

7. Terrestrial Environmental Quality

7.1 EPA environmental factor and objective

To maintain the quality of land and soils so that environmental values are protected.

For the purpose of EIA, the EPA (2016c) defines *Terrestrial Environmental Quality* as the chemical, physical, biological and aesthetic characteristics of soils. Soils are the layers of organic and inorganic weathered material that accumulate at the Earth's surface.

7.2 Relevant policy and guidance

7.2.1 EPA policy and guidance

- *Environmental Factor Guideline – Terrestrial Environmental Quality* (EPA 2016c)
- *Instructions on how to prepare an Environmental Review Document* (EPA 2021c)
- *Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans* (EPA 2020d)

7.2.2 Other policy and guidance

- *Statutory Guidelines for Mine Closure Plans* (Department of Mines, Industry Regulation and Safety 2020).
- *Identification and investigation of acid sulfate soils and acidic landscapes* (Department of Environmental Regulation 2015)
- *Treatment and management of soil and water in acid sulfate soil landscapes* (Department of Environmental Regulation 2015)

7.3 Receiving environment

7.3.1 Huntly Mine

7.3.1.1 Geology

Regional geology

The Huntly Mine lies within the Darling Plateau, an undulating lateritic regolith over Archaean granite with dolerite intrusions. The Darling Plateau occupies the southwestern fringe of the Yilgarn Craton and is bordered by the Darling Fault and Perth Basin to the west. The bedrock underlying the Huntly Mine is over two billion years in age and predominantly comprises granite with areas of granitic gneiss. Faults run in an approximate southeast to northwest direction.

Dolerite dykes are common, intruding through the granite mostly in a north-northwest direction and ranging from 1-200 m thick (about 10 m average) (Hickman *et al* 1992). The presence of granite, gneiss or dolerite is a major determinant of the characteristics of the regolith which overlies most of the bedrock. The bedrock outcrops in pockets throughout the Darling Plateau, including on hills or 'monadnocks' as well as within incised valleys where rivers have eroded through the regolith material. The bedrock has an irregular topography, with pinnacles and isolated boulders occurring at shallow depths in the regolith, at places reducing the thickness of laterite (Hickman *et al* 1992).

The regolith covering the bedrock was formed through a long period of weathering and averages about 30 m thick over the Darling Plateau (Hickman *et al* 1992). The upper layers of the regolith are lateritic, being rich in iron and aluminium derived from the bedrock, with a

characteristic rusty-red colour. The regolith has a complex vertical sequence, which is generalised as follows (from surface to bedrock) (Hickman *et al* 1992):

- Overburden, comprising sandy gravels about 0.2-4 m thick (average 0.5 m)
- Lateritic bauxite about 4-6 m thick, comprising two distinct layers:
 - Duricrust or caprock, comprising iron or aluminium cemented rock about 1-2 m thick
 - Friable fragmental layer about 2 m or more thick
- Mottled and pallid clays (saprolite) about 20-30 m thick
- Saprock, comprising rock fragments about 2-5 m thick that define a basal interface between saprolite and bedrock.

The regolith is partially or fully eroded in valleys that dissect the Darling Plateau, with the upper lateritic layers often absent and replaced by colluvial or alluvial deposits (Hickman *et al* 1992, Fordyce *et al* 2007). In some areas, the regolith is fully eroded to expose bedrock.

Local geology

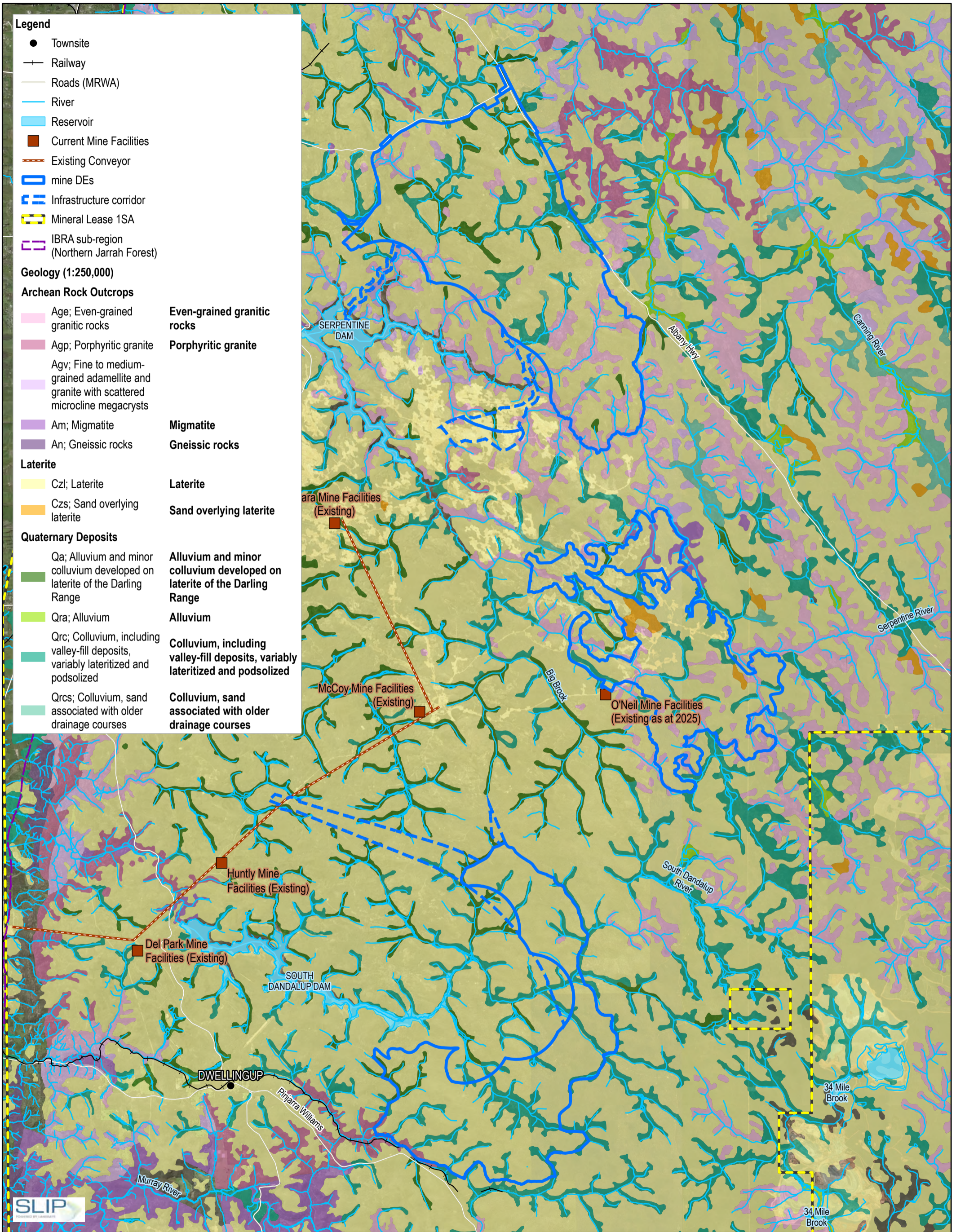
Table 7.1 and Figure 7-1 present the surficial geology of the Mine DE. The surficial geology is consistent with the wider geology of the Darling Plateau, predominantly comprising lateritic regolith (18,086 ha or 76 per cent of total) interspersed by Quaternary deposits (3,395 ha or 14 per cent of total) in streams and swamps, and Archaean rock outcrops (2,407 ha or 10 per cent of total) in hills and incised valleys. The Myara North and O'Neil DE have a greater prevalence of Archaean rock outcrops, associated with the Serpentine River valley and with Mount Solus. The Holyoake DE has limited rock outcrops as the South Dandalup River has predominantly colluvial and alluvial deposits.

Dolerite dykes are too small to be mapped on surficial geology, however, they comprise about 15 per cent of bedrock and are important determinants of regolith characteristics (Biggs and Wilde 1980).

Table 7.1 Surficial Geology present in the Mine DE

Mapping Unit	Description	Myara North DE (ha)	Holyoake DE (ha)	O'Neil DE (ha)	Mine DE total (ha)
	Archaean Rock Outcrops				
Age	Even-grained granitic rocks - fine to coarse-grained granodiorite, adamellite and granite	910	12	251	1,173
Age/Blo	Overprint, indicating bedrock largely obscured by residual and colluvial deposits on Age	584	0	394	977
Agp	Porphyritic granite - medium to coarse-grained granite with microcline megacrysts	0	64	0	64
Agv	Fine to medium grained adamellite and granite with scattered microcline megacrysts	46	0	0	46
Agv/Blo	Overprint, indicating bedrock largely obscured by residual and colluvial deposits on Agv	0	0	1	1
Am	Magmatite, including areas of banded granite gneiss	0	0	119	119
Am/Blo	Overprint, indicating bedrock largely obscured by residual and colluvial deposits on Am	0	0	27	27
	Laterite				
Czl	Laterite - chiefly massive, but includes overlying pisolithic gravel and lateritised sand	7,507	6,261	4,128	17,897
Czs	Sand overlying laterite – yellow, white or grey	0	0	189	189

Mapping Unit	Description	Myara North DE (ha)	Holyoake DE (ha)	O'Neil DE (ha)	Mine DE total (ha)
	Quaternary Deposits				
Qa	Alluvium and minor colluvium developed on laterite of the Darling Range	649	203	21	873
Qrc	Colluvium, including valley-fill deposits, variably lateritised and podsolized	959	1,084	438	2,480
Qrcs	Colluvium, sand associated with older drainage courses	38	0	3	42
Water	Reservoir – geology not mapped	12	0	0	12
Total		10,705	7,624	5,571	23,900



- Legend**
- Townsite
 - +— Railway
 - Roads (MRWA)
 - River
 - Reservoir
 - Current Mine Facilities
 - Existing Conveyor
 - mine DEs
 - Infrastructure corridor
 - Mineral Lease 1SA
 - IBRA sub-region (Northern Jarrah Forest)

Geology (1:250,000)

Archean Rock Outcrops

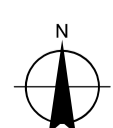
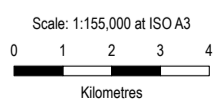
- | | |
|---|------------------------------------|
| Age; Even-grained granitic rocks | Even-grained granitic rocks |
| Agp; Porphyritic granite | Porphyritic granite |
| Agv; Fine to medium-grained adamellite and granite with scattered microcline megacrysts | |
| Am; Migmatite | Migmatite |
| An; Gneissic rocks | Gneissic rocks |

Laterite

- | | |
|------------------------------|--------------------------------|
| Czl; Laterite | Laterite |
| Czs; Sand overlying laterite | Sand overlying laterite |

Quaternary Deposits

- | | |
|---|---|
| Qa; Alluvium and minor colluvium developed on laterite of the Darling Range | Alluvium and minor colluvium developed on laterite of the Darling Range |
| Qra; Alluvium | Alluvium |
| Qrc; Colluvium, including valley-fill deposits, variably lateritized and podsolized | Colluvium, including valley-fill deposits, variably lateritized and podsolized |
| Qrcs; Colluvium, sand associated with older drainage courses | Colluvium, sand associated with older drainage courses |



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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**Surficial Geology -
Mine DE**

FIGURE 7-1

Data source: WAnow; Landgate / SLIP.

