Port Hedland Outer Harbour Development

PRELIMINARY ACID SULPHATE SOIL INVESTIGATION

- Final Revision 1
- WV03716-MV-RP-0035
- 02 October 2009

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Executive Summary

Sinclair Knight Merz (SKM) was commissioned by BHP Billiton Iron Ore to conduct a Preliminary Site Investigation (PSI) to assess potential contamination, acid sulphate soils (ASS) or other naturally occurring ground conditions that may impact upon the proposed development as part of Port Hedland Outer Harbour Development.

This report presents the results of the preliminary acid sulphate soil investigations (PASSI) carried out for the terrestrial development of the project. Investigations relating to potential contamination on the site are reported separately in the "Port Hedland Outer Harbour Development Preliminary Site Investigation" (SKM 2009c).

Based on SKM's proposal dated 25 May 2007 and in general accordance with the *Identification and investigation of acid sulfate soils and acidic landscapes* (DEC 2009a) guidelines, the objectives of this PASSI are to:

- review previous ASS investigations conducted at the Port Hedland area;
- assess the potential for ASS occurrence within the project area and identify the potential risks to the environment from the proposed development with regard to potential ASS disturbance;
- provide a conceptual model of the identified potential ASS impacts to be managed; and
- advise on the need for further ASS investigations.

The development study area covers a large area of approximately 36,000 ha, and has been divided into four zones for the purpose of this study. The PASSI covers the following study areas:

- *Zone 1 – Conveyor System and Finucane Island; Proposed* development includes ore transportation infrastructure between the proposed wharf and the proposed stockyards at Boodarie.
- *Zone 2 – Stockyards and Rail Loop;* Proposed use includes location for the new stockyards, in proximity to the decommissioned Hot Briquetted Iron (HBI) Boodarie Facility.
- *Zone 3 – Rail Line and Spurs;* Ore will be transported from mine sites along a proposed new rail line and rail spur travelling north and north-west to the new stockyard facility.
- *Zone 4 – Goldsworthy Rail Line;* Ore will be transported from mine sites along the proposed railway line and rail spur to be constructed adjacent to the existing rail line and rail spur.

Based on the findings of the PASSI the following conclusions are provided for each of the zones:

Zone 1

This zone has been identified as being in an area with '*moderate to high risk of ASS occurring in the top 3 m of natural soil surface'*. It is considered that all low lying and undisturbed mangrove or intertidal areas pose a higher risk of ASS or Potential ASS (PASS) occurrence.

The risk of ASS occurrence on the proposed development in Zone 1 is considered to be high and depending on engineering specifications for excavation. An Acid Sulphate Soil Management Plan incorporating further detailed soil investigations will be implemented to mitigate potential ASS and groundwater risks during and post construction.

Zone 2

Zone 2 contains mostly areas where '*no known risk of ASS'* occurs within the top 3 m below natural soil surface or deeper. A small area of '*moderate to high risk of ASS occurring in the top 3 m of natural soil surface'* exists in the north-west of this zone.

The risk of ASS occurrence on the proposed development in Zone 2 is considered to be moderate since deep excavations (25 m deep) are planned and the development area is located near to an area of high risk ASS occurrence. Therefore, it is anticipated that further detailed soil investigations are required. An Acid Sulphate Soil Management Plan will be implemented to mitigate potential ASS and groundwater risks during and post construction.

Zone 3

Zone 3 is located in an area where there is '*no known risk of ASS'* occurring within the top 3 m below natural soil surface or deeper. Therefore, as no deep excavations are proposed in this Zone, a further detailed ASS investigation of this zone is not required.

Zone 4

Zone 4 is located in an area where there is '*no known risk of ASS'* occurring within the top 3 m below natural soil surface or deeper. As no deep excavations are proposed in this Zone, a further detailed ASS investigation of this zone is not required.

Based on the findings of the PASSI it is considered that by adopting appropriate measures to investigate and manage potential ASS associated with proposed infrastructure within Zone 1 and Zone 2, the risks from potential ASS on the proposed development or environment will be low. Therefore, the following recommendations are provided:

- Undertake a detailed ASS investigation (DASSI) for areas within Zone 1 and Zone 2, in which excavations are planned.
- Develop and implement an ASS Management Plan (ASSMP) to address contingencies during development to mitigate potential impacts to the environment.

Contents

Appendices

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Acronyms

AASS – Actual Acid Sulphate Soils

AHD – Australian Height Datum

ASS – Acid Sulphate Soils

ASSMP – Acid Sulphate Soil Management Plan

BoM – Bureau of Meteorology

CSAM - Conceptual Site ASS Model

DEC – Department of Environment and Conservation

DASSI – Detailed Acid Sulphate Soils Investigation

EPA – Environmental Protection Authority

HBI – Hot Briquetted Iron

PAOC – Potential Area of Concern

PASS – Potential Acid Sulphate Soils

PCOC – Potential Contaminants of Concern

PER- Public Environmental Review

PSI – Preliminary Site Investigation

SKM – Sinclair Knight Merz

WA – Western Australia

Units and Symbols

°C – degree Celsius

µg/L – micrograms per litre

µg/m^3 – micrograms per metre cubed

cm – centimetre

km^2 –kilometres squared

m – metres

m^3 – metres cubed

mg/kg – milligrams per kilogram

mg/m^3 – milligrams per metre cubed

mm – millimetres

ha – hectare

km – kilometres

1 Introduction

1.1 Project Background

Sinclair Knight Merz (SKM) was commissioned by BHP Billiton Iron Ore to assess the potential for acid sulphate soils (ASS) or other naturally occurring ground conditions that may impact upon the proposed development of the Port Hedland Outer Harbour Development (the Outer Harbour Development). These findings will form part of the documents for the Public Environmental Review (PER)/ Environmental Impact Statement (EIS). This report presents the results of the Preliminary Acid Sulphate Soil Investigations (PASSI) for the Outer Harbour Development. This PASSI has been prepared in general accordance with the Government of Western Australia's Department of Environmental and Conservation's (DEC) requirements under the *Acid Sulphate Soils Guideline Series*, (2009a and 2009b). The DEC identifies the PASSI as part of a staged approach to ASS investigations, with each progressive stage being more detailed. Therefore, the findings of the PASSI form the basis of any subsequent ASS assessments and site investigations.

1.2 Purpose and Objectives

The purpose of the PASSI is to assess the potential for ASS to occur within the project area (based on a desktop study and site walkover) and to define the necessity for, and any requirements of, further investigative works to define the ASS conditions in the area of the development.

The objectives of this PASSI are to:

- review previous ASS investigations conducted in the Port Hedland area;
- assess the potential for ASS occurrence within the project area and identify the potential risks to the environment from the proposed development;
- provide a conceptual model of the identified potential impacts to be managed; and
- advise on the requirements for further ASS investigations.

1.3 Scope of Works

In order to achieve the objectives of the PASSI the following works were conducted:

- identify the project and site boundaries. (refer **Section 2**);
- summarise the broad environmental setting of the development area based on available published information. (refer **Section 3**);
- review previous ASS investigations carried out in the Port Hedland area (refer **Section 4**);
- provide a discussion of the potential environmental issues present at the proposed development areas (refer **Section 5**); and
- provide the conclusions from the findings of the PASS and recommendations for the proposed development areas (refer **Section 6**).

2 Site Setting

The site is located at Port Hedland, WA, extending from Finucane Island southwards onto the mainland. Port Hedland is one of the major towns and one of three ports operating in the Pilbara region. The development study area covers a large area of approximately 36,066 ha, and has been divided into four zones for the purpose of this study.

The site location (including Zones 1, 2, 3 and 4), existing infrastructure, proposed development and environmentally significant features are shown in **Figure 1,** in **Appendix A**.

This PASSI covers the following study areas:

- Zone 1 – Conveyor System and Finucane Island;
- Zone 2 – Stockyards and Rail Loop;
- Zone 3 – Rail Line and Spurs, and
- Zone 4 – Existing Goldsworthy Rail Line.

2.1 Zone 1

2.1.1 Location

Zone 1 is approximately 3,053 ha and is located on Finucane Island. The Port Hedland community is located approximately 4 km to the east. The site location and layout of proposed development is presented in **Figure 1A** in **Appendix A**. The proposed infrastructure footprint within this zone occupies approximately 4.2% of the total area of Zone 1.

2.1.2 Site Description

Existing infrastructure within Zone 1 includes Finucane Island BHP Billiton Iron Ore port facility, an operational BHP Billiton Iron Ore rail line which terminates at the Finucane Island BHP Billiton Iron Ore port facility and a conveyor system connecting the Boodarie Hot Briquetted Iron (HBI) plant (no longer in operation) to Finucane Island. The existing rail line and conveyor system run parallel with a large section of the existing road. The existing Finucane Island BHP Billiton Iron Ore port facility consists of stockyards/ processing area and a tailings holding area (from the former Goldsworthy Beneficiation Plant) that is bunded around all sides. Outside the footprint of the existing facility some areas of undisturbed, dunal and intertidal habitat exist.

Site photographs are presented in **Appendix B**.

2.1.3 Proposed Landuse

The proposed transfer infrastructure will require the construction of an infrastructure corridor including the conveyor system on the western side of the existing conveyor causeway approximately 6 km long (**Figure 1A**). This conveyor system will link the Boodarie Stockyards to a transfer pad on Finucane Island. The transfer pad is to be located to the west of the existing BHP Billiton Iron Ore port facility on a dunal system.

The construction of the conveyor system (adjacent to the existing road) will involve construction activities including the removal of soft clay (to an approximate depth of 1 m below ground surface (bgs)), excavation of Pindan sands or red brown silty sands (approximately to 1 m depth), cut in isolated sections where the landscape is raised (to an approximate depth of 2 m) and placement of engineered fill, (**Appendix C**).

The construction of the Transfer Pad on Finucane Island will include topsoil removal (approximately 0.15 m depth), the potential removal of soft clay (approximately 1 m depth), cut in isolated sections where the landscape is raised (approximately 5 m depth) and placement of engineered fill. Dewatering may be required depending on engineering specifications (likely depth of influence is currently unknown).

2.2 Zone 2

2.2.1 Location

Zone 2 is approximately 1,928 ha and located to the south of Finucane Island. The Wedgefield community is located approximately 6 km east, and South Hedland community is located approximately 10 km to the south-east of the site. The site location and conceptual layout of proposed development is presented in **Figure 1B** in **Appendix A**. The proposed infrastructure within this zone occupies approximately 6.9% of the total area of Zone 2.

2.2.2 Site Description

Existing infrastructure within Zone 2 includes the decommissioned Boodarie HBI Facility. The area is relatively flat with undulations representative of low lying coastal areas, predominantly sandy with a mix of aeolian dune systems and marine or river deposits.

The Boodarie HBI facility is no longer operational and is currently planned to be partially demolished. Excavation and remediation of contaminated soil material is proposed to occur under the supervision of Golder Associates and it is understood that the site will be remediated to a standard suitable for industrial use. Further information on the areas of the site proposed for remedial works is included in the *Draft Detailed Site Investigation, Boodarie Iron Port Hedland.* (Golder Associates, 2006).

The Boodarie HBI Plant is surrounded to the north by marine coastline. A tailings storage facility and landfill (existing HBI plant occupants) are located immediately south of the existing stockyard area. Site photographs are presented in **Appendix B**.

2.2.3 Proposed Landuse

Zone 2 will be used to store and manage iron ore stockpiles, being delivered by rail from BHP Billiton Iron Ore's inland mines. Proposed infrastructure includes stockyards, car dumpers, conveyor tunnels, stacker reclaimers, rail lines, conveyor (linking with the conveyor system proposed for Zone 1) and a rail loop (**Figure 1B**, **Appendix A**). It is expected that the site will also contain site offices and other facilities related to the operations. The general site use is for industrial purposes.

The eastern portion of the proposed stockyards and part of the rail loop will intersect the existing footprint of the decommissioned Boodarie HBI facility.

The construction of the stockyards includes topsoil removal, excavation of Pindan sands or red brown silty sands (approximately to 1 m depth), cut in isolated sections where the landscape is raised (approximately to 2 m depth) and placement of engineered fill, (**Appendix C**). The construction of the car dumpers and conveyor tunnels will include topsoil removal (approximately 0.15 m depth), deep excavations (approximately to 25 m depth), cut in isolated sections where the landscape is raised, and placement of engineered fill. Dewatering in the vicinity of the proposed deep excavations will be required.

The rail loop construction will involve topsoil removal (approximately 0.15 m depth), cut in isolated sections where the landscape is raised (approximately to 2 m depth), limited excavation of Pindan sands red brown silty sands, and fill (approximately to 1 m depth).

2.3 Zone 3

2.3.1 Location

Zone 3 covers an approximate area of 29,466 ha and is located to the south of Finucane Island. The Wedgefield Community is located approximately 6 km east and South Hedland community is located approximately 8 km south-east of the site. The site location and layout of proposed development is presented in **Figure 1C** in **Appendix A**. The proposed infrastructure footprint within this zone occupies approximately 0.1% of the total area of Zone 3.

2.3.2 Site Description

The proposed new Rail Line will be constructed across predominantly undisturbed ground that consists of sparsely vegetated sand, dunes and river deposits, with outcrops of quartzite, particularly in dried catchment water drainage areas.

The majority of the surrounding landuse is undisturbed bushland with access tracks for vehicles and people. A rail line and its associated maintenance access road are the only landuses in the proposed rail area. Site photographs are presented in **Appendix B**.

2.3.3 Proposed Landuse

A rail spur is required to connect the Boodarie Stockyards (Zone 2) to the existing main rail line (**Figure 1C, Appendix A**).

The construction of the rail spur includes activities such as, topsoil removal, cut in isolated sections where the landscape is raised (approximately 5 m depth) and placement of engineered fill, (**Appendix C**). Dewatering is unlikely to be required within these areas.

2.4 Zone 4

2.4.1 Location

Zone 4 covers an approximate area of 1,619 ha and is located to the south and south east of Finucane Island. The Wedgefield Community is located within this area and South Hedland community is located approximately 2 km to the west of the site. The site location and layout of the proposed development is presented in **Figure 1D** in **Appendix A**. The proposed infrastructure footprint within this zone occupies approximately 1.1% of the total area of Zone 4.

2.4.2 Site Description

Zone 4 consists of predominantly undisturbed ground that consists of sparsely vegetated sand, dunes and river deposits, with outcrops of quartzite, particularly in dried catchment water drainage areas.

The majority of the surrounding landuse is undisturbed bushland with access tracks for vehicles and people. A rail line and its associated maintenance access road are the only landuses in the area.

Site photographs are presented in **Appendix B**.

2.4.3 Proposed Landuse

The proposed new rail line will duplicate the existing Goldsworthy Rail Line. A rail spur is required to connect the Boodarie Stockyards (Zone 2) to the existing main rail line (**Figure 1D, Appendix A**).

The construction of the proposed rail line and rail spur will involve construction activities including topsoil removal, cut in isolated sections where the landscape is raised (approximately to 5 m depth) and placement of engineered fill, (**Appendix C**). Dewatering is unlikely to be required within these areas.

3 Environmental Setting

3.1 Pilbara Region

The Pilbara region covers over 500,000 km^2, with the coastal extent stretching from the Exmouth Gulf to Cape Keraudren. This area supports a diverse range of environments, both marine and terrestrial, many of which are isolated and rugged and recognised for high conservation value. Some of these areas formally recognised include Ningaloo Marine Park, Cape Range National Park, the Burrup Peninsula and the surrounding proposed Dampier Archipelago Marine Park.

3.2 Climate

The Pilbara region is located in the arid-tropics, with low and variable rainfall experienced throughout the area. Bureau of Meteorology (BoM 2007) data indicates that annual rainfall totals vary from 250 – 400 mm, with many years reporting no significant rainfalls. The area experiences hot temperatures and high humidity during the summer months. Monthly average maximum temperatures range from approximately 30 – 37^{o}C.

The coastline between Port Hedland and the Exmouth Gulf is the most cyclone-prone in Australia, with several severe cyclones causing significant damage in the past 30 years. These cyclones occur predominantly between January and March and account for the majority of rainfall in the region.

3.3 Topography, Geology, Hydrogeology, Hydrology and Soils

The Pilbara landscape is typically flat and highly weathered with low rangelands occurring in the interior, representing a landscape that has remained largely unchanged for 100 million years. The Port Hedland area consists of flat sandy lowlands, with broad areas of bare coastal mudflats, intertidal mudflats and tidal creeks, and a significantly altered open harbour at Port Hedland.

The Port Hedland area is located on the Holocene, Bossut Formation, a body of unconsolidated sedimentary soils described as sandy calcarenite, oolite and calcilutite, which outcrops discontinuously near the coast. These dune, beach ridge, beach and offshore bar deposits are predominantly marine, with the exception of the barrier dune system which is of Aeolian origin.

Finucane Island and the conveyor system occurs in the Littoral Land System unit, which is characterised by bare coastal mudflats with mangroves present on the seaward fringes, with samphire flats, sandy islands, coastal dunes and beaches (DoA 2004).

A number of geological maps exist for Port Hedland:

- *Port Hedland – Bedout Island, Western Australia*, 1:250,000 Geological Series, Geological Survey of WA, Department of National Development and Energy, 1981;
- *Boodarrie Geological Survey of Western Australia*, 1:50,000 Urban Geology Series, Department of Lands and Surveys, 1983;

- *Port Hedland Geological Survey of Western Australia*, 1:50,000 Urban Geology Series, Department of Lands and Surveys, 1983 (GSWA 1983);
- *Wallaringa Geological Survey of Western Australia*, 1:100,000 Geological Series, Department of Minerals and Energy, 2001;
- *Yule Geological Survey of Western Australia*, 1:100,000 Geological Series, Department of Minerals and Energy, 2001; and
- *Port Hedland – Bedout Island, Geological Survey of Western Australia*, 1:250,000 Geological Series, Department of Industry and Resources, 2006.

While not the most recent source of geological information, SKM have selected the 1:50,000 Urban Geology Series (GSWA 1983) for the provision of geological information due to the greater details resulting from the scale of these map. However, it should be noted that the coverage (of the 1:50,000 maps) only extends approximately half way to the southern boundary of Zone 3. No other geological maps at the 1:50,000 scale have currently been published for the area further to the south. Therefore, SKM sourced the geological information, for the remainder of Zone 3, from the 1:100,000 Geological Series (2001).maps for inclusion in this report.

The general topography of the site is presented in **Figure 2** in **Appendix A**. The general geology of the site is presented in **Figure 3** in **Appendix A**.

A summary of environmental and geophysical information is provided in **Table 3.1.** More detailed information on the site topography, geology, hydrogeology, hydrology and vegetation can be found in **Appendix D**.

