can typically reduce to a few cents per tonne kilometre. It is unlikely that the costs per tonne to be achieved in the Midwest will be as low as the Pilbara railroads, as the traffic levels will be lower, and there are multiple small deposits of minerals spread over a large area. Nevertheless, with a modern railroad designed for heavy haul, and using the technical equipment and techniques of a heavy haul railroad, a cost of a round 2 cents a tonne kilometre should be achievable (This excludes all capital charges).

This section outlines the key drivers necessary for the Oakajee Rail Corridor, and the Midwest heavy haul freight rail network as a whole, to meet these objectives.

7.1 Rail Capacity

7.1.1 Benchmarks

Rail capacity of a single track railroad into a port is typically limited to around 100 mtpa using efficient heavy haul techniques. The railway line has to be able to take into account the interface issues at both the mines and the ports. There are delays in dumping due to dumper failures, conveyer and stacker failures that prevent the ore being moved from the train to stockpiles. Similarly at the mine there are loading delays when loading equipment breaks down or there are interruptions to the mining or blending processes. Large stockpiles at both the mines and at the port are not very cost efficient and take up large tracts of land.

This means that the railroad capacity needs to be higher than the actual capacity at the mines and the port. In a typical mining logistics chain, rail is a smaller cost component compared to the mine and the port operations. Therefore for Oakajee to deliver 100 mtpa of mineral exports, the rail line feeding it should be able to carry around 120 mtpa, which allows 20% excess capacity to deal with unplanned interruptions at the interfaces.

Modern signalling systems have recently become available which allow a very considerable increase in capacity even on single tracks, and these technologies have not yet been adopted in the Pilbara railroads. The adoption of these signalling systems will increase capacity making it unlikely that a second track will be required for traffic levels up to 100 mtpa.

Most heavy haul operators including Rio Tinto and Vale duplicate the line at around this traffic level. BHPBIO in the Pilbara is the exception but has now announced “substantial duplication” when operating at around 130 mtpa. To achieve this, BHPBIO has used extremely long (approximately 3.5 km) and heavy trains. At around 100 mtpa, the number of trains required crossing loops about every 15 kilometres and the delays due to waiting for opposing trains in these crossing loops becomes very high and inefficient. Indeed above this level the added gain in capacity for each additional train in the system starts to dramatically reduce. These effects can be easily demonstrated by modelling of the capacity of the rail lines.

There are several significant differences between the existing Pilbara iron ore rail operations and those planned for the Midwest/Northern Goldfields. These include the need to
accommodate multiple rail users and lower axle load trains in the Midwest. This will make
the very high rail capacities and efficiencies being achieved in the Pilbara very difficult to
replicate in the Midwest and Northern Goldfields. It is therefore likely that to effectively cater
for the scheduling needs of the range of miners expected to use the Oakajee railroad it may
be necessary to provide double track at lower volumes than is currently the case in the
Pilbara. This is most likely to apply from Mullewa west, where the traffic from the northern
and southern groups of mines converges.

### 7.1.2 Oakajee Proposal

As stated in Section 6.1, the Oakajee Port and Rail proposal aims to cater for long term
export of up to 100mtpa utilising around 20 trains each way per day. As outlined above,
achievement of 100mtpa using a single track railroad is achievable however it is Arup’s
experience that 20 trains per day cannot be efficiently achieved on a single track main line.
This experience is backed up by the following graph (Picture 1) provided by the USA
Federal Railroad Administration, highlighting the through movement capacity of different line
types.

The graph below illustrates the rapid rise in the delays to trains when the number of trains is
increases without any additional infrastructure being added. In the case of a single track
railroad, such as the lines leading to Oakajee, with the maximum effective number of
crossing loops, located at 15 kilometre intervals (8.8 miles), the delays increase rapidly to
around 90 minutes per train each way with 20 trains per day each way. In practice railroads
have unplanned delays and the maximum practical number of trains along a single track is
around 18 trains per day each way. The three hour increase to the wagon and locomotive
cycle time requires more locomotives and ore cars to be purchased. Queuing theory also
demonstrates quantitatively that above around 18 trains per day, the congestion rises
asymptotically and the addition of more ore cars and locomotives provides very little
additional capacity.

**Figure 6: Line Capacity**

To achieve the 100mtpa target, those sections of the railroad required to cater for this level
of use will need to be duplicated, or alternatively allow for either longer or higher axle load
trains to access the port.
7.2  Track and Formation

7.2.1  Benchmarks

The key to having a highly efficient railroad is the net to tare ratio achieved in each ore car, and the maximum axle loads that can be carried on the railroad. The higher the net/tare ratio and the heavier the axle load, the more ore that can be loaded into each car, and the less cars that are required for any given traffic level. However higher axle loads require more expensive track and formation.

Most heavy haul operations operate in the 30 to 32 tonne range. Gauge does make a difference as the limit is the strength of the earthworks underneath the ballast. Generally, broader gauges allow higher axle loads.

For standard gauge railroads, they typically operate around 32 tonnes axle load. In Australia BHPBIO operates with a target axle load of 37.5 tonnes and has done so for quite some time very effectively. Fortescue Metals is now operating at the highest axle load in the world on a main line railway at 40 tonnes, but has only been doing so since May 2008. For narrow gauge, the heaviest axle load operators are Transnet Freight Rail in South Africa and Vale in Brazil with both targeting 30 tonne axle loads.