7.3.1.2 Landforms

Land systems

The Huntly Mine lies over the Darling Plateau land system, interspersed by the Murray Valleys land system as presented in Table 7.2 and Figure 7-2. The Darling Plateau land system comprises an undulating lateritic plateau which is the remnant of a once extensive peneplain (Hickman *et al* 1992).

The Murray Valleys land system comprises deeply incised valleys of larger rivers such as the Serpentine and Murray and the lower reaches of smaller rivers (e.g. South and North Dandalup) as they approach and cut through the Darling Scarp. The Darling Plateau system is associated with the predominant lateritic surficial geology of the region whereas the Murray Valleys system has a higher prevalence of exposed bedrock (see Figure 7-1).

Table 7.2 Land systems present in the Mine DE

Land System	Mapping Unit	Total Extent (ha)	Myara North DE (ha)	Holyoake DE (ha)	O'Neil DE (ha)	Proportion of Current Extent (%)
Darling Plateau System	255Dp	1,168,803	10,433	6,411	5,571	1.92
Murray Valleys System	255My	185,772	272	10	0	0.15

Landforms / land subsystems

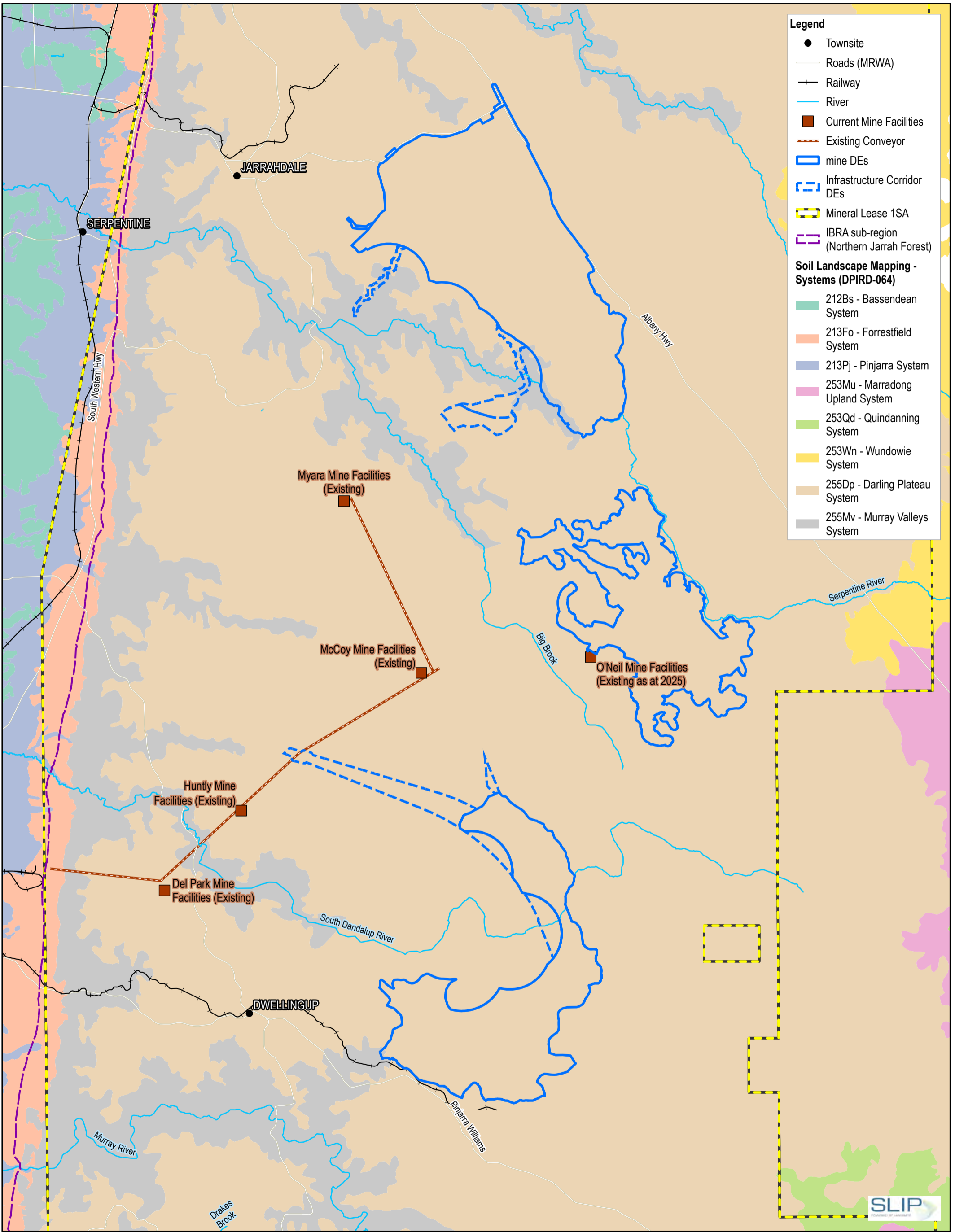
The landforms of the Darling Plateau have been described by Churchward and McArthur (1980) and are presented as land subsystems in Table 7.3 and Figure 7-3. The land subsystems were applied to vegetation mapping as the regional vegetation complexes presented in Section 5.3.4.1.

The Darling Plateau lies in a region of rejuvenated and active drainage, which is distinct from the ancient drainage to the east in the Avon-Wheatbelt region (Penn 1999). The rejuvenated and active drainage is characterised by deep incised river valleys, such that the predominant lateritic upland and minor valley landforms of the Darling Plateau are dissected by major valley and valley floor landforms.

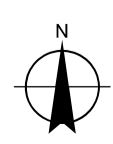
Over the Mine DE, the lateritic uplands comprise the Dwellingup system and the minor valleys comprise the Yarragil system, which are widespread across the high rainfall zones of the western Darling Plateau. These two systems comprise approximately 84 per cent of the Mine DE.

The major valleys comprise the Murray system and, within the Mine DE, are primarily associated with the Serpentine River and Big Brook in the Myara North DE. The system comprises approximately 1 per cent of the Mine DE. The Murray system also lies downstream of the Holyoake DE on the lower South Dandalup River and on the Murray River.

The Darling Plateau includes pockets of hills that can host concentrations of granite outcrops, which comprise the Cooke system. Over the Mine DE, the Cooke system includes the vicinity of Mount Solus and hilly topography in the east of the Myara North Mine Region. The Cooke system is also prevalent in the Monadnocks Conservation Park east of Myara North DE and the White Horse Hills east of Holyoake DE.



Scale: 1:170,000 at ISO A3
 0 1 2 3 4
 Kilometres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



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 Environmental Review Document

Project No. 12633192
 Revision No. 3
 Date 09/03/2025

Soil Landscape Systems –
 Mine DE

FIGURE 7-2

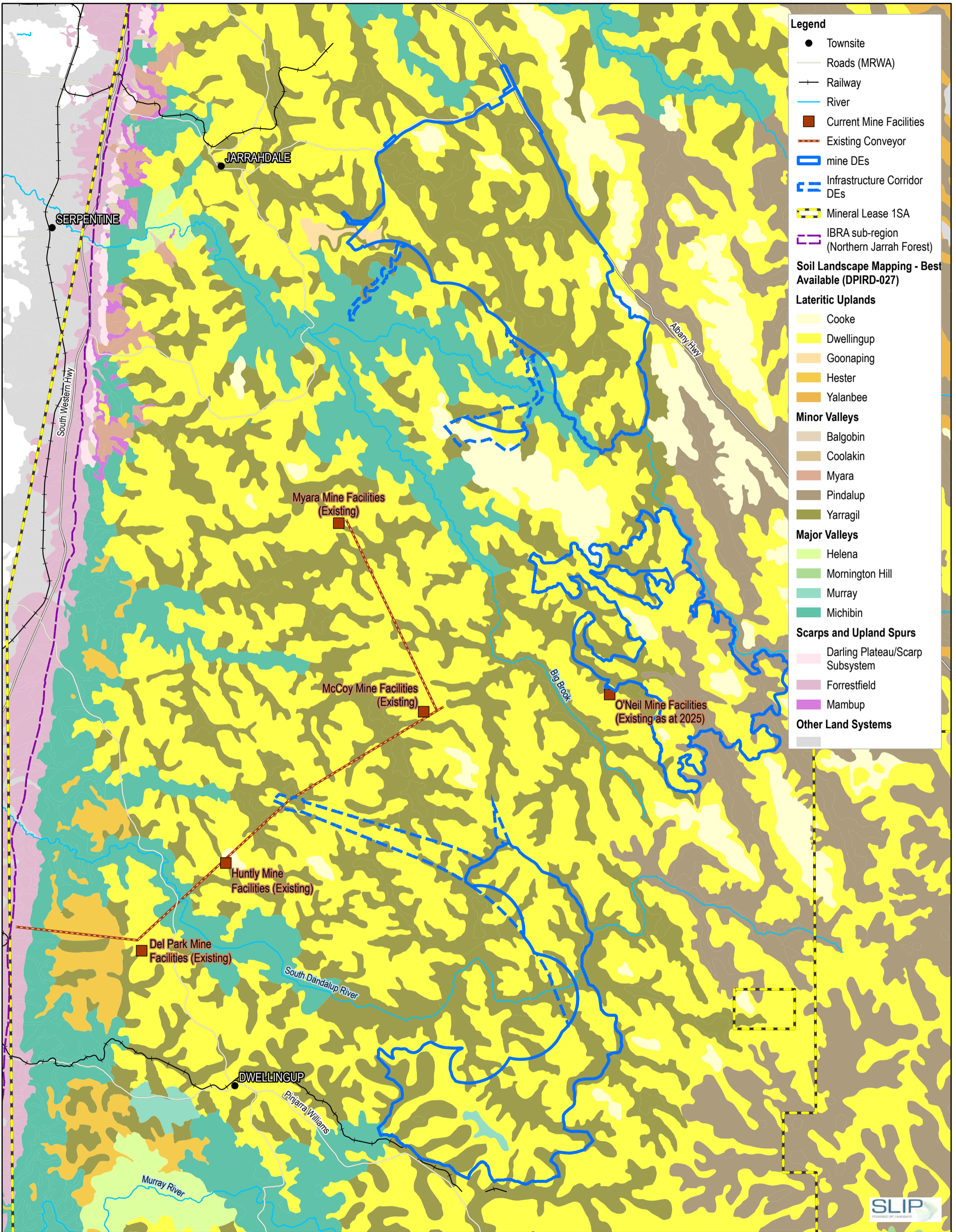
Data source: .

