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**REPORT**

# **Mulga Downs Surface Water and Groundwater Contributions for EPA Referral Document**

Prepared for Hancock Prospecting Pty Ltd

January 2013



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# Hancock Prospecting Pty Ltd

## Mulga Downs Project – Surface Water and Groundwater Contributions for EPA Referral Document

### CONTENTS

1	Introduction.....	1
1.1	Project Description.....	1
2	Overview of Existing Environment.....	3
2.1	Climate .....	3
2.2	Topography.....	6
2.2.1	Murray's Hill Mine.....	6
2.2.2	Fenceline Road .....	6
2.2.3	Proposed Camps and Access Roads .....	6
2.2.4	Railway Siding and Access Roads .....	6
2.3	Regional Surface Water Catchments.....	6
2.3.1	Fortescue River Basin.....	6
2.3.2	Port Hedland Coast Basin .....	7
2.4	Local Surface Water Catchments.....	9
2.4.1	Murray's Hill Mine.....	9
2.4.2	Fenceline Road .....	9
2.4.3	Proposed Camp Locations and Access Roads .....	9
2.4.4	Railway Siding and Access Roads .....	9
2.5	Surface Water Quality .....	14
2.6	Regional Hydrogeology .....	14
2.7	Local Hydrogeology .....	14
2.7.1	Mining Tenement Area.....	14
2.7.1.1	Site description .....	14
2.7.1.2	Groundwater quality.....	20
2.7.1.3	Recharge.....	20
2.7.1.4	Groundwater Levels and Topographically-driven Flow.....	20
2.7.1.5	Storage and Throughflow .....	21
2.7.1.6	Hydraulic Connectivity .....	21
2.7.1.7	Discharge .....	23
2.7.2	Railway Siding and Access Roads .....	23
2.7.2.1	Site description .....	23
2.7.2.2	Recharge.....	23
2.7.2.3	Groundwater Levels and Topographically Driven Flow.....	23
2.7.2.4	Storage and Throughflow .....	24

2.7.2.5	Hydraulic Connectivity .....	24
2.7.2.6	Discharge .....	24
2.7.2.7	Water Quality .....	24
2.8	Existing Groundwater Sources .....	24
2.8.1	Mining Tenement Area .....	24
2.8.2	Railway Siding and Access Roads .....	27
3	Surface Water Impact Assessment .....	28
3.1	Potential Sources of Impacts .....	28
3.2	Findings of Surveys and Investigations.....	28
3.2.1	Surface Water Flow Processes .....	28
3.2.1.1	Minesite Area .....	28
3.2.1.2	Fenceline Road .....	33
3.2.1.3	Camp Locations and Access Roads .....	33
3.2.1.4	Railway Siding Access Roads .....	33
3.3	Evaluation of options or alternatives to avoid or minimise impact.....	33
3.4	Assessment of likely direct and indirect impacts .....	34
3.4.1	Modification or interruption of existing natural drainage channels and/or flows .....	35
3.4.1.1	Minesite Area .....	35
3.4.1.2	Fenceline Road .....	35
3.4.1.3	Camp Locations and Access Roads .....	35
3.4.1.4	Railway Siding Access Roads .....	35
3.4.2	Drainage shadows and ponding.....	35
3.4.2.1	Minesite Area .....	35
3.4.2.2	Fenceline Road .....	36
3.4.2.3	Camp Locations and Access Roads .....	36
3.4.2.4	Railway Siding Access Roads .....	36
3.4.3	Increased sediment runoff and scour.....	36
3.4.3.1	Minesite and Camp Locations.....	36
3.4.3.2	Fenceline Road .....	37
3.4.3.3	Railway Siding Access Road .....	37
3.4.4	Potential hydrocarbon and chemical contamination .....	37
3.5	Cumulative Impacts .....	37
3.6	Management measures and performance standards.....	38
3.6.1	Minesite Stormwater Management Strategy .....	38
3.6.2	Access Roads Stormwater Management Strategy .....	40
3.6.3	Camp Location Stormwater Management Strategy .....	41
3.6.4	Hydrocarbon Management Strategy .....	41
4	Groundwater Impact Assessment .....	42
4.1	Groundwater Sources .....	42
4.1.1	Mining Tenement Area .....	42

4.1.1.1	Fenceline Road .....	42
4.1.1.2	Railway Siding and Access Roads .....	43
4.1.1.3	Camp Locations .....	43
4.2	Projected Water Demand for Proposed Mining Activities .....	43
4.3	Drawdown Response to Proposed Abstractions .....	46
4.3.1	Mining Tenement Area .....	46
4.3.2	Railway Siding and Access Roads .....	46
4.4	Potential Sources of Impact .....	47
4.5	Evaluation of options or alternatives to avoid or minimise impact .....	47
4.6	Assessment of Likely Direct and Indirect Impacts .....	47
4.6.1	Impacts on groundwater quality .....	47
4.6.2	Impacts to water Balance and Groundwater Levels .....	48
4.6.2.1	Mining Tenement Area .....	48
4.6.2.2	Railway Siding and Access Roads .....	48
4.6.3	Potential for and nature of any Cumulative Impacts .....	49
4.6.3.1	Mining Tenement Area .....	49
4.6.3.2	Railway Siding and Access Roads .....	49
4.7	Management measures and performance standards .....	49
4.7.1	Management Actions .....	49
4.7.2	Proposed Future Investigations .....	49
References	.....	50

## LIST OF TABLES

Table 2-1:	Operating rainfall stations in the vicinity of the Project .....	5
Table 2-2:	Project components regional catchments .....	7
Table 2-3:	Fortescue River area: regional Stratigraphic Sequence .....	17
Table 2-4:	Summary of Likely Hydraulic Parameters for the Hydrostratigraphic Units .....	18
Table 2-5:	Summary of Hydraulic Parameters from Investigations in the Mine Area .....	25
Table 2-6:	Summary of Hydraulic Parameters from Railway siding Area Bores .....	27
Table 3-1:	Peak Flows and Critical Durations for Existing Environment .....	28
Table 3-2:	Comparison of RORB output flows for existing and operational scenarios .....	29
Table 3-3:	Estimated Pit Direct Rainfall Volumes. ....	31
Table 3-4:	Estimated Waste Rock Dump Direct Rainfall Volumes. ....	32
Table 3-5:	Estimated Ore Processing Area Direct Rainfall Volumes. ....	32
Table 3-6:	Percentage Disturbance within Regional Catchments and Sub-Catchments .....	34
Table 4-1:	Summary of Hydraulic Parameters from Investigations in the Mine Area .....	42
Table 4-2:	Summary of Hydraulic Parameters from Railway siding Area Bores .....	43
Table 4-3:	Projected Water Demand for Construction and Operations .....	45
Table 4-4:	Summary of Recommended Pumping Rates for Railway Area Bores .....	47

## LIST OF FIGURES

Figure 1-1: Mulga Downs Project Location and Layout Plan .....	2
Figure 2-1: Mean monthly maximum and minimum temperatures - Wittenoom and Marble Bar.....	3
Figure 2-2: Climate and Rainfall Station Locations .....	4
Figure 2-3: Mean Monthly Rainfall vs Evaporation – Wittenoom Station (5026). .....	5
Figure 2-4: Regional Catchment Map.....	8
Figure 2-5: Existing Catchments – Minesite Area.....	10
Figure 2-6: Fenceline Road Local Catchments .....	11
Figure 2-7 : Local Sub-catchments of Railway Access Roads .....	12
Figure 2-8: Proposed Camp Locations Local Catchments.....	13
Figure 2-9: Murray’s Hill Regional Cross Section .....	16
Figure 2-10: Mulga Downs Regional Cross Section.....	19
Figure 2-11: Groundwater Hydrograph.....	21
Figure 2-12: Groundwater Contours for the Mine Area (September 2012).....	22
Figure 2-13: Existing Water Supply Bores: Railway Area.....	26
Figure 3-1: Pre and Post Mining RORB Catchments – Minesite Area .....	30
Figure 3-2: Conceptual Surface Water Management Plan – Murray’s Hill Mine .....	39
Figure 3-3: Conceptual Layout of Environmental Culverts.....	40
Figure 4-1: Proposed Borefield for Minesite and Fenceline Road .....	44

# 1 Introduction

As part of MWH's on-going involvement in the Mulga Downs Project, Hancock Prospecting Propriety Limited (HPPL) requested that MWH provide hydrological and hydrogeological contributions to the referral of a proposal to the Environmental Protection Authority (EPA). HPPL intend to submit a referral to the EPA for the above water table mining scenario at their Mulga Downs project (the Project).

This report has been compiled in response to this request and contains specific information requested by HPPL for inclusion into the referral document. As outlined in our proposal (MWH Ref: PM0482 referral doc, dated 7 September 2012) this report details the existing surface water and groundwater regime in the vicinity of the project, and undertakes a groundwater and surface water impacts assessment relating to the above water table mining scenario, according to the specific requirements of the EPA Referral Document.

At the time of writing this report, detailed groundwater and surface water investigations were being carried out by MWH for this project. A hydrology assessment for the Murray's Hill minesite has been completed and is detailed in the MWH report *Mulga Downs Project, Murray's Hill Minesite – Hydrology Assessment Report (2012)*. Groundwater investigations were still on-going and scheduled to be completed by the beginning of 2013.

## 1.1 Project Description

The Project is located in the Pilbara region of Western Australia, approximately 195 km south of Port Hedland and 185 km north-west of Newman as shown in Figure 1-1. Mulga Downs Iron Ore Pty Ltd is the proponent of the project, which is made up of the following constituents:

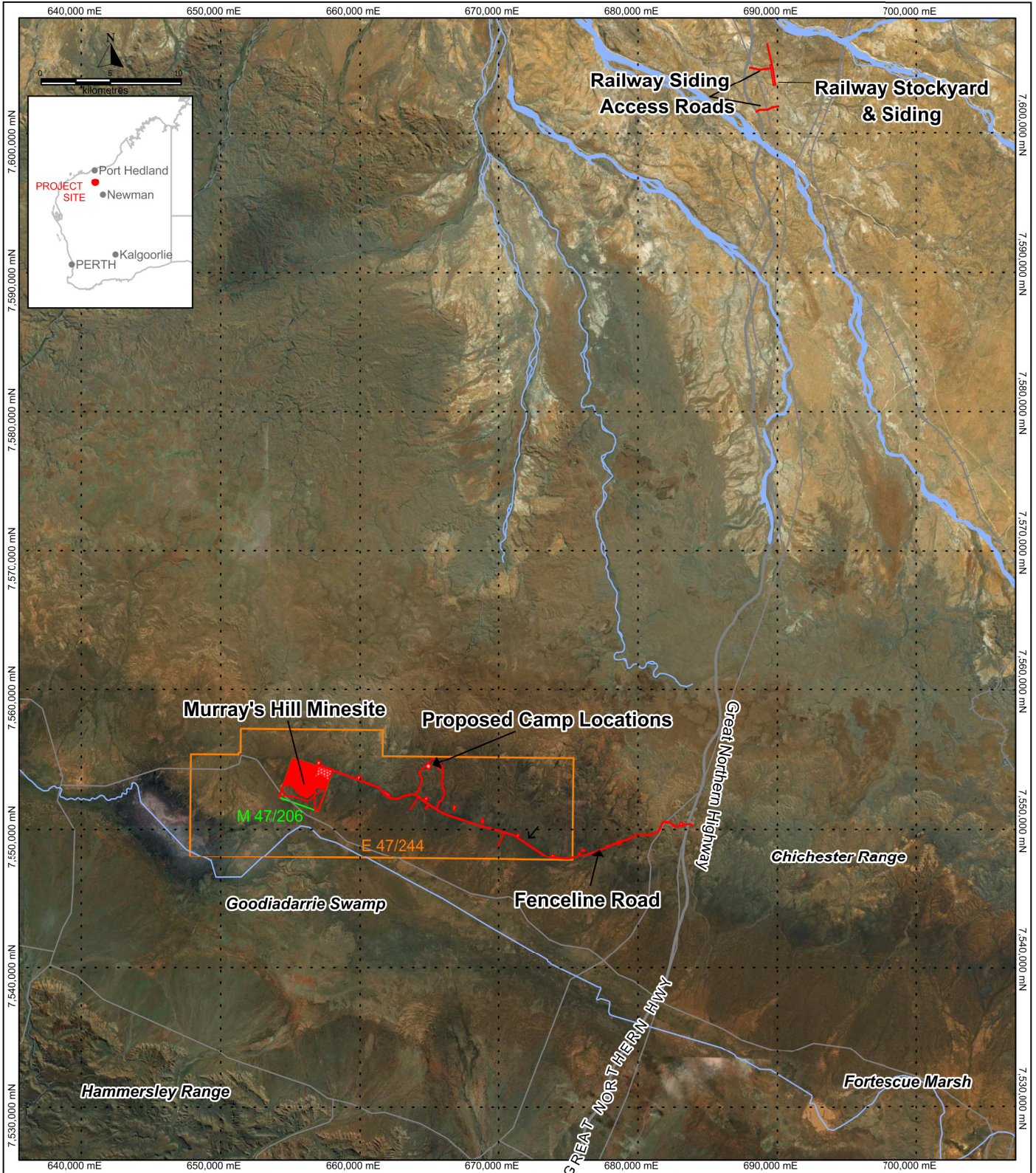
- Murray's Hill mine – included in tenement M47/206
- Fenceline Road – the access road connecting Murray's Hill mine to the Great Northern Highway falling within tenement E47/1244
- Two proposed camp locations - referred to as proposed camp location 1 and proposed camp location 2 in this study
- Railway siding and stockyard
- Railway siding access roads – access roads connecting the Great Northern Highway to rail siding facility.

The 'Project area' referred to in this study is defined as Murray's Hill mine site, Fenceline Road, the railway siding, the railway siding access roads and the proposed camps (Figure 1-1).

The railway access roads are located approximately 50km north of Fenceline Road, with a junction on the eastern side of the Great Northern Highway as seen in Figure 1-1. HPPL are assessing the viability of either one of these access roads. For the purposes of this study, the impact of both of the access roads on the surrounding surface water regime has been addressed. Groundwater for dust suppression purposes on these roads will be sourced from the siding water supply, so the groundwater impacts relating to this water supply have been assessed in this study.

The construction and operation of the rail siding currently falls under the Roy Hill Rail Project. For this reason, the impacts associated with the construction and operation of the siding and stockyard has not been covered in this assessment. However, due to the fact that the ore stockpile within the siding will require a water supply for dust suppression purposes, HPPL have requested that MWH address the impacts to groundwater associated with the supply of water for dust suppression in the siding and stockpile area. No surface water assessment for this area has been addressed by this study.

At the time of writing, two proposed camp locations were being assessed; however, only one of these camp locations will be chosen. Therefore, the impacts of both of these camps and their access roads have been addressed in this study.



**Data Conditions**

Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.

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**LEGEND**

- +++++ RAILWAY
- ROADS
- RIVERS/CREEKS
- EXPLORATION LICENSE
- MINING LICENSE
- PROJECT INFRASTRUCTURES



**FIGURE 1-1  
MULGA DOWNS PROJECT  
LOCATION AND LAYOUT PLAN**

MULGA DOWNS EPA REFERRAL

Author: DJA, OB	Date: 29 October 2012
Revised:	Project No.: 83500308
Projection: MGA 50, GDA94	Scale:

## 2 Overview of Existing Environment

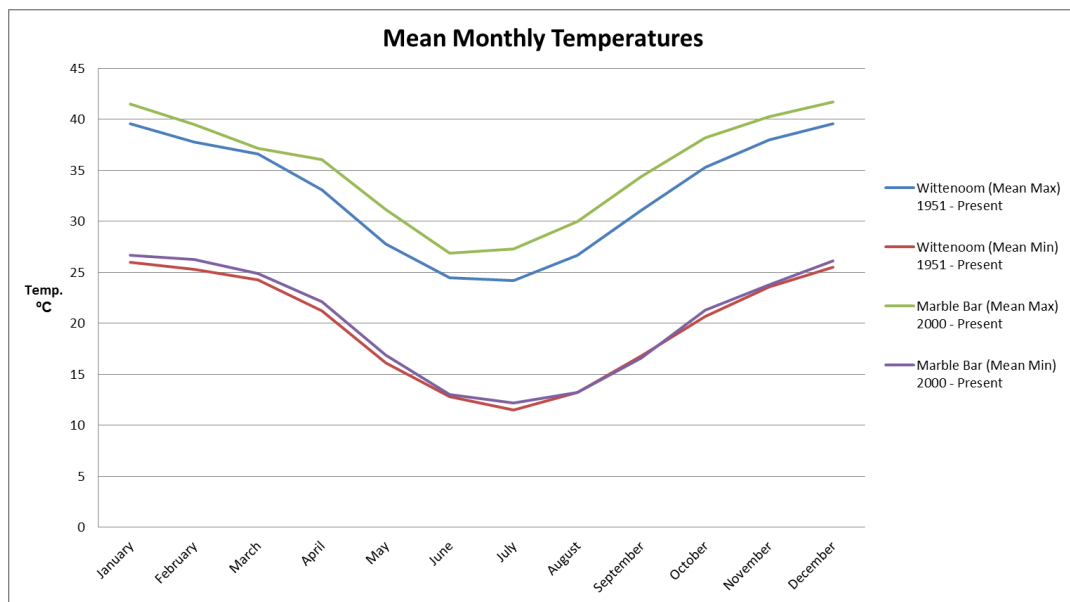
### 2.1 Climate

The climate of the project area can be classified as semi-arid to arid, with high temperatures and low, irregular rainfall, much of which falls during summer cyclones. The area experiences a climate of extremes, where severe droughts and major floods can occur at close intervals.

The two closest Bureau of Meteorology climate stations with long term climatic records are:

- Wittenoom (Station No. 005026) – located approximately 23 km south-west of Murray's Hill mine.
- Marble Bar (Station No. 004106) – located approximately 160 km north-east of Murray's Hill mine.

Figure 2-1 shows the distribution of annual temperature ranges for both these stations and Figure 2-2 shows the location of these stations relative to the Project area. The close proximity of Wittenoom station to the Project area provides an accurate climate comparison.



Source: BOM (2012)

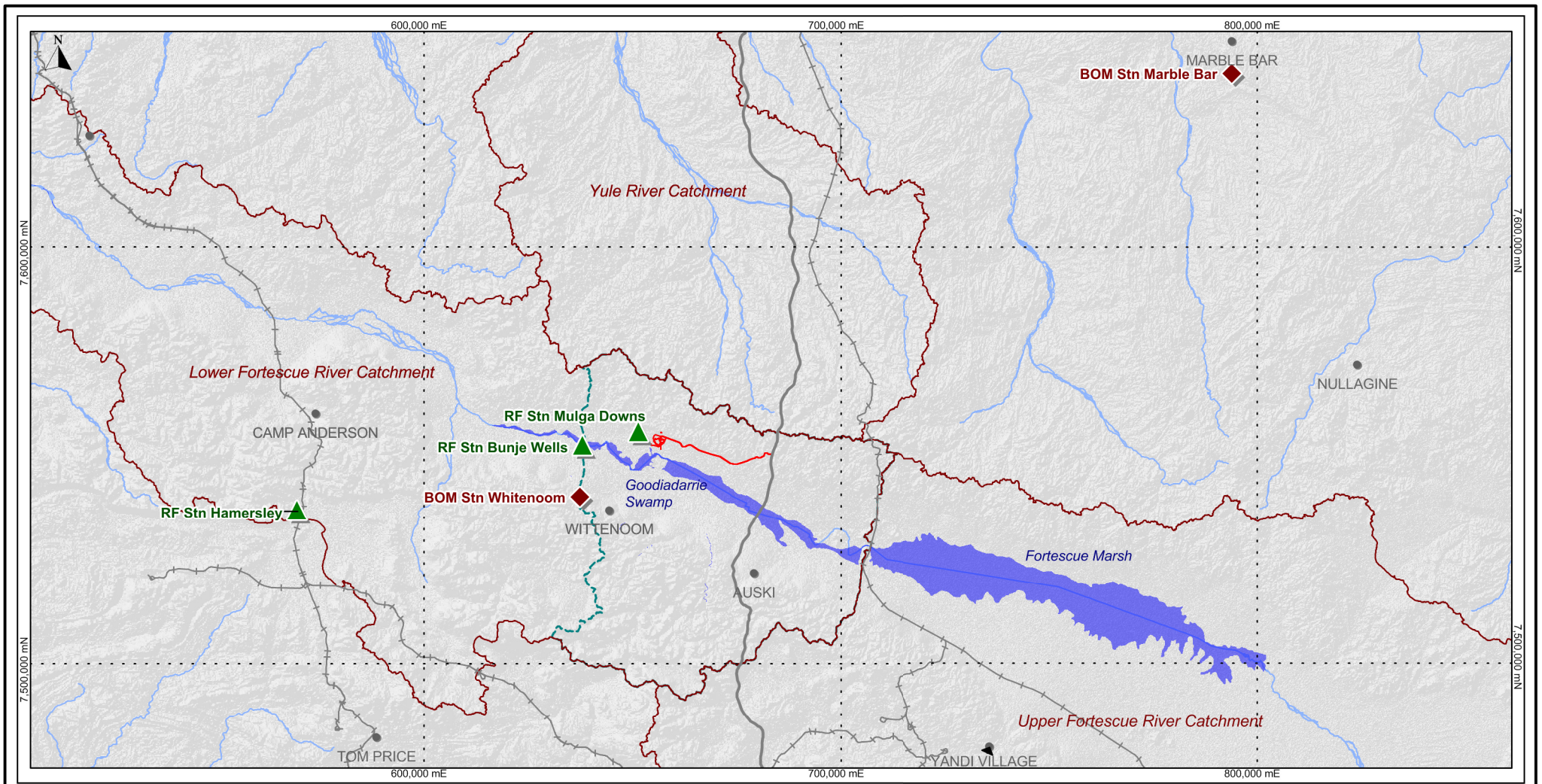
**Figure 2-1: Mean monthly maximum and minimum temperatures - Wittenoom and Marble Bar**

Daily temperatures in the summer months from November to February exceed 32°C and temperatures above 42°C are common. The winter season occurs from June to August with mean daily maximum and minimum temperatures of about 28°C and 13°C respectively.