The ability to carry more ore per car on a standard gauge railcar compared to narrow gauge can be offset by the use of longer trains if narrow gauge is used. The line congestion prevents more trains being used if the line is approaching capacity. The increase in train length required by a narrow gauge train operating with 30 tonne axle loads over a standard gauge train using 32 tonne axle loads requires a train that is 6.7% longer, a small increase.

This assumes that the narrow gauge line is built to the same grade and curvature standards as the standard gauge line. Most narrow gauge lines were built because they had a lower capital cost as narrow gauge trains can negotiate much sharper curves which in turn reduce the allowable speeds and increase train cycle times. The tendency would be to value engineer the design if narrow gauge were used and a substandard line would be constructed that has a much higher on-going operating cost due to lower speed and therefore longer transit times were longer.

The higher the axle load on a multi user railroad such as envisaged servicing Oakajee and possibly Geraldton, the more stringent the technical inspection and maintenance requirements would have to be. It is suggested that a mid range of say 30 tonne axle load for narrow gauge and 32 tonne axle load for standard gauge would be most suitable for the new network. This provides a balance between technology and practicality for a multi user network. The critical issue in this is the wheel and rail interaction, and the need to avoid at all times stressing the wheel or the rail above the limit permissible in the metal at the point of interface. This is the same for both gauges. Using these axle loads the difference between narrow gauge and standard gauge is minimal.

In all cases the route should be as short as is practically possible given the terrain and other limitations that are imposed. Typically grades should be less than 0.5% against loaded trains travelling to the port and less than 1% for the empty trains travelling back to the mine. Nearly all heavy haul railroads use grades around these levels. Clearly steeper grades can be used, but this will increase the amount of power required for a given gross train weight.

7.2.2  Existing Rail Track and Formation to Southern Group

The southern group of mines is currently serviced in part by the existing narrow gauge railroad. This existing network is typical of the lines built to service the grain industry. It was built as cheaply as possible and has 16 tonne axle loads and grades up to 1 in 40 and curves typically of 400 metre radius with some as low at 250 metre radius. The line from Geraldton to Mullewa climbs over the hills in between rather than follow the Greenough river valley just to the north. This means that there are steep grades on the line for both the empty trains from the port and the loaded trains to the port.
There are three basic or generic options on how to establish an efficient rail connection to the Southern Group of mines. These are:

- Extend existing rail to Southern Group from Morawa and upgrade existing narrow gauge network between Morawa and Geraldton;
- Replace existing narrow gauge rail with new higher standard rail to Southern Group on existing rail alignment; or
- Provide new railroad to Southern Group (ie, independent of existing alignment)

### 7.2.3 Comparison of Options

Upgrading of the existing Narngulu to Morawa narrow gauge line from 16 tonne axle load to say 26 tonnes would be a costly project and one that may potentially be very disruptive for existing services. The upgrade will require a new and strengthened capping layer below the ballast on top of the existing earthworks, new ballast, new sleepers and new rail for around 200 km of the existing line. Only the earthworks would be re-used and the line would still not provide a low cost efficient heavy haul railway as it would still have many sections of heavy grades and many sharp curves that would prevent the use of long heavy haul style trains. The operating costs of such an operation would likely be up to five times the ‘best practice’ target cost of around 2 cents per net tonne kilometre (ntk).

If the existing rail grades and horizontal curvature were to also be improved in conjunction with the increased axle load upgrading, this would add considerably to the cost and timing, and may also necessitate re-alignment of some sections outside of the existing corridor.

The narrow gauge rail upgrading option would also involve construction of a similar standard section of new narrow gauge railway eastwards from Morawa to the proposed Karara mine site, a distance of around 80km.

The alternative option is to build a new high standard, efficient narrow or standard gauge line. The construction of a new line between Narngulu and Mullewa is likely to be more practical and effective on a new alignment along the river valleys to the north of the existing corridor rather than along the existing corridor and over the many hills traversed by this corridor. This option would also be significantly less disruptive to services on the existing narrow gauge line.

### 7.2.4 Comparison of Costs

The comparative costs to build either a new narrow gauge or standard gauge line along the existing narrow gauge rail corridor, or on a new alignment would be similar, and Arup estimate that it would cost at least $3 million per kilometre to build such a line in today’s prices. The total estimated cost for 200km of new line on the existing alignment would therefore be at least $600 million.

The estimated cost of a new line on along either the existing rail corridor or an alternative alignment would be more than the cost of the narrow gauge rail upgrading alternative, but would give a long term sustainable operation in the ‘best practice’ target opex cost range of 2 cents per ntk, rather than the cheap upgrade leading to an opex of between 8 and 10 cents per ntk. Should a new alignment be preferred, the opex and capex of either gauge solution is not considered significantly different.

The above assessment is derived from very high level principles, and records, but provides a reasonable guide in both Opex and Capex for strategic and policy level consideration of these options.

### 7.2.5 Access to Oakajee Port

Another key issue for the rail system that is developed to service the southern area is that it must ultimately feed in to Oakajee, if the longer term potential of this area is to be realised. If the southern area is served by a narrow gauge railroad and the northern area by standard
gauge, then the southern railroad will have to connect to Oakajee via a separate system or via a section of mixed (dual) gauge railroad from somewhere west of Mullewa to Oakajee.

7.2.6 Conclusion
Based on the significant operational advantages and subject to more detailed studies and analysis, it would appear appropriate to construct a new railroad on an alternative alignment. It is unlikely the reduced capital costs of the two alternative options will offset this benefit.