Table 7.3 Regional soil landscape mapping in the Mine DE

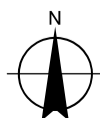
Underlying landform	Soil landscape mapping units	Description	Total Extent (ha)	Area within Myara North DE (ha)	Area within Holyoake DE (ha)	Area within O'Neil DE (ha)	Proportion of Current Extent in Mine DE (%)
Dwellingup: Gently undulating landscape with duricrust on ridges; sands and gravels in shallow depressions.	1097 Dwellingup Subsystem	Divides, lower to upper slopes and hillcrests. Duplex sandy gravels and loamy gravels with minor areas of shallow gravels, deep sandy gravels, yellow deep sands and yellow and pale deep sands, often gravelly.	328,559	4,258	3,771	3,205	3.42
	3998 Dwellingup 2 Phase	Very gently to gently undulating terrain (<10%) with well drained, shallow to moderately deep gravelly brownish sands, pale brown sands and earthy sands overlying lateritic duricrust.	91,391	242	0	0	0.27
Murray: Deeply incised valleys with red and yellow earths on slopes; narrow alluvial terraces.	4738 Murray Subsystem	Deeply incised valley of the Murray River; red and yellow earths and minor duplex soils; occasional rock outcrops; narrow sandy terrace.	86,735	272	10	0	0.33
	1127 Mornington Hill Subsystem	Low hills on laterite overlying granite, relief 40-80 m, slope 5-20%. Soils are sandy and loamy gravels with some deep sands and loamy earths.	57,228	0	111	0	0.19
Yarragil: Valleys of the western part of the plateau; sandy gravels on the slopes; orange earth in swampy floors.	1187 Yarragil Subsystem	Shallow, narrow, upper valleys of the deeply dissected Murray, Bindoon and Helena units. Alluvial, clay and loam soils, moderately well drained, often gravelly, with some sands and loams. Salt prone.	102,063	873	2,192	367	3.36
	4000 Yarragil 1 Phase	Very gentle to moderately inclined concave side-slopes. Moderately well	19,325	264	0	0	1.36

Underlying landform	Soil landscape mapping units	Description	Total Extent (ha)	Area within Myara North DE (ha)	Area within Holyoake DE (ha)	Area within O'Neil DE (ha)	Proportion of Current Extent in Mine DE (%)
		drained yellow duplex soils and yellow and brown massive earths and gravels.					
	4003 Yarragil 4 Phase	Valley floors with some poorly drained mottled yellow duplex soils and gentle lower slopes with moderately well to well drained loamy and sandy earths, gravels and duplex soils.	7,017	188	0	0	2.68
	6360 Yarragil Swamp Phase	Level to very gently inclined valley floors. Swampy river flats and terraces in granitic rocks; loamy and sandy duplex, wetsoils, non-cracking clays and loams.	7,567	1,176	33	1	16.00
	6412 Yarragil Rock Outcrop Phase	Shallow, narrow, upper valleys. Areas of rock outcrop.	283	0	12	0	4.25
	6820 Yarragil DpYGh Phase	Very gentle to moderately inclined (<20%) concave valley side-slopes. Moderately well drained yellow duplex soils and yellow and brown massive earths.	31,508	2,959	291	346	11.42
Goonaping: Shallow upland valleys with grey sands and some swamps.	3995 Goonaping Subsystem	Level to gently sloping imperfectly drained swamp margins with deep grey, yellowing brown or brown siliceous or bleached sands.	2,399	56	0	0	2.33
Cooke: Hills rising above general plateau level, mainly mantled by laterite with some rock outcrop.	3996 Cooke Subsystem	Crests and upper slopes dominated by granite outcrop and very shallow yellow duplex soils and yellow and brown massive earths.	19,771	416	0	300	3.62

Underlying landform	Soil landscape mapping units	Description	Total Extent (ha)	Area within Myara North DE (ha)	Area within Holyoake DE (ha)	Area within O'Neil DE (ha)	Proportion of Current Extent in Mine DE (%)
Pindalup: Gently undulating landscape with lateritic duricrust on ridges and slopes; sandy and gravelly soils in shallow depressions.	7096 Pindalup hillslope phase	Sideslopes of minor valleys.	39,385	0	0	1,010	2.56
	1147 Pindalup subsystem	Shallow minor valleys (5-20 m) with gentle sideslopes (3-10%), and broad swampy floors. Soils are loamy gravels, and deep sands, and non-saline wet soils on the valley floors.	57,661	0	0	81	0.14
	7097 Pindalup swampy valley floor phase	Swampy floors of minor valleys.	17,809	0	0	260	1.46
Total			868,702	10,705	6,421	5,571	2.61



Scale: 1:155,000 at ISO A3
 0 1 2 3 4
 Kilometres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



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**Soil Landscape
 Best Available/Subsystems -
 Mine DE**

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 Revision No. 3
 Date 09/03/2025

FIGURE 7-3

Data source: .

Regional land system mapping provides a broad, qualitative indication of slope across the Mine DE. Chart 7-1 presents a more detailed slope analysis based on LiDAR. As presented, the Myara North DE comprises approximately 24 per cent of land with a slope of less than 4 per cent rise, 35 per cent with a slope of 4-8 per cent rise, 34 per cent with a slope between 8 and 16 per cent rise, and 7 per cent of the DE has a slope of greater than 16 per cent rise.

The Holyoake DE has similar topography, with 22 per cent of land with a slope less than 4 per cent rise, 36 per cent at 4-8 per cent rise, 36 per cent of land with a slope between 8 and 16 per cent rise and 6 per cent at greater than 16 per cent rise.

The O'Neil DE comprises approximately 16 per cent of land with a slope less than 4 per cent rise, 30 per cent at 4-8 per cent rise, 41 per cent with a slope between 8 and 16 per cent rise, and 14 per cent at greater than 14 per cent rise.

The Myara North, Holyoake and O'Neil DEs both have gentler slopes than the existing Myara region, which has 26 per cent of land with a slope greater than 16 per cent rise, and a comparable slope to that of the historic Huntly Mine regions.

The breakdown of slope category by zone is provided in Table 7.4 and Table 7.5.