Rainfall in general is unreliable and highly variable, predominantly influenced by the random nature of localised thunderstorms and tropical lows passing through the area. Rainfall occurs mostly between January and March and is associated with the passage of tropical cyclones. A secondary peak in the monthly rainfall can occur as a result of rainfall caused by tropical cloud bands, which intermittently affect the area mostly in the months of May and June. Due to the unreliable nature of the rainfall, rainfall records show a large degree of inter-annual variation.

Most of the rainfall events occur as scattered thunderstorms, producing heavy localised falls over short periods. Cyclones, usually originating off the Pilbara coast, can also bring widespread rain to the region. This usually results in a distinct peak in rainfall distribution over any given month. Cyclonic and significant rainfall events are locally significant in terms of providing groundwater recharge and significant surface water flows.

Rainfall stations located within the vicinity of the Project area are shown in Figure 2-2. Table 2-1 is a summary of these rainfall stations.










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**LEGEND**

-  CLIMATE STATION
-  RAINFALL STATIONS
-  PROJECT AREA AND INFRASTRUCTURE
-  CREEK
-  RIVER
-  REGIONAL CATCHMENTS
-  GOODIADARRIE SWAMP SUBCATCHMENT



**FIGURE 2-2  
CLIMATE AND RAINFALL  
STATION LOCATIONS**

MURRAY'S HILLS MINESITE- HYDROLOGY ASSESSMENT

Author: DJA, OB	Date: 01 November 2012
Revised:	Project No.: 83500308
Projection: MGA Zone 50 (GDA 94)	Scale:

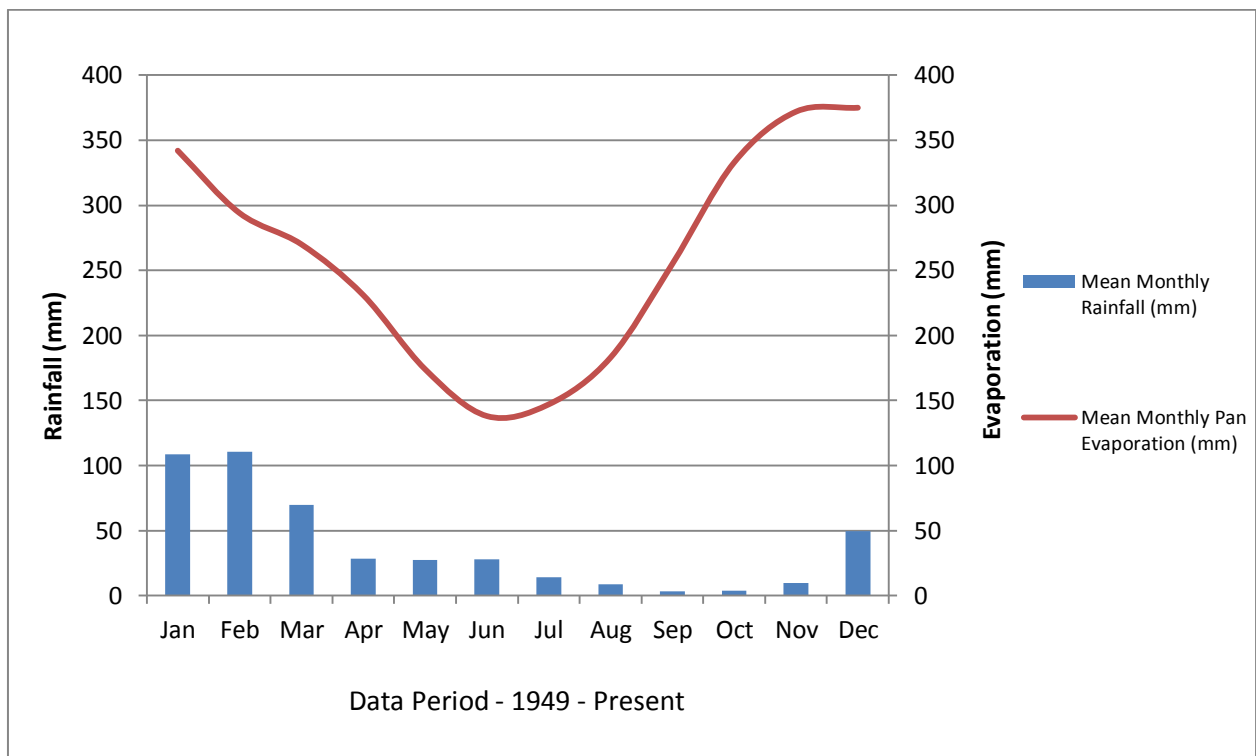
**Table 2-1: Operating rainfall stations in the vicinity of the Project**

Station No	Station Name	Operating Dates	Operating Agency
5015	Mulga Downs	1898 - Present	BOM
505022	Bunje Wells	1974 - 1986	DOW
505018	Hamersley Gorge	1973 – 1986	DOW
5026	Wittenoom	1949 - Present	BOM

Average annual rainfall varies between 334 – 459 mm/year for these local rainfall stations. This reflects the variable and unreliable nature of rainfall in the Project area. Rainfalls of between 70 and 400 mm have been recorded during cyclones that have passed through the project area. This is a considerable amount for one event considering that the annual average rainfall for this region is between 300 - 500 mm/year.

Although the Mulga Downs rainfall station (5015) is the closest station to the Murray's Hill minesite, the quality of data recorded at this site is somewhat compromised and of a lower quality to that collected at the BOM station – Wittenoom (5026). Therefore for the purposes of understanding the regional rainfall of the project area, Wittenoom station has been selected.

Figure 2-3 shows the annual distribution of rainfall and evaporation for Wittenoom Station (5026) for the period 1949 to present. As is typical of arid to semi-arid areas, the potential evaporation within the project area exceeds the rainfall by a significant amount. The annual average potential pan evaporation in this region is between 2,800 and 3,200 mm/year which is greatly in excess of the average annual rainfall of 300 – 500 mm/year.


**Figure 2-3: Mean Monthly Rainfall vs Evaporation – Wittenoom Station (5026).**

## 2.2 Topography

### 2.2.1 Murray's Hill Mine

Murray's Hill mine sits on the southern side of the Chichester Ranges and to the north of the Fortescue River (Figure 2-1). The Chichester Ranges forms a watershed between the numerous rivers flowing north to the coast and to the Fortescue River in the south. Elevations at the top of the Chichester Ranges average between 400-500 mAHD. Elevations drop to approximately 400 mAHD along the Fortescue River and Goodiadarie Swamp, to the south of the Chichester Ranges.

Murray's Hill is a distinct topographical feature within the minesite area, which forms the ore body under discussion, and has a maximum elevation of approximately 440 mAHD. The areas surrounding Murray's Hill sits at an elevation of approximately 410 to 420 mAHD.

### 2.2.2 Fenceline Road

Fenceline Road will follow the alignment of an existing access road. The elevation at the junction of this track with the Great Northern Highway is approximately 450mAHD and 423mAHD. At the point where Fenceline Road meets with Murray's Hill minesite; the average elevation of the alignment is 436mAHD. The alignment intersects several minor drainage lines but does not cross any major drainage lines. Both the minesite and Fenceline Road are positioned at the break in slope between the Chichester Ranges and the flat outwash plains of the Chichester Ranges and the area of the Goodiadarie Swamp (Figure 2-2).

### 2.2.3 Proposed Camps and Access Roads

The access roads to the proposed camp locations are located approximately 6 to 7km from the minesite, off Fenceline road (see Figure 1-1). Camp location 1 sits at an elevation of approximately 440mAHD and camp location 2 sits at approximately 450mAHD. Both camps are located approximately 3km south of Fenceline Road. Two drainage lines pass through camp location 1. Camp location 2 lies approximately 800m to the east of camp location 1 and has a very minor drainage line passing through it.

### 2.2.4 Railway Siding and Access Roads

The topography surrounding the potential locations of the proposed railway siding and two railway access roads is gently undulating. The northern most access road (Two Camel Access Road) follows a low rise ridge line that forms a watershed between several minor drainage lines. This access road runs from approximately 244mAHD at the intersection with Great Northern Highway to approximately 248mAHD where the access road is projected to intersect with the Roy Hill Railway Siding.

The second access road (Coonarrie Access Road) falls away from the Great Northern Highway, from approximately 257mAHD to 248mAHD. The alignment crosses Two Camel Creek at approximately 1km east of the highway, at approximately 248mAHD. The land east of Two Camel Creek rises again to approximately 250mAHD, before falling back down to 248mAHD at the point where the access road is projected to intersect the Roy Hill Railway line. A number of small drainage lines are cut by this proposed alignment.

## 2.3 Regional Surface Water Catchments

The various components of the Project are located within two regional drainage basins:

- Fortescue River Basin, and
- Port Hedland Coast Basin.

These drainage basins are divided into catchments and sub-catchments as shown on Figure 2-4.

### 2.3.1 Fortescue River Basin

The Fortescue River Basin covers a total area of 49,750 km<sup>2</sup> and is defined to the north by the Chichester Ranges and to the south by the Hamersley Ranges. The basin is divided into two regional catchments:

- The Upper Fortescue Catchment; and
- The Lower Fortescue River Catchment.

The Upper Fortescue Catchment is an internally draining catchment which drains into the Fortescue Marsh. The Fortescue Marsh is a unique wetland which is recognised as a wetland of national significance in the Directory of Important Wetlands in Australia (Environment Australia, 2001). The Marsh extends east from the Goodiadarrie Hills for approximately 100 km. This catchment area is approximately 29,750 km<sup>2</sup> and is not believed to be hydraulically connected – both via surface water and groundwater - to the lower Fortescue River Catchment.

The Goodiadarrie Hills form the divide between the Upper Fortescue River Catchment and the Lower Fortescue River catchment. The Goodiadarrie Swamp is located in the upper reaches of the Lower Fortescue River catchment and sits within an internally draining sub-catchment. Flows from the surrounding Hamersley Ranges and Chichester Ranges drain through the outwash plains and into the Goodiadarrie Swamp. Similarly to the Fortescue Marsh, it is believed that the Goodiadarrie Swamp is not hydraulically connected to the Upper Fortescue River Catchment or the Lower Fortescue River Catchment. The Goodiadarrie Swamp is therefore believed to be a separate hydrological system to the Fortescue Marsh and this sub-catchment is referred to as the Goodiadarrie Swamp Sub-Catchment in this study. The Goodiadarrie Swamp is recognised as a wetland of national significance in the Directory of Important Wetlands in Australia (Environment Australia, 2001).

The Lower Fortescue River Catchment drains into the Fortescue River which extends from the divide of the Goodiadarrie Swamp Catchment and flows north-west for approximately 300 km until it reaches the coast. The total area of this catchment is approximately 19,890 km<sup>2</sup>. The water quality exhibited (both surface water and groundwater) in this catchment is generally fresh and unlike the saline quality seen in the Goodiadarrie Swamp Catchment and the Upper Fortescue Catchment. This is further evidence that the three sub-catchments within the Fortescue River Catchment are not hydraulically connected. Flows in this section of the Fortescue River are fresh

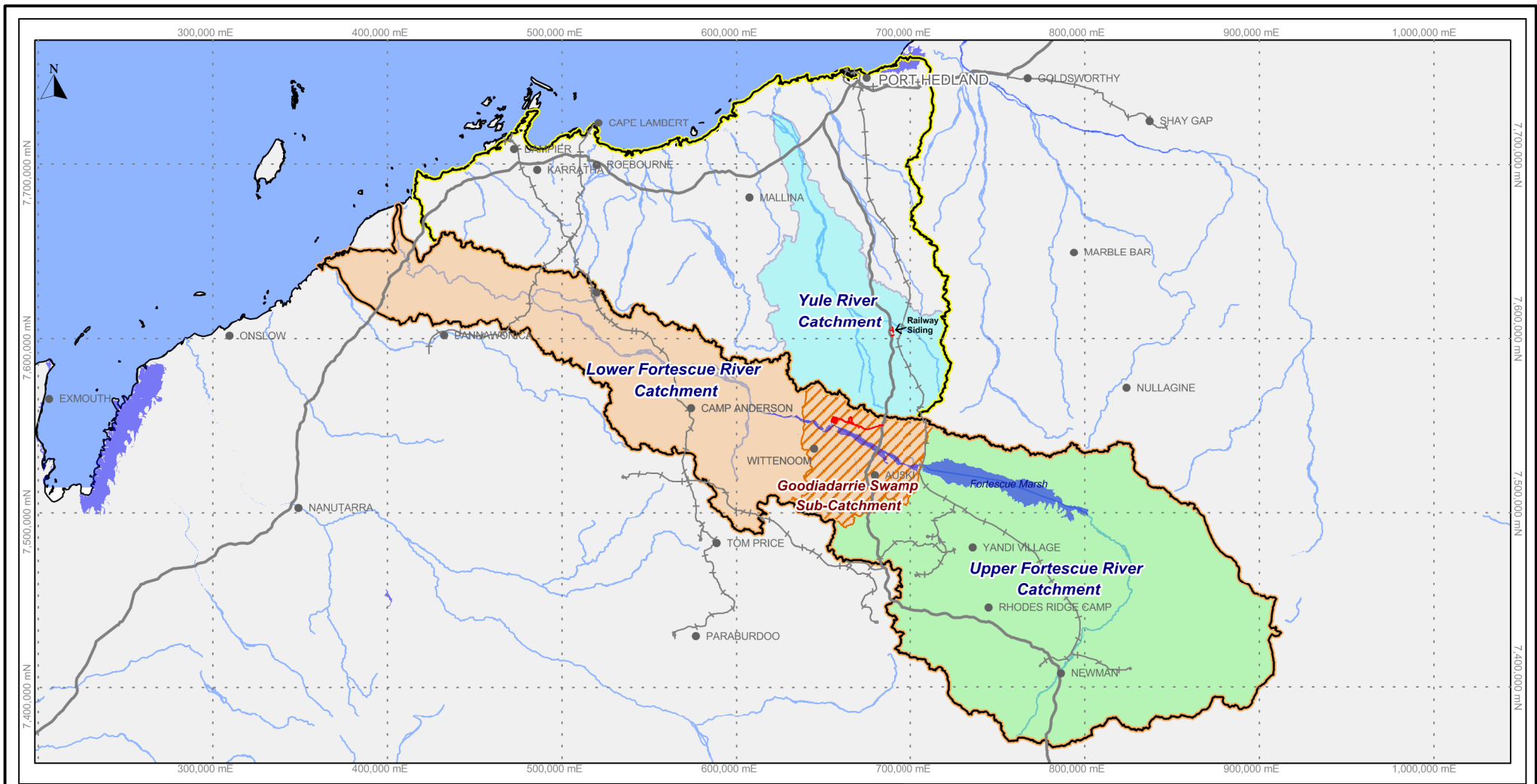
### 2.3.2 Port Hedland Coast Basin

The Port Hedland Coast Basin is made up of six major rivers: Maitland, Harding, George, Sherlock, Yule and Turner Rivers. The Yule River is the largest and longest river in the drainage basin and is bounded by the Mungarooona and Chichester Ranges (Ruprecht et al., 2000). The major tributaries of the Yule are Beabea Creek, Coonarrrie Creek and Cockeraga River. Coonarrrie Creek is in close proximity to the two proposed railway siding access roads, however, neither of these roads cross this creek.

Table 2-2 details where each of the project components sits within the drainage basins and associated catchments/sub-catchments.

**Table 2-2: Project components regional catchments**

Project Component	Drainage Basin	Regional Catchment/Sub-catchment	Catchment/Sub-Catchment Area (km <sup>2</sup> )
Murray's Hill Mine	Fortescue River Basin	Goodiadarrie Swamp Sub-Catchment	4,138
Fenceline Road	Fortescue River Basin	Goodiadarrie Swamp Sub-Catchment	4,138
Railway Siding	Port Hedland Coast Basin	Yule River Catchment	8,860
Railway Siding Access Roads	Port Hedland Coast Basin	Yule River Catchment	8,860
Camp Location 1	Fortescue River Basin	Goodiadarrie Swamp Sub-Catchment	4,138
Camp Location 2	Fortescue River Basin	Goodiadarrie Swamp Sub-Catchment	4,138



**Data Conditions**

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**LEGEND**

 DIWA WETLANDS

**BASIN OUTLINES**

 PORT HEDLAND COAST BASIN  
 FORTESCUE RIVER BASIN

**LOWER FORTESCUE RIVER SUBCATCHMENT**

 GOODIADARRIE SWAMP SUB CATCHMENT

**REGIONAL CATCHMENTS**




 YULE RIVER  
 LOWER FORTESCUE  
 UPPER FORTESCUE



FIGURE 2-4

**REGIONAL CATCHMENT MAP**

MULGA DOWNS EPA REFERRAL

Author: RS, OB, DJA	Date: 24 January 2013
Revised: OB	Project No.: 83500308
Projection: MGA Zone 50 (GDA 94)	Scale:

## 2.4 Local Surface Water Catchments

### 2.4.1 Murray's Hill Mine

Figure 2-5 shows the local catchments surrounding the proposed Murray's Hill mine. In the existing environment there are essentially three main drainage lines that are flowing within and around the proposed minesite area.

Drainage within the minesite lease boundary is primarily radial. Rainfall falling in this area finds its way down the slopes of Murray's Hill and into the lower drainage lines. Sheet flow within and upstream of the mining lease boundary is limited due to the topography of the area. It would be expected that sheet flows would emanate downstream of the mining lease boundary, as flows move towards the flat sandy plains and outwash areas of the Goodiadarrie Swamp.

Light rainfall events over extended periods in the area will produce low volumes of runoff, with low velocity and minor sediment loads. Heavier intense rainfall events are expected to produce higher velocity flows resulting in the transport of sediment and increased turbidity.

### 2.4.2 Fenceline Road

Catchments crossing the Fenceline Road have been delineated by Engenium and have been included in this report as requested by HPPL. This data was supplied to MWH by Engenium (Pers Comm. P McBurney 10/09/2012) and is shown in Figure 2-6.

In total 68 catchments were identified varying in size from 0.02 km<sup>2</sup> to 36.87 km<sup>2</sup>. The catchments generally flow from north to south. As already discussed, the alignment of Fenceline Road closely follows the break in slope between the south facing escarpment of the Chichester Range and the sandy plains of the Goodiadarrie Swamp. Due to its location, it would be expected that flows upstream of the road alignment would present in defined drainage lines, and downstream of the road flows would begin to take on sheet flow characteristics as flows move to lower elevations along the sandy plains of the Goodiadarrie Swamp.

### 2.4.3 Proposed Camp Locations and Access Roads

Figure 2-8 shows the local catchments associated with the proposed camp locations. There are two catchments upstream of camp location 1:

- CL1 East Catchment – this has an area of approximately 4.5km<sup>2</sup>
- CL1 West Catchment – this has an area of approximately 0.63km<sup>2</sup>

Both of the main drainage lines associated with these two catchments pass through the western edge of the proposed camp footprint.

Camp location 2 sits within a small catchment (CL2 Catchment) which has an area of approximately 0.63 km<sup>2</sup>. The positioning of this camp location is such that there is minimal upstream surface water flow and therefore minimal flows through the camp footprint.

### 2.4.4 Railway Siding and Access Roads

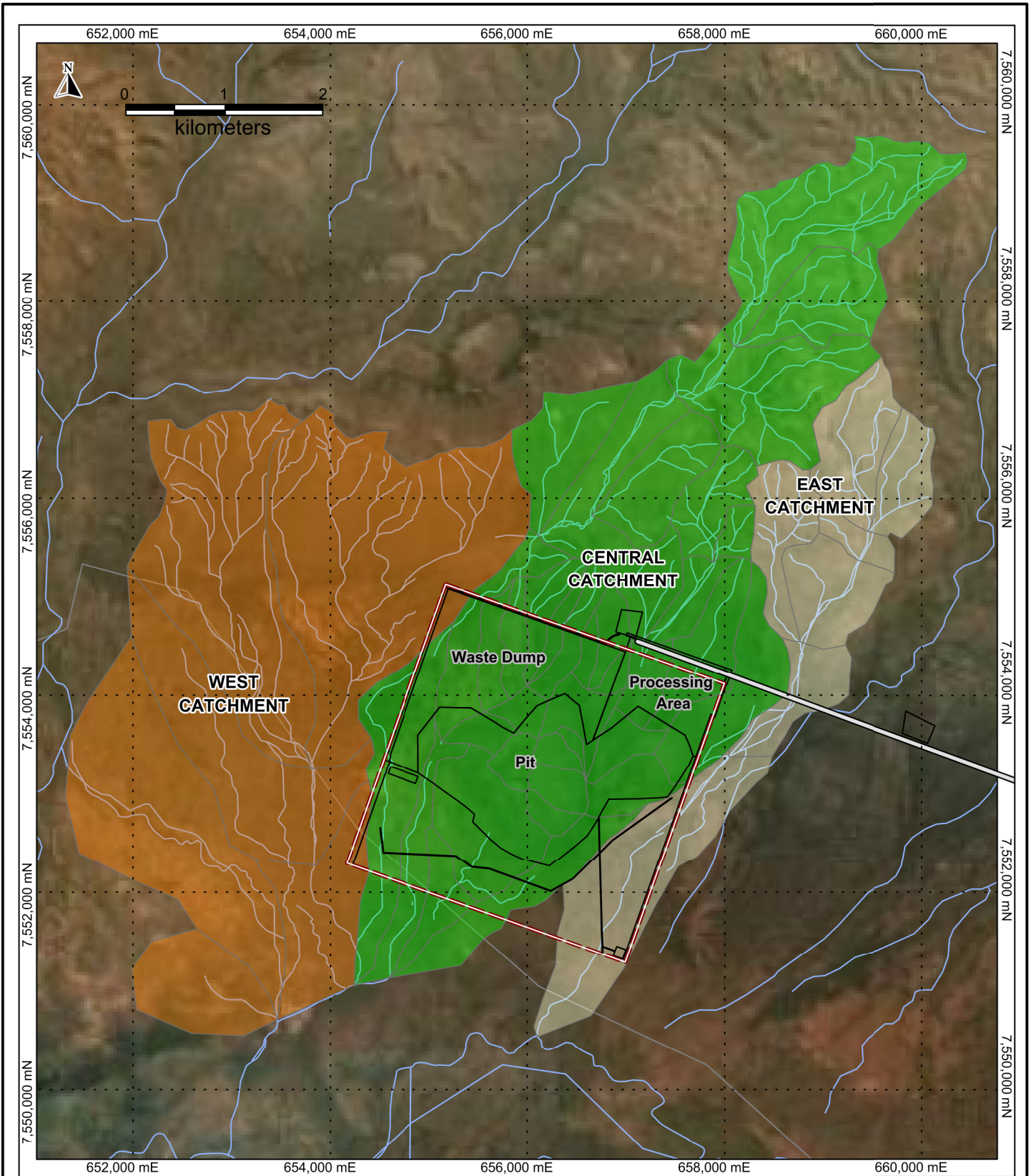
Figure 2-7 shows the local catchments for the two proposed railway siding access road options.