7.3 Connecting with Other Heavy Haul Rail Infrastructure

7.3.1 Goldfields Railway System
Any rail extension built to services the Yilgarn group might ultimately form part of a longer term strategic rail link to the Kalgoorlie-Leonora line and/or the Eastern Goldfields Rail Corridor. Therefore careful consideration should be given to the gauge and standards of the southern line and potential extensions if the option of linking the Midwest rail network with the Goldfields rail system is to be preserved. However, access to Oakajee is the priority; therefore the gauge and standards adopted for the southern railway line to Oakajee will be the key in determining the viability of future extensions to the Yilgarn group and beyond.

For connection to the Goldfields railway system to be achievable, it will need to be cost effective for the railroad to be constructed over a considerable distance. The iron ore deposits in the Yilgarn area are some 600 kilometres from Oakajee. Many heavy haul iron ore railroads in the world are longer than this. The two most notable are:

- Vale operation from Carajas in northern Brazil to the port at Sao Luis; and
- Transnet operation in South Africa from the mines in Sishen to the port in Saldanha Bay.

Both lines are around 850 kilometres long and both compete effectively in the world iron ore market. The Brazilian line carries over 80 mtpa per annum of iron ore, manganese and other products, including some agricultural products, and is being considered for duplication. The South African line is exporting around 30 mtpa at present and there are plans to upgrade it to 47 mtpa and even higher.

In benchmarking of the overall production costs of all the major iron ore producers it is clear that a rail haulage distance of up to 850 kilometres allows iron ore to be shipped cost effectively. It should be noted that the mines in Brazil and South Africa are haematite mines. (The costs associated with mining magnetite are much higher as magnetic separation is usually undertaken to achieve reasonable levels of iron in the product being shipped. Furthermore significant further processing is required for magnetite ores before they can be fed into a blast furnace. The economics of mining haematite are significantly more favourable than mining magnetite.)

It can be concluded that with a very efficient rail haulage operation, the land transport costs for the mines in the Yilgarn area should not present any barrier to the sale of their iron ore, and therefore the longer distances should not present a barrier to the development of mines in the area. Therefore flexibility to establish a strategic link between Oakajee and the Leonora-Kalgoorlie Line and/or the Eastern Goldfields Rail Corridor should be preserved if possible.

7.3.2 Pilbara Railways
A future link to the Pilbara railways can also be made going north from Jack Hills. It is unlikely that any movement of ore will be transferred from the Pilbara rail and port system to Oakajee; however the link may open up new mining opportunities north of the Northern Group of mines identified in this study. There are significant technical and operational issues in trying to connect to these railroads, as outlined elsewhere in this report.
Nevertheless, construction of a standard gauge railway from Oakajee to Jack Hills would retain the flexibility for such a connection in the future, if required.

### 7.4 Cycle Times of Rolling Stock

For a heavy haulage freight railway, such as that likely to be required to service the study area in the future, to be efficient, cycle time is important. The key way to make a railroad operate efficiently is to keep the expensive rolling stock moving. The complete cycle from an empty train leaving the port, travelling to the mine, loading, travelling back to the port and being unloaded and inspected prior to leaving the port again is known as the cycle time. The quicker the cycle time the more trips a single train can complete in a year, so the less the number of locomotives and wagons required. Minimising the rolling stock requirement will result in major cost savings with locomotives presently costing in the order of $6.5m and ore cars around $175 000 (cars designed to be dumped on a tippler or rotating dumper, and not fitted with bottom dump doors).

Therefore a key objective of the planning for Oakajee should be to ensure that the rail network and its component parts provide as direct a service as practical between the various mining areas and the port.

### 7.5 Specifying the Rail Solution (Equipment types)

The following types of equipment are recommended in order to achieve very low operating costs.

#### 7.5.1 Wagons

There are two types of rail cars that carry minerals, those that are rotated to spill out the contents, and those that are bottom dumped. Bottom dumping ore cars are fitted with doors that open to discharge the ore from the base of the wagon. These cars add additional expense and weight to the wagons, therefore displacing some ore carrying capacity. The car doors also increase maintenance costs and add the potential for door failures during transit, discharging the car contents onto the track, leaving the potential to cause a derailment.

#### 7.5.2 Locomotives

Nearly all heavy haul rail operations that use diesel locomotives purchase them from the USA from either Electro-Motive Diesel or General Electric. These two locomotives manufacturers have production lines and produce many units each year. These two locomotive brands can achieve over 95% availability and can run over 100,000 kilometres between failures. They are typically 4,400 horse power and can be fitted with either AC or DC traction motors. The latter are used by Rio and are cheaper to purchase but have less adhesion. The AC locomotives have very high adhesion but a higher purchase cost, and are used by BHPB Iron Ore. Adhesion is the ability of the locomotive to transfer pulling power to the train through the locomotive wheels, and is a measure of the “stickiness” of the locomotive. For the relatively flat country in the mid-west the DC traction motors may be sufficient. These locomotives can be made to fit either narrow or standard gauge tracks.
8 Network Shape

8.1 Introduction

There are two basic networks that have been considered to connect the northern, southern and Yilgarn iron ore groups to the proposed port at Oakajee. The first comprises a central spine extending east-west from the coast to around Sandstone, with branches to the individual mines and mining areas to the north and south.