Area	Geology and soils (as per GSWA)	Landforms/ Topography	Vegetation present	Water table depth	Hydrology	Hydrogeology
Zone 1						
Transfer Pad	High level sands Mud and silt Gravelly, medium-course grained brown sand Mangrove flats/muds (brown/grey, sandy clay to clayey sand) Calcarenite (limestone) to max depth of 1.7m bgs (cemented, course, grained and white)	Younger beaches and sand dunes Tidal flats Limestone	Grassland Shrubland Samphire Flats	1-8m bgs	Tidal marine shoreline with mangroves Nearest marine tidal zone~100m east of site	Upper superficial aquifier GW flow radial from Island to shore Tidal influence likely Numerous groundwater monitoring bores (approximately 38) indicating depth to groundwater depth between 2.5 and 8.1m bgs
Conveyor Route	mangrove flats mud and silt residual sand and dune limestone	tidal flats dune limestone	As above	0.5-3m bgs	As above	Nov 08(SKM) –groundwater monitoring bore (MW1) showing GW at 0.6m bgs
Zone 2						
Stockyards	mud and silt red brown silty sand (alluvium)	Sandplain	Grassland Shrubland Samphire Flats	1-3 m bgs	Major drainage features: Turner River and South West Creek Water flow north-east towards coast and locally to South West Creek	~20 monitoring wells GW salinity ranges 13,000-52,000mg/L TDS Depth to GW 2-5m bgs GW flows north-northwest towards coast Hydraulic gradient less than 0.05% Permeability from 7to 10 m/s below 3m bgs GW elevations vary by 2m, April peak
Car dumpers	As above	As above	Grassland Shrubland	2-3 m bgs	As above	As above
Conveyor tunnels	As above	As above	Grassland Shrubland	2-3 m bgs	As above	As above
Rail loop	As above	As above	Grassland Shrubland	2-3 m bgs	As above	As above
Zone 3						
Rail spurs-	Red brown silty sand Clayey sand High level sands	Sandplain	Shrubland Grassland	3-13 m bgs	Surface flow to intermittent creek meandering across the zone ultimately flowing to the ocean to the north.	Depth to groundwater estimated to be between 3 and 13m bgs. Groundwater flow direction anticipated to be north toward the ocean.
Zone 4						
Goldsworthy Option	Red brown silty sand Clayey sand High level sands	Sandplain	Shrubland Grassland	2-6 m bgs	Surface flow to intermittent creek meandering across the zone ultimately flowing to the ocean to the north.	Groundwater flow direction anticipated to be north toward the ocean.

- **Table 3.1 – Summary of geophysical and environmental information for Zones 1 to 4**

4 Review of Previous ASS Investigations in Port Hedland

4.1 ASS Mapping

Several maps identifying the probabilities of the presence of ASS in Western Australia were developed. Those included the DEC, Port Hedland *PilbaraCoasteline Acid Sulfate Soils Risk Map* (DEC 2006) and the Draft Only-Acid Sulphate Soils Map (CSIRO 2008). **Figure 4** in **Appendix A** shows the overall ASS Risk map for the site.

With respect to Port Hedland, the inner harbour and intertidal areas has been identified on these maps as 'having a high to moderate risk of ASS occurring within 3 m of natural soil surface' (DEC 2006) and having a 'high probability' of ASS occurring (CSIRO 2008). Furthermore, it has been identified by the DEC that shallow ASS is known to be present in riverine, estuarine, and coastal lowland areas such as mangroves and tidal flats (DEC 2006).

4.2 Dredging and Land Reclamation

Dredged areas and materials, as well as being derived from marine sediments, also comprise Holocene muds, red beds and calcarenite deposits, which are located throughout much of the Outer Harbour Development footprint. As such, information sourced from previous dredging and land reclamation projects in the Port Hedland area are relevant to this PASSI in so far as the location of onshore placement of dredge material or assessment of the results of any intrusive works (for PASS) within or in close proximity to the proposed Outer Harbour Development footprint.

Capital and maintenance dredging has been undertaken at Port Hedland between 1965 and 2007 in which approximately 21 million m^3 of material was dredged to create the approach channel, inner harbour and berth pockets. A summary of the dredging history since 1986 is provided in **Table 4.1** below.

Generally dredge material has been disposed of at ocean disposal grounds. However, significant volumes of dredge material have also been placed onshore for land reclamation. Land reclamation occurred between 1985 and 2007 and has included:

- BHP Billiton Iron Ore produced the area locally known as "spoil bank", a northward projecting spit of sediment immediately to the east of the harbour entrance;
- BHP Billiton Iron Ore reclaimed land between Hunt and Utah Points as part of the Finucane Island installation of berths;
- BHP Billiton Iron Ore land reclamation at Burgess Point;
- BHP Billiton Iron Ore land reclamation at Stingray Creek; and
- FMG reclamation located in the upper intertidal zone to the south of Anderson Point.

- **Table 4.1: Summary of Port Hedland Dredging**

Year	Dredge Volume (m3)	Proponent	Purpose of Dredge
1985 – 86	13,600,000 m^3	BHP Billiton Iron Ore	Capital and maintenance
1990	350,000 m^3	PHPA	Maintenance
1994	114,000 m^3	PHPA	Maintenance
1997	330,000 m^3	PHPA	Maintenance
2001	580,000 m^3	PHPA	Maintenance
2002	460,000 m^3	BHP Billiton Iron Ore	Capital
2004	530,000 m^3	PHPA	Maintenance
2006-07	5,000,000 m^3	FMGL	Capital

Notes:
The above data has been derived from one or more of the sources referenced in this report.
PHPA indicates Port Hedland Port Authority, m^3 indicates cubic meters, FMGL indicates Fortescue Metal Group Pty Ltd.

Historically, limited information has been gathered regarding the presence, extent and distribution of PASS in dredged material from Port Hedland. Results from previous investigations (Oceanica 2005; URS 2006a and 2006b; Coffey Geotechnics 2008), have confirmed the presence of PASS in the marine harbour sediments. Specifically, PASS appears to be isolated to the most recent Holocene (the last 10,000 years) deposits. For the Inner Harbour area at Port Hedland, these Holocene deposits generally represent the top 1 to 2 m of the seabed.

Documentation confirming the presence of ASS within land disposed dredged material in the Port Hedland area is lacking. It should be noted that there are a number of subsurface investigations at sites throughout the Port Hedland area currently being investigated.

An ASSMP (prepared by URS, 2006b) was developed in response to Ministerial Conditions and Environmental Approvals associated with dredging of material by Fortescue Metals Group (FMG) in 2006 to 2007 to ensure that strategies and procedures were in place to manage risks associated with PASS in dredged material disposed to land. It is noted that, based on communications with stakeholders, there is anecdotal information indicating that ASS may be present in the dredged material (FMGs 2006 to 2007 capital dredging activities).

4.3 Land-based ASS Investigations

Recent land-based ASS investigations have been carried out in the vicinity of the Outer Harbour Development project area bas part of the Port Hedland Port Authority's proposed Utah Point development (PHPA 2008). The study indicated that there was no Actual Acid Sulphate Soil (AASS) present within the study area but identified that PASS could be expected in the northern portion of the project site. Therefore, an ASSMP was developed to manage potential environmental impacts during as well as following the proposed construction for the Utah Point development.

A study was undertaken by URS for FMG in 2006 to produce an Acid Sulphate Soil Management Plan (ASSMP) for the proposed Pilbara Iron Ore and Infrastructure Project. The ASSMP (URS, 2006a) indicated ASS within the marine mud of the mangrove swamps and potentially within a surface Clayey Silt layer identified within the dredge spoil material.

5 ASS Assessment

This section discusses the potential environmental issues in the proposed development areas with reference to the DEC, *Pilbara Coastline Acid Sulfate Soils Risk Map* (DEC 2006). A summary of the likelihood of PASS at the site is provided in **Table 5.1**.

5.1 Zone 1

This zone has been identified as being in an area with ***moderate to high risk of ASS occurring in the top 3 m of natural soil surface*** (refer **Figure 4A** in **Appendix A**). The southern portion of this zone is located in an area which has ***no known risk of ASS*** occurring. **Table 5.1** below summarises the environmental information for Zone 1 and the potential for ASS occurring.

It is considered that all low lying and undisturbed mangrove or intertidal areas pose a higher risk of ASS or PASS occurrence. The risk from ASS is associated with ground disturbance activities and only areas where excavations are to take place into undisturbed natural ground will require investigation, in line with DEC guidelines (DEC 2009b).

The risk of ASS occurrence on the proposed development in Zone 1 is considered to be high and depending on engineering specifications for excavation, it may be necessary to allow for management of dewatering impacts during the construction phase. It is anticipated that intrusive investigation work and management plans will be implemented to mitigate potential risks during and post construction works.

5.2 Zone 2

Zone 2 contains mostly areas where ***no known risk of ASS*** occur (refer **Figure 4B** in **Appendix A**) within the top 3 m below natural soil surface or deeper. A small area of '*moderate to high risk of ASS occurring in the top 3 m of natural soil surface*' exists in the north-west corner of this zone. Proposed development is located outside of the '*moderate to high risk of ASS occurring*' area (approximately 10km northwest of development). **Table 5.1** below summarises the environmental information for Zone 2 and the potential for ASS occurring.

The risk of ASS occurrence on the proposed development in this area is considered to be moderate since deep excavations (25 m deep) are planned and the area is located near mapped high risk ASS occurrence.

Therefore, it is anticipated that management plans will required to be implemented to mitigate potential ASS and groundwater risks during and post construction.

5.3 Zone 3

Zone 3 is located in an area where there is ***no known risk of ASS*** occurring (refer **Figure 4C** in **Appendix A**) within the top 3 m below natural soil surface or deeper. The risks from ASS on the proposed development in this area are low since no deep excavations are expected to occur. **Table 5.1** summarises the environmental information for Zone 3.

5.4 Zone 4

Zone 4 is also located in an area where there is ***no known risk of ASS*** occurring (refer **Figure 4D** in **Appendix A**) within the top 3 m below natural soil surface or deeper. The risks from ASS on the proposed development in this area are low since no deep excavations are expected to occur. **Table 5.1** provides a summary of the environmental information for Zone 4.

5.5 Preliminary Conceptual Site Model

In order to understand the key environmental aspects related to the proposed development, a Preliminary Conceptual Site ASS Model (CSAM) has been prepared in **Table 5.2** to identify areas of concern as they relate to potential primary or secondary sources of ASS (referred as 'Sources'), the preferential pathways ('Pathways') through which any potential acidity generated might reach a sensitive receptor and also those identified receptors, both onsite and offsite ('Receptors').

Based on the CSAM Zones 1 and 2 have been identified as posing a potential (direct or indirect) risk of ASS occurring.

- **Table 5.1 – Potential for ASS at Proposed Infrastructure Areas**

Areas Likely to Contain ASS*	Zone 1	Zone 2	Zone 3	Zone 4
Areas depicted on geology and/or geomorphological maps as geologically recent (Holocene) such as shallow tidal flats or tidal lakes, shallow estuarine, shallow marine deposits, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes, coastal alluvial valleys, wetlands, floodplain, waterlogged areas, scalded areas, sump land, marshes or swamps.	Yes - Holocene deposits present	No but Holocene deposits present approximately 1 km to the north	No	Yes - Holocene deposits present
Areas depicted in vegetation mapping as mangroves, wetland dependent vegetation such as reeds and paperbarks (*Melaleuca spp*.), areas where the dominant vegetation is tolerant of salt, acid and/or waterlogging, conditions e.g. mangroves, saltcouch, swamp-tolerant reeds, rushes, paperbarks and swamp oak (*Casuarina spp*.).	Yes - mangroves and salt tolerant vegetation are present through the majority of the area	No	No	Yes - salt tolerant vegetation present
Areas identified in geological descriptions or in maps as bearing acid sulphide minerals, former marine or estuarine shales and sediments, coal deposits or mineral sand deposits.	Yes - former marine sediments present	Yes - but former marine sediments present approximately 1 km away	No	Yes - former marine sediments present
Areas known to contain peat or a build up of organic material.	No	No	No	No
Areas where the highest known watertable level is within 3 m of the surface.	Yes	No	No	No
Land with elevation less than 5 m above Australian Height Datum (AHD).	Yes	No	No	No
Any areas in Western Australia (including inland areas) where a combination of all the following pre-disposing factors exist: organic matter, iron minerals, waterlogged conditions or a high watertable, sulphidic minerals and deep estuarine sediments below ground surface.	Yes - waterlogged conditions or a high watertable present	No	No	No

Notes: * - *Identification and investigation of acid sulfate soils and acidic landscapes* (DEC 2009a)

- **Table 5.2 - Preliminary Conceptual Site ASS Model**

PAOC[(1)] Location	Primary Source (Activity)	Secondary Source (Media)	Release Mechanism to Media	PCOC[(2)]	Exposure Pathway	Receptor	Potential Hazard
Zone 1- *Moderate and High Risk of ASS*	Proposed development of infrastructure (Conveyor system and Transfer Pad on Finucane Island)	Contaminated soils and groundwater with acidic pH	Excavations in these areas may generate ASS, which would decrease pH and potentially release heavy metals into groundwater.	Acidic pH and dissolved heavy metals such as arsenic	Migration into groundwater through rain infiltration vertical flow or tidal waters horizontal flow	Human Construction materials Groundwater and Marine Environment	Ingestion of heavy metals in groundwater, contact with acidic soils or groundwater Concrete or other construction materials may be impacted by acidic pH in soils or groundwater Impacted groundwater may migrate to ocean or creek.
Zone 2- *No known Risk of ASS with abutting area of Moderate to High Risk of ASS*	Proposed development of infrastructure and stockyards for ore handling facilities		Deep excavations may require dewatering which may generate ASS in adjacent dewatered areas			Construction materials Groundwater and Marine Environment	Concrete or other construction materials may be impacted by acidic pH in soils or groundwater Impacted groundwater may migrate to ocean or creek.

Notes: [(1)] PAOC – Potential Areas of Concern

[(2)] PCOC – Potential Contaminants of Concern

6 Conclusions and Recommendations

6.1 Conclusions

Based on the findings of the PASSI the following conclusions are provided for each of the zones:

6.1.1 Zone 1

The proposed development lies outside the existing BHP Billiton Iron Ore Finucane Island facilities. Initial investigations have highlighted that the proposed infrastructure is located in an area of ***moderate and high risk of ASS*** occurring within 3 m of the natural soil surface.

As a result of the moderate to high risk of ASS occurring and excavations deeper than 1 m, planned within Zone 1, this zone was identified as a Potential Area of Concern, posing a possible environmental risk to the proposed development.

It should be noted that further investigation of PASS is proposed for early 2010. Following receipt and review of the result of the investigation the proposed acid sulphate soil management plan will be revised, if required, and implemented to mitigate potential ASS and groundwater risks during and post construction.

6.1.2 Zone 2

Zone 2 contains mostly areas where ***no known risk of ASS*** occurs within the top 3m below natural soil surface or deeper. A small area of '*moderate to high risk of ASS occurring in the top 3m of natural soil surface'* exists in the north-west corner of this zone. Proposed development is located adjacent to this '*moderate to high risk of ASS occurring'* area.

The risk of potential ASS occurrence on the proposed development in this area is considered to be moderate since deep excavations (up to 25 m deep) are planned and the area is located adjacent to an area mapped as high risk of ASS occurrence. It should be noted that further investigation of PASS is proposed for early 2010. Following receipt and review of the result of the investigation the proposed acid sulphate soil management plan will be revised, if required, and implemented to mitigate potential ASS and groundwater risks during and post construction.

6.1.3 Zone 3

Zone 3 is located in an area where there is ***no known risk of ASS*** occurring within the top 3m below natural soil surface or deeper. The risks from ASS on the proposed development in this area are low since no deep excavations are expected to occur. Therefore, further detailed ASS investigation of this zone is not required.

6.1.4 Zone 4

Zone 4 is located in an area where there is ***no known risk of ASS*** occurring within the top 3m below natural soil surface or deeper. The risks from ASS on the proposed development in this area are low since no deep excavations are expected to occur. Therefore, further detailed ASS investigation of this zone is not required.

6.2 Recommendations

Based on the findings of the PASSI it is considered that by adopting appropriate measures to investigate and manage potential ASS at Finucane Island and Boodarie, the risks from ASS on the proposed development or environment will be low. Therefore, the following recommendations are provided:

- Undertake a detailed ASS investigation (DASSI) at areas within Zone 1 or Zone 2, in which excavations are planned, including groundwater assessment and at a sampling density and frequency in general accordance with DEC 2009b requirements.
- SKM recommends that soil investigation be undertaken with samples collected to a depth of approximately 2.5 m bgs (this assumes excavations less than 1.5 m bgs) at approximately 0.25 m intervals over a 4.5 km route at 200 m[1] intervals (where access constraints permit) along the existing causeway and at nine locations on Finucane Island. Further SKM recommend soil samples be collected across the stockyards (approximately 30 locations) and at 4 locations in the vicinity of the car dumpers. The proposed sample locations are identified in **Appendix E.**
- SKM recommends three monitoring wells be installed on the the area of proposed infrastructure on Finucane Island and five monitoring wells be installed in the area surrounding the car dumpers. The proposed location of the monitoring wells are identified in **Appendix E**.
- The "Port Hedland Outer Harbour Development Acid Sulfate Soils Management Plan", September 2009b, SKM should be updated (if required) following completion of the proposed additional investigation works to reduce the potential for adverse impacts (from ASS) during development.

[1] DEC (2009b) recommend 1 sample per 50 m for major linear project. However, SKM recommend a reduced sample density due to the low likelihood of excavation for the majority of the proposed development (with the exception of the propose car dumpers). SKM consider the reduced sampling density suitable to provide a broad understanding of the likelihood of ASS occurrence on the identified risk areas and therefore information on likely ASS management measures for inclusion in the ASS management plan.

7 Limitations of Report

This section presents information that will help the reader understand the uncertainties relating to the interpretation by SKM of the data obtained during this investigation and the recommendations presented in the report.

This report has been prepared by SKM for the sole use of BHP Billiton Iron Ore ("the Client") and in accordance with the scope of services detailed in the agreement dated 25 May 2007. SKM has relied upon and presumed accurate certain information (or absence thereof) relative to the information provided by the Client. Except as otherwise stated in the report, SKM has not attempted to verify the accuracy or completeness of any such information.

Undertaking an assessment or study of the on-site conditions may reduce the potential for exposure to the presence of contaminated or inadequate bearing ground and/or groundwater. All reports and conclusions that deal with sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. The Client should be aware that this report contains interpretations and conclusions which are uncertain, due to the nature of the investigations. No study can completely eliminate risk, and even a rigorous assessment and/or sampling programme may not detect all problem areas within a site.