#### **Two Camel Access Road:**

Two Camel access road lies to the north of a natural watershed between two minor drainage lines that feed into Two Camel Creek, approximately 1.75 km to the west of the Great Northern Highway. The proposed alignment sits just north of a local watershed, and intersects seven sub-catchments of relatively small sizes, varying from 0.002 km<sup>2</sup> to 0.1 km<sup>2</sup>.

#### **Coonarrie Access Road:**





Coonarrie access road runs east from the Great Northern Highway to Two Camel Creek and beyond, to the proposed Roy Hill Railway line. The alignment crosses Two Camel Creek approximately 1 km east of the Highway. As the alignment follows the gradient downslope this road option will intersect three sub-catchments, all of which lie close to the Highway. The sub-catchments vary in size from 0.03 km<sup>2</sup> to 0.16 km<sup>2</sup>.




**Data Conditions**

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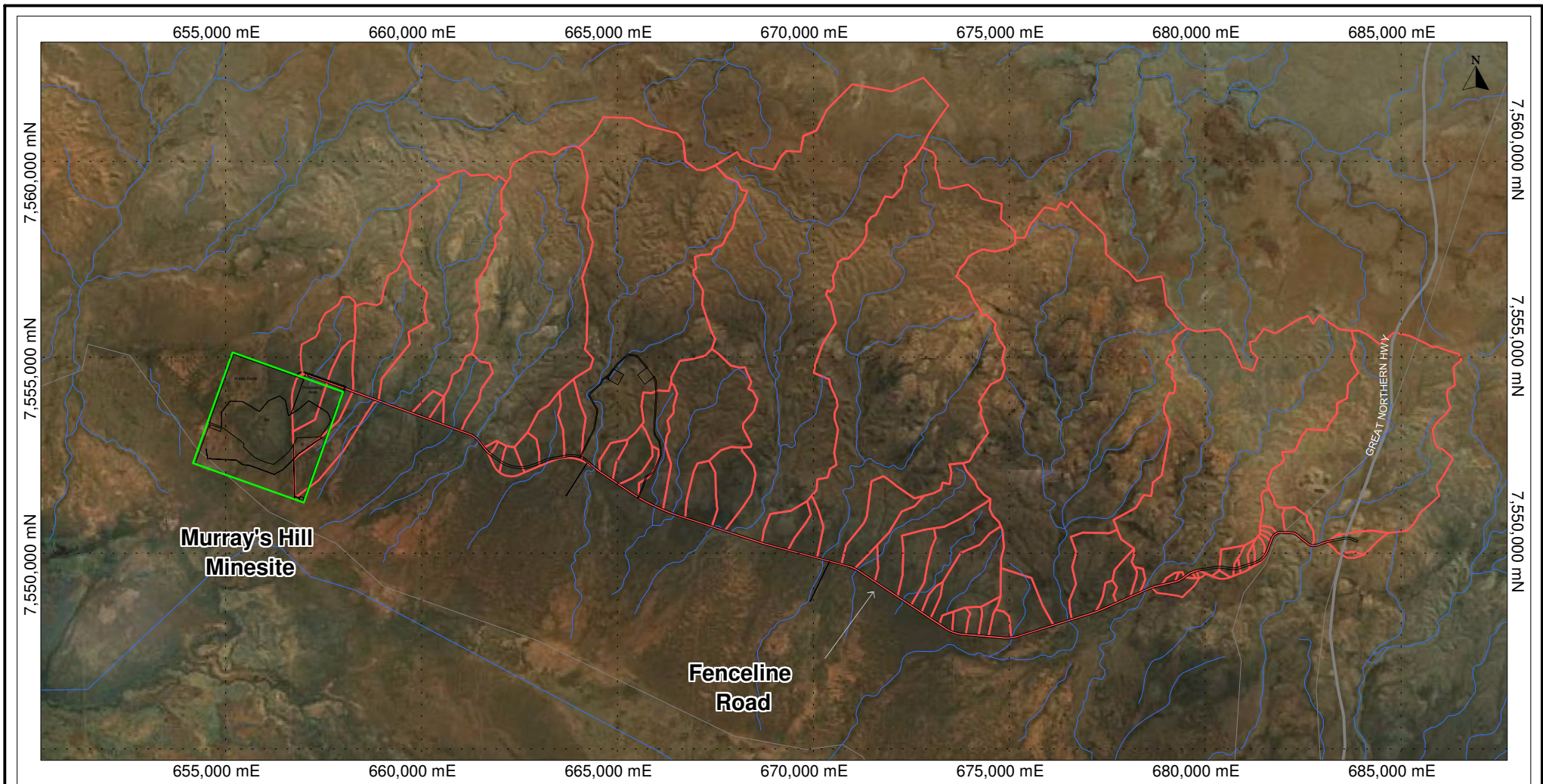
To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

LEGEND	
	FENCELINE ROAD
	TENEMENT BOUNDARY
	MINESITE INFRASTRUCTURE
	EXISTING CATCHMENTS



**FIGURE 2-5**  
**EXISTING PROJECT AREA**  
**CATCHMENTS**  
 MULGA DOWNS EPA REFERRAL

Author: RS, OB	Date: 23 October 2012
Revised: DJA	Project No.: 83500308
Projection: MGA 50, GDA94	Scale:








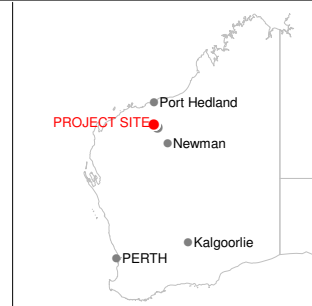
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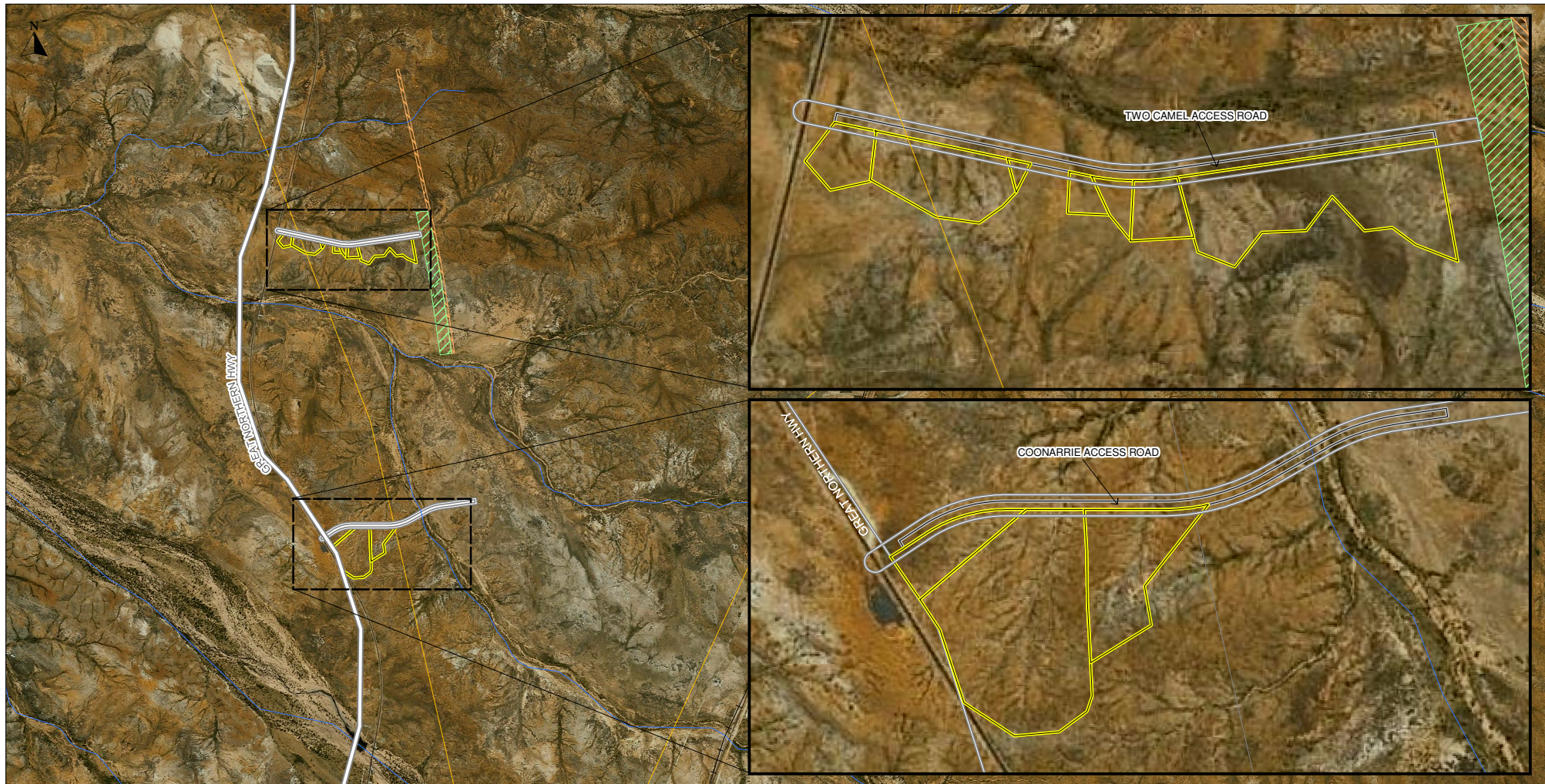
**Legend**

-  DRAINAGE LINES
-  HIGHWAY
-  MINESITE INFRASTRUCTURE
-  TENEMENT BOUNDARY
-  ENGENIUM-SUPPLIED CATCHMENTS



**FIGURE 2-6  
FENCELINE ROAD  
LOCAL CATCHMENTS  
MULGA DOWNS EA REFERRAL**

Author: OB	Date: 23 October 2012
Revised: DJA	Project No.: 83500308
Projection: MGA Zone 50 (GDA 94)	Scale:



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To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

**Legend**








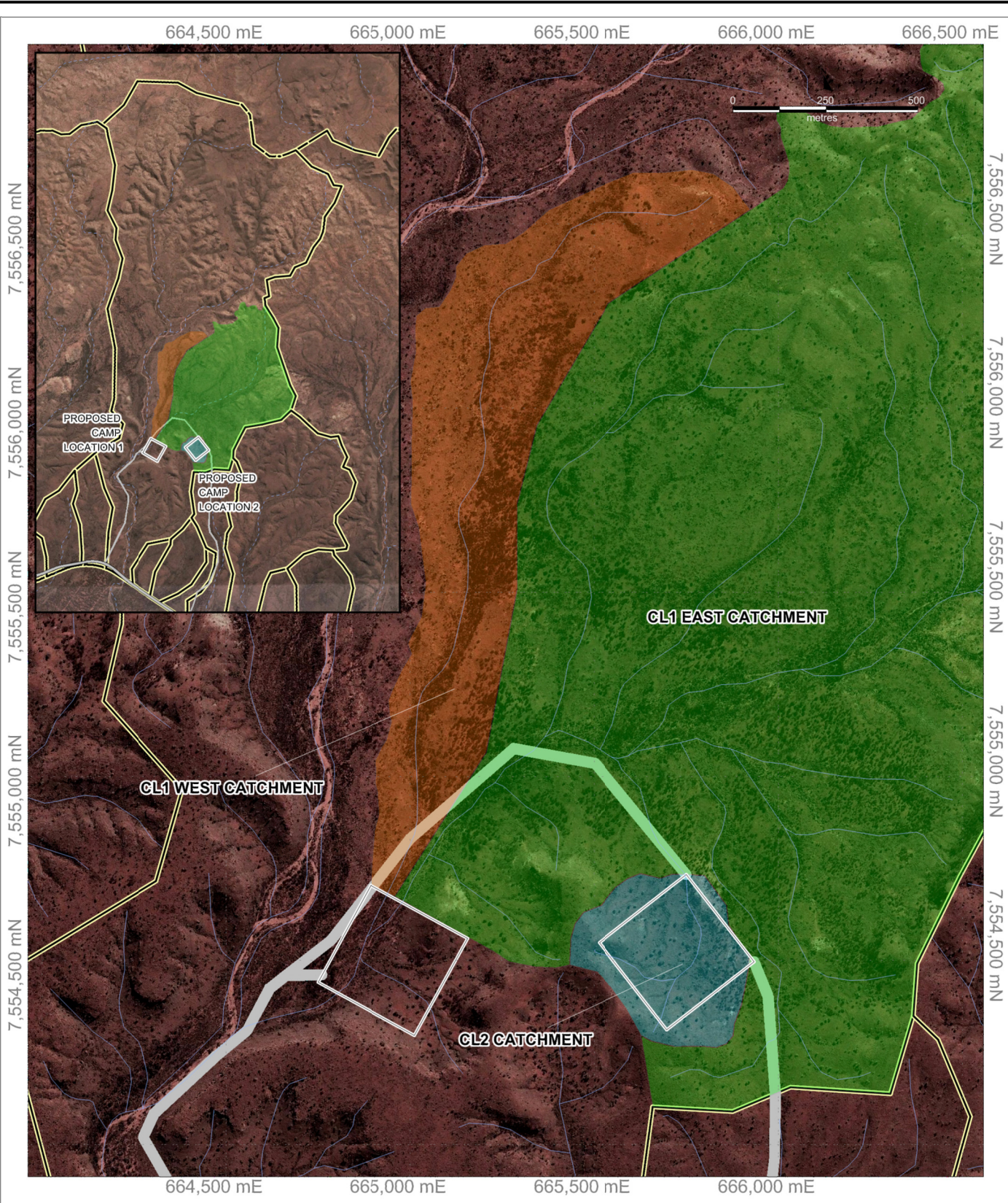
-  DRAINAGE LINES
-  HIGHWAY
-  ACCESS ROAD
-  SUBCATCHMENTS
-  ROAD CATCHMENT
-  PROPOSED SIDING
-  PROPOSED STOCKYARD



FIGURE 2-7  
**LOCAL SUBCATCHMENTS OF RAILWAY ACCESS ROADS**  
 MULGA DOWNS EPA REFERRAL

Author: RS, OB	Date: 23 October 2012
Revised: DJA	Project No.: 83500308
Projection: MGA Zone 50 (GDA 94)	Scale:








**Data Conditions**

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To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

**LEGEND**

-  DRAINAGE LINE
-  SUBCATCHMENTS
-  ACCESS TRACKS
-  FENCELINE ROAD
-  PROPOSED CAMPS



**FIGURE 2-8  
PROPOSED CAMP LOCATIONS  
LOCAL CATCHMENTS**

MULGA DOWNS EPA REFERRAL

Author: LVW, OB	Date: 23 Oct 2012
Revised:	Project No.: 83500308
Projection: MGA 50, GDA94	Scale:

## 2.5 Surface Water Quality

There are currently no operating streamflow or water quality gauging stations within the Goodiadarrie Swamp Catchment.

The closest streamflow gauging station to the railway siding and access road in the Yule Catchment is Jelliabidina Wells (Station No. 709005), which is located approximately 130km downstream of the proposed siding site.

The collection of any historical surface water quality data relevant to the project area is therefore not possible and the only means of estimating expected surface water quality in the project area is to make deductions from data collected at other sites with similar geology and topography in the Pilbara region.

Surface water quality in the Pilbara tends to be dominated by high sediment loads caused by the large runoff events generated by significant rainfall events and cyclones. The primary water quality parameters measured in the Pilbara are salinity and turbidity. In the absence of long term continuous water quality data, the seasonal variations in water quality and its interdependence on flows are difficult to understand. Salinity of surface water in the Pilbara region typically comprises calcium, bicarbonate, chloride and sodium. The relative composition of ions does not follow seawater and is considered to be derived from the weathering of the soils and rocks within the region (Ruprecht et al., 2000).

The relationship between flow rates and turbidity for rivers in the Pilbara has been examined (Ruprecht et al., 2000). In general, as the flow rate within rivers increases, during significant rainfall events, the turbidity increases. During flood events the turbidity levels are extremely high. This, however, is the opposite for flow and stream salinity. During low flows the salinity levels can be high relative to the salinity levels observed during high flow and flood events. This can be attributed to a combination of evaporative concentration and streamflows receiving groundwater discharge during the low flow periods.

## 2.6 Regional Hydrogeology

The regional hydrogeology of the Project area is closely related to the underlying geology. The mining tenement, Fenceline Road and camp locations are in a different geological province from the railway access roads and siding. The former is in the Central Pilbara Iron Ore geological province and the latter is in the Fractured Zone geological province.

The specific geology and hydrogeological characteristics pertaining to each site are discussed below.

## 2.7 Local Hydrogeology

### 2.7.1 Mining Tenement Area

#### 2.7.1.1 Site description

The mining tenement area (which incorporates Murray's Hill mine area, Fenceline Road and the proposed camp locations) lies along the northern flank of the Fortescue Valley, approximately midway between the Chichester Range and the internally draining Goodiadarrie Swamp to the south (Figure 2-9). The Goodiadarrie Swamp is bounded to the east by the Fortescue Marsh which lies within the Upper Fortescue River Catchment. The internally draining Fortescue Marsh contains highly saline groundwater.

The Goodiadarrie Hills form a major surface water and potential groundwater divide between the Fortescue Marsh and the Goodiadarrie Swamp. Groundwater in the Goodiadarrie Swamp is brackish to saline. Overflow from the Fortescue Marsh into the Goodiadarrie Swamp is considered unlikely owing to the elevation differences between the two systems. Available topographical data indicate that bed levels of the Fortescue Marsh lie between 400 mARL and 405 mARL, and that a flood elevation in the Marsh would need to exceed approximately 415 mARL to result in flood waters spilling westwards beyond the Goodiadarrie Hills.

The Goodiadarrie Swamp is bounded to the west by the Lower Fortescue River Catchment. Another surface water and potential groundwater divide is inferred to exist along this boundary, as suggested by differing water qualities. Shallow groundwater in the internally draining Goodiadarrie Swamp is brackish to saline whereas water in the lower portion of the Fortescue River is fresh, thus inferring the presence of a groundwater and surface water divide between the two hydrogeological systems. Although fresh water may collect on the surface of playa lakes within the Goodiadarrie Swamp during prolonged 'wet'

periods, overflow from the swamp into the Lower Fortescue River is considered unlikely based on the topography.

Figure 2-9 presents a schematic of the regional hydrogeology based on regional data, where available. At the mine site the alluvial deposits occur on the lower slopes and in general, their thickness increases in a south-westerly direction towards the Goodiadarrie Swamp. Tertiary calcrete outcrops to the south of the mining tenement area, where it is deposited widely along major drainage lines and on the fringes of the Goodiadarrie Swamp. The calcrete is considered to represent a zone of chemical precipitation of carbonates and silica in proximity to an historical water table. The calcrete unit is generally highly permeable. The detrital deposits comprise colluvial and alluvial sediments and include mineralized goethitic materials with hematite and maghemite pisoliths. The detrital deposits appear to be the primary water bearing unit within the stratigraphic sequence (Figure 2-9).

Dolomite of the Wittenoom Formation is inferred to exist in the south of the mining tenement area, and in the Goodiadarrie Swamp, where it is overlain by the Mt Sylvia Formation and Mt McRae Shale (Figure 2-9).

Regionally, the Marra Mamba Iron Formation consists of the Nammuldi, MacLeod and Mount Newman Members. The basal unit of the Marra Mamba Iron Formation, the Nammuldi Member, outcrops along the southern edge of the Chichester Range (Figure 2-9). The remaining members, Macleod and Mount Newman, are inferred to be either in sub crop below the Quaternary and Cainozoic sedimentary sequence that occupies the paleochannel of the Fortescue River, or have been removed by erosion (Figure 2-9).