The second network comprises a central spine extending east-west from the coast to around Mullewa, with two arms extending from the central spine to the northeast and southeast respectively. The northern arm is to service the Northern Group of mines (Weld Range and Jack Hills), with a possible extension further eastwards to the Wiluna area; and the southern arm extending through to the Southern Group of mines (Koolyanooka and Karara) with a potential link to the Yilgarn group and the existing Goldfields standard gauge network.

The networks illustrated in this document are conceptual in nature and do not take into account any of the physical features of the land through which they pass. Similarly no research has been done on environmental, native title and land ownership issues at this stage.

8.2 Central Spine Network

The conceptual shape of this network option is shown in Figure 7.

The major advantage of this network is that it would directly service other mineral deposits and mines located along the central spine and further east within the Northern Goldfields. The servicing of the Northern Goldfields mineral deposits would require an eastward extension of the central spine as shown indicatively in Figure 7. Such an extension might also then facilitate a linkage to the Kalgoorlie-Leonora line as shown. However, the mineral deposits that would be serviced directly by the central spine are secondary rail transport drivers at best and unlikely to generate the level of transport demand required to support development of this style of network.

A major disadvantage of this style of network is that it does not directly service any of the three defined major iron ore groups which are the primary drivers of rail transport demand in the study area. The only known iron ore deposit that would be directly serviced by this network is at Yalgoo. This deposit is relatively small and of low grade when compared with the deposits in the three defined groups.

Other disadvantages are that the indirectness of this network would impose additional operating costs on the iron ore producers which are the major users, and it requires more rail infrastructure to be built than the alternative network option and hence involve higher capital costs.

The central spine network has the potential to be extended northwards, via the Weld Range/Jack Hills line, to the Pilbara area, where there are extensive rail networks. Such a link would not likely be used to transport minerals from this area for export through the Pilbara ports or vice versa, because the cost of land transport, even by rail is much higher than blue water rates. However, if significant mineral deposits were to be discovered in the area between the Northern Group and the Pilbara the northern extension of the Weld Range/Jack Hills line would facilitate the development of those deposits.

8.3 Two Arm Network

The conceptual shape of this network option is shown in Figure 8.

There are several significant advantages of this style of network when compared with the central spine option. The first is that it has the potential to directly service all three defined
major iron ore groups in the study area, and hence provide the more cost effective solution in terms of operating costs for these major users.

The second advantage is that it requires less railway infrastructure to be constructed. Hence this network will have a lower capital cost and therefore will require less initial funding. This is important as the railroad will start with a small amount of traffic, and its presence will then enable other mines to be set up, catalysed by having a good efficient transport network to an export port.

The third advantage is that this network can be more easily and cost effectively staged, and is therefore likely to be more acceptable to the iron ore miners and rail infrastructure providers that will ultimately be required to fund the development of the network.

The northern arm of this network has the potential to be extended northwards to service any new major mineral deposits between the Northern Group and the Pilbara area, and connect to the Pilbara railway networks should that be required.

The northern line will be similar to that suggested by rail infrastructure proponents taking the shortest applicable route, within grade, curve limitations suitable for heavy haul operations. The route should be designed to avoid the 70km radius exclusion zone for the SKA, and to take into account other land use matters such as environmental, heritage, hydrological and native title issues. The northern line will need to make provision for a possible future junction at Weld Range for a potential link line to the Wiluna area.

The southern arm of the network has the potential, subject to compatibility of gauge and standards, to be extended eastwards to link to the Goldfields standard gauge network either to the Leonora to Kalgoorlie line as shown indicatively in Figure 8, or to the Perth to Eastern Goldfields line via a southwards extension through the Yilgarn iron ore group. There are advantages and disadvantages of both connections, but with the large number of exploration licenses in the northern part of the Yilgarn, a connection with the existing or a new line between Kalgoorlie and Leonora is likely to provide a more direct service to more potential mine sites, and a more direct service to the southern and eastern Goldfields more generally.

### 8.4 Comparison of Options

Assuming full build out of each of the networks total indicative rail road lengths are as follows:

- **Spine Network** – 1 350 km
- **Two Arm Network** – 1 155 km

**Oakajee to Mullewa** - This section of the network is common to both the central spine and two arm networks. It is approximately 100 km in length.

**Mullewa to Morawa and Karara** - This section of the network is common to both the spine and two arm networks. It is approximately 220 km in length.

**Mullewa to Weld Range and Jack Hills** – Whilst the alignments of the two networks are different, the network lengths are approximately equal, measuring 490 km for the central spine and 480 km for the two arm network.

Overall the indicative total length of railroad for the Two Arm network is estimated at around 1155 km, which is some 195 km shorter than indicative length of the Central Spine option.
8.5 Conclusions

The actual on ground development of new mines and the proving of present exploration leases will clarify the direction of the final network layout, within the broad framework set out in this report.

By inspection though, it can be seen that the Two Arm network is more flexible in responding to future mining opportunities both within the Northern Group, Southern Group and Yilgarn.

The tariff to be charged will be a combination of capex and opex, and with this type of operation, with low start up traffic levels it is important to reduce the capex.

There appears to be no benefit in pursuing the Spine Network option. Extensions to the Two Arm Network allow for more cost effective extensions to Wiluna for the Northern Group and the Yilgarn for the Southern Group.

The “Two Arm Network” is recommended as the advantages as described above are significant in its favour. The reason to build the network is not just to transport minerals from existing mines, but to also facilitate the development of more mines in the study area in the longer term.
9 Alignment Discussion

9.1 Oakajee to Weld Range Railroad

The initial impetus to develop Oakajee and provide a new highly efficient railroad to service the port came from the two miners in the Weld Range and Jack Hills area (Northern Group). A new railroad along the northern arm of the recommended two arm rail network would provide an efficient transport route for these two miners and other potential mine developments such as at Wiluna.