This Report should only be presented in full and should not be used to support any objective other than those detailed within the Agreement. In particular, the Report does not contain sufficient information to enable it to be used for any use other than the project specific requirements for which the Report was carried out, which are detailed in our Agreement. SKM accepts no liability to the Client for any loss and/or damage incurred as a result of changes to the usage, size, design, layout, location or any other material change to the intended purpose contemplated under this Agreement.

It is imperative to note that the Report only considers the site conditions current at the time of investigation, and to be aware that conditions may have changed due to natural forces and/or operations on or near the site. Any decisions based on the findings of the Report must take into account any subsequent changes in site conditions and/or developments in legislative and regulatory requirements. SKM accepts no liability to the Client for any loss and/or damage incurred as a result of a change in the site conditions and/or regulatory/legislative framework since the date of the Report.

The Report is based on an interpretation of factual information available and the professional opinion and judgement of SKM. Unless stated to the contrary, SKM has not verified the accuracy or completeness of any information received from the Client or a third party during the performance of the services under the Agreement, and SKM accepts no liability to the Client for any loss and/or damage incurred as a result of any inaccurate or incomplete information.

The Report is based on assumptions that the site conditions as revealed through selective sampling are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of our knowledge) they represent a reasonable interpretation of the current conditions on the site. However, these interpretations and assumptions cannot be substantiated until specifically tested and the Report should be regarded as preliminary advice only.

Any reliance on this report by a third party shall be entirely at such party's own risk. SKM provides no warranty or guarantee to any third party, express or implied, as to the information and/or professional advice indicated in the Report, and accepts no liability for or in respect of any use or reliance upon the Report by a third party.

This report makes no comment on the presence of hazardous materials, unless specifically requested.

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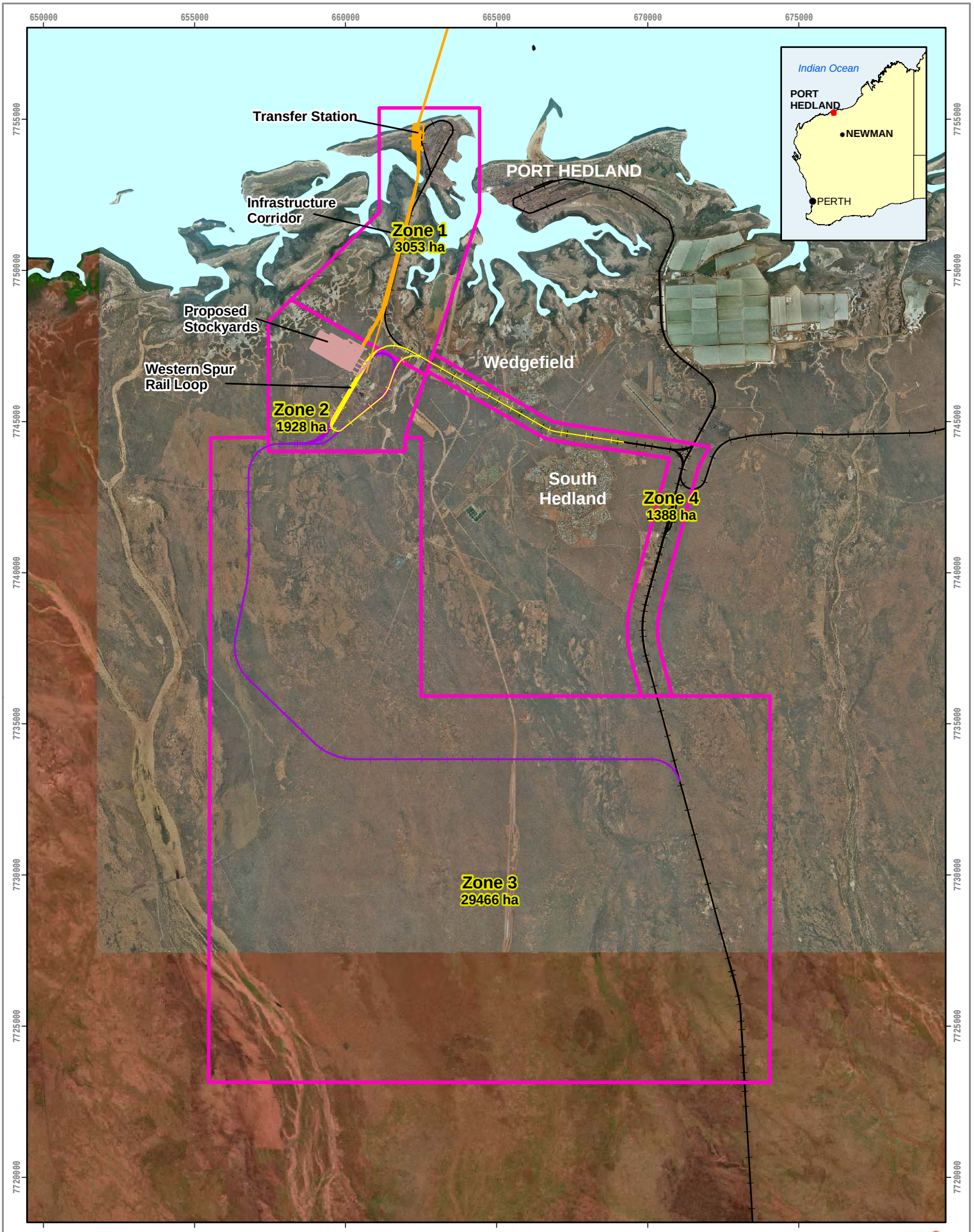
Appendix A Figures



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 1 2 3 4
kilometres

Scale = 1:160,000 at A4

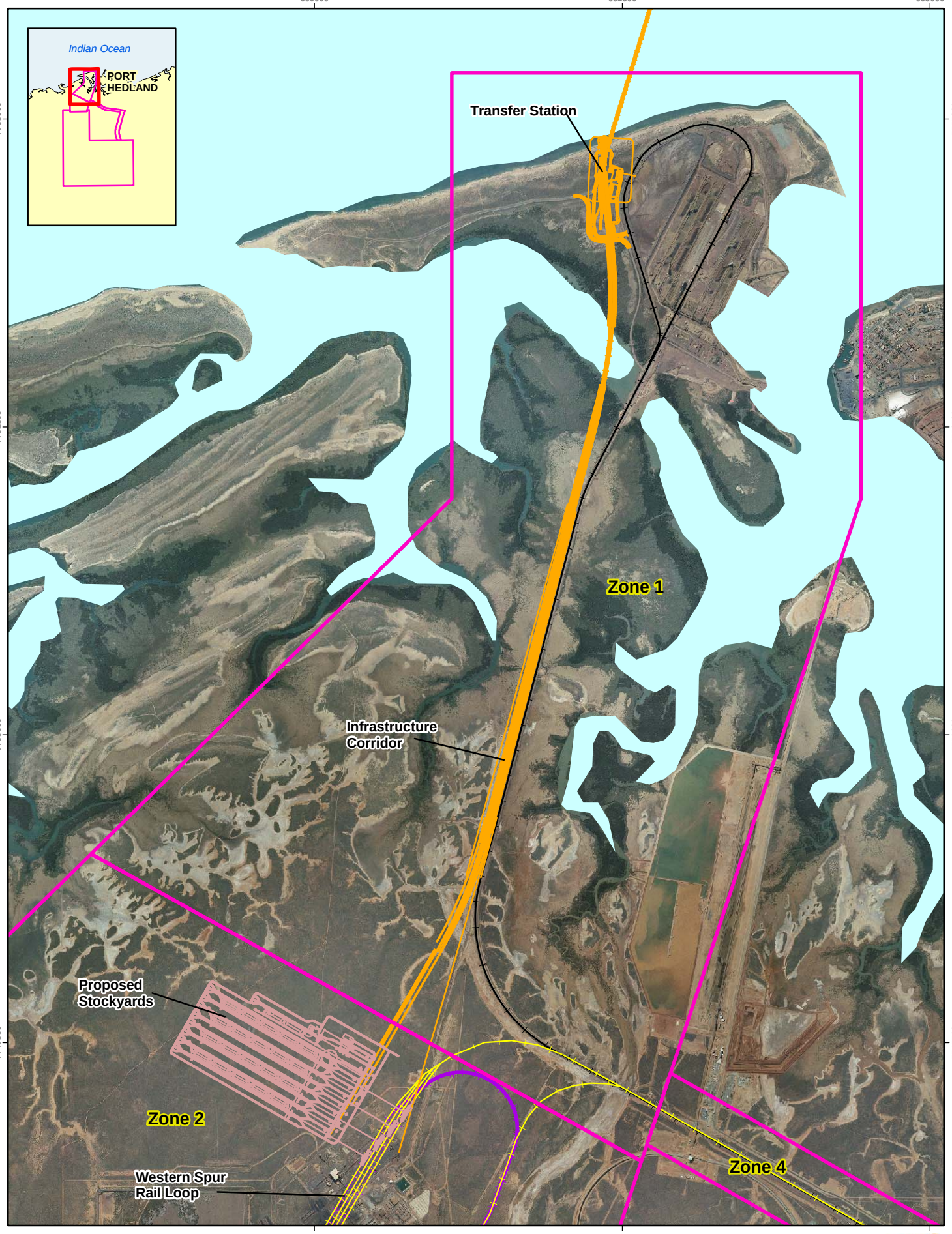
Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 8/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

320\g097_WV03716_Rev0

Figure 1 - Site Location and Proposed Development Footprint



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 0.25 0.5 0.75 1
kilometres

Scale = 1:40,000 at A4
Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
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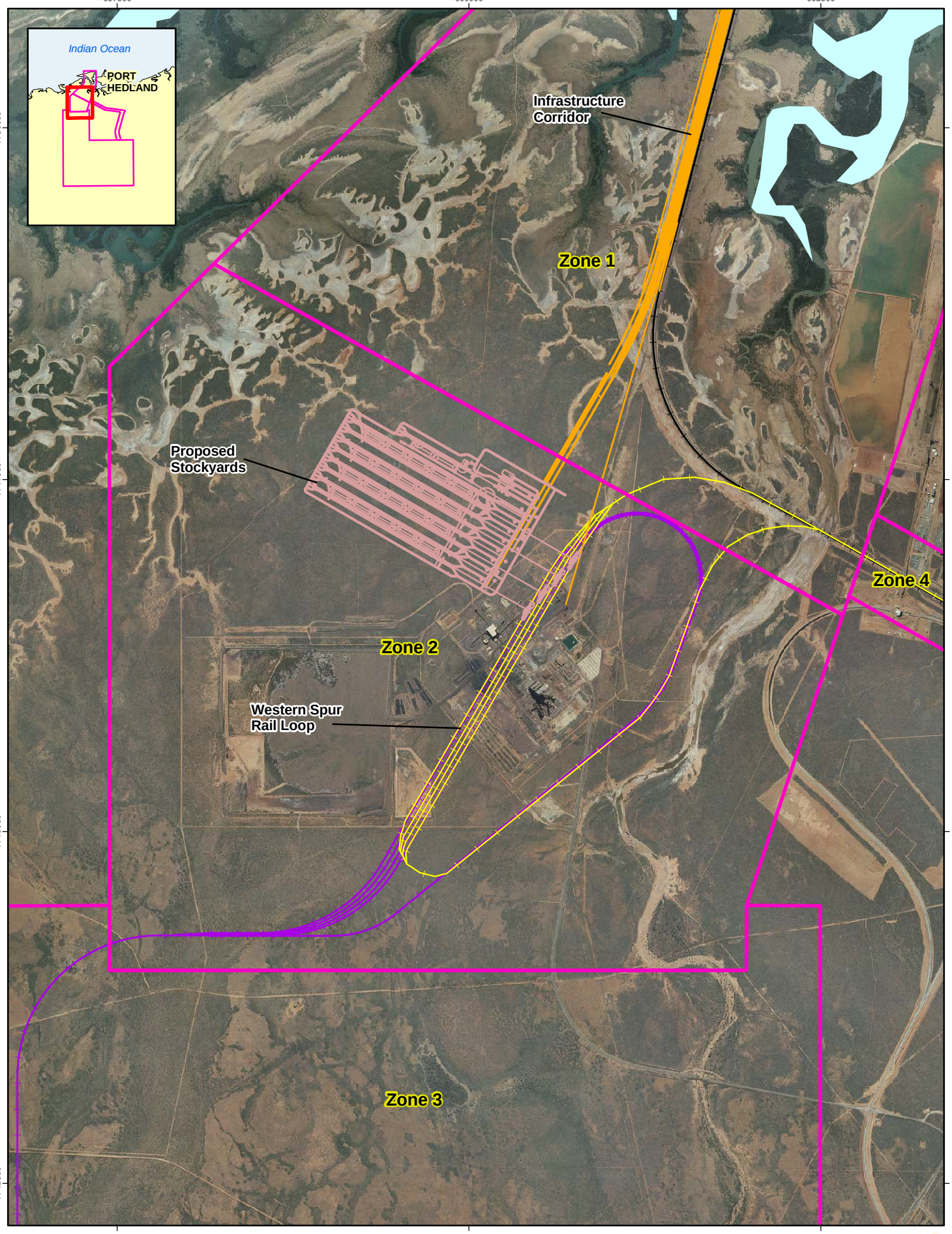
Figure 1A - Site Location and Proposed Development Footprint - Zone 1



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 0.25 0.5 0.75 1
kilometres
Scale = 1:35,000 at A4
Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
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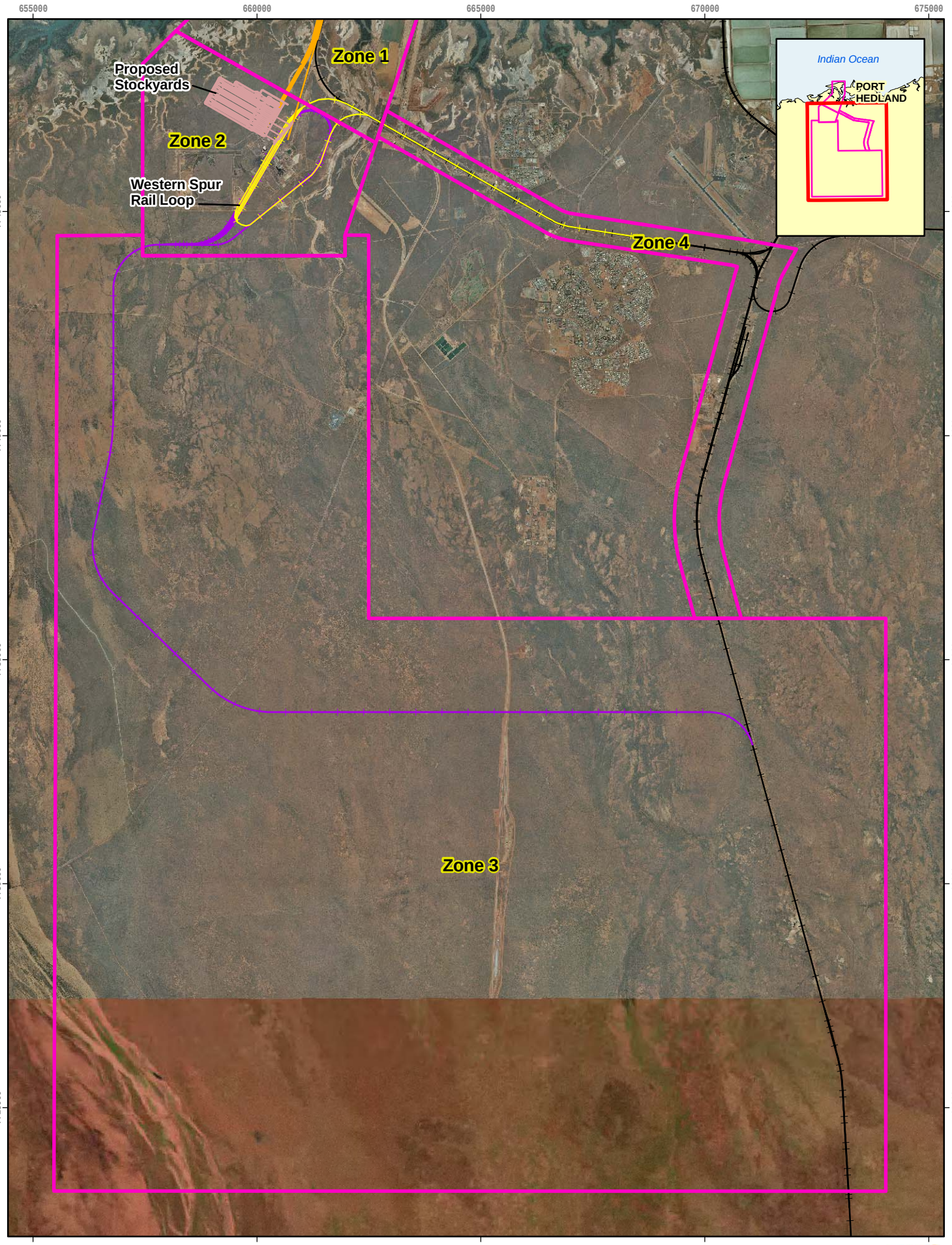
Figure 1B - Site Location and Proposed Development Footprint - Zone 2

320\g136_WV03716_Rev0



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 0.5 1 1.5 2
kilometres

Scale =1:110,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
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Figure 1C - Site Location and Proposed Development Footprint - Zone 3