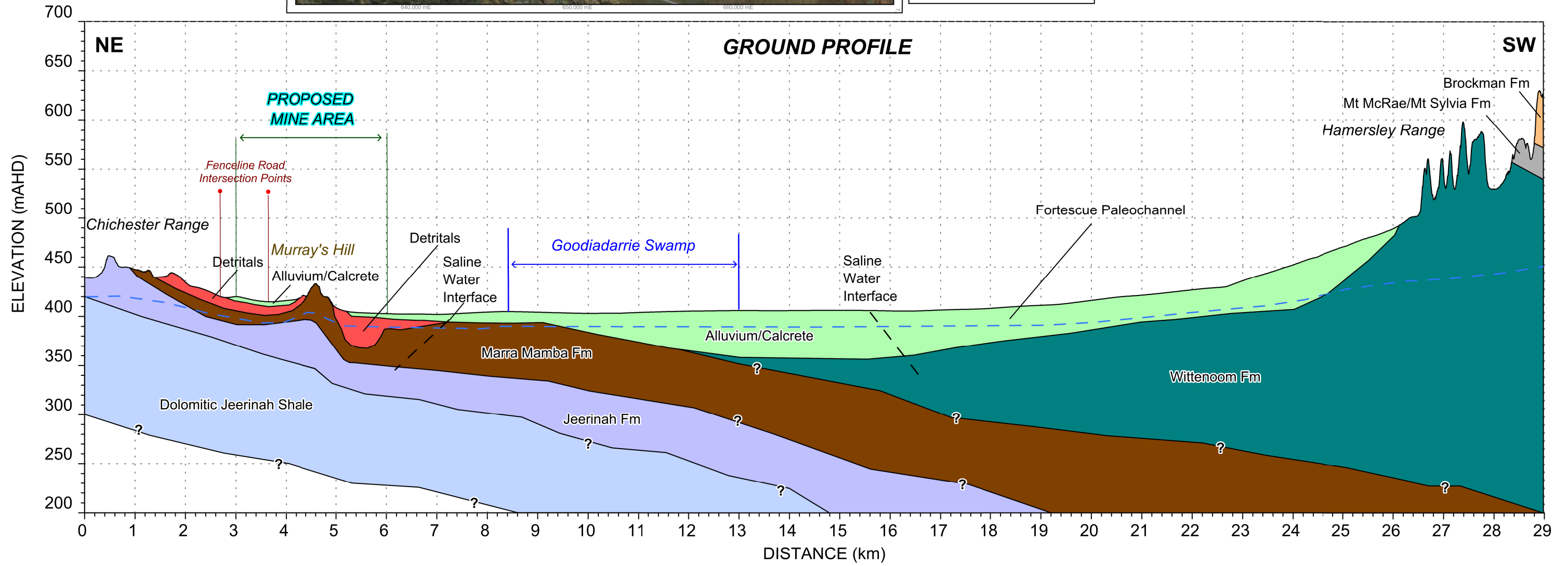
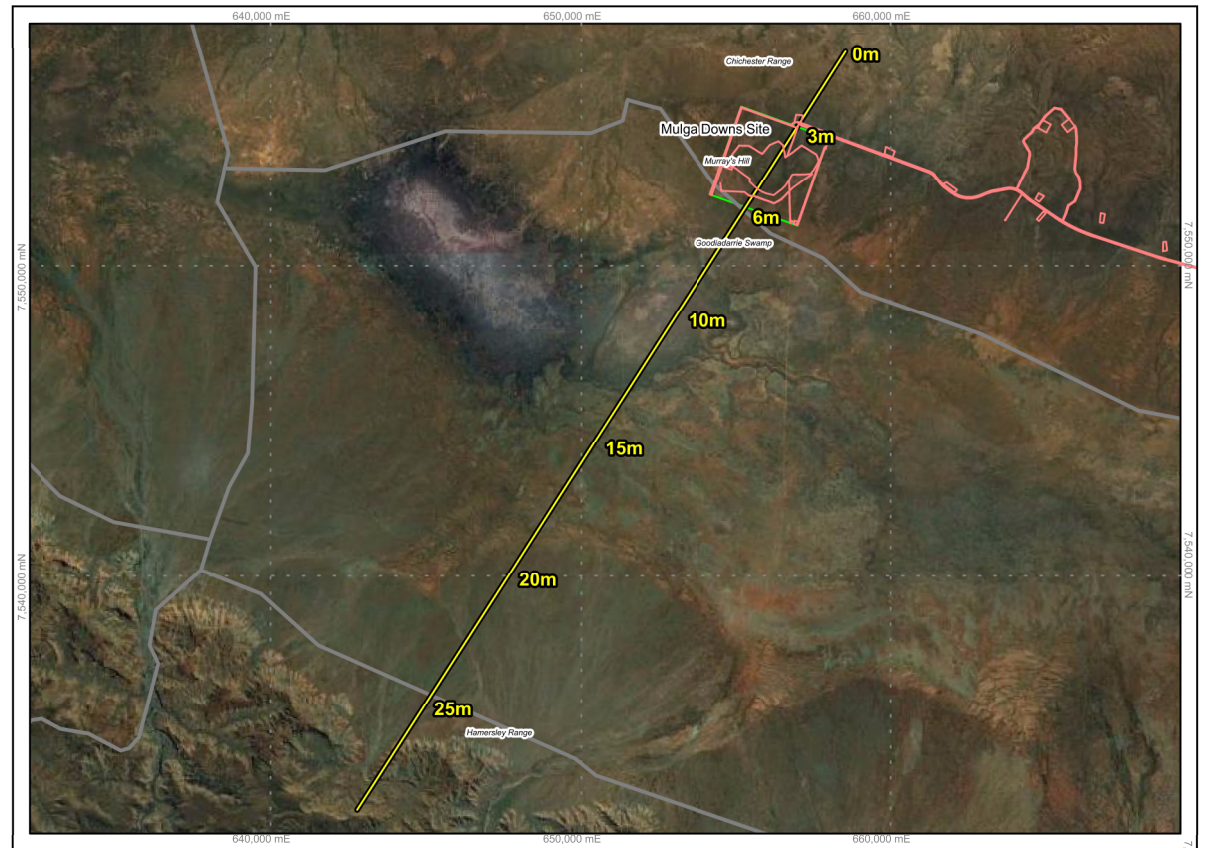


Fig 2-9

**MURRAY'S HILL REGIONAL CROSS SECTION**

MULGA DOWNS EPA REFERRAL

PROJECT NO: 83500308	DRAWN BY: OB	CHECKED BY: LS	REVISION: A
DATE MODIFIED: 28/09/2011	DATUM AND PROJECTION: MGA ZONE 50, GDA 94	SCALE: NTS	
WORKSPACE LOCATION: P:\Visual\GIS\Site\83500308 - Murray's Hill Surface Water Investigations\Workspaces_Hydrology\Figure2-9_Regional Cross-Section.wor			

NB: Data Conditions:- Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.



The Roy Hill Shale is the uppermost unit of the Jeerinah Formation. The Roy Hill Shale generally has low permeability, although some zones of relatively enhanced hydraulic conductivities associated with weathering and fracturing may be present. These permeable zones are typically associated with chert-dominated horizons. The Roy Hill Shale overlies the Warrie Member of the Jeerinah Formation, and conformably overlies the dolomitic upper part of the Warrie Member. The Warrie Member consists of shale, chert, mudstone, and dolomite, all of which are usually described as thin-bedded. This unit is typically weathered white on exposure, and characteristically dark grey or black in unweathered sections. The unit also commonly has spheroidal pyrite concretions about 1 to 3 centimetres in diameter (Geological Survey of Western Australia, 1990).

A summary of the main groundwater-related hydrogeological units in the mining tenement area is presented in Table 2-4.

**Table 2-3: Fortescue River area: regional Stratigraphic Sequence**

Formation	Member	Description and general hydraulic characteristics
<b>Alluvium</b>		Expected to be of low to moderate transmissivity where saturated based on visual inspection; moderate to high storage; may potentially accept significant recharge during major flood events, and facilitate subsequent leakage to underlying units.
	--	Carbonates / silicates to the south of the mining tenement area; generally highly permeable.
		Consist of goethite, hematite, chert, and clays; mineralized, pisolitic; moderate to high permeability and storage where saturated; considered to be a major water bearing unit.
<b>Wittenoom Formation</b>	--	Dolomite, chert and shale; to the south of the Project area; potentially enhanced permeability where dissolution may have occurred.
<b>Marra Mamba Formation</b>	Mount Newman Member	Banded Iron Formation (BIF), minor thin shales
	MacLeod Member	Shales, chert, and Banded Iron Formation (BIF)
	Nammuldi Member mineralised	Mineralised Banded Iron Formation (BIF); mineralisation results in enhanced permeability; major water bearing unit.
	Nammuldi Member unmineralised	BIF with chert and shale; low permeability
<b>Jeerinah Formation</b>	Roy Hill Shale Member	Black graphitic shale and chert; locally pyritic; low permeability
	Warrie Dolomite	Shale, chert (locally ferruginous), mudstone, and dolomite

Based on data available to date, some hydraulic characteristics have been inferred. Additional data will be available once on-going field investigations and data evaluation is complete. Present knowledge is

that depth to groundwater in the mining tenement area ranges from 5 to 40 mbgl, but may be as shallow as 3 mbgl at the southern margin of the area towards the Goodiadarrie Swamp.

A summary of likely hydraulic parameters for each of the hydrostratigraphic units based on review of data from similar stratigraphic sequences in surrounding areas is presented in Table 2-5. Geological and hydrogeological investigation sites in and surrounding the minesite are shown in Figure 2-10 and the estimates of the hydraulic parameters are summarised in Table 2-5.

**Table 2-4: Summary of Likely Hydraulic Parameters for the Hydrostratigraphic Units**

Stratigraphic Unit/Member	Range of K (m/d)	Mean K (m/d)	S <sub>y</sub>	Aquifer Type
Alluvium (where saturated)	NA	NA	1 - 3%	Aquifer (where saturated)
Calcrete/Silcrete	12-37	20	1 - 5%	Aquifer
Detritals	0.2 - 8	4	1 - 5%	Aquifer
Wittenoom/Carawine Dolomite	9-35	17	2 - 5%	Aquifer (where fractures/solution cavities exist)
Mineralised Nammuldi Member	2-500	69	1 - 3%	Aquifer
Unmineralised Nammuldi Member	NA	NA	0.1 - 1%	Aquitard
Jeerinah Formation	NA	NA	0.1 - 2%	Aquitard

K = Hydraulic Conductivity

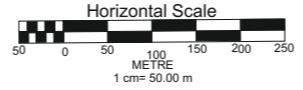
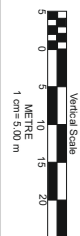
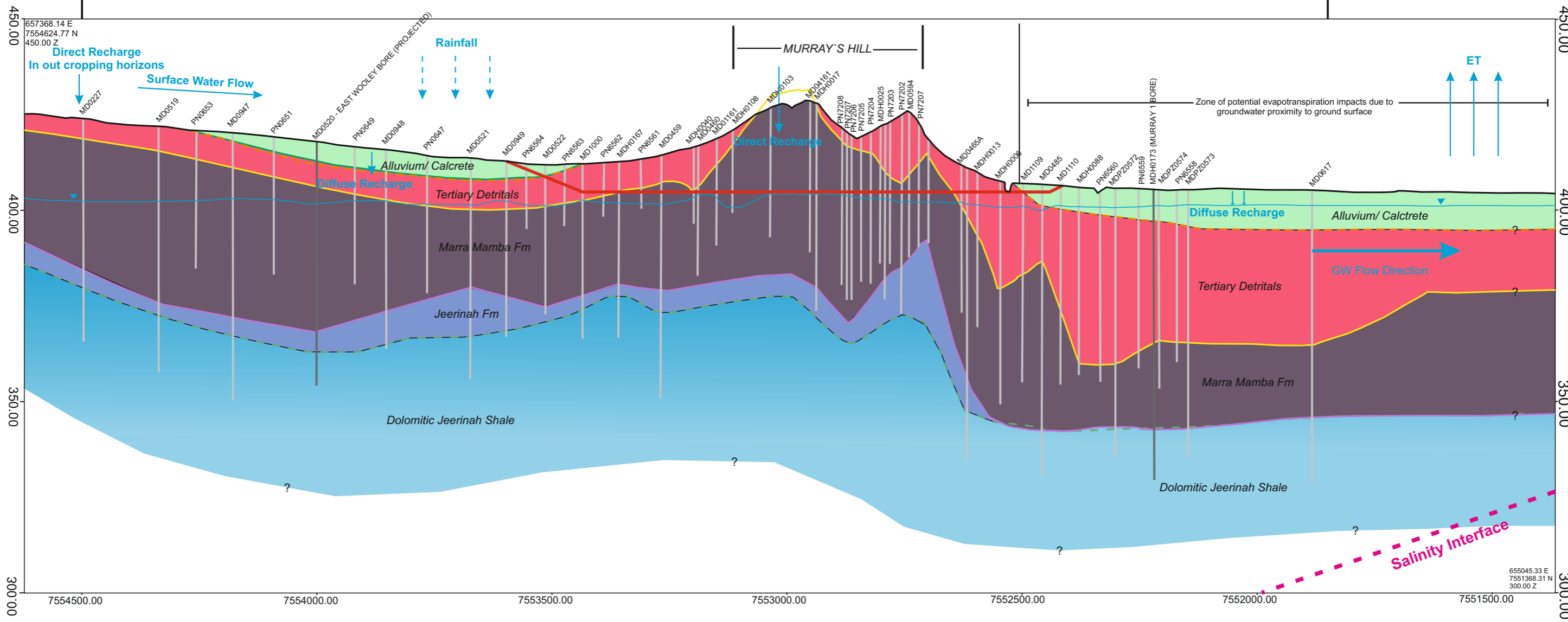
NA = Not available

S<sub>y</sub> = Specific Yield

NE

SW

MINE AREA TENEMENT LIMITS



**LEGEND**

- Alluvium/ Calcrete
- Tertiary Detritals
- Marra Mamba Formation
- Jeerinah Fm
- Jeerinah Dolomite
- RC BORES
- Pit Shell

Fig.2.10

MULGA DOWNS REGIONAL CROSS SECTION

MULGA DOWNS EPA REFERRAL

PROJECT NO: 83500228	DRAWN BY: FS	CHECKED BY: GC	REVISION: NO.
DATE MODIFIED: 19/09/2012	DATUM AND PROJECTION:		SCALE:
WORKSPACE LOCATION: P:\Visual\Core\Draw\Site\HPL Mulga Downs\Cross Section Mulga downs			

Data Conditions:  
 Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.



### 2.7.1.2 Groundwater quality

Relatively fresh groundwater exists within the colluvium fans extending south from the Chichester Range and within the mineralised down-dip portion of the Marra Mamba Iron Formation close to the northern edge of the valley (Figure 2-9). Groundwater salinity increases toward the Goodiadarrie Swamp and generally increases with depth toward the southern extent of the mine area. Figure 2-10 presents a hydrogeological cross-section across the mining tenement limits extending from the northeast to the southwest extent of the mine area based on site data from resource evaluation investigations.

A preliminary assessment of data from an airborne time-domain electromagnetic (TEM) survey undertaken over the mine tenement area in 2008 indicates a moderately low apparent conductivity groundwater zone underlying the Murray's Hill deposit. This zone becomes progressively thinner to the south as saline water is encountered at progressively shallower depths. A north-dipping saline water/fresh water interface is inferred in the shallow groundwater at approximately 2 km to the south of the mining tenement area (Figure 2-10).

Based on groundwater sampling during test pumping at two water supply bores within the mine area in 2009, shallow groundwater within the saturated alluvium, detritals, and upper mineralized Marra Mamba Formation is fresh (<1,000 mg/L TDS) to brackish (1,000 – 2,000 mg/L), with the higher concentrations recorded at the southern edge of the mine area. The groundwater is pH-neutral (7 to 7.5).

Salinity generally increases south towards the Goodiadarrie Swamp, and generally increases with depth at the southern extent of the mining tenement area. This trend is observed in salinity profile surveys performed quarterly in existing piezometers across the mining tenement area.

Groundwater samples collected from the two water supply bores in the mine area in 2009 indicate that the dominant cations are sodium, calcium, and magnesium, with the dominant anions being chloride, sulphate, and bicarbonate.

### 2.7.1.3 Recharge

As shown in Figure 2-10 groundwater recharge over the mining tenement area occurs via areal 'diffuse' recharge from precipitation events. The area receives an average of approximately 351 mm of rainfall annually (Bureau of Meteorology, Mulga Downs Station Station No. 5015). Aquifers within the alluvium/colluvium, detritals, and Marra Mamba Formation units are recharged via rainfall infiltration.

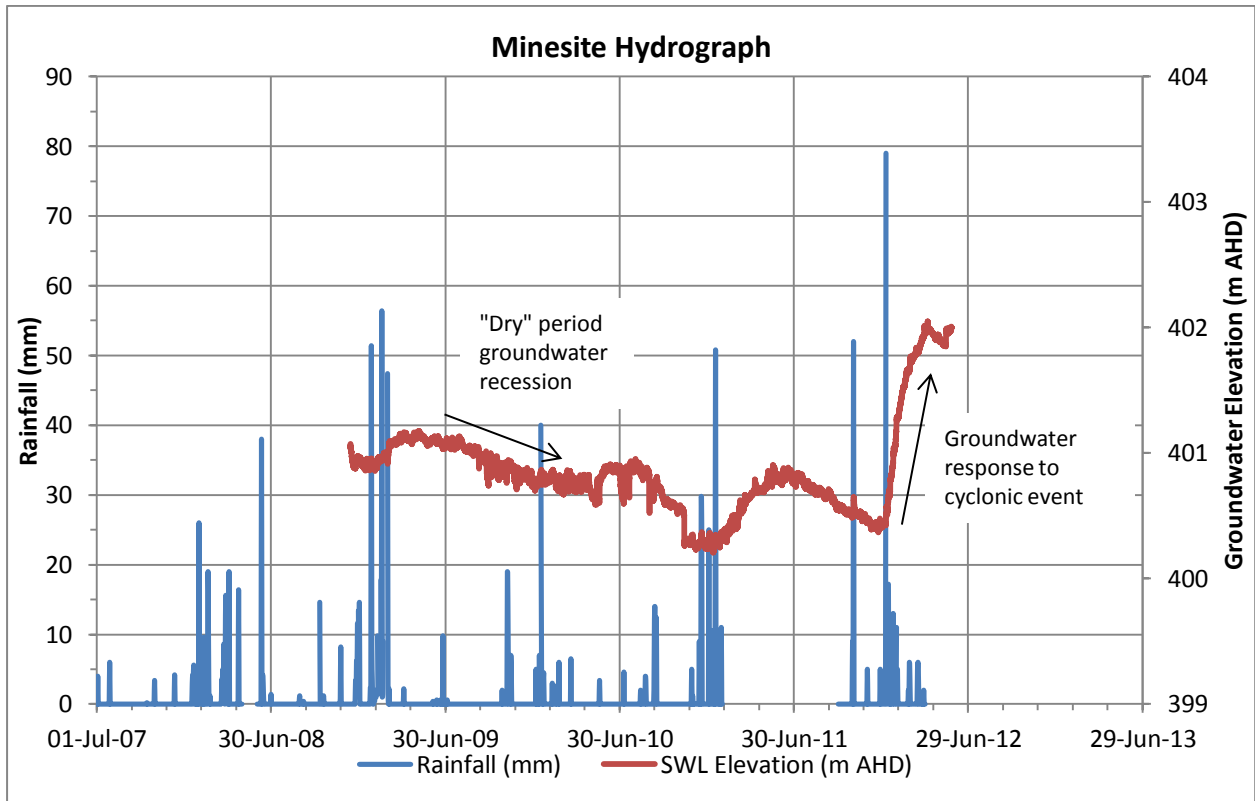
Direct rainfall recharge to the Marra Mamba Formation occurs where the formation outcrops along the southern flanks of the Chichester Range. Indirect diffuse recharge to the Marra Mamba Formation occurs via leakage from the overlying alluvium and detrital deposits. High evapotranspiration rates and moderate precipitation limit regional infiltration.

Estimates of recharge from rainfall in the Pilbara region range from 1 to 3% of mean annual precipitation. As such, areal recharge from rainfall infiltration in the general area is expected to be in the range of 3 to 10 mm/a. Substantial groundwater recharge occurs as a result of large cyclonic events.

### 2.7.1.4 Groundwater Levels and Topographically-driven Flow

Shallow groundwater flow in the vicinity of the mining tenement area is generally south away from the Chichester Range toward the Goodiadarrie Swamp area (Figure 2-10). Depth to groundwater varies from 35 to 40 m below ground level (mbgl) near the base of the Chichester Range, to 3 to 10 mbgl at the southern reaches of the mine area. Significant seasonal fluctuations have been observed, with groundwater levels rising up to 2 m at some locations following large cyclonic events. The piezometers within the Mine area are fitted with high frequency data loggers. Figure 2-11 is a hydrograph showing water table response to hydrologic events over a 4-year period for one of these piezometers. The hydrograph illustrates relatively rapid water table response to cyclonic events and groundwater recession during prolonged 'dry' periods.

Groundwater flow within the shallow groundwater system in the mining tenement area and vicinity generally mirrors the topography, with higher hydraulic heads from episodic rainfall infiltration on the elevated southern flanks of the Chichester Range driving groundwater movement towards areas of lower hydraulic head in the valley. Hydraulic gradients are higher (0.2%) in the northern portion of the mine area and flatten (0.1%) at the southern edge of the Mine area toward the Goodiadarrie Swamp. A water table contour map of the Mine area is presented in Figure 2-12.



**Figure 2-11: Groundwater Hydrograph**

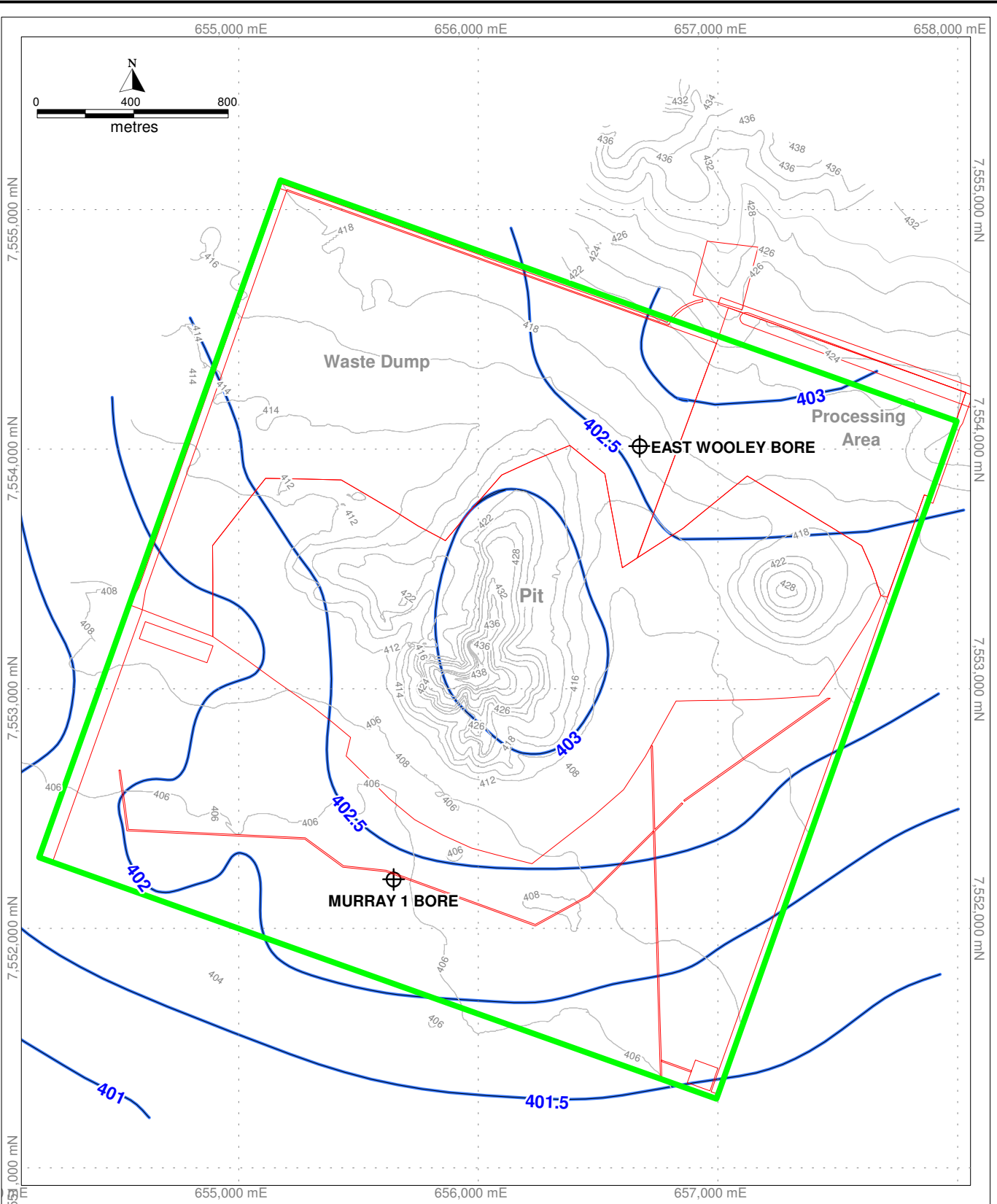
### 2.7.1.5 Storage and Throughflow

The mineralized detrital and mineralized Nammuldi Member aquifers are expected to have the greatest groundwater storage capacity based on visual observations and preliminary test pumping of two water supply bores in the mine area in 2009. Where saturated, the alluvium is also expected to contain low to moderate storage capacity.