A range of alignment options have been suggested for the Oakajee to Weld Range/Jack Hills rail line. Two such options are shown in Figure 9. From a strategic perspective the preferred alignment is one which follows the shortest route, as long as the grades for both the loaded and empty trains are acceptable, generally 0.5% (or less) against the loaded and 1.0% against the empty cars, with large radius curves that can be negotiated at the full speed of the trains, (about 75 kilometres per hour) and avoids the SKA 70km radius exclusion zone.

The “yellow” route option in Figure 9 provides the more direct route between the Northern Group and Oakajee, but does not provide a direct service for the iron ore deposits at Yalgoo. The “red” route provides a more direct service for the Yalgoo deposits but a much less direct and therefore less efficient service for all of the known and prospective iron ore reserves in the Northern Group.

On balance it appears that the benefits offered by the “yellow” route to the greater mass of deposits in the Northern Group would outweigh any disadvantages to the Yalgoo deposits if the “yellow” were to be adopted. However, it’s desirable that some further work be undertaken to review and confirm the optimum route for the northern arm from Mullewa to Weld Range.

9.1.1 Future Extensions

While the Oakajee to Weld Range segment comprises the primary component of the railway to the northern iron ore group, there are two extensions, to Jack Hills and Wiluna that are of major significance. The routes and standards for these lines should also follow the strategic framework and principles outlined in this report in terms of directness, gauge and grades etc. The Weld Range to Wiluna line would service the iron ore deposits in the Wiluna area and possibly also the nickel deposits in this area that are presently serviced by road/rail into Leonora and to Kalgoorlie.

The Weld Range to Jack Hills line might also serve as the route of a future link to the Pilbara railways and provide services to any new mineral discoveries in the area between the Northern Group and the Pilbara.

There are small proven resources and many prospects in the Robinson Range to the north of Jack Hills that may ultimately generate demand for an extension to that area, and this may in turn provide opportunities for connection of the Midwest and Pilbara rail systems should that offer sufficient benefits in the longer term.

9.2 Southern Route

The Southern Group iron ore miners (Koolanooka, Karara etc) will also require rail services to Oakajee port. A rail line along the southern arm of the recommended two arm network would provide an efficient transport route for these miners, and also other potential mines at Mt Gibson/Extension Hill and in the Yilgarn Group. The southern line could connect to either the “red” route or the “yellow” route around Mullewa without unduly compromising the efficiency of the southern services.

The alignment of the southern route will be initially driven by the need to provide direct and efficient services to the iron ore deposits in the Karara area including the deposits at Koolanooka. The decision on a preferred route for this line will be dependent on a range of
factors including gauge and interface issues relating to the existing narrow gauge corridor, and strategic flexibility for future connections to the Yilgarn Group and beyond.

The Karara area currently contains the largest proven iron ore reserves in the study area and these are critical to the development of a strategic transport network. Further, more detailed work needs to be undertaken to assess the route options for the southern railroad and to select a preferred solution that is both achievable and consistent with the strategic framework and principles outlined elsewhere in this report.

### 9.2.1 Future Extensions

The future extension of the southern line and possible linking to the Eastern Goldfields standard gauge network has a number of options:

- a branch line from Karara to Extension Hill/Mount Gibson;
- main line from Karara to the northern part of the Yilgarn area to pick up deposits/resources here; and
- main line from the northern Yilgarn Area to connect with the Kalgoorlie – Leonora railway line.

The potential ultimate network would provide a rail link distance from Leonora and Kalgoorlie to Oakajee that would be competitive with the rail link to Esperance and Fremantle Ports. The advantage of Oakajee is immense in that the blue water sailing distance to South East Asia is almost 2,000 kilometres shorter than from Esperance, and the export logistics chain does not pass through any major population centres as do the current transport links between the Northern Goldfields and the Esperance and Fremantle Ports.
10 The Gauge Issue

This is a crucial matter that has been mentioned in general terms in the previous sections of this report. Broadly, building the new network on either standard or narrow gauge will cost roughly the same for both Opex and Capex. Whilst all heavy haul railroads (greater than 30 Tonne Axle Loads) in Australia are built using standard gauge (Queensland’s Coal narrow gauge coal railways operate at 25 tonne axle loads), equally low cost narrow (metre) gauge lines operate in Brazil using the same locomotives and equipment. They also operate in South Africa between Sishen and the port at Saldanha Bay, near Cape Town.

The gauge options for the rail infrastructure to be built to service the Oakajee Port are standard gauge, narrow gauge or dual gauge, for either the whole or parts of the new infrastructure.

This section explains the gauge options that are available for development of the rail network in the study area and logic for adoption of one gauge to ensure progressive development of a fully integrated and efficient rail system. In particular we should be confident that if we were to look back from 2030, it could be readily demonstrated that today’s gauge decision did indeed deliver the most efficient solution.

10.1 Reasons to choose a single gauge

It has taken Australia over 150 years of rail to gain a single gauge network that links all the capital cities. To start to build a new transport network to catalyse the development in the mining sector in the Midwest of Western Australia with a gauge split network is not an effective or efficient start.