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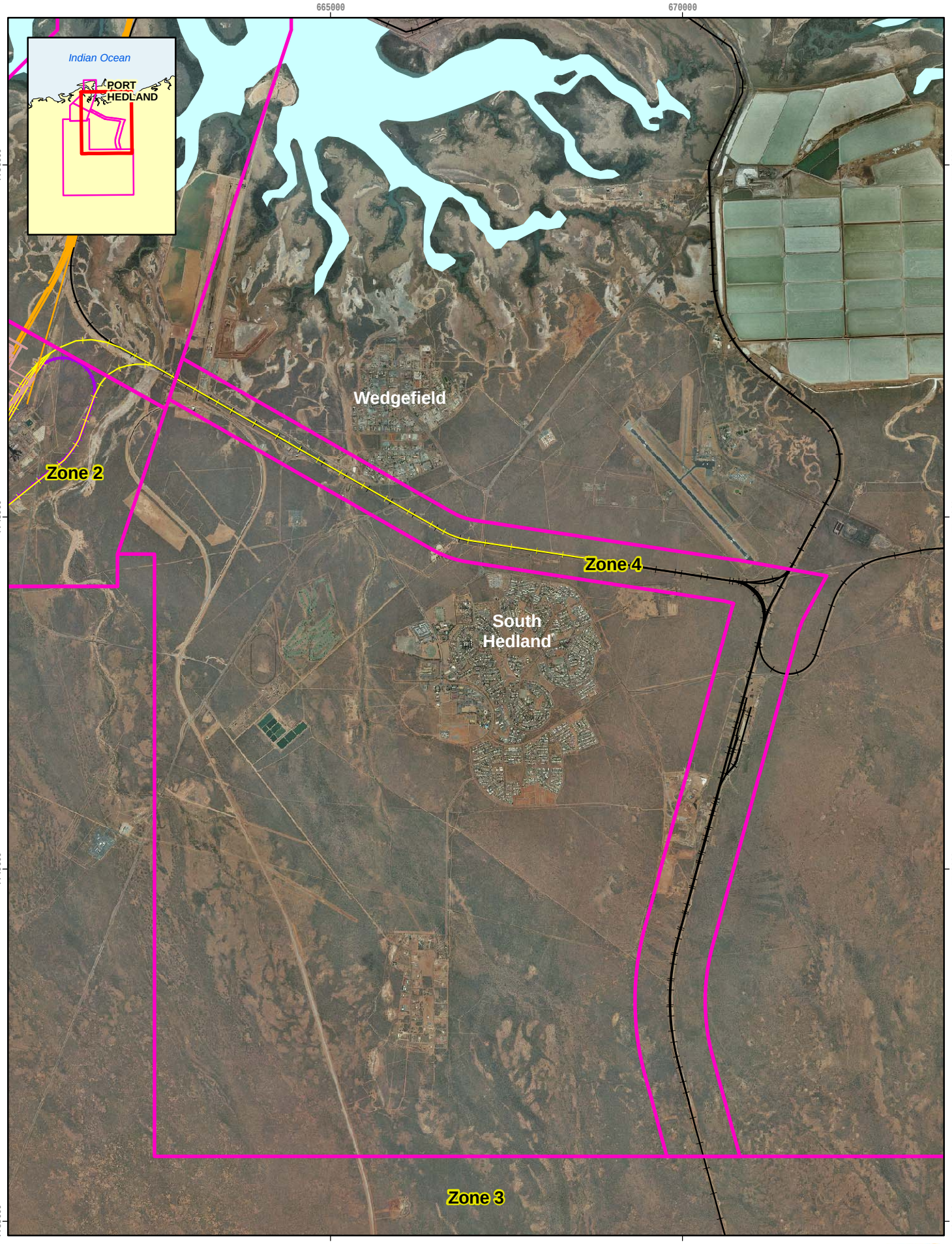

Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 0.5 1 1.5 2
kilometres
Scale = 1:70,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
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Figure 1D - Site Location and Proposed Development Footprint- Zone 4

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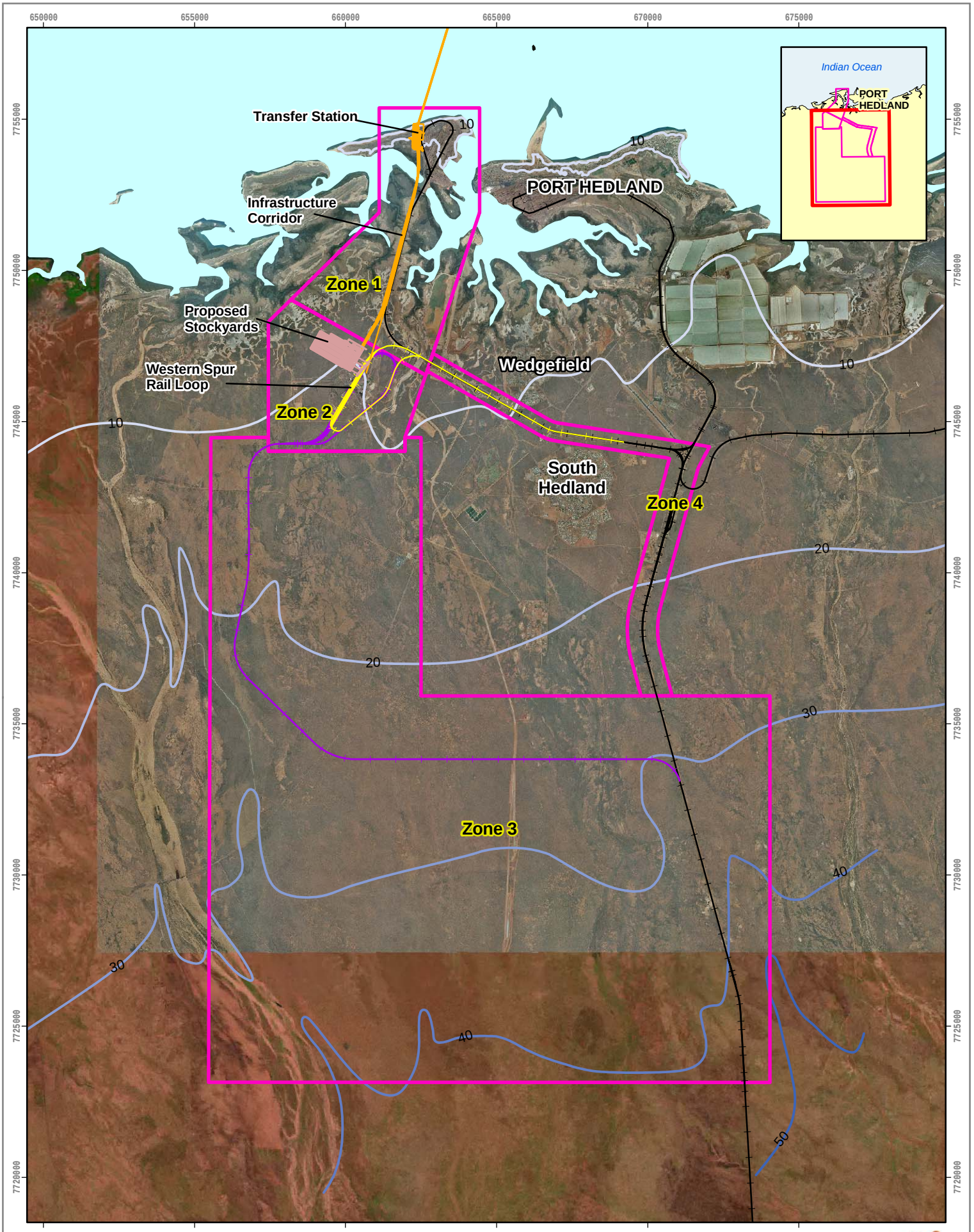


Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 1 2 3 4
kilometres

Scale = 1:160,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 04/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

320\g153_WV03716_Rev0

Figure 2 - Site Topography with Infrastructure Layout

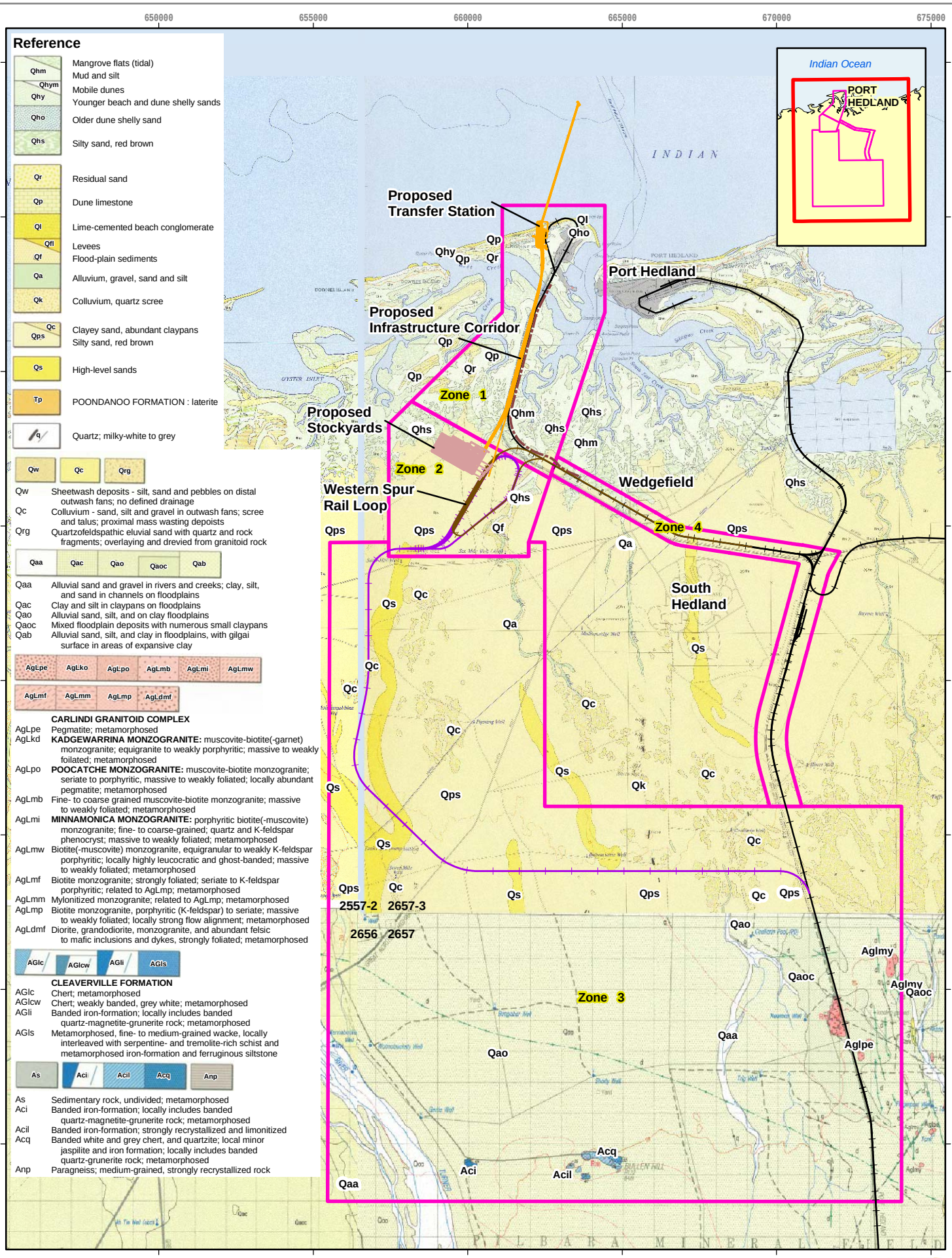
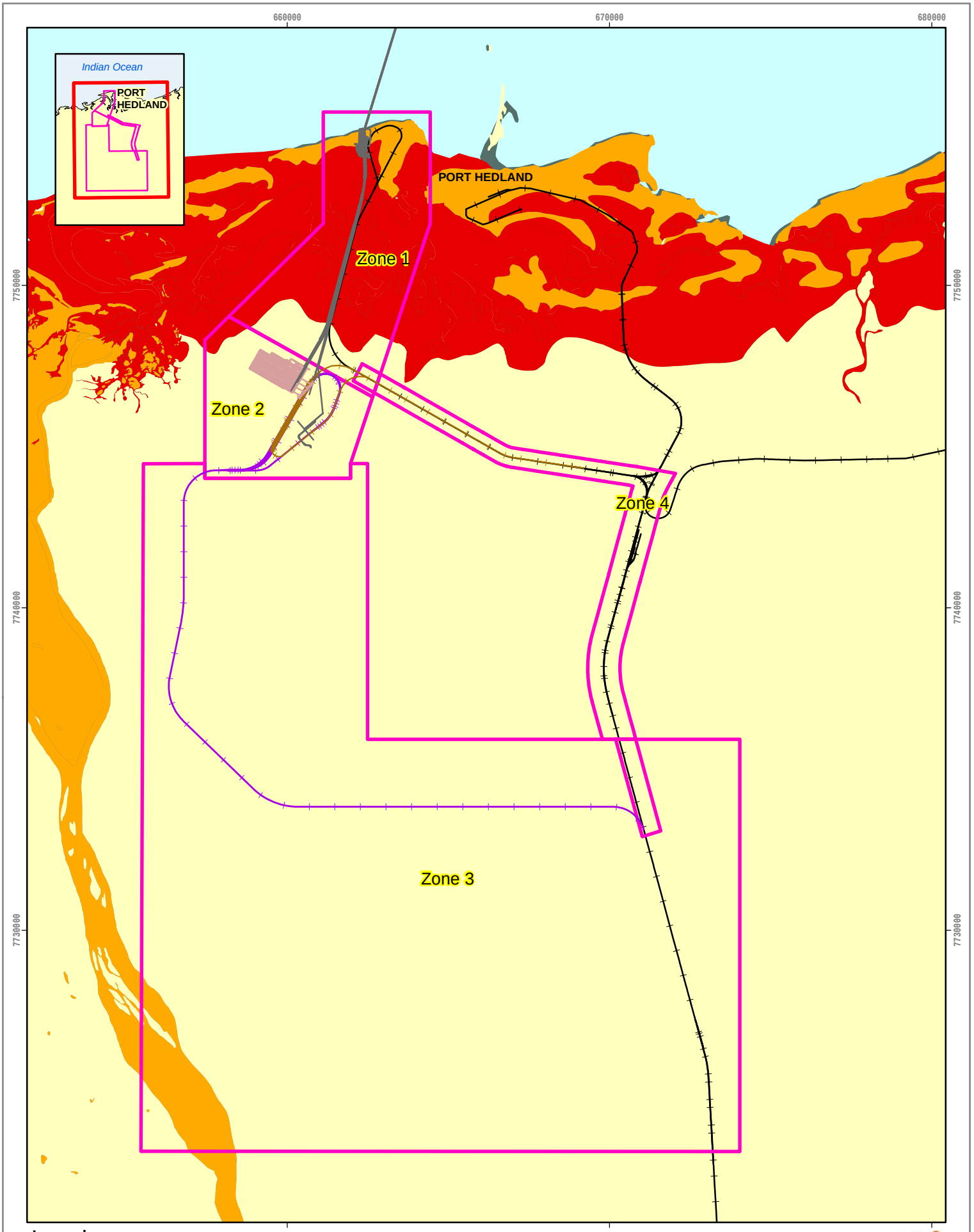


Figure 3 - Site Geology with Infrastructure Layout



Legend

Acid Sulfate Risk Map (DEC, 2006)
- High to moderate risk
- Moderate to low risk
- No known risk

Proposed Rail
- Western Spur Railway
- Goldsworthy Railway

Railway

Proposed Stockyards

Proposed Infrastructure

Contaminated Areas
- Zone Boundary

0 1 2 3 4
Kilometres

Scale =1:150,000 at A4

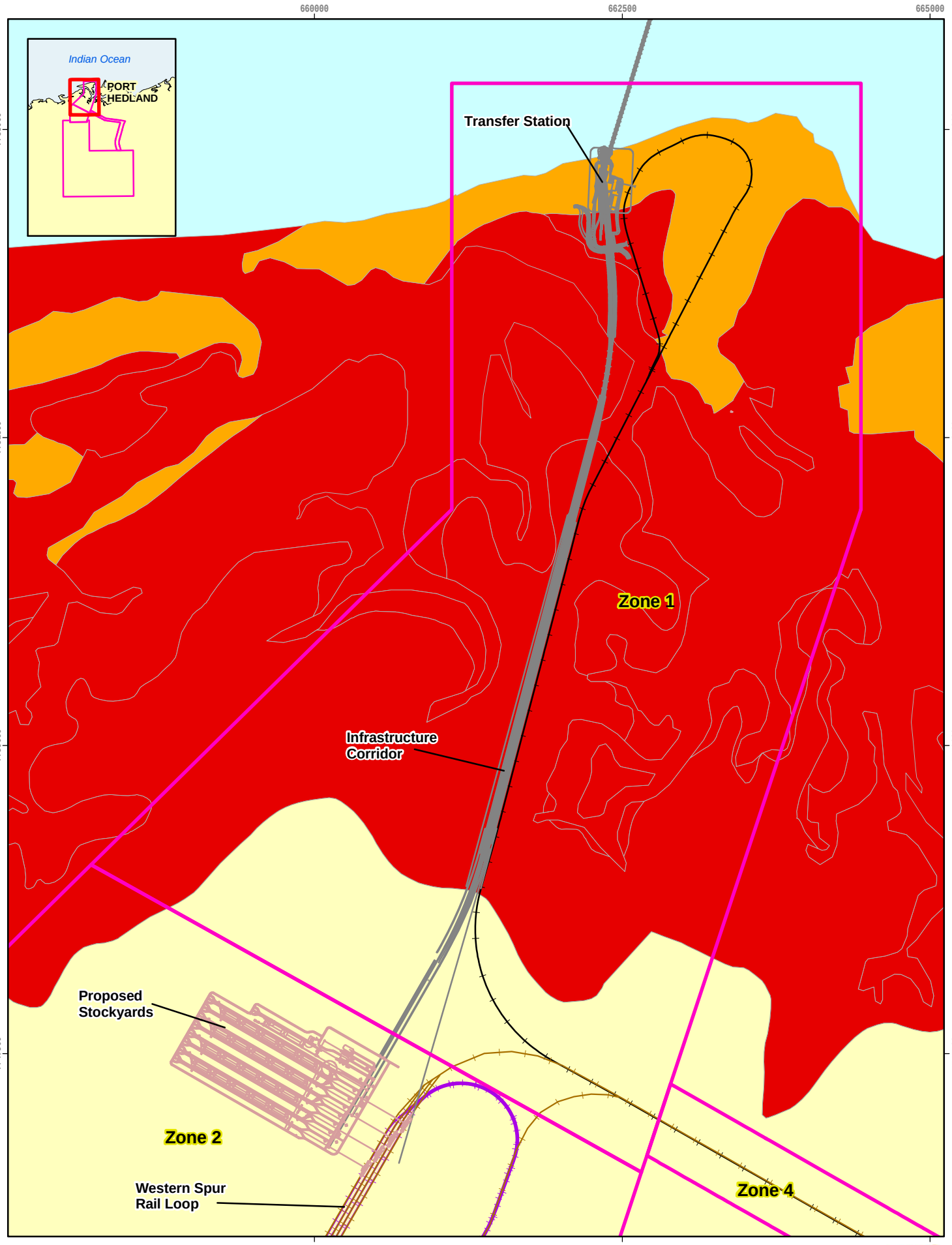
Datum: GDA94
Map Grid: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3 (Copyright Commonwealth of Australia, 2006)
ASS: Department of Environment and Conservation (2006)

Figure 4 - Acid Sulphate Soil Risk Map

320\g128_WV03716_Rev1



Legend

Acid Sulfate Risk Map (DEC, 2006)
- High to moderate risk
- Moderate to low risk
- No known risk