The majority of throughflow is considered to take place within the mineralized detritals and upper Marra Mamba Formation aquifers. As shown in Figure 2-10 most of the recharge to these aquifers is from direct precipitation particularly in upland regions along the Chichester Range, and vertical leakage from the overlying alluvium.

### 2.7.1.6 Hydraulic Connectivity

The connection between recent alluvial deposits, the underlying mineralized detritals and the upper mineralized Marra Mamba Formation is potentially significant, as documented by notable rises in water levels (up to 2 m) in alluvium and underlying detrital/upper Marra Mamba Formation aquifers shortly after a cyclonic storm event (Figure 2-11). On-going field investigations will provide additional data for evaluation of hydraulic connectivity between these units.








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To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

**LEGEND**

-  EXISTING BORES
-  WATER TABLE CONTOURS (mAHd)
-  GROUND CONTOURS (mAHd)
-  PROJECT AREA AND INFRASTRUCTURES
-  TENEMENT BOUNDARY



**FIGURE 2-12  
GROUNDWATER CONTOURS  
FOR THE MINE AREA (SEPTEMBER 2012)**

MULGA DOWNS EPA REFERRAL

Author: OB	Date: 23 October 2012
Revised: DJA	Project No.: 83500308
Projection: MGA 50, GDA94	Scale:

### 2.7.1.7 Discharge

No springs or surface expressions of groundwater occur within the mining area.

Given the shallow groundwater depth at the southern extent of the mining tenement area, potential exists for groundwater discharge via evapotranspiration (ET) processes. Figure 2-10 highlights areas where ET losses are considered likely to occur given the proximity of the water table to the ground surface. ET losses are also a function of vegetation types. To further assess potential impacts of ET processes on the shallow water table, a literature review of vegetation types in the surrounding areas was performed.

Studies carried out at Cloudbreak mine (FMG, 2010) to the southeast of the Mulga Downs mine area indicate that vegetation types in the vicinity of the mining tenement area are not expected to contribute significantly to ET losses based on vegetation characteristics and areas of occurrence. However, further studies would be needed to evaluate specific ET losses from the Mulga Downs project area.

Potential also exists for groundwater discharge at the freshwater/saline water interface along the fringes of playa lakes in the Goodiadarrie Swamp, particularly during prolonged wet periods when fresh water ponds on the surface of the Swamp, and groundwater approaches ground surface. However, discharge through this mechanism is likely to be a small component of the regional groundwater discharge.

## 2.7.2 Railway Siding and Access Roads

### 2.7.2.1 Site description

The area lies approximately 80 km to the northwest of the Mulga Downs Mine area near Chainage 155 km along the proposed Roy Hill Rail alignment (Figure 1-1). This area is approximately 155 km south of Port Hedland along the Great Northern Highway. The area is located within *Water Areas* 23 and 24 along the Proposed Roy Hill Rail alignment. Each Water Area represents one of 49 separate areas targeted for a rail construction water supply investigation along the proposed rail alignment in 2012.

The Railway access roads and siding area is located between the Yule River and Coonarrrie Creek and in the vicinity of Two Camel Creek and is underlain by alluvium, and variably consolidated colluvium, derived from granitoid rocks. The underlying bedrock is pegmatite of the Yule Granitoid Complex, with possible areas of amphibolite containing abundant granitoid dykes and veins. The granitoid bedrock is bisected by a number of northwest/southeast trending regional fault, which is concealed by the superficial deposits.

Exploration drilling for water supply indicates the area is underlain by pockets of superficial alluvium comprising sand, silt and clay floodplain deposits, saprolitic clays, with sand and gravel alluvial channel deposits. These deposits, along with the upper weathered section of the underlying granitoid complex, form the primary water bearing aquifer in the area, and are underlain by relatively low permeability granitoid bedrock. The water table is relatively shallow at 3 to 9 mbgl.

### 2.7.2.2 Recharge

Groundwater recharge over the railway area occurs as areally 'diffuse' from precipitation events and also 'focused' from creeks following cyclonic events. Significant recharge of aquifers within the alluvial deposits likely results from direct recharge from the creek beds following cyclonic events based on the hydrological setting of the area.

The area receives an average of approximately 336 mm of rainfall annually (Bureau of Meteorology, Hillside Station No. 4015). Potentially high evapotranspiration rates and moderate precipitation limit regional recharge from rainfall.

Regional estimates of recharge from rainfall in the Pilbara region range from 1 to 3% of mean annual precipitation. As such, areal recharge from rainfall infiltration in the area is expected to be in the range of 3 to 10 mm/a, with substantial recharge occurring as a result of large cyclonic events.

### 2.7.2.3 Groundwater Levels and Topographically Driven Flow

A comprehensive evaluation of groundwater flow patterns in the area was unavailable at the time of reporting, due to on-going investigations. Groundwater elevation data from production bores in the vicinity of Water Area 23 suggest a northward flow gradient. However, local flow patterns are likely to mimic the surface water flow directions, northerly for the northern access road, and easterly for the southern access road.

#### 2.7.2.4 Storage and Throughflow

Based on visual observations the superficial alluvium and sand and gravel alluvial channel deposit aquifers are expected to contain the greatest groundwater storage capacity. The saprolitic clays will have low to modest storage. Where significantly weathered, the upper surface of the granitoid bedrock is expected to have significant storage capacity.

The majority of throughflow is considered to be within the sand and gravel alluvial channel deposit aquifers. Most of the recharge to these aquifers is considered to be via vertical leakage from the overlying alluvium and via direct infiltration for outcropping areas.

#### 2.7.2.5 Hydraulic Connectivity

Limited data are available to reasonably characterise hydraulic connectivity between adjacent hydrogeological units in this area. However, the connection between the superficial alluvium and underlying sand and gravel alluvial channel deposits is likely to be significant, as inferred from drilling and test pumping data from investigations carried out in 2012.

#### 2.7.2.6 Discharge

Depth to groundwater in the railway area ranges from 3 to 5 mbgl, but may be as deep as 9 mbgl further south. No springs or surface expressions of groundwater have been observed within the area or its vicinity.

Given the proximity of the water table to ground surface within the area, potential exists for groundwater discharge via evapotranspiration (ET). Studies carried out at Cloudbreak mine (FMG, 2010) to the southeast of the railway area suggest that vegetation types in the area are not expected to contribute significantly to ET losses based on vegetation characteristics and areas of occurrence.

#### 2.7.2.7 Water Quality

Preliminary hydrochemistry data from bores in the area indicates that the quality of shallow groundwater within the area is variable, ranging from a brackish 8,400 mg/L total dissolved solids [TDS] at PB155/23-1 to 560 mg/L TDS at PB161/24-2 approximately 6 km to the south (Figure 2-13). These values exceed the National Health and Medical Research Council (NHMRC) Guidelines for good quality drinking water (<500 mg/L). The water is slightly basic, with pH in the range of 8 to 8.4.

Groundwater samples from these bores indicate that the dominant cations are sodium and potassium, with the dominant anions as chloride and bicarbonate.

### 2.8 Existing Groundwater Sources

The proposed mining activities at Mulga Downs Murray's Hill deposit will be limited to mining above the water table. However, these activities are expected to utilise groundwater resources in the area to support construction and mining operations such as dust suppression, road construction and maintenance, and camp domestic water supplies.

This section discusses existing groundwater sources, pertinent characteristics of the groundwater resource within the Project area and immediate vicinity, and provides preliminary evaluation of the resource. A number of existing shallow pastoral bores exist throughout the area. Potential impacts of groundwater abstraction and the expected water demand for the proposed construction activities and mining operations is discussed in Section 4.0.

#### 2.8.1 Mining Tenement Area

Limited investigations have been conducted in the past within the mining tenement area to characterise the quantity and quality of the groundwater resources. These include preliminary test pumping of two water supply bores (Figure 2-11) and monitoring of groundwater levels at installed piezometers and open drill holes. The water supply bores were installed for drilling water supply only, and as such were not specifically designed to provide data for detailed hydrogeological assessments. However, data from these bores has been utilized in this review with recognition of their limitations.

Additional investigations in these areas are on-going. Hydraulic parameters from preliminary investigations in the mine area are presented in Table 2-5. These are derived from data collected from test pumping at two water supply bores in the mine area (Figure 2-11). Data from bores along Fenceline

Road are not available at the time of writing as test pumping of the bores is pending. Based on the noted similarities in preliminary drilling data and hydrostratigraphy, hydraulic characteristics of the stratigraphic sequence along Fenceline Road are expected to approximate those of the mine area.

The data presented in Table 2-6 represent bulk aquifer properties as the bores are screened across several hydrostratigraphic units, with a potential bias toward the more permeable units. A review of the field data (test duration, discharge rates/pump capacity, drawdown, etc.) suggest the hydraulic parameters listed in Table 2-6 are potentially overestimated. Minimal drawdown was observed in the pumped aquifers during the tests (0.1 m at Murray 1 Bore) at discharge rates of 10 L/s. As such, more comprehensive test pumping of the planned hydrogeological testing bores is required to define acceptable long-term abstraction rates.

On-going investigations at the mining tenement area will provide additional data for estimation of other pertinent aquifer parameters (amount of groundwater in storage, throughflow, etc).

**Table 2-5: Summary of Hydraulic Parameters from Investigations in the Mine Area**

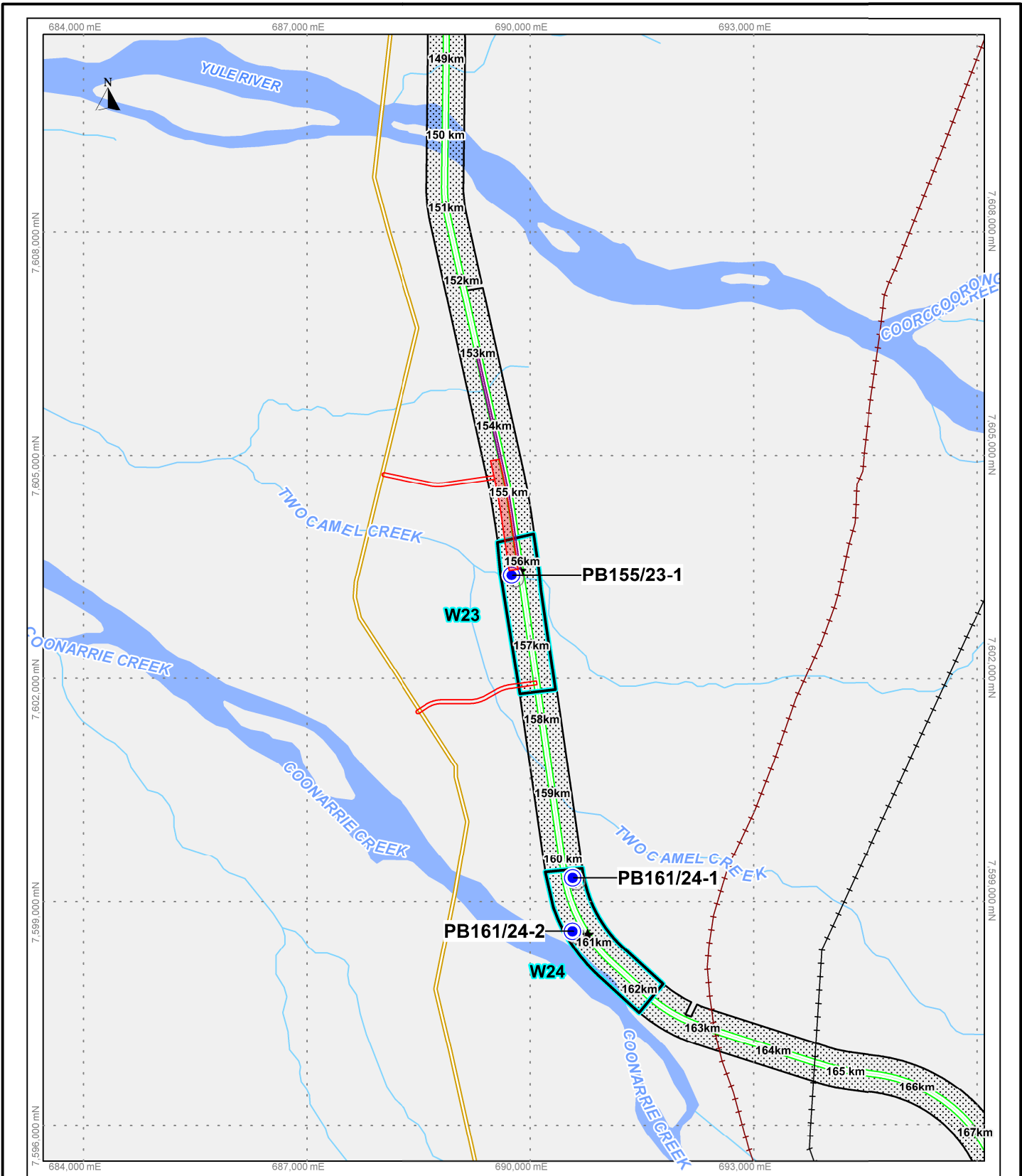
Bore name	Formation/Unit	T (m <sup>2</sup> /d)	K (m/d)	Storativity	Specific Yield
East Wooley	Alluvium	433	8.4	0.012	0.03 – 0.1
	Mineralised Detritals				
	Mineralised Nammuldi(?)				
Murray 1	Mineralised Detritals	982	17.9	0.012	0.01 – 0.28
	Mineralised Nammuldi				

K = Hydraulic conductivity

T = Transmissivity

m/d = metres per day

The local hydrogeology surrounding the proposed camp locations will be similar to that of Fenceline Road as the camp locations sit within the same aquifer system as that of Fenceline Road, albeit up-gradient of the road.













**Data Conditions**

Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.

To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

**LEGEND**

-  Production Bores (Recommended 1 Year Sustainable Yield (L/s) Indicated when Known)
-  BHP Rail
-  FMG Rail
-  Highway
-  RHIO Rail Alignment
-  PROPOSED STOCKYARD
-  PROPOSED SIDING
-  Water Areas
-  RHIO SRL 4SA
-  PROPOSED ACCESS ROADS



**FIGURE 2-13  
EXISTING WATER SUPPLY  
BORES: RAILWAY AREA**

MULGA DOWNS EPA REFERRAL

Author: OB	Date: 24 October 2012
Revised: DJA	Project No.: 83500308
Projection: MGA 50, GDA94	Scale:

## 2.8.2 Railway Siding and Access Roads

Prior investigations to characterise the quantity and quality of the groundwater resources in the vicinity of the Railway siding area have included drilling and installation of water supply bores at designated *Water Areas* along the proposed Roy Hill Rail alignment. The proposed Railway siding area is adjacent to water supply bore PB155/23-1 (Figure 2-13). Data from test pumping of this bore have been utilised in the discussion below. Data from PB161/24-1 and P161/24-2 located approximately 5 km and 6 km, respectively, to the south along the proposed rail alignment are also presented as these bores will likely be utilised for water supply.

A summary of pertinent hydraulic parameters derived from test pumping at PB155/23-1, PB161/24-1 and PB161-24-2 is presented in Table 2-7 below.

**Table 2-6: Summary of Hydraulic Parameters from Railway siding Area Bores**

Bore ID	Chainage (km)	Static Water Level (mbgl)	Transmissivity (m <sup>2</sup> /d)	Recommended Pumping Rate* (L/s)	TDS (mg/L)
PB155/23-1	155	3.17	3.95	1.5	7,300
PB161/24-1	160	9.95	27.9	2.0	1,200
PB161/24-2	161	9.16	38.0	7.0	570

L/s = Litres per second

m/d = metres per day

T = Transmissivity

\* based on maximum available drawdown

## 3 Surface Water Impact Assessment

### 3.1 Potential Sources of Impacts

The Project and its proposed infrastructure (including the mining pit) has the potential to impact on the surrounding surface water regime in the following ways:

- Modification and/or interruption of existing natural drainage channels and flows
- Upstream ponding and downstream shadowing effects
- Increased sediment runoff and scour
- Possible hydrocarbon and chemical contamination.

Within the Goodiadarrie Swamp catchment, the main downstream environmental value that is dependent on local surface water flows is the Goodiadarrie Swamp and its associated ecosystems.

Within the Yule River catchment, no environmentally significant features have been identified within the vicinity of the railway siding and its access roads

### 3.2 Findings of Surveys and Investigations

#### 3.2.1 Surface Water Flow Processes

Hydrological modelling was undertaken by MWH for the Murray's Hill minesite area to obtain a more detailed understanding of catchment response during rainfall events for both the base case scenario – i.e. existing environment – and the post-mining scenario. This section summarises the findings of this modelling investigation.

##### 3.2.1.1 Minesite Area

To understand the existing surface water regime in and around the minesite, a rainfall runoff model (RORB) was applied to the three sub-catchments surrounding the minesite area, as shown in Figure 3-1. These catchments define the main drainage paths for surface water flows that currently pass through and around the proposed minesite area. It should be noted that whilst the infrastructure is shown on Figure 3-1 no account has been taken of the presence of this infrastructure during the modelling for the existing scenario. The infrastructure is merely overlaid on this figure to allow the reader to visualise the location of the proposed infrastructure.

Table 3-1 summarises the RORB outputs for these three catchments for the critical storm durations in the existing environment. The critical storm duration can be defined as the duration of a rainfall event that causes maximum flow at a catchment outlet. These model peak flows therefore show what would currently be expected to occur immediately downstream of the minesite during flood events.

**Table 3-1: Peak Flows and Critical Durations for Existing Environment**

Catchment ID	Catchment Area (km <sup>2</sup> )	5-Year		10-Year		50-Year		100-Year	
		Flow (m <sup>3</sup> /s)	hrs	Flow (m <sup>3</sup> /s)	Hrs	Flow (m <sup>3</sup> /s)	Hrs	Flow (m <sup>3</sup> /s)	Hrs
West Catchment	17.9	57	12	83	12	150	6	212	6
Central Catchment	20.7	54	12	79	12	150	12	206	6
East Catchment	6.3	8	12	11	12	29	12	40	12

To understand how the surface water flow processes will be affected by the proposed mining activities and its associated infrastructure, the RORB model has been applied to a scenario which places the proposed operations and infrastructure within the existing sub-catchments. The outputs from this model scenario can then be compared with the existing scenario to establish the extent of the impact that mining within these catchments will have on the downstream flow regime.

Placing infrastructure within the minesite catchments will cause surface water flows to be intercepted at the upstream edge of the mining area (or mining lease boundary) and then diverted around the mining

operations. This ensures that the mine pit and associated infrastructure are protected from flood flows and the upstream “clean” surface water flows can pass the mining operations without the quality being compromised by the mining operations.

This diversion of surface flows effectively changes the shape and size of the catchments contributing to flows reaching the Goodiadarrie Swamp. These modified catchments are referred to as the operational RORB catchments for the minesite area. Figure 3-1 shows the existing and operation catchments, and how these will be modified by the diversion of flows around the minesite area.

From Figure 3-1 it can be seen that the area occupied by the mine pit, waste rock dump and processing area no longer contribute to catchment areas that flow into the Goodiadarrie Swamp. Rain falling on this area will be collected either in the pit or sedimentation ponds and will not find its way downstream, unless it is pumped out of the pit or released from the sedimentation ponds when of a suitable quality standard.

The West Catchment has effectively increased in size due to the diversion channels – from 17.9km<sup>2</sup> to 26.8km<sup>2</sup>. Likewise the East Catchment has effectively increased from 6.3km<sup>2</sup> to 9.2km<sup>2</sup>. Consequentially, the Central Catchment area has effectively decreased from 20.7km<sup>2</sup> to 3.1km<sup>2</sup>. Flows that now originate upstream of the mine that were previously flowing towards Goodiadarrie Swamp through the Central Catchment will be diverted into the East and West Catchments during operations. This increases the catchment area contributing to the outflows of the East and West Catchments, but decreases the outflow from the Central Catchment.

Overall, the three runoff catchment areas reduce from 44.9km<sup>2</sup> to 39.1km<sup>2</sup>. This reduction of 5.8km<sup>2</sup> is the area associated with the waste rock dump, the pit, the processing area and associated infrastructure. The Goodiadarrie swamp catchment has a total area of 4,138km<sup>2</sup>. Therefore the mining operations will reduce the total runoff area of the Goodiadarrie swamp catchment by 0.14%.

Table 3-2 is a summary comparison of the flows for the existing scenario (i.e base case) and the operational scenario. It can be seen from this table that the reduction in catchment area is reflected by a 36m<sup>3</sup>/s reduction in flood flows for the 5 yr ARI event and flows are similarly, reduced for all other events.