Development of separate different gauge networks will inevitably mean duplication of some of the rail infrastructure and higher overall capital expenditure. Construction of mixed (dual) gauge track is also more expensive than single gauge as it requires a third rail and special sleepers. In addition mixed gauge increases operating costs significantly as there have to be two separate sets of wagons and locomotives that service different parts of the network, and there will be two different car dumpers, on for each gauge. Infrastructure maintenance if higher as all switches are more complicated and there is increased wear as there are two frogs, (rail-crossings where wheels cross a gap in the running rail) in each set of switches.

A single gauge enables one type of locomotive and ore car to be purchased, and allows the full flexibility of any train going from port to any mine. Any division of the fleet on to two gauges reduces this system wide flexibility, and reduces the ability to pick up a shortfall in production in one or more mines by diverting trains at short notice to other mines.

Much of the locomotive and ore car maintenance equipment will need to be duplicated to handle both gauges, and it may well eventuate that special dumpers will need to be built to handle the two different types of ore cars.

10.2 Why Prefer/Select Standard gauge?

The emotive argument in favour of standard gauge is that narrow gauge is a second class low tonnage railway. This is incorrect. Arup has viewed the highly efficient iron ore operations on narrow gauge in Brazil and South Africa. This argument therefore has little value in terms of determining the preferred gauge for the Oakajee railway.

An equally emotive argument is that the new network should be built to a narrow gauge standard to capitalise on the use of the existing narrow gauge rail infrastructure and/or land corridor. However, as has been outlined elsewhere the existing narrow gauge rail infrastructure is not of a suitable standard to accommodate the bulk freight transport needs in the study area, and to efficiently undertake this task the existing narrow gauge railway would have to be replaced by new higher standard infrastructure. And if a new narrow gauge railway is to be built then there are better alignments than the existing corridor on
which to build such a line. Therefore this argument also has little value in determining the preferred gauge for the Oakajee railway.

One compelling argument when viewed from 2030 is that the new rail network servicing the Port and the adjoining Oakajee Industrial Estate should have the potential to be linked into the Leonora-Kalgoorlie and the Eastern Goldfields Rail Corridor standard gauge lines. This can be achieved in several ways as outlined elsewhere in this report. The preference is that this connection between the Oakajee and Goldfields rail networks should occur through progressive extension of the proposed southern Oakajee railroad. The reasons for this preference are outlined in Section 9, but the achievement of this strategic outcome is contingent on the southern railway being built as a standard gauge line.

Such a link will enable minerals from the Goldfields to be exported through Oakajee, and when being consigned to Asia have a shorter shipping journey, without a significantly longer rail journey when compared with export through Esperance. The complete network could open other wider opportunities such as the transport of mineral sands from the eastern edge of the Nullarbor to access the mineral sands treatment plant in Geraldton with an efficient logistics chain.

A standard gauge network based on Oakajee may also facilitate a fast freight rail link direct to Perth that could remove from road a great deal of the heavy freight traffic on that corridor. The present narrow gauge lines that link Perth with the Geraldton area are very slow and have sharp curves as they were designed to service the grain industry and they did not envisage the need for an inter-city freight link to Geraldton.

If the southern line were built to narrow gauge, none of these long term strategic links would be possible, and some of the strategic benefits of the new rail network would not be achieved. Therefore the gauge issue will most likely be determined by the gauge of the railroad that is built to serve the Southern iron ore group.

If standard gauge is adopted as the gauge for all the new railways in the study area, and the southern railway is built to standard gauge, the standard gauge system could operate separately from the existing narrow gauge network, which would remain primarily for grain and mineral sands traffic.

Another significant advantage of building the network standard gauge is that if the demand for iron ore exports through Oakajee expands then there is the ability to introduce heavier axle loads with modern wheel and rail profile techniques, and this would further reduce the operating costs, though increase rail efficiency. There is no option to further increase axle loads with a narrow gauge rail network.

### 10.3 Recommended Solution

The recommended solution is to build all of the new rail infrastructure as a standard gauge network, and install dual gauge in the Geraldton area where and if required to link the existing narrow gauge network into the new standard gauge system.

The alternative second best solution is to build an all narrow gauge network, all to a high quality heavy haul standard, including replacing the existing narrow gauge line from Geraldton to Morawa.

The least preferred solution is a standard gauge line to the north and a narrow gauge line to the south, and managing the interface issues with a link narrow gauge line, or dual gauge line to Oakajee.
11 The case for Coordinated Rail Network Development

There are two significant issues that are likely to hinder the development of a cohesive rail transport network to service Oakajee, which are discussed in this section. Unless these are discussed and dealt with early in the process, then the best solution may not be selected, and at worst, ad hoc solutions may be put in place that are sub-optimal and inefficient. Already these have commenced with iron ore being railed using 16 tonne axle loads from the southern area into Geraldton. One mine is planning to build a slurry pipe line, various separate routes have been proposed to service the Weld Range and Jack Hills area, and various routes and gauge options are being considered to service the Karara area. Urgent action is required to commence coordination of these developments. This report offers a strategic framework for the rail network, and if the recommendations are adopted then all further investment in the rail network in the area should be aligned to support development of the preferred strategic network.

11.1 Key Issue 1 - The Number of Mines

The Pilbara is similar to the major iron ore deposits in Brazil and South Africa; where there are very large iron ore deposits in close proximity that easily justify the construction of a railroad from these deposits to port. In the Midwest there are many smaller deposits, actual and potential and most are not large enough to justify a railroad being constructed, where high tonnages over many decades are required to recover the initial capital expenditure. Aggregating all the smaller deposits in each area does provide sufficient ore to justify a new port and rail network. However the mines are largely under different ownership and coordinating development will not be easy. Some of the mines that have proposed a new railroad to service the northern group have relatively small dispersed proven deposits, and with the reduced spot price for iron ore, may no longer be able to finance and recover the cost of building a new railroad to serve those deposits alone.