Proposed Rail
- Western Spur Railway
- Goldsworthy Railway

Railway

Proposed Stockyards

Proposed Infrastructure

Contaminated Areas
- Zone Boundary

0 0.25 0.5 0.75 1
kilometres

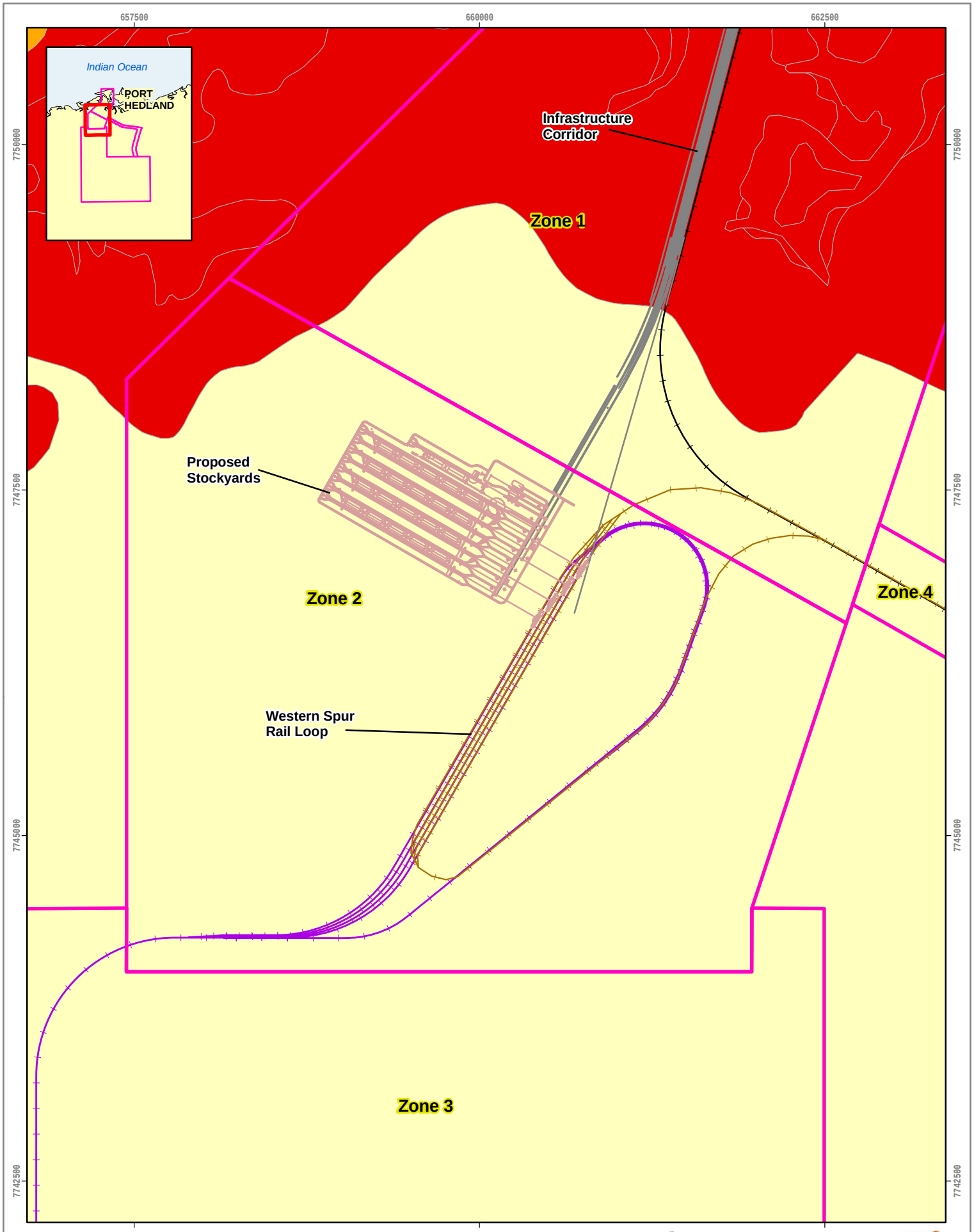
Scale =1:40,000 at A4
Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
ASS: Department of Envrionment and Conservation (2006)
Topography: Geoscience Australia, GEODATA Topo 250K V3

320\g140_WV03716_Rev1

Figure 4A - Acid Sulphate Soils Risk map - Zone 1



Legend

Acid Sulfate Risk Map (DEC, 2006)

- High to moderate risk
- Moderate to low risk
- No known risk

- Railway

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

- Proposed Stockyards
- Proposed Infrastructure

Contaminated Areas

- Zone Boundary

0 0.25 0.5 0.75 1
kilometres

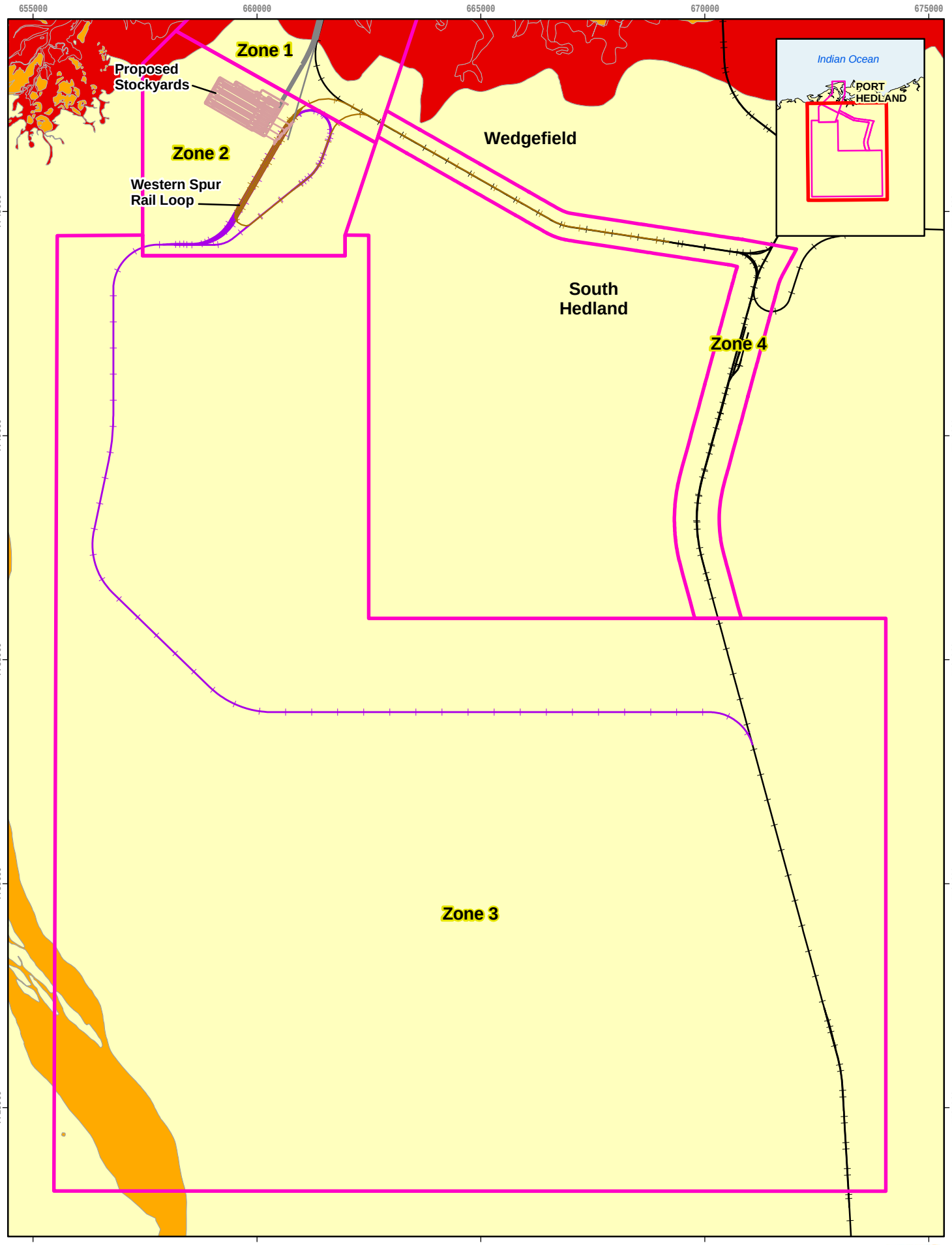
Scale =1:35,000 at A4
Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
ASS: Department of Conservation and Envrionment (2006)
Topography: Geoscience Australia, GEODATA Topo 250K V3

Figure 4B - Acid Sulphate Soils Risk Map- Zone 2

320\g141_WV03716_Rev1



Legend

Acid Sulfate Risk Map (DEC, 2006)
- High to moderate risk
- Moderate to low risk
- No known risk

- Railway

Proposed Rail
- Western Spur Railway
- Goldsworthy Railway

- Proposed Stockyards
- Proposed Infrastructure

Contaminated Areas
- Zone Boundary

0 1 2 3 4
kilometres

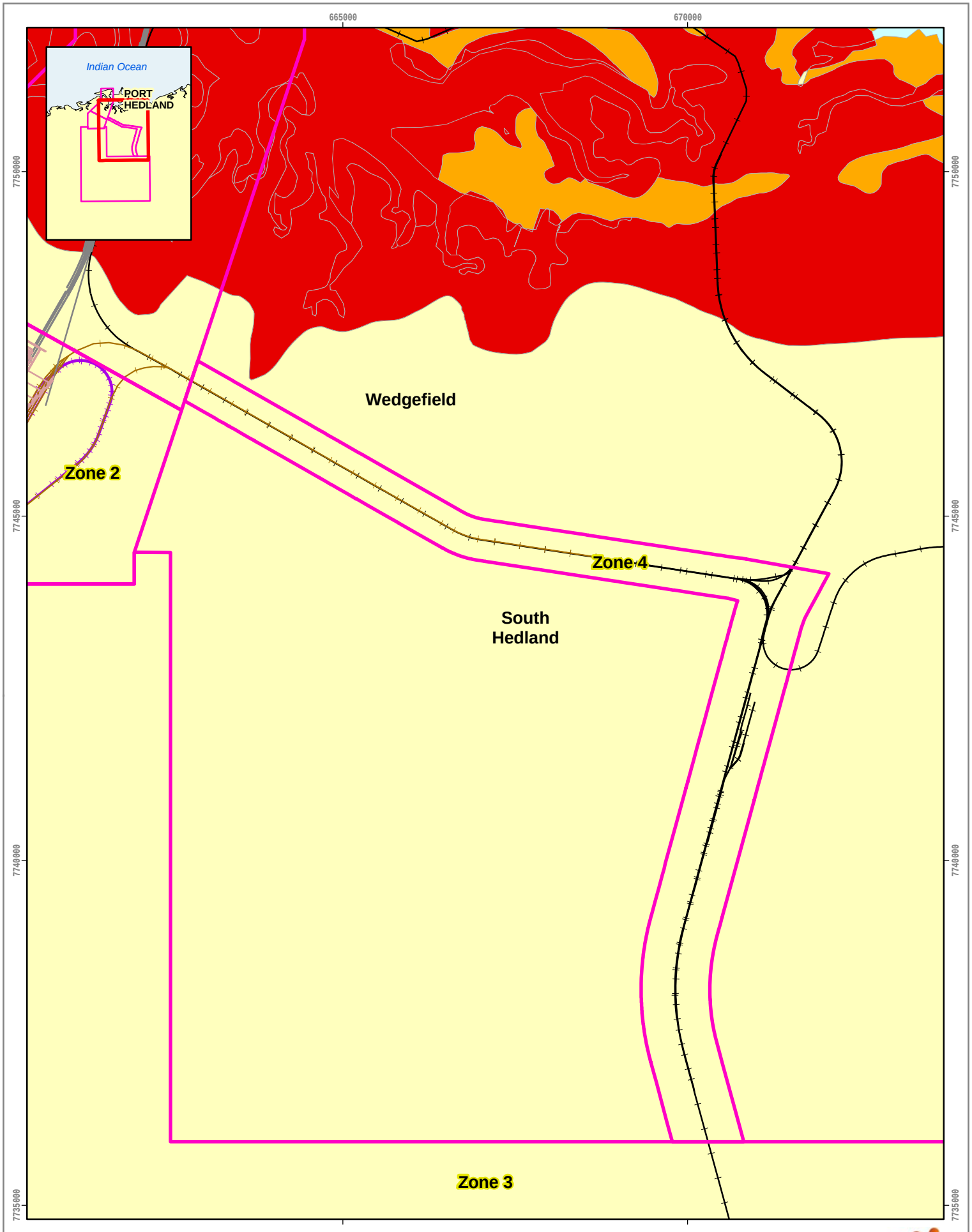
Scale =1:110,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

320\g142_WV03716_Rev1

Figure 4C - Acid Sulphate Soils Risk Map - Zone 3



Legend

Acid Sulfate Risk Map (DEC, 2006)
- High to moderate risk
- Moderate to low risk
- No known risk

Proposed Rail
- Western Spur Railway
- Goldsworthy Railway

Railway

Proposed Stockyards

Proposed Infrastructure

Contaminated Areas
- Zone Boundary

0 0.5 1 1.5 2
kilometres
Scale = 1:70,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
ASS:Department of Conservation and Environment (2006)
Topography: Geoscience Australia, GEODATA Topo 250K V3

320\g143_WV03716_Rev1

Figure 4D - Acid Sulphate Soils Risk Map - Zone 4

Appendix B Site Photographs

Zone 1: View looking north east along existing road on Finucane Island. Tailings bund from existing BHP Billiton Iron Ore operations to right of picture, low lying marginal lands to the left with ocean in background. Transfer Pad to be located immediately to the west.

Zone 1:View looking south west on existing road on Finucane Island at low lying marginal lands with ocean to the right of the frame. Transfer pad to be located in background.

Zone 1: Aerial photograph showing existing road and causeway to Finucane Island (located in background). Existing BHP Billiton Iron Ore operations on Finucane Island can be seen. Mangroves and tidal flats are located either side of the existing road. The proposed conveyor system is to be located to the west of the existing road.

Zone 1: View looking south-east from existing road to Finucane Island. HBI plant located in the background

Zone 1: View looking east from existing road to Finucane Island showing tidal flats present and samphire vegetation and mangroves in the background.

Zone 2: View from the Boodarie HBI Facility, looking west north west at region expected to be used for stockpile facility

Zone 2: View looking east from south of HBI plant showing typical shrubland / grassland vegetation

Zone 3: Dry river bed in vicinity of existing rail line and proposed rail spur locations

Zone 3: Access track and existing rail line in vicinity of proposed rail spurs

Zone 3: View looking west from existing rail line in direction of proposed new rail line from Stockpile facility. Vegetation consists predominantly of shrublands and grasslands.

Appendix C Proposed Infrastructure Construction Details

Area	Dimensions	Total areas to be disturbed	Estimated Excavation depth	Excavation volume (m^3)	Construction activities
Zone 1					
Proposed Transfer Pad	958m long 112m wide	21 ha	Topsoil removal 0.15m For soft clay removal (if present) generally less than 1m (approx.) Cut of higher ground may require 5m (approx.)	Topsoil: 30,500 Soft clay:84,000 Cut: 63,000	Topsoil removal Ground levelling / Cut of higher ground Possible excavation of soft clay depending on presence Possible dewatering Placement of engineered fill
Proposed Infrastructure Corridor	6km length 60m wide 36 ha	36 ha	For soft clay removal generally less than 1m (approx.) Cut of higher ground may require 3m (approx.)	Topsoil: 54,000 Soft clay:147,000 Pindan Sands: 118,125 Cut: 8,895	Ground levelling / Cut of higher ground Excavation of soft clay Excavation of Pindan sands and red brown silty sand Possible dewatering Placement of engineered fill
Zone 2					
Proposed Stockyards	NA	157ha	Topsoil removal 0.15m 2m (approx.)	Topsoil: 180,000 Cut: 434,000 Pindan sands: 500,000	Topsoil removal Ground levelling /Cut Excavation of Pindan sands and red brown silty sand Possible dewatering Placement of Engineered Fill
Proposed Car dumpers	4 car dumpers, Each: 53m wide 100m length	12.5 ha (general area) Each car dumper to occupy surface area of 0.5 ha	25m max	Topsoil removal (general area): 18,750 Each car dumper excavation: 46,000	Topsoil removal Deep excavation Possible Dewatering to 25m Placement of Engineered Fill

Area	Dimensions	Total areas to be disturbed	Estimated Excavation depth	Excavation volume (m^3)	Construction activities
Proposed Conveyor tunnels	4 conveyor tunnels Each: 143m length 16-100m width	Each conveyor tunnel to disturb 0.83 ha	1-25m	Each conveyor tunnel excavation 54,000	Topsoil removal Ground levelling / Cut Deep excavation Possible Dewatering to 25m Placement of Engineered Fill
Proposed Rail loop	10km length 50m wide 50 ha	50 ha	Topsoil removal 0.15m Excavations generally less than 1m	Topsoil and cut: 139,000	Topsoil removal Ground levelling / Cut Limited excavation of Pindan sands and red brown silty sands Placement of Engineered Fill
Zone 3					
Proposed Rail spurs	24.5km length 50m wide 122.5 ha	122.5 ha	Topsoil removal 0.15m Excavations generally less than 1m except for isolated hilly sections which may require 4-5m	Topsoil and cut 160,000	Topsoil removal Ground levelling Excavation limited to localised hilly areas Placement of Engineered Fill
Zone 4					
Proposed Goldsworthy rail alignment	17.2km length 10m wide 17.2 ha	17.2 ha	Topsoil removal 0.15m Excavations generally less than 1m except for isolated hilly sections which may require 4-5m	Topsoil and cut 180,000	Topsoil removal Ground levelling Excavation limited to localised hilly areas Placement of Engineered Fill

Appendix D Environmental Characteristics of Proposed Outer Harbour Development

D.1 Topography

Zone 1

The coastal areas within Zone 1 are generally flat with gently sloping beaches, numerous headlands, and many offshore islands (SKM, 2008). Finucane Island ranges from 1 to 20m above sea level, with berms along the north shore. The mainland of zone 1 ranges from 1m to 15 m above sea level (the topography for Zone 1 is presented in **Figure D1** in **Appendix D)**.

Zone 2

Zone 2 is situated on a coastal plane, which is generally flat, low lying and ranges between 1m and 20m above sea. The topography for Zone 2 is presented in **Figure D2** in **Appendix D**.

Zone 3 and Zone 4

Zone 3 and 4 are generally flat, and gently slopes from the north to the south and south east, ranging from 2 m to 56 m above sea level. The topography for Zone 3 is presented in **Figure D3** in **Appendix D**. The topography for Zone 4 is presented in **Figure D4** in **Appendix D**.

D.2 Geology

Zone 1

According to the Port Hedland Geological Survey of Western Australia, 1:50,000 Urban Geology series, Department of Land and Surveys (GSWA, 1983), the two major units in Zone 1 consist of the following geological profiles:

- Qhm: Mud, silt and Mangrove flats (tidal); found on the majority of Finucane Island from the southern section (Stanley Point) extending to the north and north west. It also covers the majority of the mainland in Zone 1 except for the southwest corner of Zone 1.
- Qhs: Silty sand, red-brown containing *Anadara granosa*; found in the southern section of the mainland.