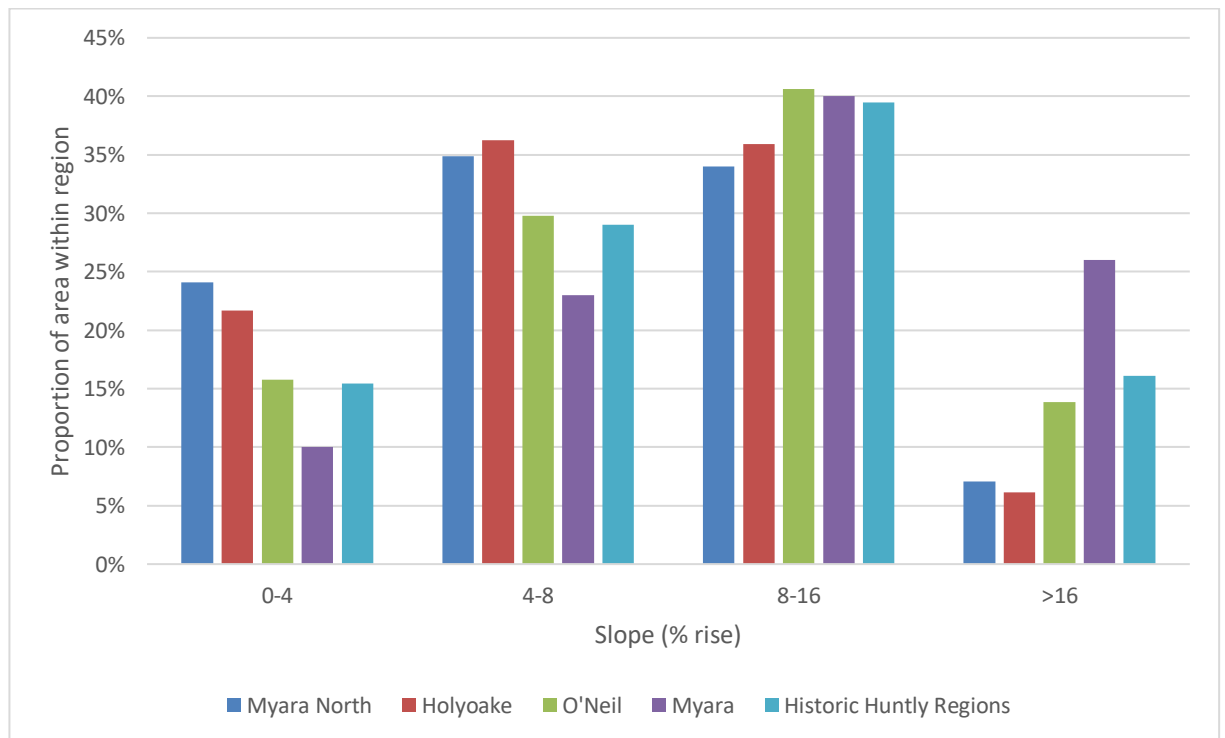


Chart 7-1 Slope categories – Huntly Mine

Table 7.4 Slope category by DE and Zone - area

Slope	Myara North			Holyoake			O'Neil			Total			
	AZ (ha)	LDA (ha)	MDZ (ha)	AZ (ha)	LDA (ha)	MDZ (ha)	AZ (ha)	LDA (ha)	MDZ (ha)	AZ (ha)	LDA (ha)	MDZ (ha)	DE total (ha)
< 4%	1,360	272	944	357	411	886	332	79	466	2,049	762	2,295	5,106
4 - 8%	1,460	399	1,872	541	623	1,597	593	136	928	2,594	1,158	4,397	8,150
8 - 16%	1,144	449	2,047	524	501	1,713	828	174	1,259	2,497	1,124	5,020	8,640
> 16%	328	152	275	127	76	267	328	99	346	782	327	888	1,997
Grand Total	4,292	1,272	5,138	1,550	1,611	4,463	2,081	488	2,998	7,923	3,371	12,599	23,893

Table 7.5 Slope category by DE and Zone – percentage

Slope	Myara North			Holyoake			O'Neil			Total			
	AZ (%)	LDA (%)	MDZ (%)	AZ (%)	LDA (%)	MDZ (%)	AZ (%)	LDA (%)	MDZ (%)	AZ (%)	LDA (%)	MDZ (%)	DE total (%)
< 4%	31.7	21.4	18.4	23.1	25.5	19.8	15.9	16.2	15.5	25.9	22.6	18.2	21.4
4 - 8%	34.0	31.3	36.4	34.9	38.7	35.8	28.5	27.9	31.0	32.7	34.4	34.9	34.1
8 - 16%	26.7	35.3	39.8	33.8	31.1	38.4	39.8	35.6	42.0	31.5	33.3	39.8	36.2
> 16%	7.6	11.9	5.4	8.2	4.7	6.0	15.7	20.3	11.5	9.9	9.7	7.0	8.4

7.3.1.3 Soils

Superficial soils on the Darling Plateau comprise a thin veneer of topsoil (typically less than 0.1 m thick), which contains sand, silt and the majority of the seedbank, over a sandy gravel overburden layer (Hickman *et al* 1992). The overburden ranges from about 0.2-4 m thick and averages about 0.5 m. The overburden is underlain by lateritic bauxite, which is approximately 4-6 m thick and comprises a caprock (duricrust) layer and an underlying friable fragmental layer. The caprock layer is discontinuous and varies from absent to a thickness of a few metres.

Figure 7-4.1 and Figure 7-4.2 present mapping of overburden and caprock thickness within the Myara North DE and Figure 7-5.1 and Figure 7-5.2 presents the overburden and caprock thickness within the Holyoake DE. Mapping is based on exploration drilling in lateritic geology within the Mine DE. Charts 7-2, 7-3 and 7-4 present a histogram of the overburden and caprock thickness in the Myara North, Holyoake, and O'Neil DEs, respectively.