Techniques in developing the new transport network will need to take this into account.

11.2 Key Issue 2 - Uncoordinated Development

The diverse ownership, geographic spread and the diverse range of ore types and quality has already resulted in each mine being at a different stage of its development. They range from operating mines using either the existing narrow gauge rail network or road transport, to those in late stages of development and those that are still on the exploration stage. The reality is that without an efficient transport network some of the mines are unlikely to move into production, and this will be exacerbated if the spot price for iron ore and other minerals remains low. Therefore the co-ordinated development of the new transport network, including the railroad and the port will become a catalyst for new and as yet unforeseen mining development, as well as responding to the present push from some players to build their own lines. This catalyst role is essential in enabling the region to reach its full potential, and this objective is unlikely to be achieved if development of this key transport infrastructure is not effectively co-ordinated.

11.3 Other Issues

11.3.1 Transport Network Ownership and Funding

The rail access regime in Western Australia is very prescriptive about separation and transparency, and with multiple mine ownership, it would be preferable for one operating company to be set up to operate the rail network, and that ownership of the rail operating company would not be a single miner.

Financing will be a difficult task from the private sector alone as the initial start up will be slow and the guaranteed returns from large traffic flows will only come later. This is due to
the role that the new rail transport network will provide in the region. Instead of being built to service a very large proven reserve in one local area, the network is proposed to be built to facilitate the development of the many ore deposits in the region. Many of these deposits are not financially viable to develop at present as there is no transport infrastructure in place that can transport the minerals for export to a port at a cost that makes the development of the deposit into an operating mine viable.

Appendix B contains a broad and general example of ore body and transport infrastructure economic relationships.

It would not be impossible to privately finance construction of the port and rail infrastructure needed to catalyse development of the Midwest iron ore industry, however the present financial market will make private financing difficult (January 2009). Similar projects have been developed by asking potential clients to commit to future tonnages, and provide bankable guarantees. This process is frequently used in developing countries to bring production capacity on stream in advance to facilitate development.

11.3.2 The Operating Company

In order to achieve very low cost operation, it is essential that the contract to a company to operate the network is very precisely worded and that the appointed company clearly understand the concepts of operating a heavy haul railroad. Operating multi-user railroads needs an operating philosophy that manages the system very efficiently, adopts the latest technology and flexible train operating practices.

11.4 Suggested Development Programme

As the miners and infrastructure providers with interests in the Jack Hills and Weld Range area have previously been strongly suggesting they can finance the rail line, it is suggested that the northern railway could be constructed independently of the southern line, along a route and to standards consistent with the strategic framework and recommendations in this report.

The southern railway needs a full review of the feasibility and costs of the various options currently being considered to select a preferred option that is both consistent with the strategic framework and recommendations in this report and also achievable in practice. The three generic options for this line are, upgrade and extend the existing narrow gauge railway; construction of a new higher standard narrow gauge railway (either along the existing rail alignment or in a new corridor); or construction of a new standard gauge railway (either along the existing narrow gauge corridor or in a new corridor).

The cost comparison must include both Capex costs and the ongoing Opex costs for the various options, and the wider evaluation criteria must include consideration of the strategic issues, framework and recommendations in this report.

The feasibility and benefits of possible future extension of the southern line to the Yilgarn area and the connection to the existing Goldfields standard gauge network would be issues to be addressed in greater detail in the future and in the context of the decisions regarding the route, gauge and standards adopted for the initial development of the southern line.

11.5 Looking Back from 2030

As stated, the efficiency of the narrow gauge and standard gauge rail solutions is potentially similar. The drive to connect the proposed lines servicing the new Oakajee Port to the Goldfields and interstate standard gauge network is the principle reason that this report recommends standard gauge. Supplementary reasons are the flexibility to upgrade the system to higher axle load standard if required in the future. The use of existing narrow gauge network can be considered a low capital cost option, however the standards of the existing network, including horizontal and vertical alignment, are below internationally recognised benchmarks and will restrict future development of the mining region.
If the Oakajee and Goldfields railway systems are connected in the future, through the Yilgarn then the standard gauge recommendation will be vindicated. However, if the exploration and the mine development east of Karara and in the Yilgarn Group envisaged as the primary catalyst for the southern rail extensions does not take place, and the connection is not made, the principal disadvantage from the recommendation is the possible increase of rail gauge interface problems in the Midwest that might have otherwise been avoided.

It is suggested that a review is undertaken to ascertain the level of industry and wider stakeholder support for the strategic framework and directions recommended in this report prior to any final Government decisions.
12 Recommendations

This report is the first stage of a study to evaluate rail corridor proposals to link the Weld Range and Jack Hills iron ore areas with the new mineral export port at Oakajee.

In order to properly review the corridor route options, it has been important to develop a strategic framework for a new rail network centred on the Oakajee Port and which has the potential to also link to the rail system that services the Geraldton Port should that be required.