Figure D5 in **Appendix D** shows:

- the mainland of Zone 1 consists of tidal mangrove flats and mud and silt (Qhm) around the coastal areas, pockets of residual sand (Qr) and dune limestone (Qr and Qp) towards the western boundary.
- that Finucane Island consists of higher level sands (Qs), younger beach and sand dunes (Qhy) along the northern shore, and tidal mangrove flats and mud and silt (Qhm), covering a majority of the island.

An environmental site assessment conducted at the former Goldsworthy Plant on Finucane Island confirmed that the natural superficial geological profile consisted of gravelly, medium to coarse grained, brown sand (Coffey Environments Pty Ltd, 2007).

A geotechnical investigation conducted at Utah Point, east of the former Goldsworthy Plant on Finucane Island confirmed that the natural geological profile consisted of mangrove flats/muds (brown to grey, sandy clay to clayey sand) and calcarenite (limestone) to a maximum depth of 1.7 m bgs. Calcarenite was well cemented, coarse grained and white (Coffey Geotechnics, 2007).

Zone 2

The Western Australia 1:50,000 urban geology series Port Hedland map (GSWA, 1983), indicated Zone 2 consists of the following superficial geological profiles:

- Qa: Alluvium, gravel, sand and silt; found within South West Creek limited to the southeast section of Zone 2.
- Qf: Flood plane sediments; found adjacent to the banks of South West Creek which flows (approximately parallel with the zone boundary) across the eastern portion of Zone 2.
- Qhm: Mud, silt and Mangrove flats (tidal); found within South West Creek and on the northwest corner of Zone 2.
- Qhs: Silty sand, red brown containing *Anadara granosa*; forming the part of the banks of South West Creek (limited to the north east section), found in isolated pockets along the northern boundary with the majority found on the northwest corner of Zone 2.
- Qps: Silty sand, red brown, clayey sand, abundant claypans; found across the majority of Zone 2.
- Qs: High level sands; found on the southwest corner of Zone 2.

Figure D6 in **Appendix D** shows that the north west of Zone 2 consists of mud, silt and mangrove flats (Qhm), and red-brown silty sand containing shell material (Qhs). Red-brown silty sand and clayey sand (Qps) covers the majority of the zone. Flood plain sediments (Qf), mud, silt and mangrove flats (Qhm), red-brown silty sand containing shell material (Qhs) and alluvium, gravel, sand and silt (Qa) occurred in the immediate vicinity of South West Creek. South West Creek flows parallel with the eastern boundary of Zone 2 and was located on the eastern section of the zone.

A detailed site investigation conducted within the decommissioned Boodarie HBI Plant and facilities found that the natural geological profile consisted of brown to orange clayey sand/sandy clay, confirming the expected superficial alluvium profiles (Golder Associates, 2006).

Zone 3 and Zone 4

A review of the Western Australia 1:50,000 urban geology series maps (1983), the northern half of Zone 3 (the map did not extend further to the south and no additional maps of the area, at the same scale, had been published) consists of the following superficial geological profiles:

- Qa: Alluvium, gravel, sand and silt; found on the northeast corner of the zone associated with South West Creek and two isolated pockets on the eastern section of the zone.
- Qc: Clayey sand, abundant claypans; found mainly on the northern and eastern sections of Zone 3.
- Qf: Flood plain sediments; found adjacent to the banks of South West Creek which flows across the northeast corner on the zone.
- Qps: Silty sand, red brown, clayey sand, abundant claypans; found across the majority of Zone 3.
- Qs: High level sands; found on the western (running parallel to the boundary of the zone), northern sections and an area on the centre of the zone
- q: Quartz, milky-white to grey; found in three small areas on the eastern extent of Zone 3.

The superficial geological profile for the remainder of Zone 3 (approximately the southern half of the site) was sourced from the 1:100,000 Geological Series (2001) maps. The superficial geological profile from these maps indicating:

- Aci: Banded iron-formation; locally includes banded quart-magnetite-grunerite rock; metamorphosed; found in one small area on the southeast section of the zone.
- Acil: Banded iron-formation; strongly recrystallized and limonitized; found in three small areas in close proximity to the southern boundary of Zone 3.
- Acq: Banded white and grey chert and quartzite; local minor jaspilite and iron formation; locally includes banded quartz-grunerite rock; metamorphosed; found in two small areas on the southern section of the zone.
- AgImy: **Myanna Leucogranite**: biotite-muscovite monzogranite; locally with quartz and K-feldspar phenocrysts; massive to weakly foliated; metamorphosed; found localised on a small area immediately adjacent to part of the eastern boundary of Zone 3.
- AgIpe: Pegmatite; metamorphosed; found in three small areas on the eastern section of the zone.
- d: Dolerite and gabbro dykes; found widely spaced across Zone 3 with a higher density on the eastern portion.
- q: Quartz vein; generally found on the eastern quarter of the zone.
- Qaa: Alluvial sand and gravel in rivers and creeks; clay, silt and sand in channels on floodplains; found within the Turner River (located on the southwest corner of the zone) on the eastern section of zone 3 (to the west of the Port Hedland rail line).
- Qao: Alluvial sand, silt and clay on floodplains; covers the majority of Zone 3.
- Qaoc: Mixed floodplain deposits with numerous small claypans; found on the northeast corner of the zone.

The Western Australia 1:50,000 urban geology series Port Hedland map (GSWA, 1983), indicated Zone 4 consists of the following superficial geological profiles:

- Qa: Alluvium, gravel, sand and silt; found associated with South Creek and its tributary on the northwest section of the zone.
- Qc: Clayey sand, abundant claypans; found in a number of isolated pockets on the most southen section of Zone 4.
- Qhm: Mud, silt and Mangrove flats (tidal); found associated with South Creek and its tributary (northwest of the zone), on the northwest and northeast extant of Zone 4.
- Qhs: Silty sand, red brown containing *Anadara granosa*; generally found associated with mud, silt and mangrove flats (Qhm) (i.e. associated with South Creek and its tributary (northwest of the zone), on the northwest and northeast extant of Zone 4).
- Qps: Silty sand, red brown, clayey sand, abundant claypans; comprises the majority of Zone 4.

Figure D7 and **Figure D8** in **Appendix D** shows that Red-brown silty sand (Qhs) covers the majority of Zone 3 and 4, with bands of clayey sand (Qc) and high level sands (Qs).

D.3 Hydrogeology

Generally the coastal plain comprises alluvial deposits (clay, silt and sand). Calcrete has been encountered in the southern part of the OHD. The groundwater aquifer generally appears to be associated with the sand and gravel in the alluvial deposits.

The Department of Water (DoW) groundwater bore search indicated the depth to groundwater ranged from approximately 27m (southern extent of the OHD) to less than 1 m (near the coast) as shown on **Figure D9** in **Appendix D.** Available information indicated that salinity of the groundwater ranged from 400mg/L to 8,000mg/L total dissolved solids.

Zone 1

Information on groundwater at Finucane Island was taken from *Environmental Preliminary Site Investigation,* (IT Environmental, 2004). A summary of the local and regional hydrogeology is provided below:

- An upper superficial aquifer is at a variable depth of between 1-13m bgs. Groundwater depth monitored at the northern end of the island indicates levels at the deeper range due to the height of the landscape.
- A freshwater lens of groundwater overlying saline groundwater at depth and near the coastline can be expected.
- The inferred regional groundwater flow direction is radial from the island to the shore.
- A tidal influence to the shallow groundwater is likely, particularly closer to the shoreline.
- Numerous groundwater monitoring bores (approximately 38) have been installed in close proximity to the existing BHP Billiton Iron Ore infrastructure and within the BHP Billiton Iron

Ore operational boundaries. The field data collected indicated that the groundwater depth ranged from approximately 2.5m to 8.1m bgs or approximately 1m to 3.2m above Australian height datum (AHD).

Zone 2

From data gathered from *Site Contamination Preliminary Site Investigation Boodarie Iron Plant,* (Golder Associates, 2006), there are approximately 20 monitoring wells located within the Boodarie Station.

The groundwater salinity in the HBI plant site area ranges from about 13,000-52,000mg/L TDS. Monitoring well results indicate that the depth to groundwater from the natural surfaces vary across the site from 3-5m bgs in the HBI plant area and from 2-3m bgs closer to the ocean. Groundwater levels show that the groundwater flows north, north-west towards the coast with a gentle hydraulic gradient across the site, at less than 0.05%. Groundwater elevations across the site vary seasonally by up to 2m, this is directly attributable to rainfall recharge of the shallow unconfined groundwater aquifer. Groundwater elevations peak in April for most monitoring wells (which appears to be due to high rainfall at the beginning of the year) and generally decline for the remainder of the year. Constant head tests conducted in several bores indicated permeability in the range of 7 to 10 m/s below 3m bgs. Material above this depth (sands/silts) exhibits a higher permeability.

D.4 Hydrology

The hydrology of the site is dominated by the permeable sandy surface soils which can support infiltration rates greater than most of the high rainfall intensities experienced by storm rainfall. The proximity of the shallow groundwater near to (<1m) the ground surface in areas on the site is indicative of water logging and flooding during winters.

Zone 1

A tidal marine shoreline with mangroves is the nearest surface water features to the site. The nearest marine tidal zone is located approximately 100m east of the site and forms part of the coastal marine environment.

Zone 2

From information contained in the *Detailed Site Investigation, Boodarie Port Hedland,* (Golder Associates, 2006), major surface drainage features in this Zone are the ephemeral, that is the Turner River and South West Creek. The Turner River is 7km west of the HBI plant site, whilst South West Creek runs about 0.7km to the east of the HBI plant site in a south to north direction prior to discharging into the Headland Harbour.

Surface water flow is to the north-east towards estuaries along the coast and locally towards the South West Creek, which is located to the east of the plant.

Zone 3 and Zone 4

Generally Zones 3 and 4 are relatively flat with a number of intermittent creeks meandering across these sections of the study area. These creeks ultimately flow to the north into Port Hedland harbour or to the ocean. It is expected that surface flow across Zones 3 and 4 would be toward these intermittent creeks prior to flowing north and discharging into the harbour or the ocean.

D.5 Vegetation

The information for this section was obtained from a vegetation map created in *Port Hedland Outer Harbour Development Flora and Vegetation Assessment Part 1*, ENV, 2008, (unpublished).

Zone 1

This zone is characterized predominantly by the presence of the following vegetation:

- Mangroves – A high closed Ceriops tagal and Avicennia shrubland.
- Dunes – Scattered Acacia bivenosa shrubs over a low open Crotalaria cunninghamii shrubland over a *Cenchrus ciliaris tussock grassland over scattered *Aerva javanica herbs.
- Samphire – Scattered Avicennia marina shrubs over a low open Halosarcia halocnemoides subsp. Tenuis, Halosarcia halocnemoides and Trianthema turgidifolia shrubland.

Zone 2

This zone is characterized predominantly by the presence of the following vegetation:

- Sandplain – Low Acacia stellaticeps shrublans over Triodia epactia and Triodia secunda hummock grasslands / Triodia epactia and Triodia secunda hummock grassland mosaic.
- Sandplain – An open Acacia colei var. colei shrublands over low Acacia stellaticeps shrublands over Triodia epactia and Triodia secunda hummock grasslands / low Acacia stellaticeps shrublands over Triodia epactia and Triodia secunda hummock grassland mosaic.
- Samphire – Scattered Avicennia marina shrubs over a low open Halosarcia halocnemoides subsp. tenuis, Halosarcia halonemoides and Trianthema turgidifolia shrubland.

Zone 3

This zone is characterized predominantly by the presence of the following vegetation:

- Sandplain – An open Acacia colei var. colei shrublands over low Acacia stellaticeps shrublands over Triodia epactia and Triodia secunda hummock grasslands / low Acacia stellaticeps shrublands over Triodia epactia and Triodia secunda hummock grassland mosaic.
- Sandplain – A low open Corymbia flavescens woodland over an open Acacia colei var. colei shrubland over a low Acacia stellaticeps shrubland over a Triodia epactia hummock grassland / low Acacia stellaticeps shrublans over Triodia epactia and Triodia secunda hummock grasslands / Triodia epactia and Triodia secunda hummock grassland mosaic.

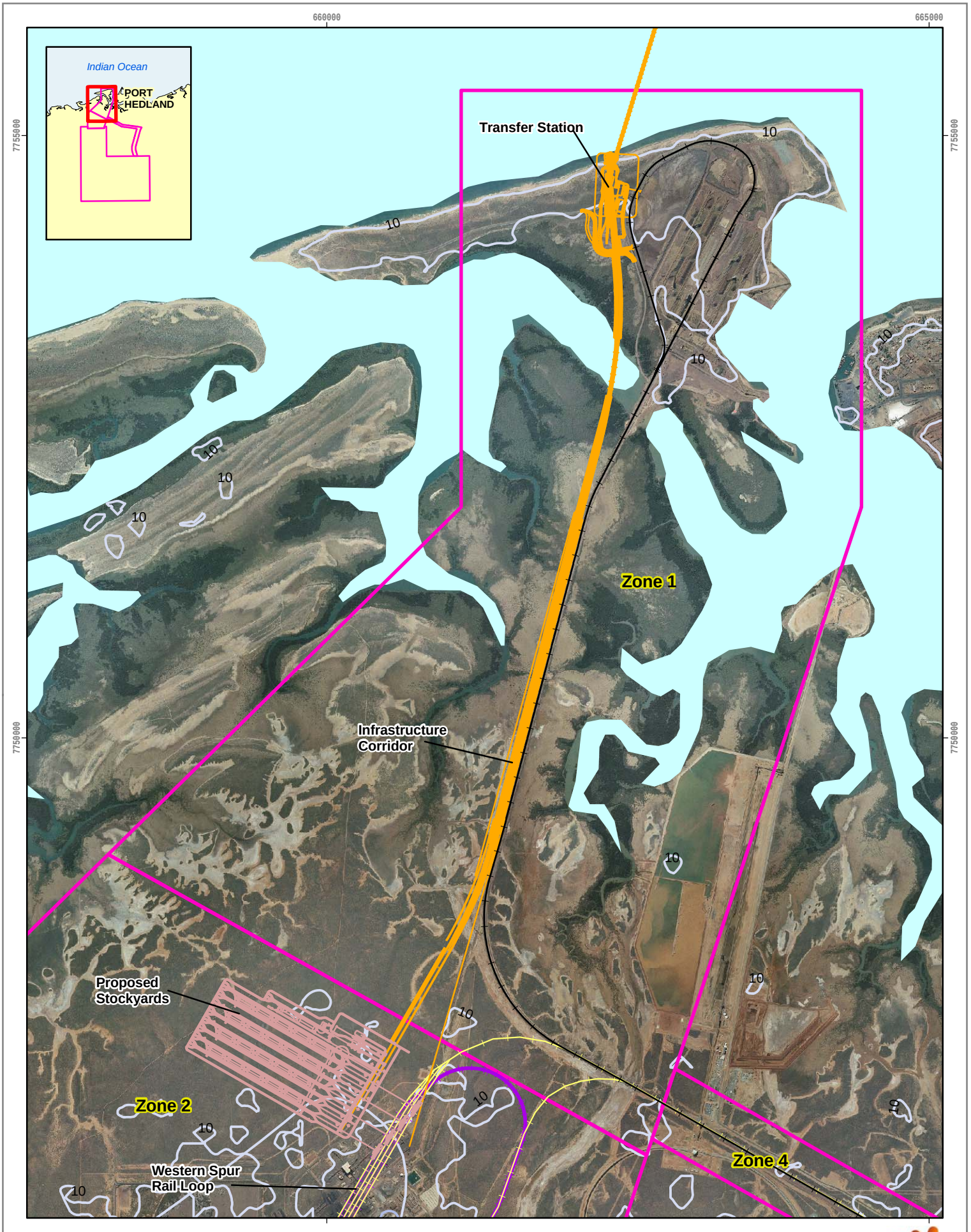
- Sandplain – An Acacia tumida var. pilbarensis shrubland over a low Acacia stellaticeps shrubland over a Triodia epactia hummock grasslands / low Acacia stellaticeps shrubland over a Triodia epactia hummock grassland / Triodia epactia hummock grassland mosaic.
- Sandplain – Scattered low Owenia reticulate trees over an Acacia tumida var. pilbarensis and Acacia colei var. colei shrubland over a low Acacia stellaticeps shrubland over a Triodia epactia hummock grassland / low Acacia stellaticeps shrubland over a Triodia epactia hummock grassland mosaic.
- Sandplain – An Acaica tumida var. pilbarensis and Acacia colei var. colei shrubland over a low Acacia stellaticeps shrubland over a Triodia epactia hummock grassland / Acacia stellaticeps shrubland over a Triodia epactia hummock grassland mosaic.
- Low Hill – An Acacia tumida var. pilbarensis shrubland over a low Acacia stellaticeps shrubland over a Triodia epactia hummock grassland.

Zone 4

This zone is characterized predominantly by the presence of the following vegetation:

- Sandplain – A low open Corymbia zygophylla woodland over an open Acacia ancistrocarpa, Acacia inaequilatera, Acacia tumida var. pilbarensis and Acacia sericophylla shrubland over Acacia stellaticeps low open shrubland over Triodia epactia and Triodia lanigera hummock grassland.
- Sandplain – Scattered low Eucalyptus victrix and Coymbia hamersleyana trees over an open Acacia anistrocarpa, Acacia tumida var. pilbarensis, Acacia inaequilatera and Acacia trudgeniana shrubs over a low open Acacia stellaticeps shrubland over a Triodia epactia and Triodia lanigera hummock grassland.
- Sandplain – Scattered low Corymbia flavescens trees over an open Acacia ancitrocarpa and Acacia bivenosa shrubland over scattered low Acacia stellaticeps shrubs over a Triodia epactia and Triodia lanigera hummock grassland.
- Major Drainage Line – Scattered low Eucalyptus victrix trees over a high open Melaleuca argentea, Acacia ampliceps and Acacia trachycarpa shrubland over scattered Adriana urticoides var. urticoids and Pluchea ferdinandi-muelleri shrubs over an open Triodia epactia hummock grassland.
- Grassland – Triodia epactia hummock grassland.