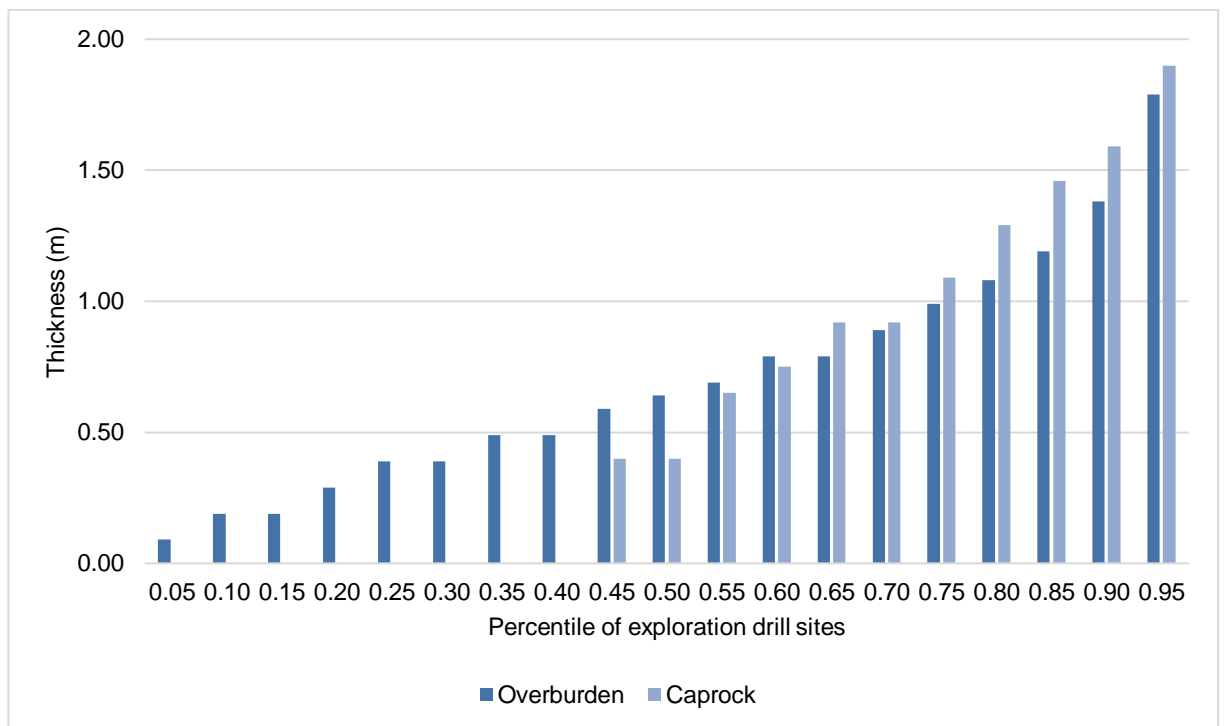


Chart 7-2 Overburden and caprock thickness – Myara North DE

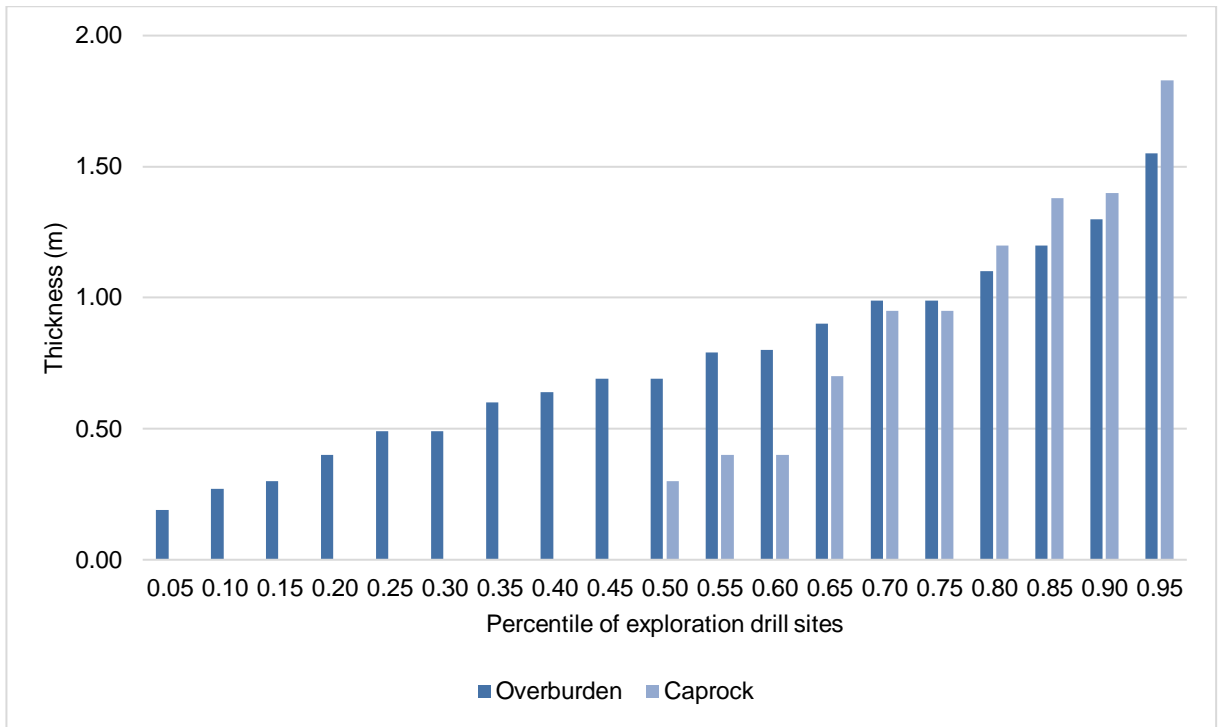


Chart 7-3 Overburden and caprock thickness – Holyoake DE

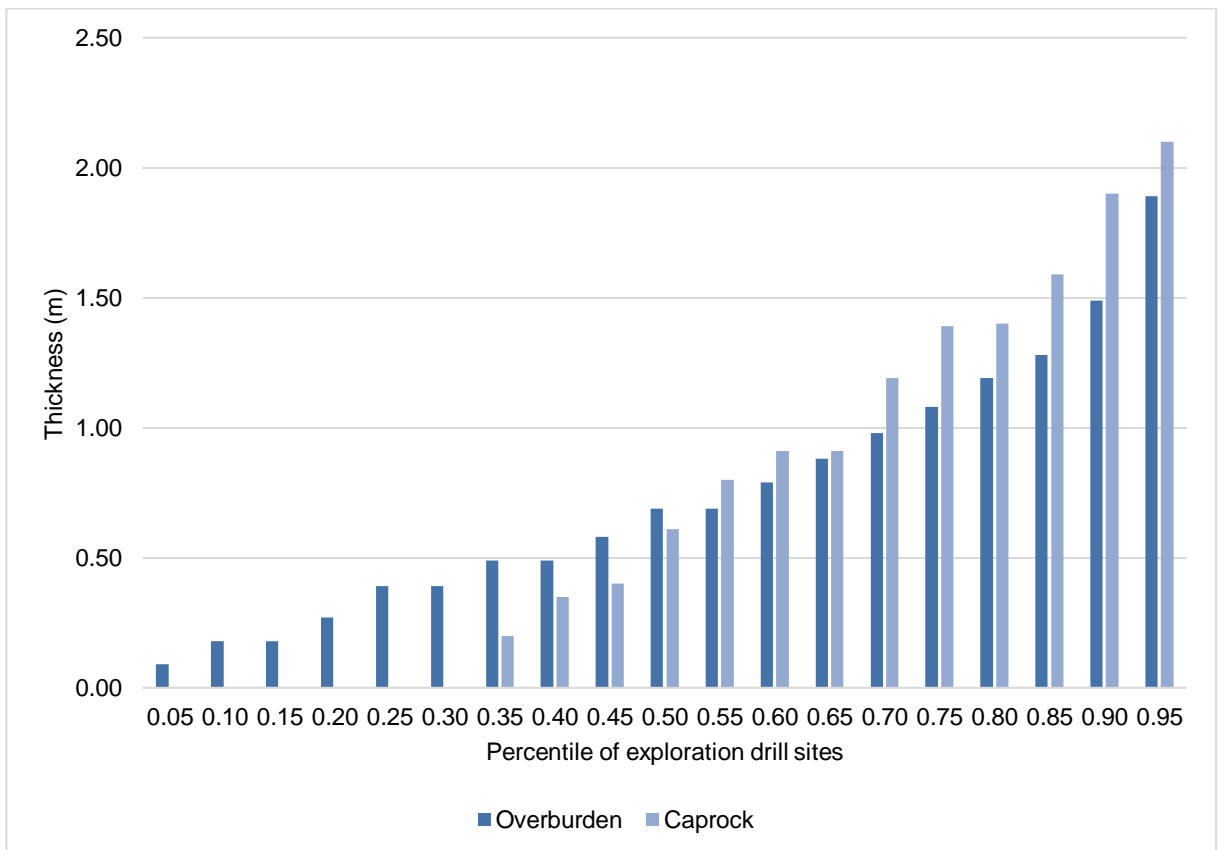


Chart 7-4 Overburden and caprock thickness – O'Neil DE

As presented in Figure 7-4.1 and Chart 7-2, overburden occurs across the laterite in the Myara North DE, ranging from 0.1 m to 1.8 m thick and 0.3 m or more at 80 per cent of drill sites. Allowing for bulking upon excavation, the exploration data indicates that the majority (> 80 per cent) of mine pits are likely to have sufficient overburden to supply at least 0.3 m for rehabilitation as specified in the current prescription. As presented in Figure 7-4.2 and Chart 7-2, caprock is absent over about 40 per cent of the laterite in Myara North, and where present, ranges in depths from approximately 0.4 m to 1.9 m.

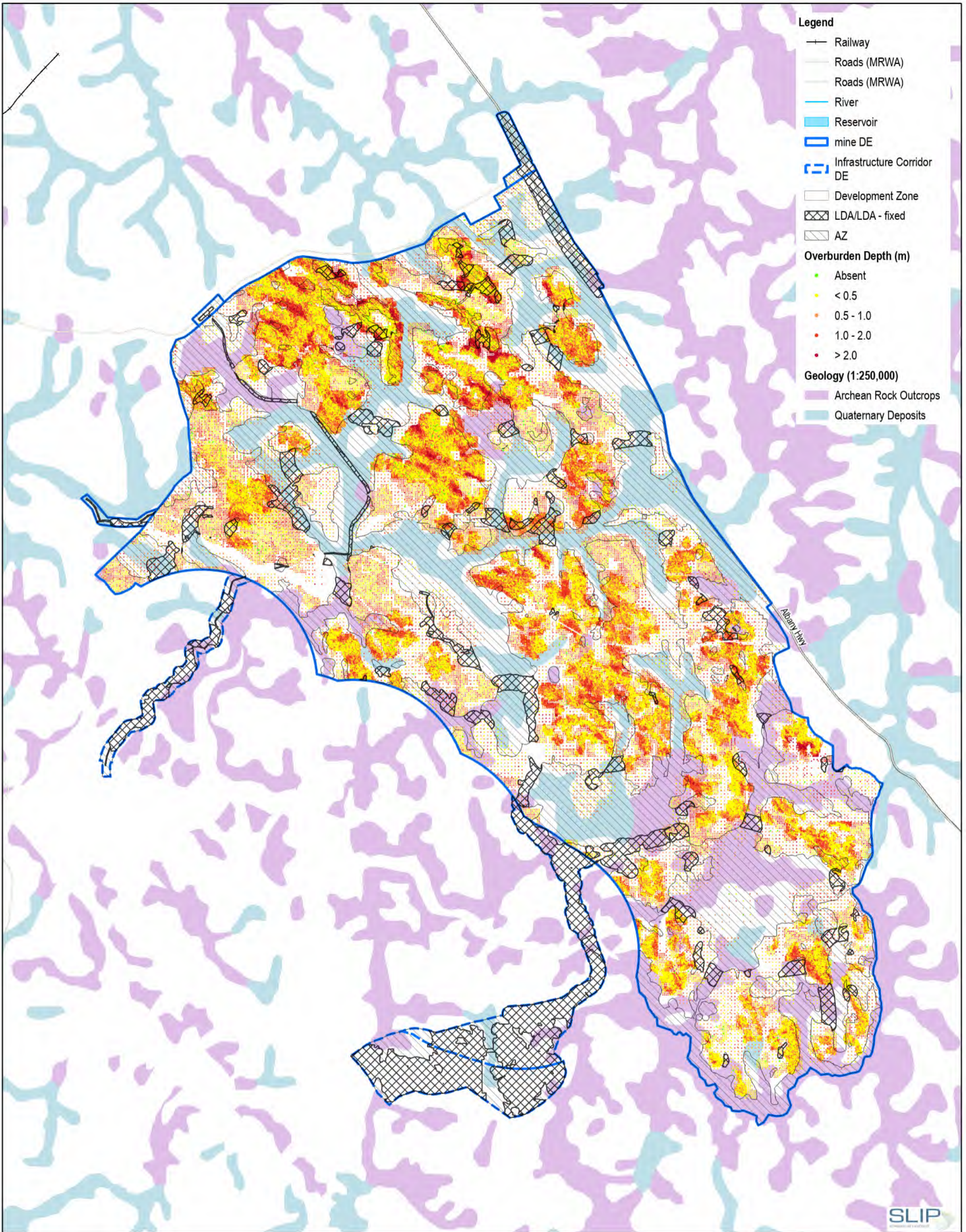
As presented in Figure 7-5.1 and Chart 7-3, preliminary drilling in the Holyoake DE indicates that overburden is likely to occur across the laterite, ranging from about 0.2 m to 1.5 m thick and occurring at 0.3 m or more at over 85 per cent of drill sites. This indicates that the majority (> 85 per cent) of mine pits are likely to have sufficient overburden to supply at least 0.3 m for rehabilitation as specified in the current prescription. As presented in Figure 7-5.2 and Table 7.2, caprock may be absent over about half of the laterite in Holyoake, and where present, ranges in depths from approximately 0.3 m to 1.8 m.

As presented in Figure 7-6.1 and Chart 7-4, overburden occurs across the laterite in the O'Neil DE, ranging from 0.1 m to 1.9 m thick and 0.3 m or more at 80 per cent of drill sites. This indicates that the majority (>80 per cent) of mine pits are likely to have sufficient overburden to supply at least 0.3 m for rehabilitation as specified in the current prescription. As presented in Figure 7-6.2 and Chart 7-4, caprock is absent over about 30 per cent of the laterite in O'Neil, and where present, ranges in depths from approximately 0.2 m to 2.1 m.

The overburden in each of the Myara North, Holyoake and O'Neil DEs are comparable to that of the existing and historic Huntly Mine regions, which have overburden ranging on average from 0.1 m to 1.7 m thick (0.67 m average). The caprock at Myara North, Holyoake and O'Neil is less extensive than that of the existing and historic Huntly Mine regions, which have caprock absent over about one quarter of laterite and where present ranging on average from 0.2 to 2.1 m thick (average 0.85 m).

The bauxite friable fragmental layer beneath the overburden and/or caprock contains nodules, pisoliths and weathered rock fragments in fine-grained, loose earth or sands. The friable fragmental layer is generally about 2 m thick but can be up to 10 m thick on the Darling Plateau (Hickman *et al* 1992). Beneath the bauxite layers lie mottled, pallid and saprolite clay layers that are typically 20-30 m thick, which transition into weathered saprock and then fresh bedrock (Hickman *et al* 1992). These underlying layers form the pit floor following bauxite mining (see Section 7.4.2.3).

The soil catena of the Darling Plateau varies from the lateritic uplands (Dwellingup system) to the valleys (Yarragil system). The regolith is partially eroded in minor valleys, with the upper lateritic layers often absent and replaced by colluvial or alluvial deposits (Section 7.3.1.1). Whereas the upper and mid slopes comprise shallow gravelly sands, the lower slopes and valleys comprise thicker deposits of finer grained soils including silts, clays and loams (Hickman *et al* 1992, Fordyce *et al* 2007). Churchward and McArthur (1980) describe the soils of the minor valleys (Yarragil system) as orange earth and those of the major valleys (Murray system) as comprising red and yellow earth with some red and yellow duplex soils.