This report makes the following recommendations about the development of the rail network serving Oakajee:

- The new rail network should be standard gauge to facilitate a future connection to the standard gauge lines to the east and south of the Yilgarn area (and potentially also to the Pilbara standard gauge railways should that be required in the future).
- The rail network should be built to the best heavy haul standards but because of the multiple user access, it is suggested that the axle load be limited to 32 tonnes.
- The network should be constructed along the “Two Arm Network” model to minimise the upfront initial requirement for capital and provide the most efficient routes to port for the various geographically diverse iron ore deposits.
- A suitable operating model for the ownership and operation of the railway should be developed, that conforms to Western Australia’s Rail Access regime requirements.
- The optimum route to service the Jack Hills and Weld Range area is essentially the most direct route to Oakajee Port having regard for the various topographical, economic, social and environmental issues and constraints.
- The capital requirements, timescales and practical implications of upgrading the present narrow gauge line to the southern area should be compared to the cost of building a new standard gauge heavy haul line. The review must incorporate the Capex and ongoing Opex of both operations, and the benefits of full flexibility to achieve the desired longer term strategic outcomes.
- All future rail infrastructure development in the region should be undertaken in accordance with the strategic framework and principles outlined in this study, subject to consultation with key stakeholders, and endorsement by Government.
Figures

The following figures are provided:

Figure 1 – Study Area Locations
Figure 2 – Known Mine Sites, Proposed Mines and Prospects;
Figure 3 – SKA Exclusion Zone
Figure 4 – Central Spine Scenario
Figure 5 – Two Arm Scenario
Figure 7 – Central Spine Rail Network
Figure 8 – Two Arms Rail Network
Figure 9 – Proposed Options
Factors Impacting on Rail Alignments
Figure 3
Oakajee Rail Corridor - Strategic Rail Network Study
Appendix A

JORC Compliance
A1 JORC Compliance Definition

The quantities of ore quoted within this report are measured and indicative JORC compliant mineral resource estimates provided by the Department of Mines and Petroleum. This appendix details the definition of Mineral Resources and their respective JORC compliance grade. The following definitions have been obtained directly from “The Australasian Code for Reporting Exploration Results, Mineral Resources and Ore Reserves – The JORC Code 2004 edition.

A1.1 Mineral Resource

“A ‘Mineral Resource’ is a concentration or occurrence of material of intrinsic economic interest in or on the Earth’s crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

An ‘Inferred Mineral Resource’ is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which may be limited or of uncertain quality and reliability.

An ‘Indicated Mineral Resource’ is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.

A ‘Measured Mineral Resource’ is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.”

In respect to the figures within this report, only the Measured and Indicated Mineral Resource figures from DMP have been quoted.

A1.2 Ore Reserve

“An ‘Ore Reserve’ is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Ore Reserves are sub-divided in order of increasing confidence into Probable Ore Reserves and Proved Ore Reserves.

A ‘Probable Ore Reserve’ is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and
governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.

A ‘Proved Ore Reserve’ is the economically mineable part of a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.”

All quantities of ore defined by Ore Reserves are quoted within the figures provided in the report.
Appendix B

Economics of Ore Bodies
**B1 Economics of Ore Bodies**

The complexity of developing a modern rail network to service Oakajee is caused largely because there is no single ore body that is large enough to make the construction of the port and railroad viable, therefore no single company is likely to afford construction of an economically viable ‘best practice’ railroad for their own mining activities alone. As a guide, and to demonstrate this point the following construction cost example is provided:

**B1.1 Construction cost example**

Assume that 600 kilometre railroad needs to be constructed. Even at the lowest estimated construction cost of $3 million per kilometre, this amounts to $1.8 billion. To fund this investment, a very considerable cash flow above and beyond the operating cost of the railroad is required.

The driver tree below is representative of the costs involved in forming a business case that includes the rail line. In terms of commitments to justify the port, rail and mine costs of $3.8 billion it can be expected that in order of 40mtpa of ore would be required to be shipped for a period of 20 years. This equates to around 800 million tonnes of iron ore reserves as a minimum requirement to support such a project. This business case is for example purposes only and subject to the assumptions that may change as the project progresses.

It can be concluded that based on a capital investment of $3.8 billion with a required return on capital of 10%, the company would be required to earn $380 million a year for the mining activity to be viable. The example below shows a better than required result at $413 million per annum, a $33 million surplus above the required return on capital.
B1.2 Discussion

When the spot price of iron ore was around $100 per tonne the economics of the development are clearly favourable. With the spot price at around $60 per tonne or even less, the economics of an ore body such as Jack Hills (547 million tonnes), or Weld Range (199 million tonnes) are not likely to be viable on their own unless greater volumes of reserves are proven. Even combined, the ore deposits of these mines within the Northern Group still represent a marginal asset on which to base a massive investment.

Considering the Southern Group there are deposits in the Koolanooka and Karara areas that could be viable in their own right. Karara alone has 2.511 billion tonnes of ore.

In the Yilgarn the deposits are all relatively small; however the amount of exploration has been limited. The development of a railroad to Karara would potentially stimulate further exploration and drilling to determine reserves in the area.

Clearly ore deposits in the same area can be considered as one and the viability of a proposed railroad judged on the sum of the deposits. To improve the viability of areas containing these smaller deposits, a common loading terminal can be constructed and the smaller mines can truck or use short conveyers to deliver ore to the central loading area. Stockpiles would need to be developed to segregate ore from different owners. Distances of up to 15 or 16 kilometres can be efficiently serviced in this way.
## Job title
Oakajee Rail Corridor

## Job number
206033

## Document title
Strategic Rail Network Study

## File reference

### Document ref

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