D.6 Figures – Appendix D



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure
- **Proposed Rail**
- Western Spur Railway
- Goldsworthy Railway
- Contours (mAHD)
- **Contaminated Areas**
- Zone Boundary

0 250 500 750 1,000
metres

Scale = 1:40,000 at A4

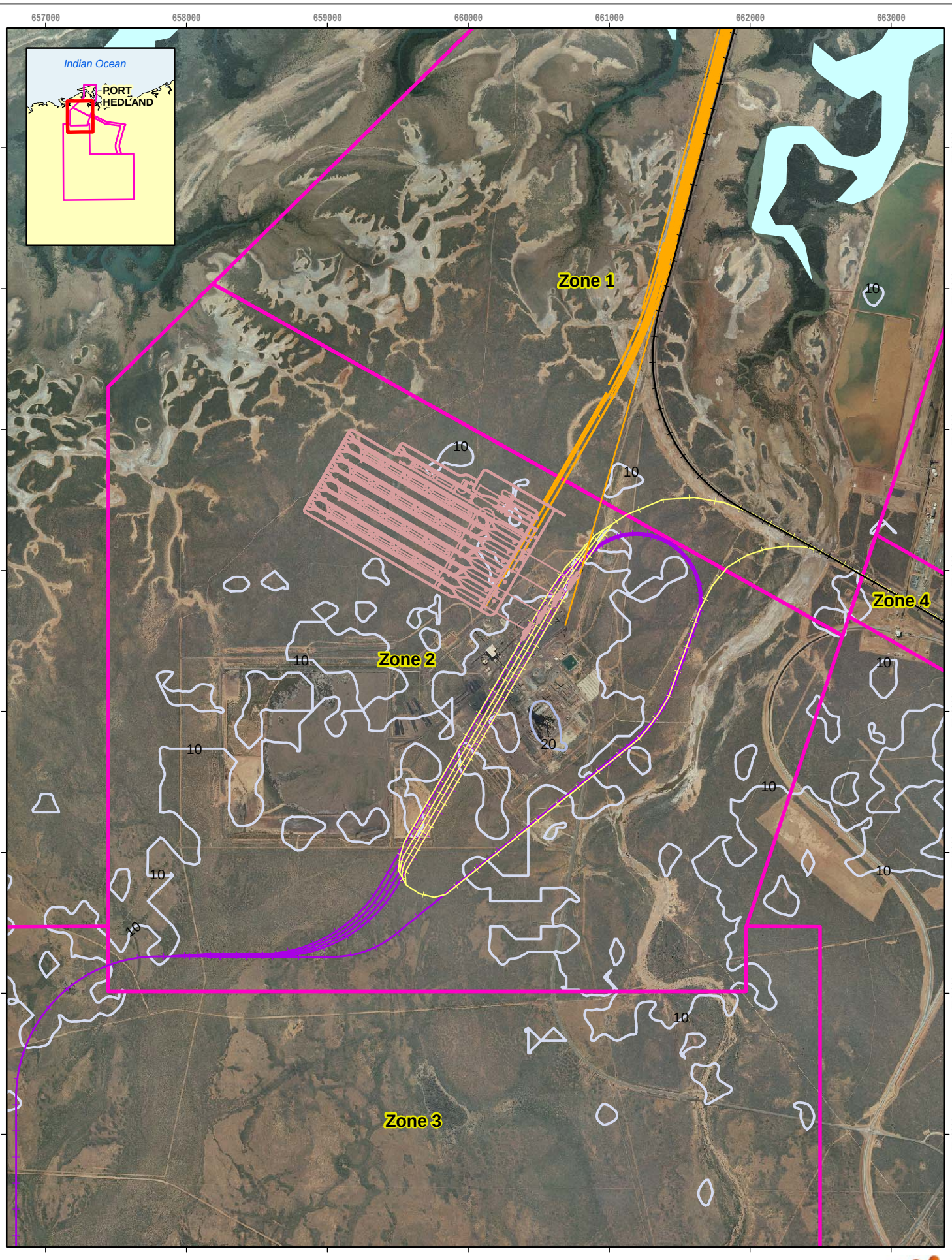
Datum: GDA94
Projection: MGA94 Zone 50

Source:
Elevation: Geoscience Australia, 3 sec DEM (2006)
Orthorectified Aerial Photograph: 04/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

bhpbilliton

Figure D1 - Site Topography with Infrastructure Layout - Zone 1

320\g099_WV03716_Rev1



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

- Contours (mAHD)

Contaminated Areas

- Zone Boundary

0 250 500 750 1,000
metres

Scale =1:35,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

Source:
Elevation: Geoscience Australia, 3 sec DEM (2003)
Orthorectified Aerial Photograph: 04/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

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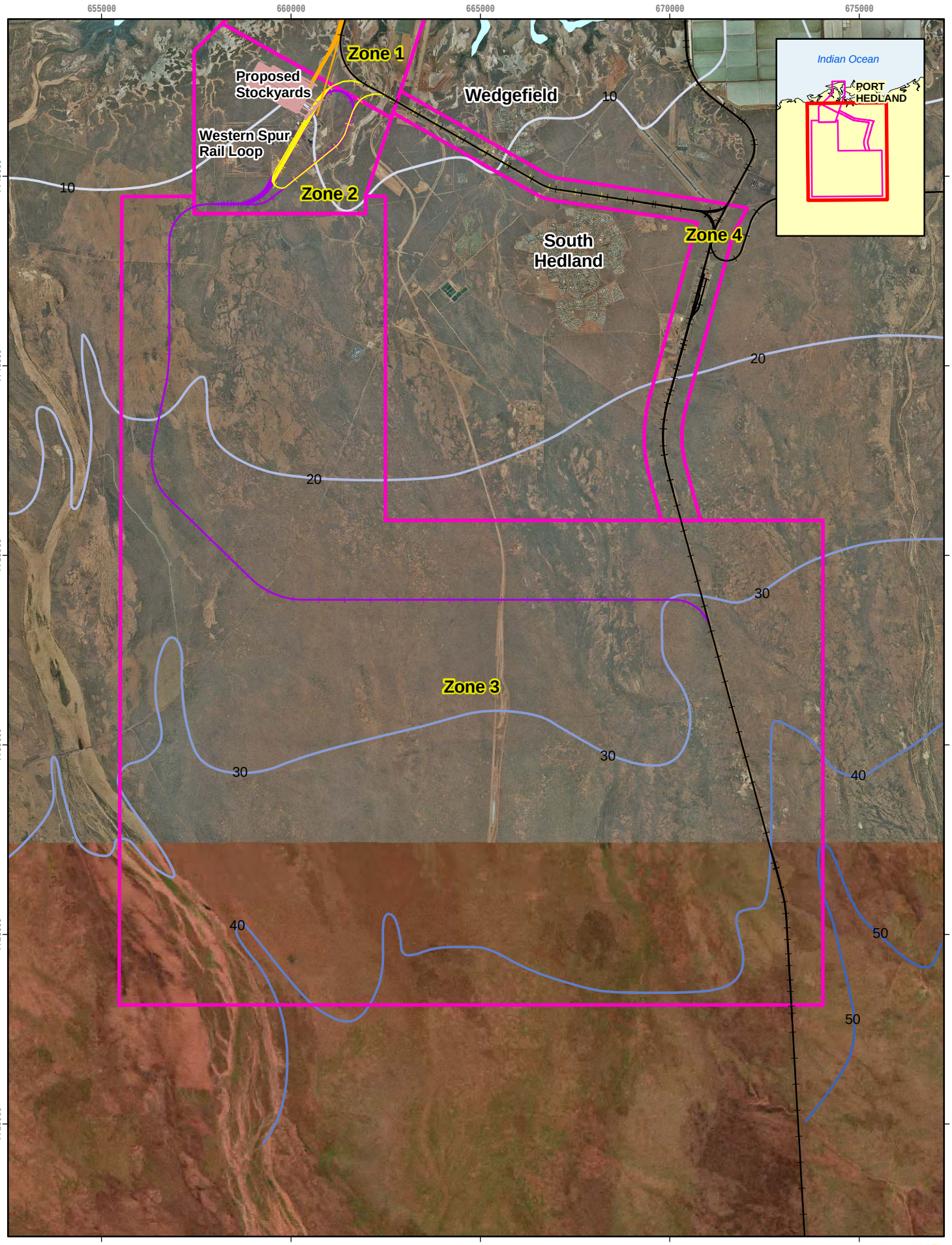
Figure D2 - Site Topography with Infrastructure Layout - Zone 2

320\g100_WV03716_Rev1



Legend

- Existing Railway
- Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

- Contours (mAHD)

Contaminated Areas

- Zone Boundary

0 1 2 3 4
kilometres

Scale = 1:130,000 at A4

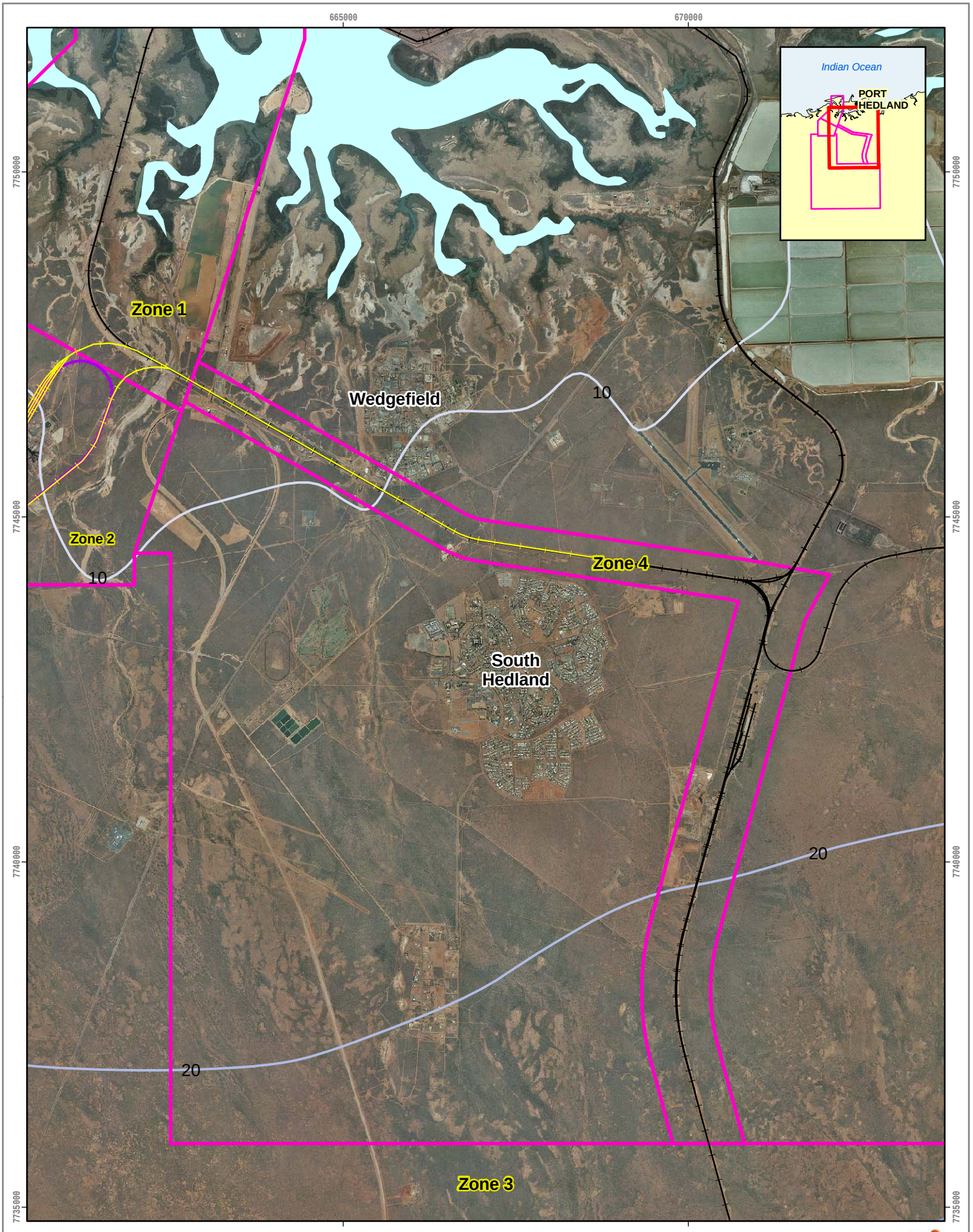
Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Elevation: Geoscience Australia 3 sec DEM (2003)
Orthorectified Aerial Photograph: 04/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

320\g101_WV03716_Rev1

Figure D3 - Site Topography with Infrastructure Layout - Zone 3



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

- Contours (mAHD)

Contaminated Areas

- Zone Boundary

0 0.5 1 1.5 2
kilometres

Scale = 1:70,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Elevation: Geoscience Australia, 3 sec DEM (2003)
Orthorectified Aerial Photograph: 04/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo 250K V3
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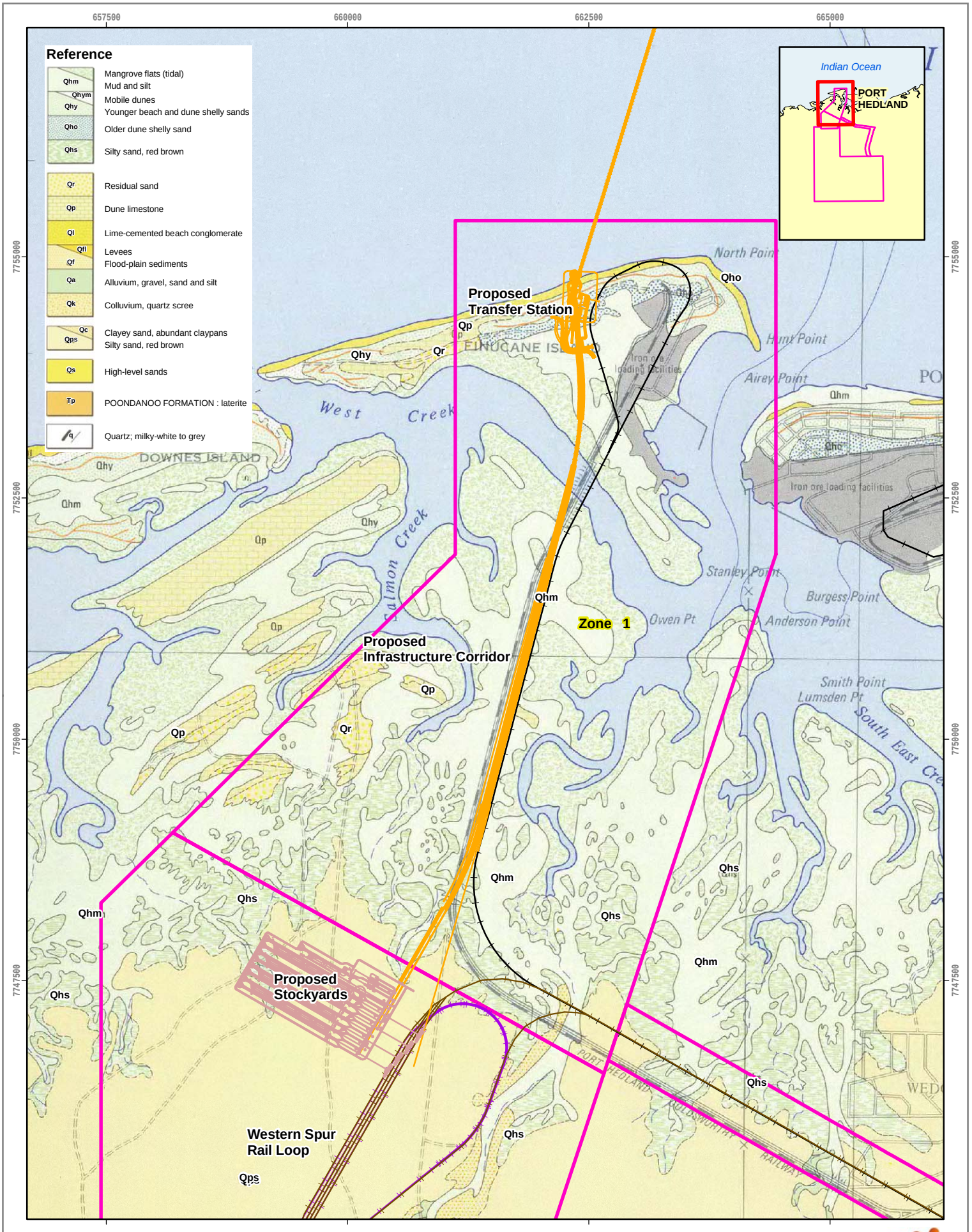
320\g102_WV03716_Rev1

Figure D4 - Site Topography with Infrastructure Layout - Zone 4



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 0.5 1 1.5 2
kilometres

Scale = 1:50,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

Source:
50k Urban Geology: 2557-II (1983), 2657-III (1983) GSWA
100k 2556 (Yule), 2656 (Wallaringa) (GSWA)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

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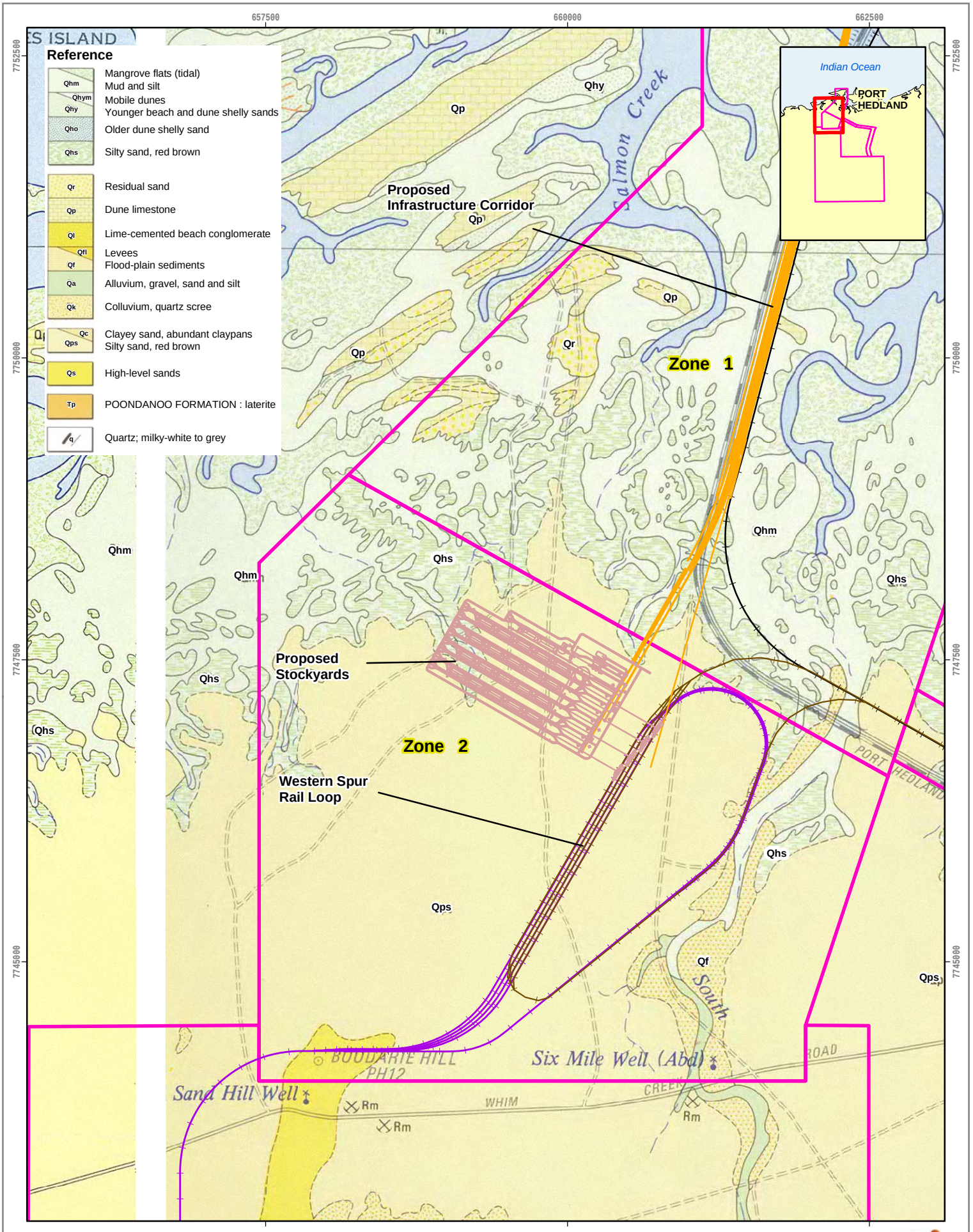
Figure D5 - Site Geology with Infrastructure Layout - Zone 1