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 Kilometres

Map Projection: Transverse Mercator
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 Grid: GDA 1994 MGA Zone 50



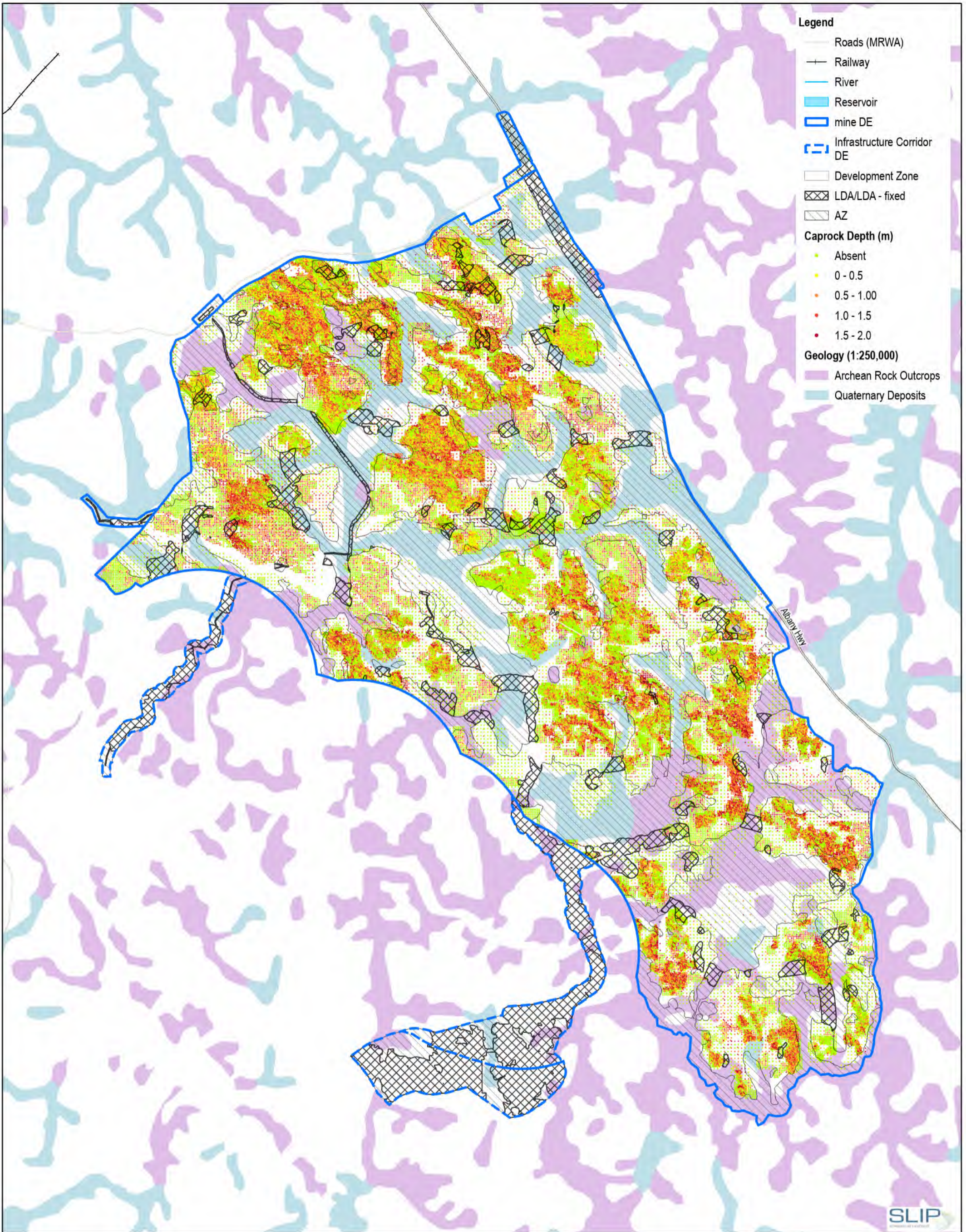
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**Overburden Thickness -
 Myara North Mine Region**

FIGURE 7-4.1

Data source:



- Legend**
- Roads (MRWA)
 - Railway
 - River
 - Reservoir
 - mine DE
 - Infrastructure Corridor DE
 - Development Zone
 - LDA/LDA - fixed
 - AZ
- Caprock Depth (m)**
- Absent
 - 0 - 0.5
 - 0.5 - 1.00
 - 1.0 - 1.5
 - 1.5 - 2.0
- Geology (1:250,000)**
- Archean Rock Outcrops
 - Quaternary Deposits

Scale: 1:60,000 at ISO A3
 0 0.5 1 1.5 2
 Kilometres

Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



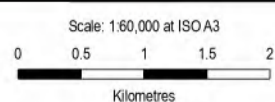
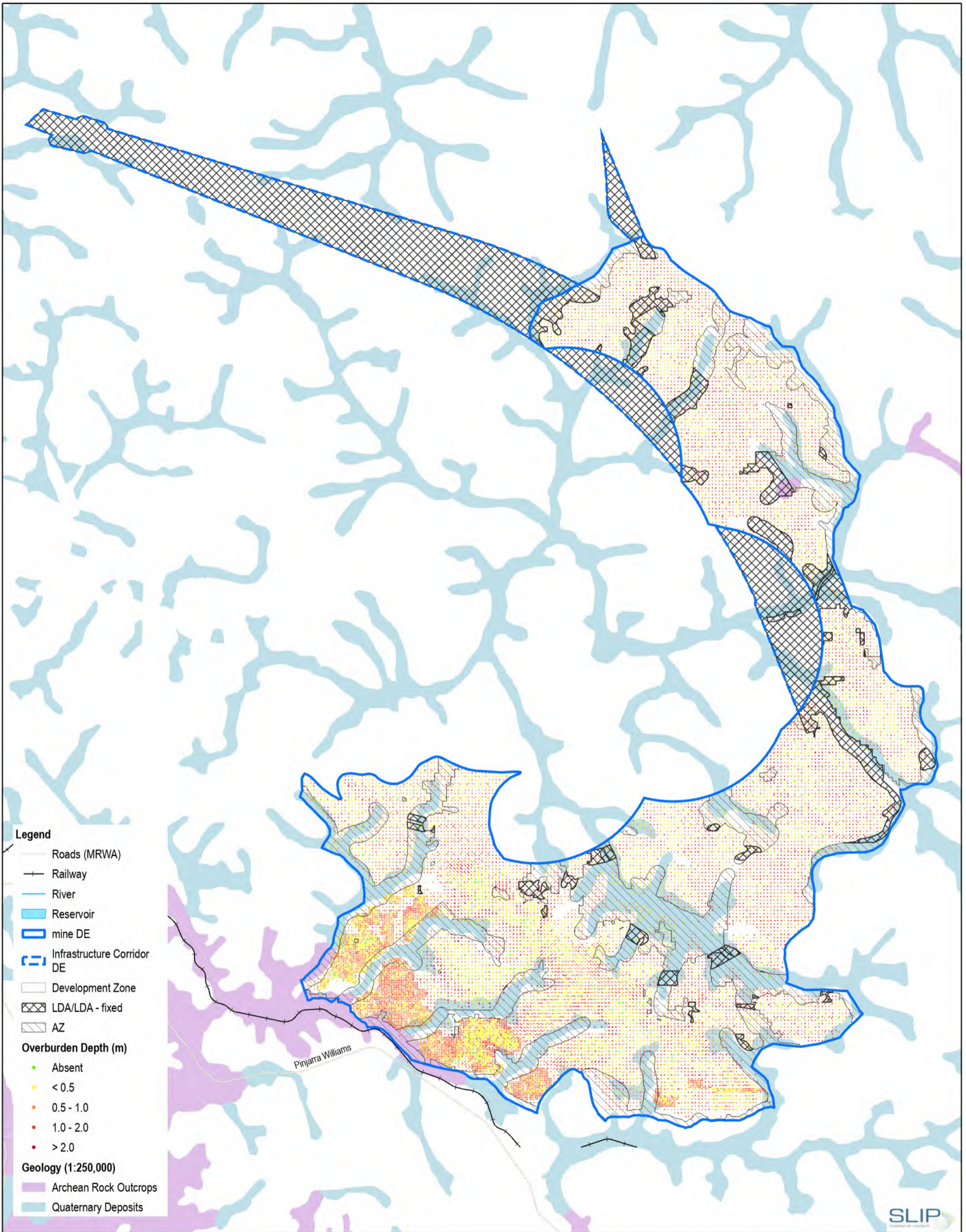
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Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Caprock Thickness -
 Myara North Mine Region**

FIGURE 7-4.2

Data source:



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



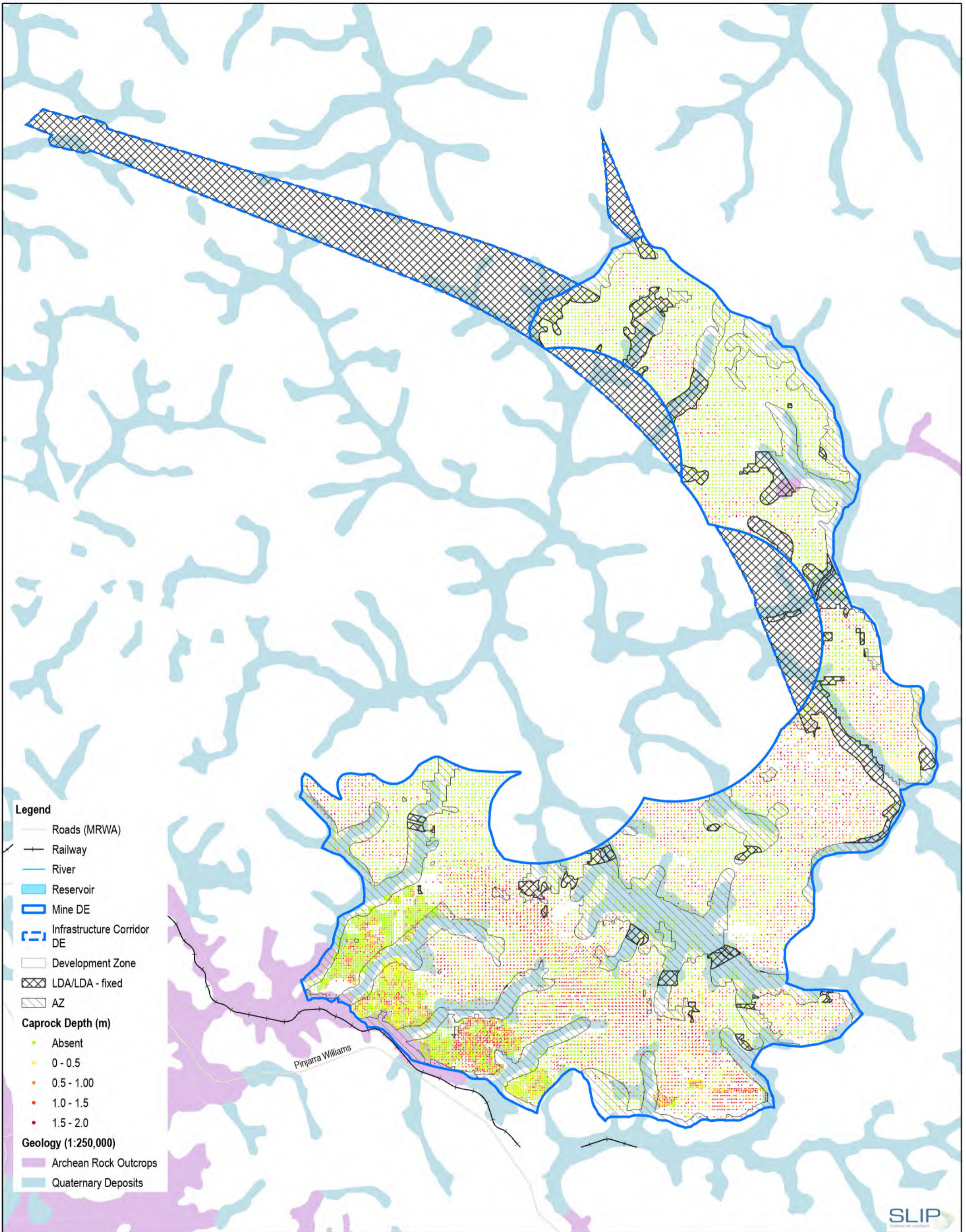
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Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Overburden Thickness -
 Holyoake Mine Region**

FIGURE 7-5.1

Data source:



- Legend**
- Roads (MRWA)
 - Railway
 - River
 - Reservoir
 - Mine DE
 - Infrastructure Corridor DE
 - Development Zone
 - LDA/LDA - fixed
 - AZ
- Caprock Depth (m)**
- Absent
 - 0 - 0.5
 - 0.5 - 1.00
 - 1.0 - 1.5
 - 1.5 - 2.0
- Geology (1:250,000)**
- Archean Rock Outcrops
 - Quaternary Deposits

Scale: 1:60,000 at ISO A3
 0 0.5 1 1.5 2
 Kilometres

Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



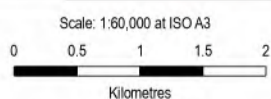
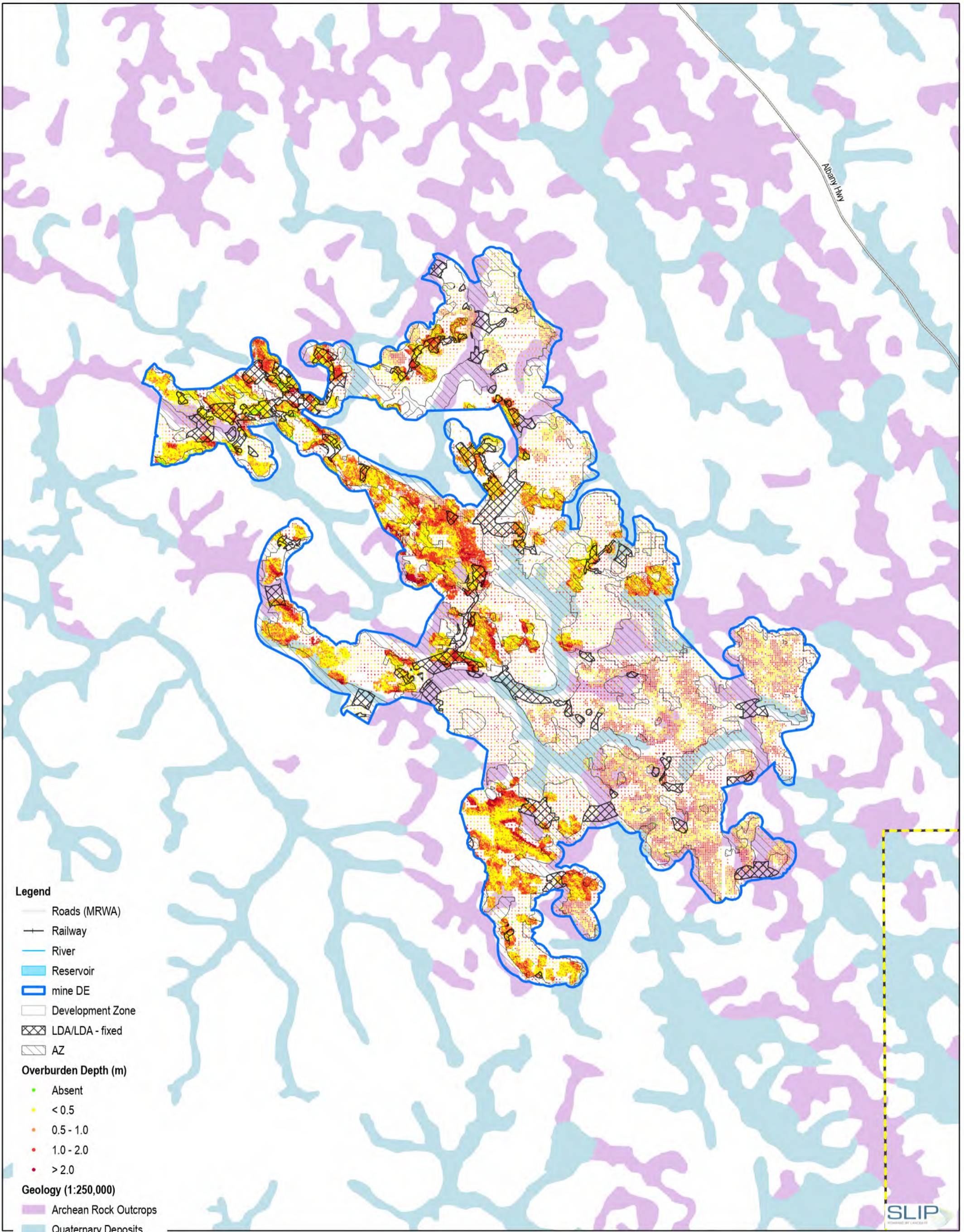
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Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Caprock Thickness -
 Holyoake Mine Region**

FIGURE 7-5.2

Data source:



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



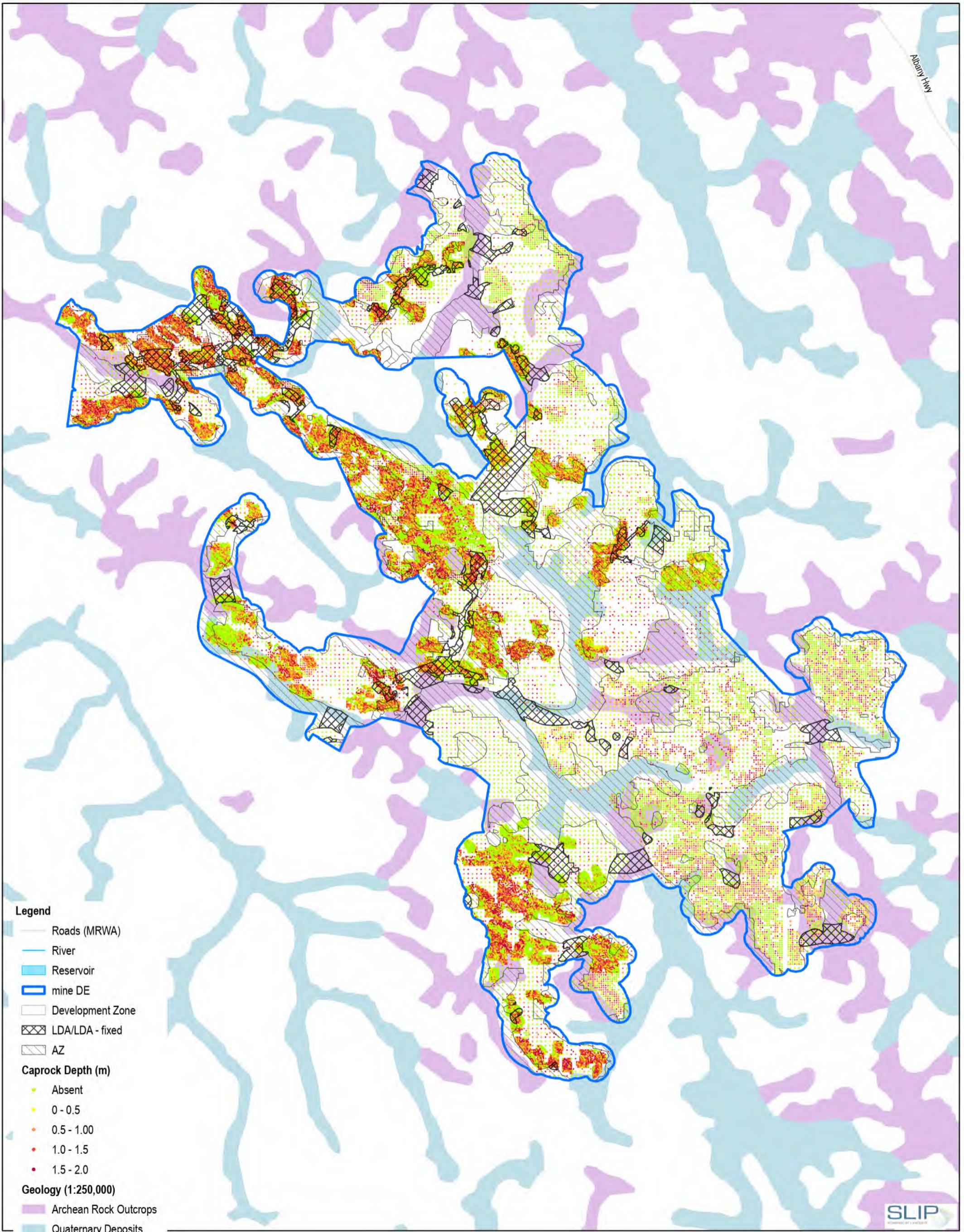
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 Environmental Review Document