**Table 3-2: Comparison of RORB output flows for existing and operational scenarios**

Catchment	Scenario	Catchment Area (km <sup>2</sup> )	5-Year ARI		10-Year ARI		50-Year ARI		100-Year ARI	
			Flow (m <sup>3</sup> /s)	Critical Duration (hrs)	Flow (m <sup>3</sup> /s)	Critical Duration (hrs)	Flow (m <sup>3</sup> /s)	Critical Duration (hrs)	Flow (m <sup>3</sup> /s)	Critical Duration (hrs)
West Catchment	Existing	17.9	57	12	83	12	150	6	212	6
	Operational	26.8	61	12	89	12	183	12	242	6
Central Catchment	Existing	20.7	54	12	79	12	150	12	206	6
	Operational	3.1	13	12	20	12	30	1	46	1
East Catchment	Existing	6.3	8	12	11	12	29	12	40	12
	Operational	9.2	9	12	14	12	40	12	54	12
Totals	Existing	44.9	119		173		329		458	
	Operational	39.1	83		123		253		342	
Difference in Total (Operational minus Existing)		-5.8	-36		-50		-76		-116	

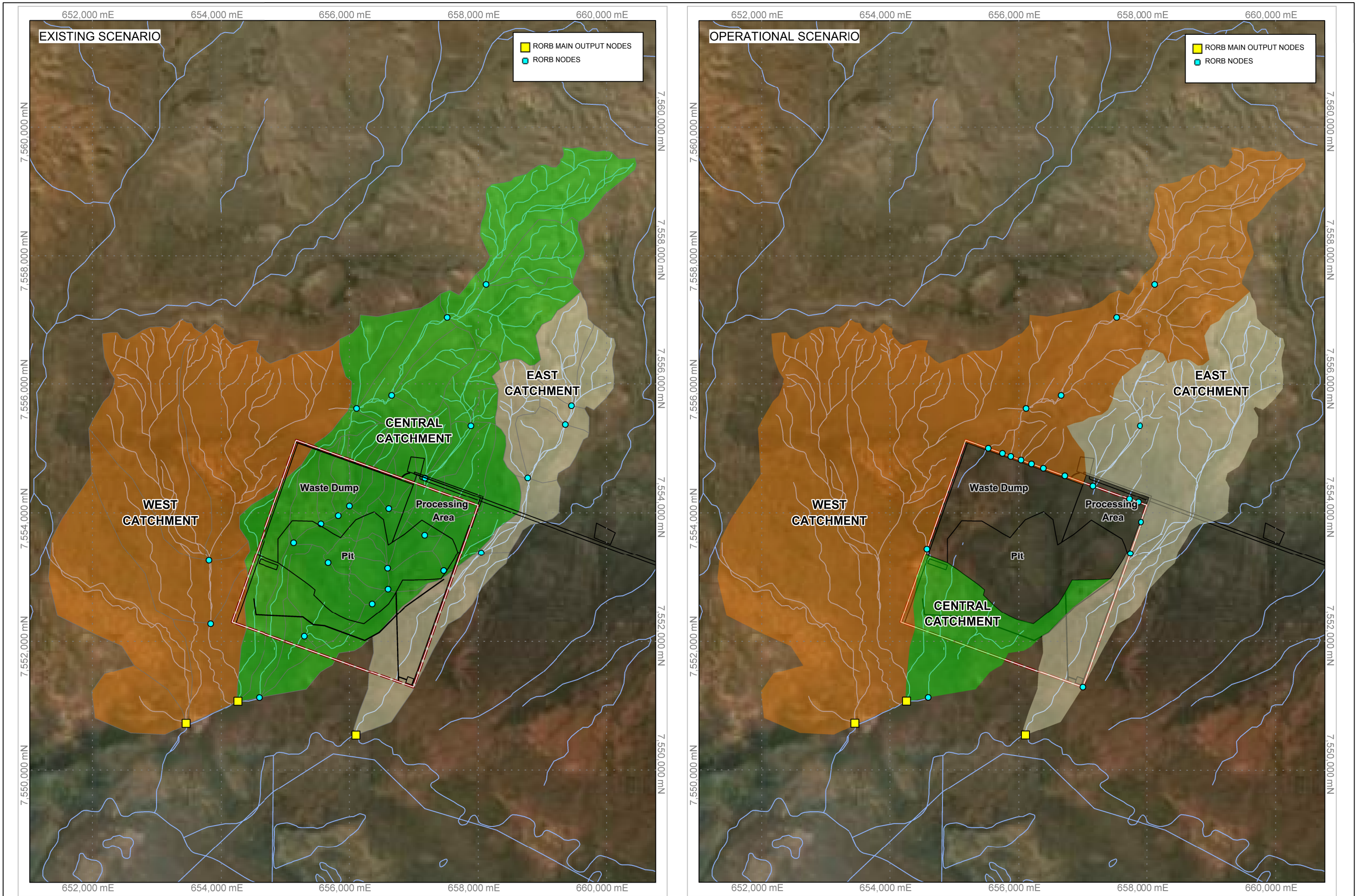


FIGURE 3-1

**PRE AND POST MINING RORB CATCHMENTS - MINESITE AREA**

MULGA DOWNS EPA REFERRAL

PROJECT NO: 83600308	DRAWN BY: DJA	CHECKED BY: LWW	REVISION: A
DATE MODIFIED: 24/10/2012	DATUM AND PROJECTION: MGA ZONE 50, GDA 94	SCALE: NTS	
WORKSPACE LOCATION: P:\Visual\GIS\83600308\Murray Hill Surface Water Investigations\Workspaces_Hydrology\EPA Referral Doc\Figure3-1_PreAndPostRORBCatchments.WOR			

NB: Data Conditions:- Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.



Of the catchments identified within the RORB modelling, three of the operational scenario catchments are not well represented by RORB, as it is primarily a catchment rainfall-runoff model. These catchments are those of the pit, the waste rock dump and the ore processing area. Within each of these catchments there is limited to no routing and a volumetric calculation of direct rainfall is more appropriate. The volume of runoff can be calculated from design rainfall depth, assumed losses to infiltration and evaporation and catchment area.

Rainfall losses were derived using the initial loss - continuing loss method. The design rainfall losses for the Pilbara region were adjusted to reflect a conservative approach to the modelling and to take into account the uncertainties and assumptions that are required for each of the three catchments. The conservative method saw the Pilbara region halved to allow for increased runoff and a conservative estimate of volumes. Some of the assumptions and uncertainties include, but are not limited to, runoff and infiltration rates within the waste rock dump, compaction of waste rock dump material, proximity of groundwater, benching within the pit, pit excavation strategy and the construction and compaction of the ore processing area.

Tables 3-3 to 3-6 shows the estimated direct rainfall volumes for the pit, waste rock dump and ore processing area. The critical peak volumes are highlighted in bold text within the tables. The critical duration storm event for each ARI has been highlighted as bold. The highlighted values show the maximum potential volume of runoff that could accumulate within each of the catchments for the given return period.

The total volume of runoff that reaches the Goodiadarrie Swamp will remain relatively unchanged as only direct rainfall within the pit will be lost from the catchment runoff. The area within which the loss occurs is only 2.86 km<sup>2</sup>, which makes up 0.07% of the total catchment area contributing to Goodiadarrie Swamp. The waste rock dump and the ore processing area runoff will be captured and diverted via sedimentation ponds to ensure that the water quality is improved prior to discharge back into the natural drainage channels and Goodiadarrie Swamp. This will delay the time of concentration for these small sub-catchments and reduce the overall peak flow. Direct rainfall into the pit area is not expected to reach Goodiadarrie Swamp, unless pumped out and discharged. This volume is lost from the catchment through evaporation and infiltration whilst trapped within the pit. The pit, waste rock dump and the ore processing areas represent 5.8km<sup>2</sup>, which is 0.14% of the total catchment area contributing to Goodiadarrie Swamp.

**Table 3-3: Estimated Pit Direct Rainfall Volumes.**

Duration	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
10 minutes	5,339			1,907	37,180	62,443
20 minutes	23,738	18,685	14,395	37,657	81,033	112,493
30 minutes	36,465	36,751	35,893	63,635	112,970	148,720
1 hour	59,488	70,928	77,220	114,400	176,462	222,794
2 hours	75,218	100,958	117,546	167,024	246,818	308,022
3 hours	81,224	117,260	141,284	199,914	294,294	366,938
6 hours	<b>83,626</b>	140,426	181,610	260,832	385,242	483,626
12 hours	70,756	<b>153,468</b>	<b>214,214</b>	317,460	479,622	610,610
24 hours	24,424	134,592	<b>214,214</b>	<b>343,543</b>	<b>544,830</b>	<b>703,274</b>
48 hours		30,945	127,728	279,022	509,137	697,783
72 hours				156,156	404,118	607,864

**Table 3-4: Estimated Waste Rock Dump Direct Rainfall Volumes.**

Duration	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
10 minutes	3,976			1,420	27,690	46,505
20 minutes	17,679	13,916	10,721	28,045	60,350	83,780
30 minutes	27,158	27,371	26,732	47,393	84,135	110,760
1 hour	44,304	52,824	57,510	85,200	131,421	165,927
2 hours	56,019	75,189	87,543	124,392	183,819	229,401
3 hours	60,492	87,330	105,222	148,887	219,177	273,279
6 hours	<b>62,281</b>	104,583	135,255	194,256	286,911	360,183
12 hours	52,696	<b>114,296</b>	<b>159,537</b>	236,430	357,201	454,755
24 hours	18,190	100,238	<b>159,537</b>	<b>255,856</b>	<b>405,765</b>	<b>523,767</b>
48 hours		23,047	95,126	207,803	379,183	519,677
72 hours				116,298	300,969	452,710

**Table 3-5: Estimated Ore Processing Area Direct Rainfall Volumes.**

Duration	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
10 minutes	1,512			540	10,530	17,685
20 minutes	6,723	5,292	4,077	10,665	22,950	31,860
30 minutes	10,328	10,409	10,166	18,023	31,995	42,120
1 hour	16,848	20,088	21,870	32,400	49,977	63,099
2 hours	21,303	28,593	33,291	47,304	69,903	87,237
3 hours	23,004	33,210	40,014	56,619	83,349	103,923
6 hours	<b>23,684</b>	39,771	51,435	73,872	109,107	136,971
12 hours	20,039	<b>43,465</b>	<b>60,669</b>	89,910	135,837	172,935
24 hours	6,917	38,119	<b>60,669</b>	<b>97,297</b>	<b>154,305</b>	<b>199,179</b>
48 hours		8,764	36,175	79,024	144,196	197,624
72 hours				44,226	114,453	172,157

### 3.2.1.2 Fenceline Road

To date MWH have not carried out any rainfall runoff modelling along the alignment of the Fenceline Road catchments as this is being covered by the road engineers.

Fenceline Road will form a barrier to surface water flows draining into the Goodaidarrie Swamp. To understand the types of surface water flows expected in the catchments which cross Fenceline Road, catchments have been categorised according to their size:

- small catchments – area < 2 km<sup>2</sup>,
- medium catchments – area > 2 km<sup>2</sup> < 15 km<sup>2</sup>
- large catchments > 15 km<sup>2</sup>.

Along Fenceline Road 68 catchments have been identified - 55 are small, 6 are medium and 7 are large. Although surface water flows will follow some of the smaller creeks and drainage lines, sheet flow may also be a characteristic flow mechanism within some of these small to medium sized catchments. However, the positioning of the road alignment at the break of the slope and the gradient off the escarpment is likely to induce channel flows upstream of the road alignment, and sheet flows on the upstream side of the alignment will be minimal. On the downstream side of Fenceline Road, sheet flow will become the primary form of surface runoff as flows move into the sandy outwash plains of the Goodaidarrie Swamp.

Sheet flow is defined as overland flow or the downslope movement of water which takes the form of a thin, continuous film over relatively smooth soil, rock surfaces or saturated surfaces. In contrast to channel flow, sheet flow is not concentrated into channels larger than rills (shallow gullied channels).

### 3.2.1.3 Camp Locations and Access Roads

MWH have not carried out any hydrological modelling on the catchments associated with the proposed camp locations. Figure 2-8 shows the local catchments that are upstream of the proposed camp locations.

#### ***Camp Location 1***

Camp location 1 has two upstream catchments, the flows from which will need to be diverted around the camp and its associated infrastructure. This ensures that the camp is protected from flood flows and the upstream “clean” surface water can pass around the camp without the quality being compromised. Diverted flows will be directed back into the same drainage line just downstream of the camp location

#### ***Camp Location 2***

Camp location 2 sits within a very small sub catchment area of 0.16km<sup>2</sup>. The total footprint for the proposed camp is 0.09km<sup>2</sup>. This leaves a very small upstream catchment area for this proposed camp location, and very little diversion of surface flows will be necessary to protect the camp.

### 3.2.1.4 Railway Siding Access Roads

To date MWH have not carried out any rainfall runoff modelling along the alignment of either of the proposed access roads as this is being covered by the road engineers.

Two Camel Access Road intersects seven sub-catchments all of catchment sizes less than 0.1 km<sup>2</sup>. Coonarie Access Road crosses Two Camel Creek and intersects three sub-catchments, all of which are less 0.16 km<sup>2</sup> in extent. Due to the location and nature of these catchments, it is not expected that sheet flow will be a predominant form of runoff for these catchments.

## 3.3 Evaluation of options or alternatives to avoid or minimise impact

The evaluation of options or alternatives to avoid or minimise impacts as a result of mining are limited by the location and extraction of the mineral resource.

The most significant option utilised to avoid and minimise impacts is the proposal above water table mining option. This implies that no surface water expression or dewatering of groundwater will be required.

### 3.4 Assessment of likely direct and indirect impacts

To gain an understanding of the extent of the impact of mining on the local and regional surface water regime it is important to establish the percentage disturbance that the operations will cause within the local and regional catchments. Table 3-3 shows the percentage of the total catchment areas that are to be occupied by the various project components.

**Table 3-6: Percentage Disturbance within Regional Catchments and Sub-Catchments**

Regional Catchment	Catchment/Sub-Catchment Area (km <sup>2</sup> )	Project Component	Footprint (km <sup>2</sup> )	% Disturbance
Goodiadarrie Swamp Catchment	4,138	Mine operations area  (Pit + Waste dump + Infrastructure)	5.8 (580 ha)	0.14%
Goodiadarrie Swamp Catchment	4,138	*Fenceline Road  (including borrow pits)	1.95 (195 ha)	0.05%
Goodiadarrie Swamp Catchment	4,138	Camp Location 1	0.2 (20 ha)	0.005%
Goodiadarrie Swamp Catchment	4,138	Camp Location 2	0.2 (20 ha)	0.005%
<b>Goodiadarrie Swamp Sub-Catchment Totals</b>			<b>7.95 (795 ha)</b>	<b>0.2%</b>
Yule River Catchment	8,860	Railway Siding	0.18 (18 ha)	0.002%
Yule River Catchment	8,860	Two Camel Access Road	0.08 (8 ha)	0.0009%
Yule River Catchment	8,860	Coonarrie Access Road	0.08 (8 ha)	0.0009%
<b>Yule River Catchment Totals</b>			<b>0.26 (26 ha)</b>	<b>0.003%</b>

The percentage of the total catchment area of the Goodiadarrie Swamp Catchment that the project components will occupy is 0.2%. This is a relatively small percentage of the total catchment area of 4,138km<sup>2</sup>, which implies any alteration to the surface water regime may be noticed at a local level around the minesite, Fenceline Road and camp locations, but will not be a significant impact within the Goodiadarrie Swamp Catchment. The impact that the mining operations will have on the inflows into the Goodiadarrie Swamp is therefore relatively insignificant.

The railway siding and its access road constitute a 0.003% disturbance in the Yule River Catchment. This implies that any alteration to the catchment hydrology at this level of disturbance would be insignificant.

Although the overall significance of the impact of mining on the hydrological regime is insignificant based on the above percentages of disturbance it is worth considering the impacts in more detail.

### **3.4.1 Modification or interruption of existing natural drainage channels and/or flows**

#### **3.4.1.1 Minesite Area**

As discussed in Section 3.2, the proposed mining operations will interrupt and modify natural drainage lines and will capture rainfall within pit area. As discussed, the overall effect of this diversion is not considered to be significant as most flows are diverted around the infrastructure and still find their way into the receiving Goodiadarrie Swamp. Only small volumes – equivalent to the rainfall depth of an event – will be captured in the mine pit and will not reach the Goodiadarrie Swamp.

#### **3.4.1.2 Fenceline Road**

The access road may intercept some catchments that display sheetflow, however, due to the location of all access roads the impact that these roads will have on interrupting sheet flows is minimal.

#### **3.4.1.3 Camp Locations and Access Roads**

Camp location 1 will interrupt flows from two small upstream sub-catchments (shown in Figure 2.8). These diverted flows will be directed back into their original drainage lines just downstream of the camp. The impact of this flow modification will therefore be minimal.

Camp location 2 sits within a small catchment and does not have much through-flow of surface water. Minimal surface water diversion will be necessary at this site and the impacts on the modifications of flows at this site are insignificant.

It is understood that the camp access roads will be constructed at grade so the presence of these roads will not significantly interrupt or modify any existing drainage patterns.

#### **3.4.1.4 Railway Siding Access Roads**

Out of the two proposed railway siding access road options, the modification or interruption of flow impacts will be larger for Two Camel Access Road as it intersects more catchments than Coonarrie Access Road and runs across the local topography. Sheet flow is more likely along the alignment of Two Camel Creek than Coonarrie Access Road due to the gently undulating topography around Two Camel Creek Access Road. As Coonarrie Access Road follows the local topography down towards Two Camel Creek the impact of the road will be less than that of Two Camel access road, as the flows are not likely to be interrupted by the road alignment.

Overall the impact of the roads, in terms of the modification or interruption of existing flow, will be negligible due to the access roads representing only 0.001% of the total Yule River Catchment.

### **3.4.2 Drainage shadows and ponding**

Where surface water flows are intercepted and/or modified by the presence of mining operations and the associated infrastructure, there is an increase in the potential for localised ponding to occur immediately upstream of the infrastructure and water shadows to develop immediately downstream. This impact is most likely to occur when sheet flows are interrupted and is less likely to occur if channel drainage is intercepted.

Downstream shadows can also occur downstream of infrastructure areas where flows are diverted away from their natural drainage lines and into adjacent drainage lines

#### **3.4.2.1 Minesite Area**

As already discussed, the occurrence of sheet flows in the minesite area is minimal. Therefore the likelihood of ponding upstream of the minesite area is highly unlikely.

Figure 3-1 shows the adjustment to catchments as a result of the interruption of the natural drainage lines and Section 3.2 discusses the changes in flow regimes as a result of the diversion of flows around the minesite area. Table 3.1 details the changes in downstream flood flows in the operational scenario.

The diversion of flows from the East and West Catchments (Figure 3-1) will have the effect of reducing the flows in the Central Catchment. This will create a shadow effect for the remaining portion of the Central Catchment. This may have an impact on the ecosystems occurring locally within this catchment that may need to be investigated further by the relevant ecological specialists. However, the effect of this within the Goodiadarrie Swamp catchment will be minimal.

### 3.4.2.2 Fenceline Road

Along the alignment of Fenceline road, the potential for drainage shadows and ponding will be greatest within the small and medium catchments where sheet flow is a characteristic of the natural flow regime. However, as already discussed, it is not expected that sheet flow is a primary runoff characteristic within many of these catchments.

The impact of any potential ponding and drainage shadow is likely to be small and localised given the presence of the existing Fenceline Road and the use of the floodways and causeways in the construction of the road upgrade.

To identify areas that may be sensitive to the alteration of sheet flows, it is recommended that further studies be done to:

- Identify the catchments along the alignment that display sheet flow characteristics;
- Identify any significant upstream or downstream environmental values that may be affected by potential ponding and shadowing.

### 3.4.2.3 Camp Locations and Access Roads

Camp location 1 will have the effect of a minor downstream shadow as flows are diverted around the camp area. However, this impact will be very insignificant as flows will be diverted back into their original drainage lines just downstream of the camp.

Camp location 2 will not have any upstream ponding or downstream shadowing impact as minimal surface water diversion will be necessary at this site.

As the camp access roads will be constructed at grade, there should be an insignificant impact on ponding and shadowing along this alignment.

### 3.4.2.4 Railway Siding Access Roads

Minor amounts of drainage shadow and ponding may occur in some areas along the Two Camel Access Road alignment. The impacts will be localised and minimal due to the close proximity of the catchment watershed to the road alignment, the short length of the road and the small catchment sizes involved.

Drainage shadow and ponding is not likely to occur along the Coonarie Access Road as the road cuts across the contours and does not intersect many drainage lines.

## 3.4.3 Increased sediment runoff and scour

### 3.4.3.1 Minesite and Camp Locations

An increase in sediment runoff and scour is likely to occur as a result of ground disturbance and vegetation removal required for mining operations and associated mine infrastructure. The diversion of flows into defined channels (diversion channels) has the potential to concentrate flood flows and increase flood velocities, thereby increasing the potential for scour. The extent of these impacts is largely dependent on the engineering design of the diversion channels which will carry surface flows from the upstream side of the mining operations to the downstream side. These diversion channels and the recommendations for the mitigation of this potential impact are discussed in more detail in Section 3.6.

The waste rock dump has the potential to increase sediment runoff as it is susceptible to erosion during high rainfall events. Minor rainfall events will not pose a high potential for erosion as the initial losses of a waste rock dump are relatively large. The extent of these impacts is largely dependent on the engineering design of a downstream sedimentation pond. This management and mitigation option is discussed in more detail in Section 3.6.

Any impacts to the water quality as a result of the mining operations will be minimal due to the small percentage of total area that is occupied by the mining activities – 0.2% (Table 3-3).

### 3.4.3.2 Fenceline Road

The upgrade of Fenceline Road is not likely to greatly increase the potential for erosion and scouring of channels and banks of natural surface drainage lines.

Existing drainage lines which intersect the road alignment are well defined and flows during significant rainfall events will be typically of high velocity and short duration in nature as flows come down off the Chichester Ranges. These are likely to be historically dominated by high levels of turbidity related to the levels of flow that occur during a runoff event. However, flows on the downstream side of the road alignment are more likely to have a higher sediment load than those on the upstream side. This is due to the geology of the Chichester Ranges and the presence of outcrops on the upstream side, as opposed to the sandy out wash plains on the downstream side.