320\g104_WV03716_Rev1



Legend

- Railway
- Proposed Stockyards
- Proposed Infrastructure

Proposed Rail

- Western Spur Railway
- Goldsworthy Railway

Contaminated Areas

- Zone Boundary

0 0.25 0.5 0.75 1
kilometres

Scale = 1:40,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

Source:
50k Urban Geology: 2557-II (1983), 2657-III (1983) (GSWA)
100k 2556 (Yule), 2656 (Wallaringa) (GSWA)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

Figure D6 - Site Geology with Infrastructure Layout - Zone 2

320\g105_WV03716_Rev1

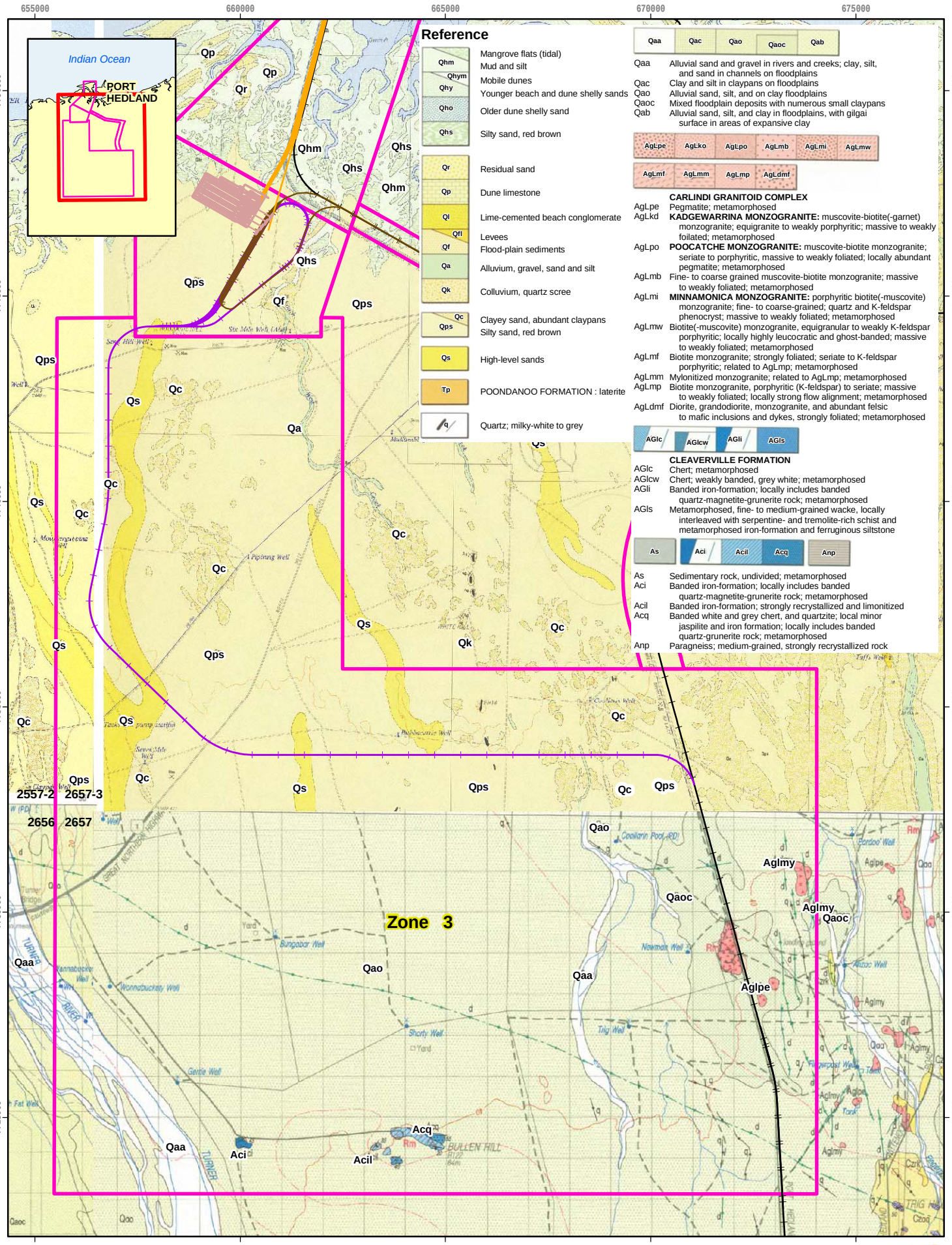


Figure D7 - Site Geology with Infrastructure Layout - Zone 3

320\g106_WV03716_Rev1

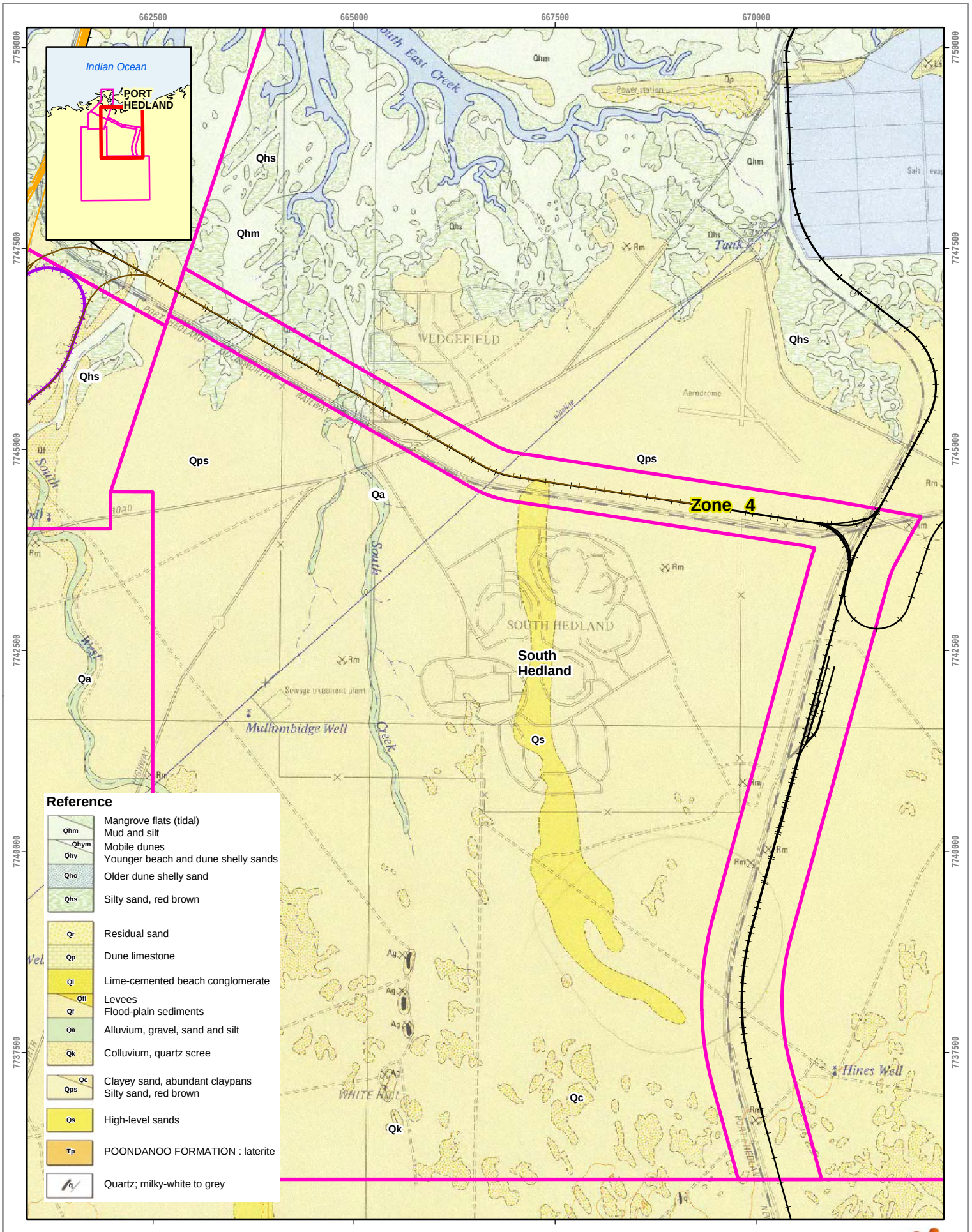
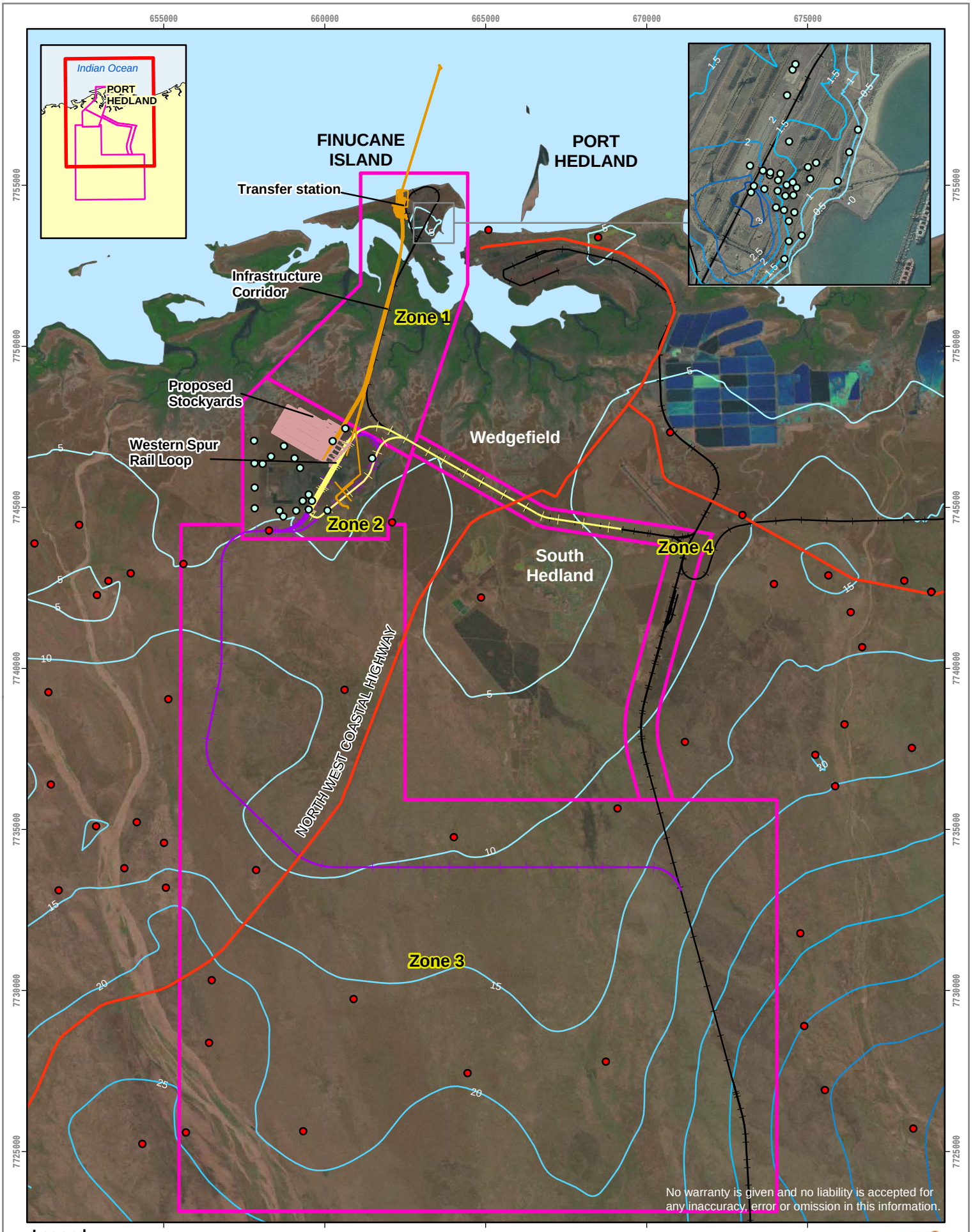


Figure D8 - Site Geology with Infrastructure Layout - Zone 4

320\g107_WV03716_Rev1



Legend

- Rationalised Subset of WIN Sites used for Modelling (DoW, 2008)
- Rationalised Subset of BHPBIO Monitoring Bores used for Modelling (BHPBIO, 2008)
- Groundwater Contour (m AHD)
- Principle Road
- Proposed Infrastructure
- Proposed Stockyards
- Railway

Proposed Rail

- Goldsworthy Railway
- Western Spur Railway

Contaminated Areas

- Zone Boundary

0 1 2 3 4
kilometres

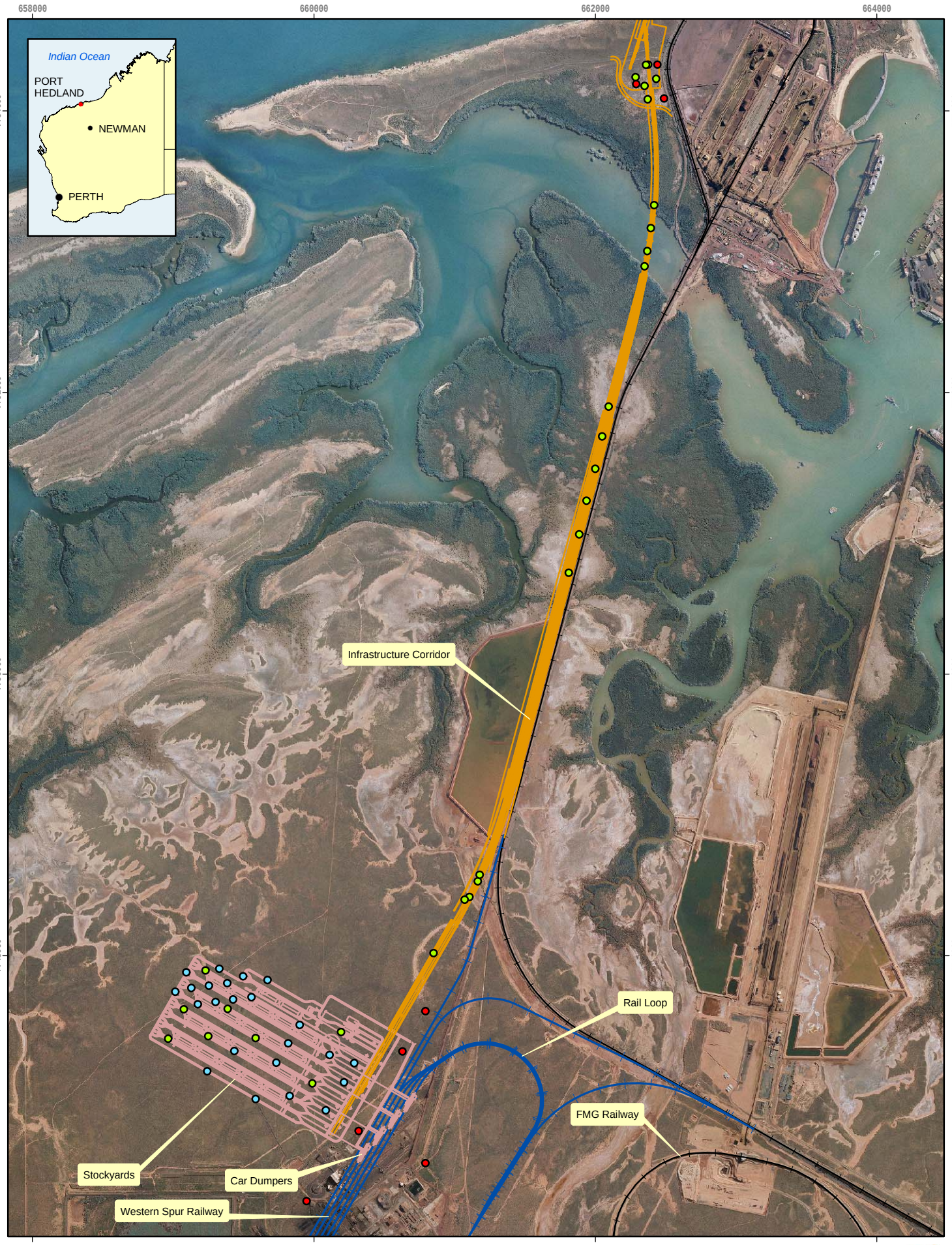
Scale = 1:150,000 at A4
Vertical Datum: AHD71
Horizontal Datum: GDA94
Map Grid: MGA94 Zone 50

Source:
Orthorectified Aerial Photograph: 08/06/2008 (BHPBIO)
Topography: Geoscience Australia, GEODATA Topo
Groundwater Contours: 2008 (SKM)

320\g144_WV03716_Rev1

Figure D9 - Anticipated Hydrogeological Gradient

Appendix E Proposed Sample Locations



Legend

- Borehole
- Test Pit
- Monitoring Well
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Western Spur Railway
- Existing Railways

0 1
kilometres

Scale = 1:35,000 at A4

Datum: GDA94
Projection: MGA94 Zone 50

bhpbilliton

Source:
Orthorectified Aerial Photograph: 08/06/2009 (BHPBIO)
Topography: GEODATA Topo 250K V3

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Figure E1 - Proposed Acid Sulphate Soils Sample Locations