These potential impacts need to be managed by the correct construction of floodways and causeways. This is discussed in more detail in Section 3.6

### 3.4.3.3 Railway Siding Access Road

The Two Camel Access Road alignment is likely to have the least impact out of the two proposed alignments as the catchment areas are small and the gradient is such that flow volumes will be relatively small and of low velocity.

The potential for erosion and scouring along the Coonarrie Access Road alignment is greater as the alignment cuts across the contours and will channel water directly towards Two Camel Creek, this channelling is likely to generate new drainage channels along the boundary of the new roadway unless the roadside drainage channels are designed appropriately.

Again, these potential impacts need to be managed by the correct construction of floodways and causeways. This is discussed in more detail in Section 3.6.

## 3.4.4 Potential hydrocarbon and chemical contamination

Mining activities have the potential to contaminate surface water with hydrocarbons and chemicals. If best practices are adhered to, the risk of this potential occurring is significantly reduced. Examples of how chemical and hydrocarbon contamination can occur include but are not limited to:

- a hydrocarbon or hazardous substance spill
- discharge of untreated sewage
- overflow of sedimentation pond
- hydrocarbon contaminated water from workshops and wash-down areas flowing into natural drainage line.

The likelihood of chemical and hydrocarbon contamination occurring is low and the significance of the impact on the regional catchments would be minimal due to the relatively small percentage of disturbance that the minesite occupies within the regional catchment areas.

The potential for these impacts can be significantly reduced using best practices and appropriate management measures as described in Section 3.6.

## 3.5 Cumulative Impacts

Within the Goodiadarrie Swamp Catchment there is currently no other mining operations. It is therefore not necessary to consider the impact of the Mulga Downs Project within the Goodiadarrie Swamp Catchment as a cumulative impact.

Within the Yule River catchment there are some mining operations and associated infrastructure. However, the size of the area of disturbance that will be created by the Mulga Downs Project within the Yule River Catchment is 0.04%. This percentage disturbance is minimal and the impact of this project when considered as a cumulative impact with other operations with the Yule River Catchment will be negligible.

## 3.6 Management measures and performance standards

The stormwater management strategy for the Project will have two primary focusses:

- Minimising the risk of flood to the mining operations to ensure the safety of personnel and efficiency of mining
- The minimisation of any potential impacts to the receiving downstream environment.

To achieve this, mitigation measures need to be implemented to ensure flood flows are safely diverted around the operations and best practices should be adhered to ensure the minimisation of any potential environmental impacts.

### 3.6.1 Minesite Stormwater Management Strategy

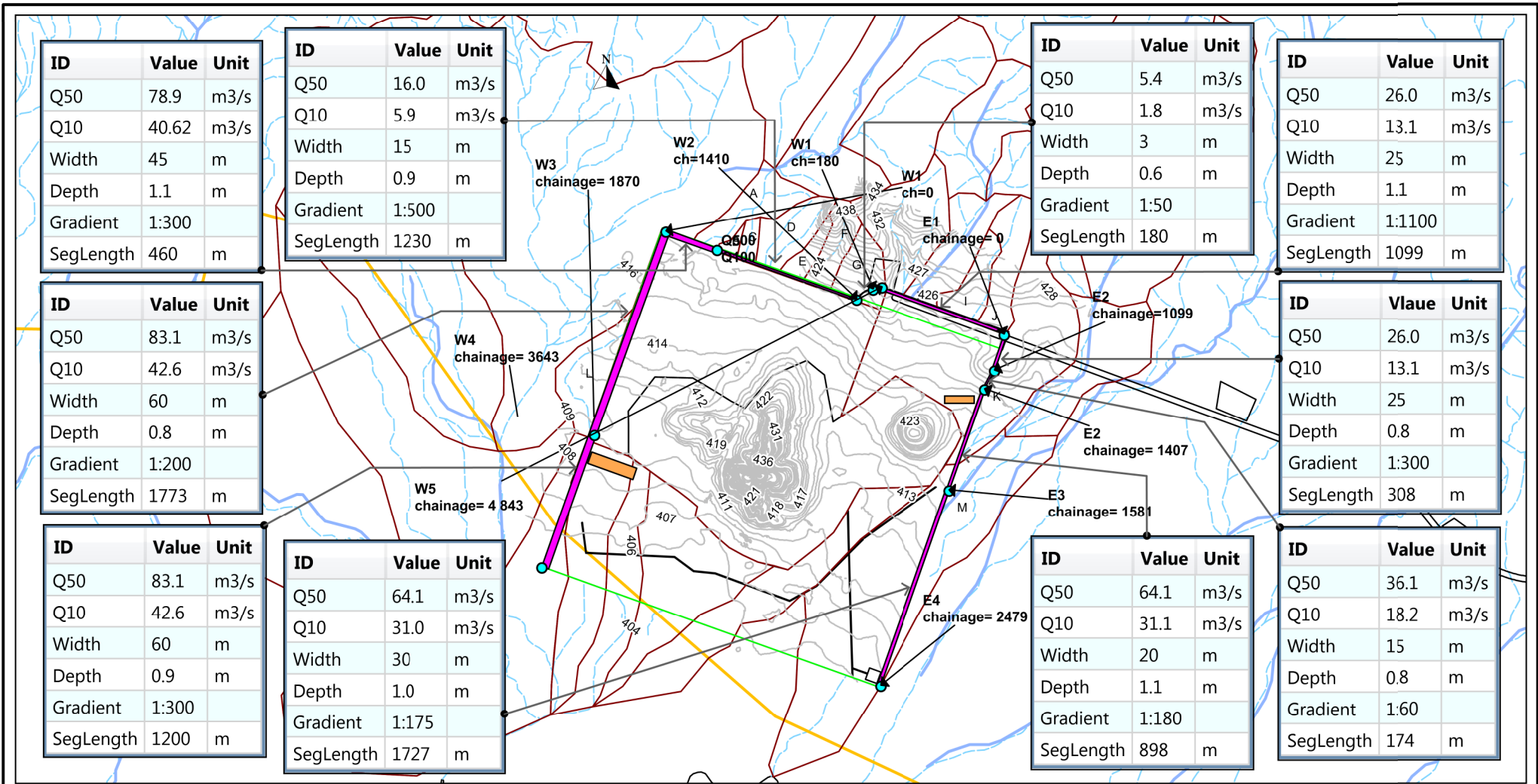
Bunding systems and flood prevention levees to divert uncontaminated stormwater away from the minesite area are the primary methods of reducing the volume of stormwater on site. Diverted water from the minesite area will enter the nearest existing natural drainage line and will continue to flow into the Goodiadarrie Swamp.

Based on the hydrological modelling as explained in Section 3.2.1, a conceptual scheme plan has been developed for diversion channels to divert upstream surface water flows around the minesite area and into the downstream receiving drainage lines. Figure 3-2 provides a conceptual design of the proposed channels together with the associated channel design width, depth and gradient

Stormwater diversion should be designed and maintained to control erosion and downstream sedimentation. The size, cross-sectional shape and gradient of the channel should be designed to avoid scouring and sudden changes in velocity.

Runoff contained within the site should utilise site drainage (earthen drains and bunds) to separate natural runoff from water generated by mining and processing operations. This will reduce the amount of treatment required prior discharge to the environment. The main form of treatment will be to retain the storm water through sediment detention ponds to reduce sediment and particulates in the water which have accumulated as a result of the mining process.

A Minesite Stormwater Management Plan will require production and implementation to be consistent with Water Quality Protection Guidelines No. 6 Mining and Mineral Processing – Minesite Stormwater (DoW, 2000).



**Data Conditions**

Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.

To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

**LEGEND**

- Mine Diversion Node
- Existing Road
- Contour
- Minesite Infrastructure
- Diversion Channel Layout
- Conceptual Sedimentation Ponds
- Catchment
- Tenement Boundary



**MWH**

FIGURE 3-2  
**SURFACE WATER MANAGEMENT  
- CONCEPTUAL DESIGN**  
MULGA DOWNS EPA REFERRAL

Author: RS, OB	Date: 12 November 2012
Revised: DJA	Project No.: 83500308
Projection: MGA Zone 50 (GDA 94)	Scale:

### 3.6.2 Access Roads Stormwater Management Strategy

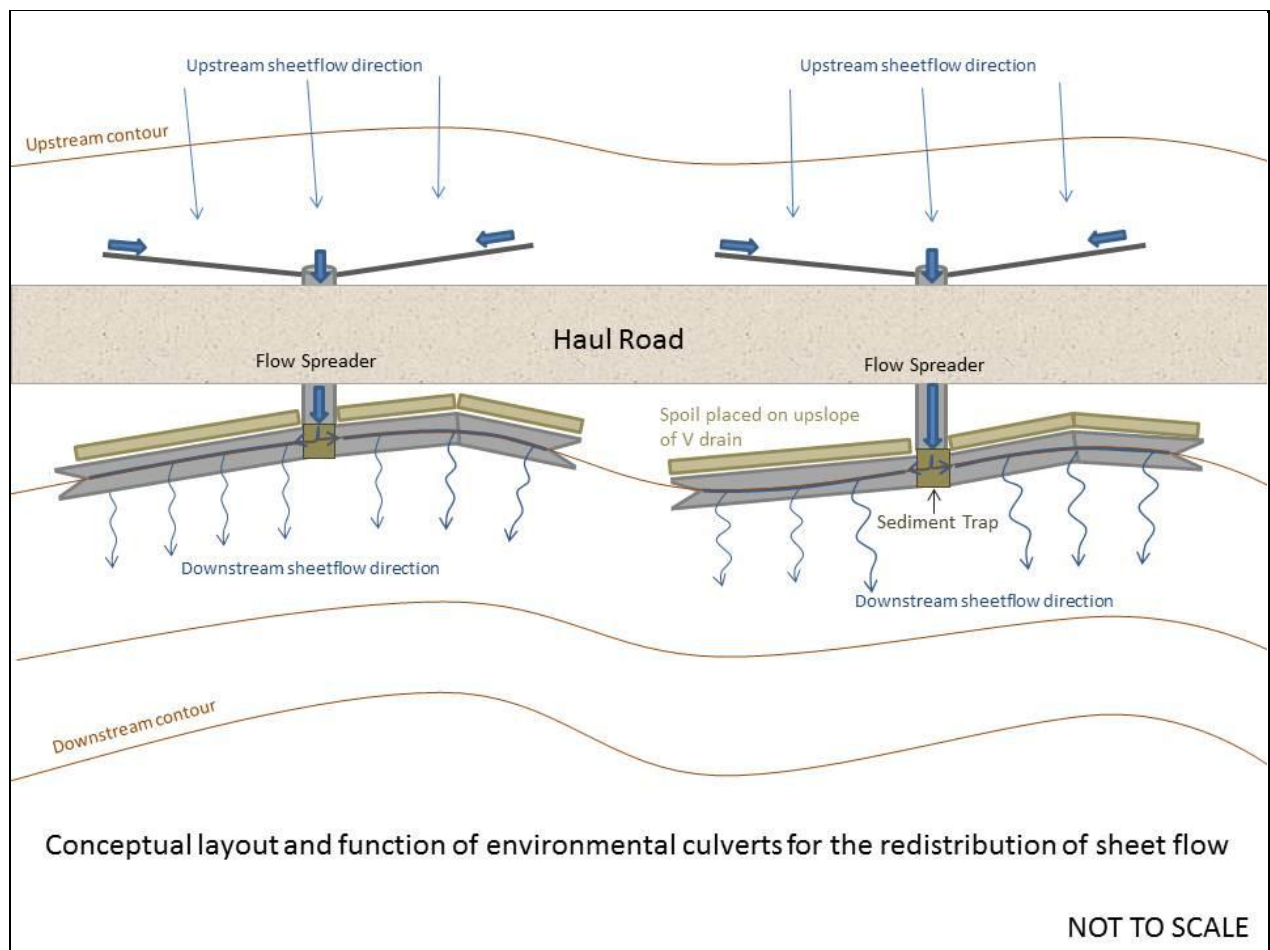
#### Large Catchment Crossings

To protect and maintain the pre-existing hydrological conditions of drainage lines associated with large catchments floodways and culverts will be constructed to allow for the surface water flows across the road alignment. These structures should be designed according to the potential volumes and flows that are likely to occur at the crossing with the haul road alignment.

#### Small and Medium Catchment Crossings

As already discussed, the interruption of sheet flows in small to medium catchments can result in upstream ponding and downstream shadowing. To mitigate this impact it is recommended that further studies be undertaken to establish any areas which would be at risk of having significant amounts of sheet flows intercepted. Should such areas be identified, the upstream and downstream environmental values of these areas should then be assessed for their dependency on sheet flows and the potential risk to these ecosystems if their habitats were to become inundated by ponding or affected by shadowing.

Following this, if any areas of significant impact were identified, it is recommended that environmental culverts be used to prevent upstream ponding and re-establish downstream sheet flows. Figure 3-3 is a conceptual drawing of environmental culverts which demonstrates the ability of such a structure to redistribute sheet flows downstream of a road alignment.



**Figure 3-3: Conceptual Layout of Environmental Culverts**

### 3.6.3 Camp Location Stormwater Management Strategy

As for the mine operations, the camp will need to be protected from surface water flooding during significant rainfall events. At the time of writing this report, no rainfall-runoff modelling had been undertaken around the proposed camp locations. It is recommended that some simple rainfall-runoff modelling be undertaken for the two proposed camp locations so that the local surface water regime be understood and a conceptual flood mitigation plan can be designed.

### 3.6.4 Hydrocarbon Management Strategy

The potential for hydrocarbon and chemical contamination to enter the surface water system is present during both the construction and operational phases of the Project. Construction mitigation, prevention and contingency planning will reduce the potential for contamination.

In addition to HPPL's standard operating procedures for construction and operational work, it is recommended that the following environmental guidelines will be adhered to:

- 'Minimum Construction Requirements for Water Bores in Australia Edition 3' (NUDLC, 2012) describes mandatory requirements to ensure that the potential for water contamination is minimised.
- Main Roads 'Handbook of Environmental Practice for Road Construction and Maintenance Works' (Lamont 2005).

Mitigation measures that will reduce the likelihood and impact of surface water and groundwater contamination during the construction phase include:

- Storage areas for fuel, plant refuelling facilities and other hazardous substances to be kept at appropriately bunded areas and set away from drainage lines and areas subject to flooding,
- Wash down areas away from sensitive areas, and
- Contingency planning to limit the impacts of equipment malfunctions and contaminant discharges.

The application of the standard operation procedures and the above mitigation measures will decrease the likelihood of the potential impacts of the contamination sources from moderate to low.

## 4 Groundwater Impact Assessment

### 4.1 Groundwater Sources

The proposed mining activities at Mulga Downs Murray's Hill deposit will be limited to mining above the water table. However, these activities are expected to utilise groundwater resources in the area to support construction and mining operations such as dust suppression, road construction and maintenance, and camp domestic water supplies. In addition, groundwater will be abstracted from up to 3 existing bores along the proposed Roy Hill Rail alignment to support dust suppression activities at the chosen Railway access road and siding area (Figure 2-13).

This section provides preliminary evaluation of the resource relative to projected water demand for proposed construction activities and mining operations. Potential impacts of groundwater abstraction are discussed in this section.

#### 4.1.1 Mining Tenement Area

Investigations to characterise the quantity and quality of the groundwater resources within the mining tenement are limited to preliminary test pumping of two water supply bores (East Wooley and Murray 1 shown in Figure 2-12) and monitoring of groundwater levels at piezometers and open drill holes. The water supply bores were installed for water supply only, and as such were not specifically designed to provide data for detailed hydrogeological assessments. However, data from these bores have been used being mindful of these limitations.

Additional investigations are on-going. Hydraulic parameters from preliminary investigations in the Mine area are presented in Table 4-1. These are derived from data collected from test pumping at two water supply bores in the mine area, East Wooley and Murray 1 (Figure 2-12).

The data presented in Table 4-1 represent bulk aquifer properties as the bores are screened across several hydrostratigraphic units, with a potential bias toward the more permeable units. A review of the field data (test duration, discharge rates/pump capacity, drawdown, etc.) suggest the hydraulic parameters listed in Table 4-1 are overestimated. Minimal drawdown was observed in the pumped aquifers during the tests (0.1 m drawdown in Murray 1) at discharge rates of 10 L/s. As such, more comprehensive test pumping of the planned hydrogeological test bores is required to define acceptable long-term abstraction rates.

On-going investigations at the mining tenement area will provide additional data for estimation of other aquifer parameters (amount of groundwater in storage, throughflow etc.).

**Table 4-1: Summary of Hydraulic Parameters from Investigations in the Mine Area**

Bore ID	Formation/Unit	T (m <sup>2</sup> /d)	K (m/d)	Storativity	Specific Yield
East Wooley	Alluvium	433	8.4	0.012	0.03 – 0.1
	Mineralised Detritals				
	Mineralised Nammuldi (?)				
Murray 1	Mineralised Detritals	982	17.9	0.012	0.01 – 0.28
	Mineralised Nammuldi				

K = Hydraulic conductivity      T = Transmissivity      m/d = metres per day

#### 4.1.1.1 Fenceline Road

Based on similarities in preliminary drilling data and hydrostratigraphy, hydraulic characteristics of the stratigraphic sequence along Fenceline Road are expected to approximate those of the Mine area.

Hydrogeological investigations along Fenceline Road are on-going, and include planned installation of up to 3 investigation water supply bores at 10 km spacing along Fenceline Road (Figure 4-1). Completion of drilling and installation is expected in late September 2012 with completion of test pumping and data analysis by late November 2012.

#### 4.1.1.2 Camp Locations

At the time of writing this report no information was available for a suitable water supply for the proposed camp locations. To assist in identifying a water supply for the proposed camp locations, investigations will need to be undertaken in the vicinity of these camp locations.

### 4.1.2 Railway Siding and Access Roads

Prior investigations to characterise the quantity and quality of the groundwater resources in the vicinity of the Railway siding area have included drilling and installation of water supply bores at designated *Water Areas* along the proposed Roy Hill Rail alignment. The proposed Railway siding area is adjacent to water supply bore PB155/23-1 (Figure 2-13). Data from test pumping of this bore have been used in the discussion below. Data from bores PB161/24-1 and P161/24-2, located approximately 5 km and 6 km respectively to the south along the proposed rail alignment, are also presented as these bores are likely be used for water supply.

A summary of pertinent hydraulic parameters derived from test pumping at PB155/23-1, PB161/24-1 and PB161-24-2 (Figure 2-13) is presented in Table 4-2 below.

**Table 4-2: Summary of Hydraulic Parameters from Railway siding Area Bores**

Bore ID	Chainage (Km)	Static Water Level (mbgl)	Transmissivity (m <sup>2</sup> /d)	Recommended Pumping Rate* (L/s)
PB155/23-1	155	3.17	3.95	1.5
PB161/24-1	160	9.95	27.9	2.0
PB161/24-2	161	9.16	38.0	7.0

*L/s = Litres per second; m/d = metres per day; T = Transmissivity*

*\* based on maximum available drawdown.*

## 4.2 Projected Water Demand for Proposed Mining Activities

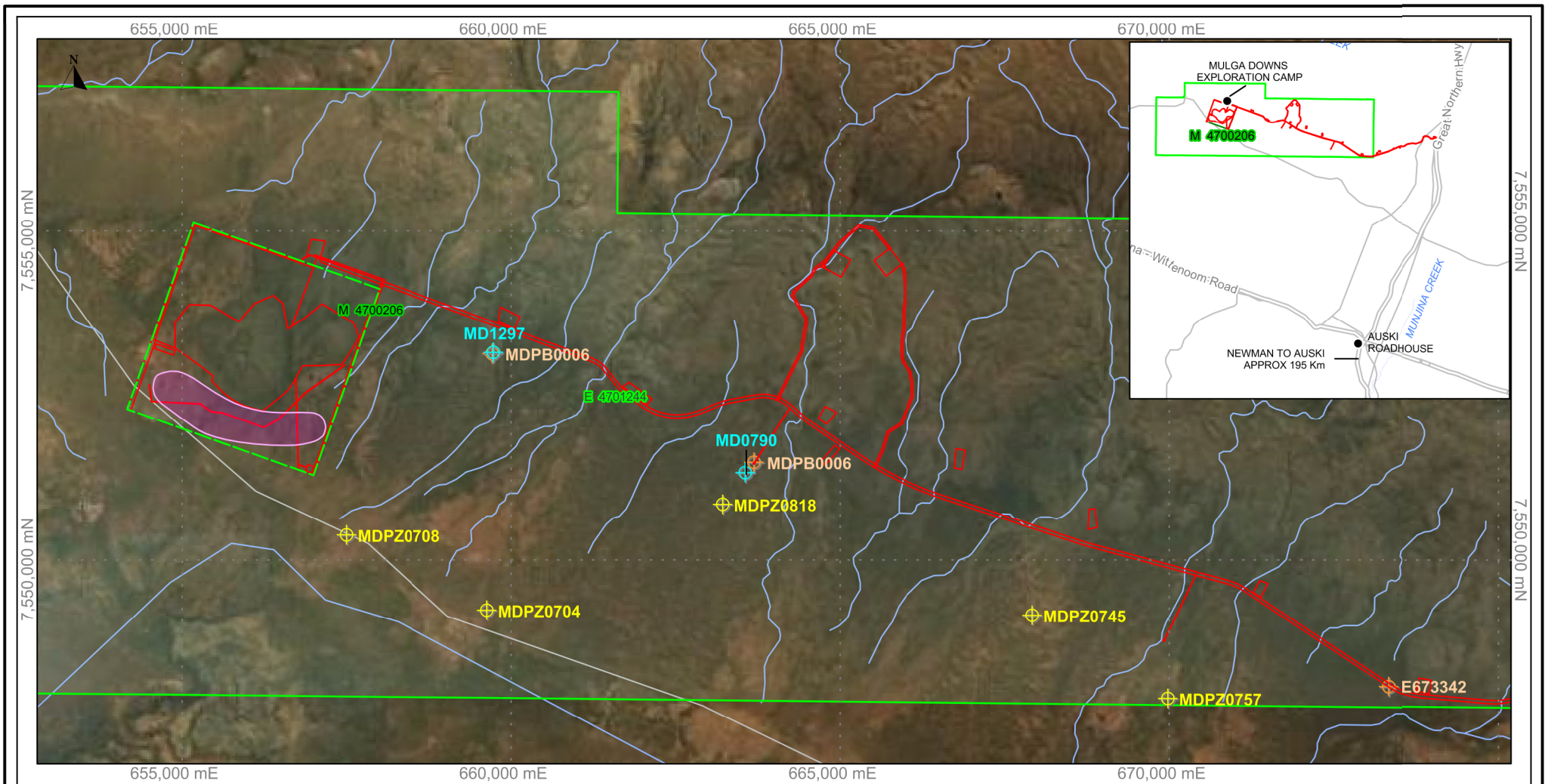
Water demand estimates for the construction and operations phases of the proposed mining project are shown in Table 4-3. These estimates assume the following:

### Construction

- Water used for construction of infrastructure within the mine tenement will be abstracted from water supply bores at the southern edge of the Mine area (Figure 2-12). Water used for construction of camp facilities will be sourced from Fenceline Road bores (Figure 4-1) or from potential future water supply bore(s) near the camp location (to be determined);
- Water for construction activities at the Railway siding area will be sourced from one or two of the existing bores in the vicinity of the siding area (Figure 2-13);and
- Proposed construction activities are expected to be completed within approximately 6 months.

### Operations

- Water used for mining operations at the Mine area will be sourced from bores at the southern end of the Mine area (Figure 2-12); and
- Water used for haulage road maintenance will be abstracted from up to 3 supply bores along Fenceline Road (Figure 4-1).
- Potable water for the camp will be sourced from an appropriate source within the vicinity of the camp.



**Data Conditions**

Considerable care has been taken to avoid errors and omissions and the latest information has been sought out and included. MWH does not accept any responsibility for any errors, omissions or inaccuracies.

To ensure formatting consistency this map should only be viewed using Adobe Viewer 7.0 or later.

**Legend**







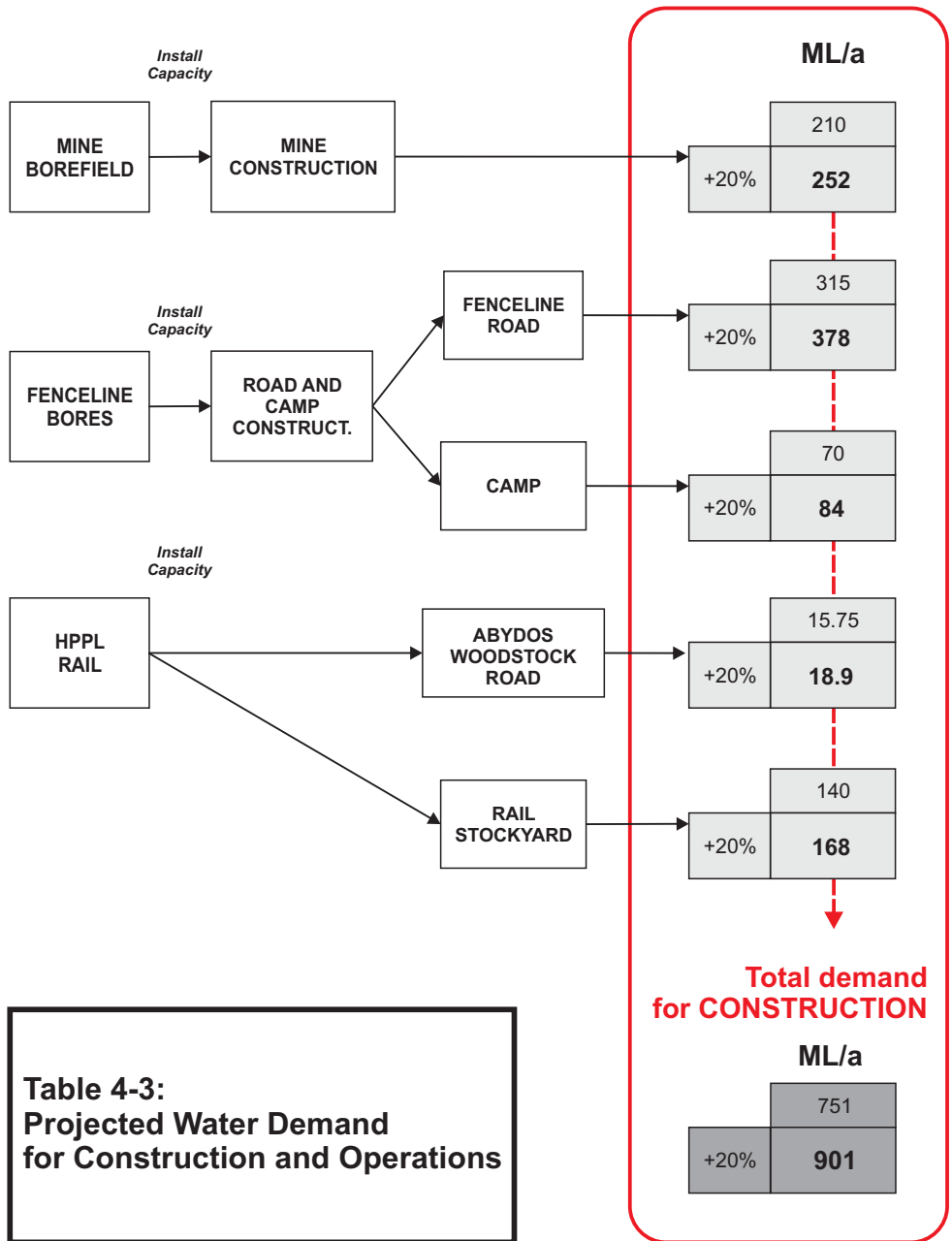
-  CONCEPTUAL BOREFIELD
-  MINING TENEMENT
-  PROJECT INFRASTRUCTURES
-  EXPLORATION HOLES USED FOR OBSERVATION
-  EXISTING PIEZOMETERS
-  PRODUCTION BORES
-  EXPLORATION TENEMENT
-  ROADS
-  WATERWAYS



FIGURE 4-1  
**PROPOSED BOREFIELD FOR MINESITE AND FENCELINE ROAD**  
 MULGA DOWNS EPA REFERRAL

Author: OB	Date: 24 October 2012
Revised: DJA	Project No.: 83500308
Projection: MGA Zone 50 (GDA 94)	Scale:

# Project Water Demand - CONSTRUCTION



**Table 4-3:  
Projected Water Demand  
for Construction and Operations**

# Project Water Demand - OPERATIONS

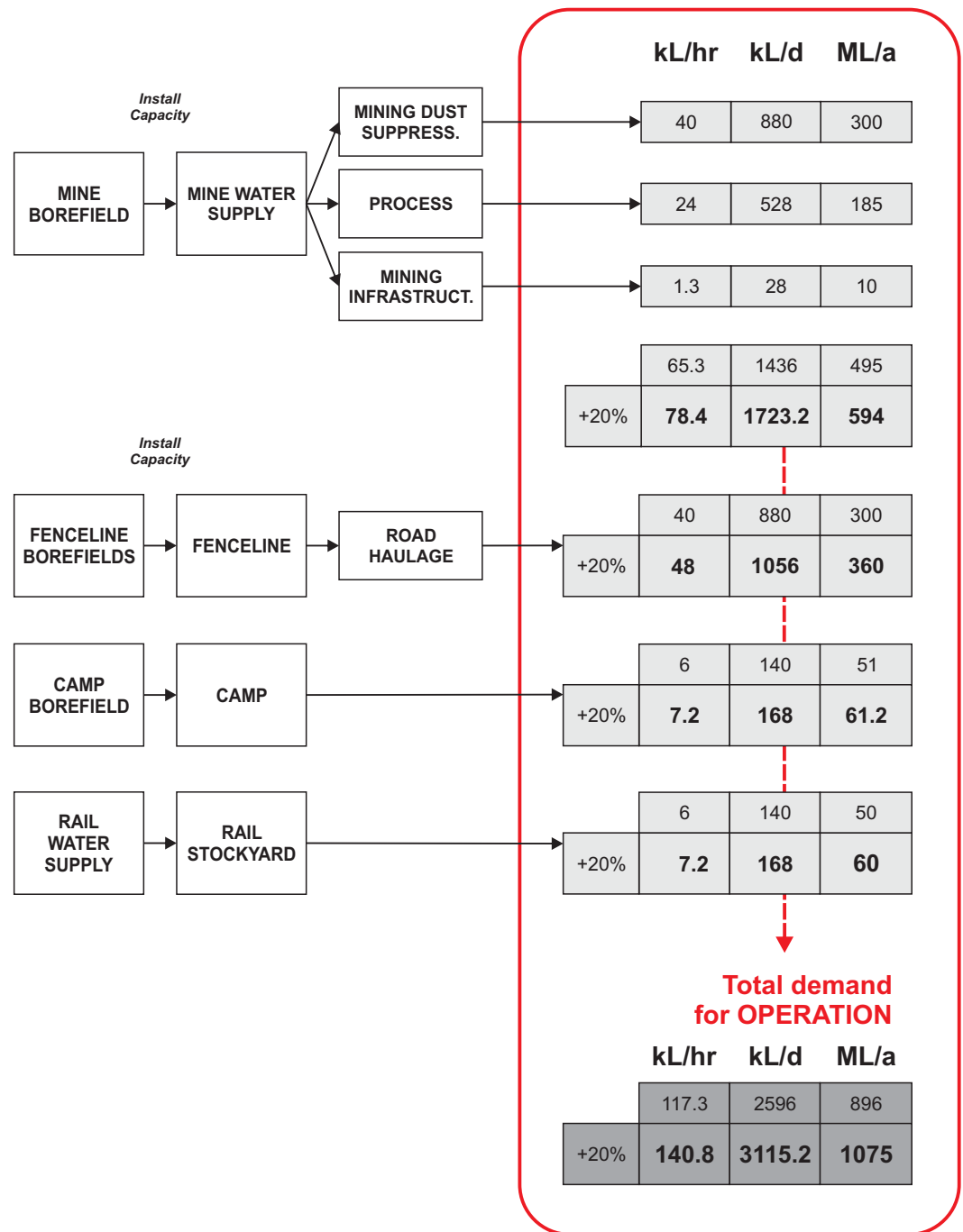


Table 4-3 shows total projected water demand for construction activities at the proposed mine to be approximately 252 ML/a, inclusive of a 20% uncertainty factor. This includes construction of mine infrastructure and dust suppression during construction. Construction of the haulage road and camp facilities would require approximately 400 ML/a over the duration. The highest projected water demand is associated with operations at the mine (594 ML/a). Railway siding area water demand is projected to be a modest 188 ML/a for construction activities and 60 ML/a for long term operations. Potable water demand for the camps will be 41 MLpa – based on 350L/person/day for a 400 room camp running at 80% occupancy.

## 4.3 Drawdown Response to Proposed Abstractions

### 4.3.1 Mining Tenement Area

Drawdown from the proposed abstraction within the mining tenement area will be defined once test pumping has been completed at the testing bores. Drilling and installation of these bores is taking place at the time of writing and is expected to be completed by late November 2012. Test pumping of the bores is expected to be completed by mid-December 2012.

Based on the projected water demand shown in Table 4-3, it is anticipated that abstraction rates required to meet the water demand in both the Mine area and along Fenceline Road will result in minimal drawdown of the water table. This assumption is based on the following observations and preliminary assessments:

- **Mine Area:** The pumping test at Murray 1 bore was performed at a discharge rate of approximately 10 L/s. As minimal drawdown (0.1 m) was recorded during the test pumping of this bore it appears the discharge rate of 10 L/s (315 ML/a) will be more than adequate for provision of the projected water demand for mine construction activities (252 ML/a). However, long term (weeks to months/years) abstraction impacts on the local groundwater regime will be evaluated following installation and comprehensive test pumping of the planned hydrogeological testing bores.
- **Fenceline Road:** Preliminary data from drilling conducted for resource evaluation indicate that the stratigraphic sequences in the Fenceline Road area are generally similar to those encountered within the mine area, although more extensive mineralisation may result in enhanced permeability of mineralised sequences within the Mine area. It is likely that groundwater abstraction from up to 3 bores at approximately 1 -kilometre spacing along Fenceline Road would be capable of meeting the projected water demand to support road and camp construction (400 ML/a) and road haulage maintenance needs during mine operations (360 ML/a). Sustainable groundwater yields and long term abstraction impacts on the water table will be evaluated following test pumping of the planned Fenceline Road bores (Figure 2-13).
- **Camp Locations:** It is expected that the stratigraphic sequences in the camp locations area will be generally the similar to those in the Fenceline Road and mine area. Hydrogeological investigations in this area would provide details on the expected drawdown response of a camp supply bore.

### 4.3.2 Railway Siding and Access Roads

The drawdown response to abstraction in the Railway siding area has been assessed during the test pumping of 3 water supply bores shown in Figure 2-12. Projected drawdowns at each of the bores after one year of continuous pumping at the recommended flow rates are listed in Table 4-4 below.

The recommended rates in Table 4-4 are based on the 'safe yield' concept and take into account the available drawdown in the bore based on the maximum saturated thickness at each location.

**Table 4-4: Summary of Recommended Pumping Rates for Railway Area Bores**

Chainage (km)	Bore ID	Easting (MGA94)	Northing (MGA94)	Recommended Sustainable Rate for 1 year (L/s)	Projected Drawdown (m)
158	PB155/23-1	689763	7603392	1.5	28
160	PB161/24-1	690584	7599321	2	13
161	PB161/24-2	690581	7598605	7	18
<b>Total:</b>				<b>10.5</b>	

#### 4.4 Potential Sources of Impact

Groundwater in the mining tenement area is primarily used for pastoral activities. Project-related activities that may potentially impact groundwater include:

- Contamination of groundwater from hydrocarbons and chemicals from drilling and other operations
- Contamination of groundwater from camp waste water and sewage
- Lowering of groundwater levels through abstraction for water supply.

Potential impacts of these activities are evaluated below.

#### 4.5 Evaluation of options or alternatives to avoid or minimise impact

**Avoidance of Impact** - The only option to avoid impacts to groundwater would be to completely avoid any abstraction of, or interaction with groundwater. This could potentially be achieved by trucking water into the Project area; however, this option is highly uneconomical. The proposed abstraction and likely minimal drawdown of the water table in the mining tenement area is considered to result in a negligible change to the groundwater regime. Further, drawdown in the Railway siding area is likely to be localised and structurally controlled in the fractured rock aquifers. As such, drawdown effects in the regional aquifer are likely to be minor.

**Minimization of Impact** - Groundwater abstracted from bores within the overall Project area is necessary for the operation of the mine site (i.e. dust suppression, domestic use and operations). Given that the proposed mine void will be located above the water table, the only interaction with groundwater will be via abstraction bores. Based on the projected water demand and results of test pumping in the Mine area, abstraction from the bores is expected to result in minimal drawdown of the water table over the life of the project. However, additional data will project long term drawdown. Drawdown in the bores along Fenceline Road is also expected to be minimal based on the similarity of the hydrostratigraphic units to those in the Mine area. Continuous pumping at the Railway siding bores will result in the projected drawdowns given in Table 4-4. These values assume continuous pumping for a one-year period. This scenario is unlikely, and as such drawdown in these bores is expected to be within acceptable limits. Abstraction management strategies to mitigate drawdown effects would be implemented as needed. Cumulative Impacts are further discussed in Section 4.6.3.

Placing a camp supply upstream of the waste water and sewage systems will minimise the likelihood of contaminating groundwater supply to the camp.

#### 4.6 Assessment of Likely Direct and Indirect Impacts

The following section describes the likely direct and indirect impacts of the project on groundwater.

##### 4.6.1 Impacts on groundwater quality

The maximum excavated depth of the proposed mine void will be above the water table. As such, there will be no direct interaction with groundwater in the pit void, thereby reducing the potential for contamination and eliminating the need for dewatering.

Potential exists for a chemical or hydrocarbon spill to impact groundwater quality, particularly if surface water flows were sufficient to transport the contaminants into the groundwater system. The potential for contaminant transport is greater within the confines of the mine void owing to the reduced thickness of buffering material above the water table. The potential for chemicals and/or hydrocarbons to enter the groundwater system is considered low, based on the limited avenues via which these substances could enter the groundwater system. Further, HPPL will adopt appropriate management practices to mitigate any impacts.

Potential exists for impacts to groundwater from exposure of potential acid forming minerals within some of the stratigraphic horizons (e.g., Jeerinah Formation, which may locally contain oxidisable pyrite) to the atmosphere. If these minerals are encountered during excavation, HPPL will implement mitigation actions to prevent groundwater contamination via metalliferous drainage. Additionally, The Jeerinah Formation in the Project area and vicinity is also known to contain dolomitic horizons, which may provide adequate buffering capacity to counter the acid forming potential of sulphide minerals, if present.

No impact on water quality is predicted from the proposed abstraction activities. However, data from the planned comprehensive pumping tests in the mining tenement area are required to provide reasonable projections of groundwater quality, particularly with regard to potential for up-coning of any saline groundwater.

## **4.6.2 Impacts to water Balance and Groundwater Levels**

### **4.6.2.1 Mining Tenement Area**

Based on the projected water demand, groundwater abstraction is proposed from up to two bores at the southern edge of the mine area and from up to three bores along Fenceline Road. Detailed estimates of total recharge and throughflow in these areas have not been computed pending additional site characterization. However, a conservative preliminary estimate of groundwater throughflow in the Mine area was derived based on available site data and utilising Darcy's Law for groundwater flow through a porous medium. As per Darcy's Law, discharge of groundwater through a porous medium is proportional to the product of hydraulic conductivity, cross-sectional area of flow and the change in water level over a distance (hydraulic gradient). Data utilised in the calculation are as follows:

- Hydraulic conductivity estimated from prior test pumping at Murray 1 water supply bore of 14 m/d (a slightly lower value was used to account for potential overestimate inferred from test pumping data review);
- Cross-sectional area of flow as the product of average saturated thickness of the aquifer in the area of proposed water supply bores (estimated from existing bore logs) of 45 m and approximate width of the Mine area tenement boundary (2,500 m); and
- Average hydraulic gradient based on water level data in the vicinity of the proposed Mine area water supply bores (0.15%).

The computation yields an estimated throughflow in the order of 900 ML/a. This total exceeds the total annual water demand of 252 ML/a for mine construction activities (Table 4-3) and for operations (594 ML/a) which would be abstracted from the proposed mine borefield. As such, no change to the natural groundwater flow regime or water balance is expected.

Once a supply bore for the camp has been identified it is recommended that test pumping be undertaken to determine the potential impact to the water balance and surrounding groundwater levels.

### **4.6.2.2 Railway Siding and Access Roads**

Based on the projected water demand, groundwater abstraction is proposed from up to three supply bores within a 6 km stretch of the proposed Roy Hill Rail alignment (Figure 2-13). Data from test pumping of the bores indicates that abstraction from both PB155/23-1 and PB161/24-1 will meet projected water demand for mining operations of 60 ML/a. However, abstraction from all 3 bores may be needed to meet projected water demand for short-term construction activities (188 ML/a). The projected drawdowns assume sustained pumping for one year. As the projected annual water demand for construction activities is likely to be required over a significantly shorter period, higher pumping rates would result in a higher-than-projected drawdowns. In this event, appropriate abstraction management would be implemented to prevent over-abstraction and excessive drawdowns in the bores. Such management strategies would include continuous monitoring of water levels to inform adjustment of pumping rates.

### **4.6.3 Potential for and nature of any Cumulative Impacts**

#### **4.6.3.1 Mining Tenement Area**

The potential cumulative impacts on groundwater quantity and quality as a result of this proposed project are likely to be minor. However, additional data from the on-going site investigations in the area, including modelled regional water balance estimates, will reasonably predict cumulative impacts.

Impacts on groundwater quantity are likely to be minimal as abstracted volumes will be significantly less than estimated throughflow. Impacts on groundwater quality are likely to be minimal as the only interaction with groundwater is through water abstraction. Potential exists for small chemical or hydrocarbon spills to migrate to the groundwater system in the event of an accidental spill. However, mitigation efforts in accordance with HPPL's best management practices would limit the potential for these contaminants to migrate into the underlying groundwater. Therefore, there are no predicted cumulative impacts on groundwater quality.

#### **4.6.3.2 Railway Siding and Access Roads**

The potential cumulative impacts on groundwater quantity and quality as a result of proposed abstraction in the Railway area are likely to be minor. The combined sustainable yield from the three bores in the area based on recommended sustainable pumping rates exceeds total projected water demand. Additionally, appropriate abstraction management strategies would be implemented to prevent over-abstraction.

Any impacts on groundwater quality as a result of small chemical or hydrocarbon spills would be managed in accordance with HPPL's management practices to limit the potential for these contaminants to migrate into the underlying groundwater, as described above. Therefore, there are no predicted cumulative impacts on groundwater quality.

## **4.7 Management measures and performance standards**

### **4.7.1 Management Actions**

A groundwater operating strategy for the project will be submitted as part of a Department of Water abstraction permit (5C licence). The operating strategy will include a detailed description of the following:

- Identifying and managing impacts
- Operating rules for abstraction
- Monitoring and reporting
- Contingency and trigger levels

HPPL will adopt appropriate management practices to minimise the risk of spills and potential groundwater contamination. Abstraction from the water supply bores will be managed to minimise drawdown, which may affect other beneficial uses in the area (i.e. livestock watering). Management will include continuous water level monitoring and ongoing adjustment of pumping rates to eliminate the potential for over-abstraction.

### **4.7.2 Proposed Future Investigations**

Field investigations within the mining tenement area are currently on-going. These investigations include drilling and installation of hydrogeological testing bores, test pumping, and collection of water samples for hydrochemical assessment. These investigations are designed to provide additional data for a detailed evaluation of the hydrogeological system and groundwater regime in the area. These data will aid in further evaluation of the effect of the proposed abstraction on the water balance, groundwater quality and groundwater levels. Existing piezometers will be used to enhance the groundwater monitoring network.

To identify a suitable water source for the camp, it is recommended that field investigations are undertaken to determine an appropriate water supply.

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