Project No. 12633192
 Revision No. 3
 Date 09/03/2025

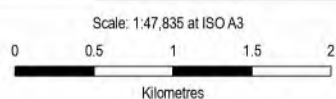
**Overburden Thickness -
 O'Neil Mine Region**

FIGURE 7-6.1

Data source:



- Legend**
- Roads (MRWA)
 - River
 - Reservoir
 - mine DE
 - Development Zone
 - LDA/LDA - fixed
 - AZ
- Caprock Depth (m)**
- Absent
 - 0 - 0.5
 - 0.5 - 1.00
 - 1.0 - 1.5
 - 1.5 - 2.0
- Geology (1:250,000)**
- Archean Rock Outcrops
 - Quaternary Deposits



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



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 Pinjarra Refinery Revised Proposal -
 Environmental Review Document

Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Caprock Thickness -
 O'Neil Mine Region**

FIGURE 7-6.2

Data source:

7.3.1.4 Acid forming materials

The Darling Plateau has not been mapped by State Government for the presence of acid sulfate soils (ASS) nor are there published studies into the presence of acid forming materials in the regolith or bedrock. Within Western Australia, ASS are known to be present within the following landforms (DER 2015):

- riverine, estuarine and coastal lowland areas, such as mangroves, brackish lakes, tidal flats, salt marshes, salt pans, swamps and seasonally-inundated plains
- wetland areas
- beneath the watertable in podsolised sandy soils that contain limited amounts of carbonate minerals (e.g. Bassendean Sands)
- saline inland areas.

Soils or sediments that are of most concern for ASS are those which formed within the last 10,000 years, when seawater inundated coastal plains and sulfate mixed with land sediments containing iron oxides and organic matter (DER 2015). This resulted in formation of ASS as iron sulfides in waterlogged environments. Such processes are not expected to have occurred in the Darling Plateau given its elevation and lack of recent sea inundation.

ASS may also form in inland wetlands where there is sufficient iron, sulfate and organic matter. Sulfate may originate from rainfall and groundwater. Groundwater monitoring conducted for the Proposal indicates low levels of sulfate in groundwater, ranging from 5-107 mg/L (average 23 mg/L) over the Myara North mine region and ranging from 8-248 mg/L (average 50 mg/L) over the Holyoake mine region. This suggests limited sulfate with which to form strong ASS, however, there remains the potential for some ASS to have formed in the seasonally waterlogged / inundated swamps in valley floors.

The surface waters of the Mine DE are seasonal, and swamps are expected to be subject to seasonal drying, which may have increased due to the observed decline in groundwater levels in the regolith (see Section 8.3.3). Any potential ASS within the swamps may therefore have already been subject to oxidation. However, there is a lack of site-specific soil and groundwater data with which to confirm the presence or absence of ASS in swamps within the Mine DE.

ASS is not expected to be present in the lateritic uplands, which comprise gravelly sands that are well drained and have limited organic matter apart from a thin veneer of topsoil (less than 0.1 m thick).

Acid forming materials can be present as sulfide bearing minerals in rocks. Chemical assay of granite and dolerite bedrock to about 0.1 per cent has not identified the presence of sulfur (Hickman *et al* 1992). It is therefore unlikely that trace quantities of sulfur in bedrock have sufficiently accumulated in the lateritic upper regolith during the weathering process such that there is a high risk of acid formation during bauxite mining.

7.3.1.5 Contamination

There are contaminated sites within five kilometres of the Mine DE, which are being managed separately under the *Contaminated Sites Act 2003* and do not require consideration by this assessment.

Unrecorded soil contamination may be present in the Mine DE due to past land uses such as equipment and vehicles for timber harvesting and forest management, or historic use of PFAS for fire response activities. Monitoring of surface water within the Mine DE recorded water quality that was relatively unimpacted by anthropogenic use (see Section 8.3.2.3), indicating that soil contamination (if present) is likely to be insignificant.

7.4 Potential environmental impacts

7.4.1 Identification of potential impacts

The following Proposal activities have the potential to impact terrestrial environmental quality:

- Clearing of native vegetation
- Alteration of natural drainage regimes
- Waste disposal
- Storage and handling of contaminants
- Closure and decommissioning.

The Proposal may result in the following potential impacts to terrestrial environmental quality:

- Soil salinisation as a result of mining-induced saline groundwater rise
- Disturbance of potential acid sulfate soils
- Erosion of post-mining landforms
- Contamination from spills and/or leaks from storage and handling of hazardous materials and waste.

7.4.2 Huntly Mine

7.4.2.1 *Soil salinisation as a result of mining-induced saline groundwater rise*

Section 8.4 assesses the potential for the Proposal to result in saline streamflow discharges and increases in the salinity of drinking water reservoirs. As presented in Section 8.4.3, groundwater modelling indicates that the Proposal is expected to cause groundwater mounding beneath and in the vicinity of mine pits, due to the clearing of native vegetation and increased recharge of rainfall. Groundwater level mounding, typically ranging from 1 to 10 m, is predicted to occur in the Myara North, Holyoake, and O'Neil DEs as mining progresses. The highest groundwater rise is predicted to occur in the vicinity of mined areas, with more limited groundwater rise in valleys where shallow groundwater may occur. The latter observation arises from enhanced recharge in previously mined areas (Myara), even after rehabilitation (GHD 2023a).

Groundwater levels are predicted to rise over the first 15 years and then slowly decline towards an un-mined baseline. Greater mounding is predicted for wetter climatic conditions. The Proposal is not expected to cause groundwater declines.

Groundwater within the Mine DE is predominantly fresh, with salinity averaging about 450 mg/L total dissolved solids (TDS) in the Myara North mine region and about 400 mg/L TDS in Holyoake (see Section 8.3.3.4). A small number of groundwater bores have recorded salinity above 500 mg/L and may be regarded as brackish or saline.

Of the 125 groundwater monitoring bores identified across the Myara North mine region, a total of 92 bores (74 per cent of total) recorded salinity less than 500 mg/L, 16 bores (13 per cent of total) recorded salinity of 501-1,000 mg/L, 8 bores (6 per cent of total) recorded salinity of 1,001-2,000 mg/L and 9 bores (seven per cent of total) recorded salinity of more than 2,000 mg/L. The highest salinity recorded was 3,807 mg/L. The bores with salinity greater than 500 mg/L are scattered in the southeast portion of the Myara North region and a small cluster in the northeast portion, surrounded by bores with freshwater quality.

Of the 16 groundwater monitoring bores identified across the Holyoake mine region, a total of 14 bores (88 per cent of total) recorded salinity less than 500 mg/L, 1 bore recorded salinity of 501-1,000 mg/L and 1 bore recorded salinity of 1,001-2,000 mg/L. The highest salinity recorded was 1,341 mg/L.

Of the 14 sampled bores in the O'Neil mine region, three bore recorded salinity of less than 500 mg/L, six recorded salinity of 501-1,000 mg/L, two recorded salinity of 1,001-2,000 mg/L, and one of greater than 2,001 mg/L. The average salinity was 680 mg/L.

Due to the predominantly freshwater quality of groundwater recorded in the Proposal mine regions, it is unlikely that mining-induced groundwater rise will result in widespread salinity impacts on soils. Groundwater monitoring data indicates that there may be pockets of saline groundwater within the mine regions that have the potential to increase salinity in the overlying regolith in the event of groundwater rise over these pockets. The majority of groundwater rise will occur over the deeper regolith beneath mine pits on middle to upper slopes, with more limited rise occurring beneath valleys.

Groundwater rise that is close to the surface, and may therefore impact soils, will be predominantly in valleys that have been subject to shallow groundwater in the past, prior to the decline of groundwater levels with declining rainfall (see Section 8.3.3.2). Accordingly, the modest groundwater rise expected near valleys that may result in shallow groundwater depths is likely to return soil salinity to past levels to which vegetation would be adapted.

7.4.2.2 Disturbance of potential acid sulfate soils

ASS may potentially be presented in swamps within the Mine DE but is not expected to occur in lateritic soils, nor are strongly acid forming materials expected to occur in the regolith (see Section 7.3.1.4).

Mining occurs above the groundwater table and no dewatering is undertaken of mine pits. Any potential acid forming materials in the regolith are therefore expected to already be oxidized at the depths to which mining occurs. There is no waste rock storage within the mine, with all the overburden replaced on rehabilitation. Overburden comprises predominantly gravelly sands which are not expected to be ASS.

Mining will not occur in any swamps, as these areas are devoid of economic bauxite. Swamps may be disturbed for infrastructure crossings such as haul roads and conveyors. Depending on geotechnical requirements, swamp deposits may require excavation and replacement with engineered fill for the infrastructure crossings. As noted in Section 7.3.1.4, swamps may have been subject to prolonged drying with declining groundwater levels and potential ASS if present may have already been subject to oxidation to actual ASS. However, there is a lack of site-specific soil and groundwater data with which to confirm the presence or absence of potential or actual ASS in swamps within the Mine DE. Accordingly, excavation of swamp deposits for infrastructure crossings may have the potential to cause disturbance to potential or actual ASS.

Disturbance of potential acid sulfate soils for river crossings

The Proposal will involve construction of river crossings over the Serpentine and South Dandalup rivers, including:

- primary haul road crossing over the Serpentine River, to connect the Myara North mine DE to the existing Myara crusher
- conveyor, mine access road and primary haul road crossings over the South Dandalup River, to service the Holyoake mine facilities.

Indicative locations of the Serpentine and South Dandalup river crossings are presented in Figure 1-4 (Myara North) and Figure 1-5 (Holyoake).

The Proposal will also involve construction of stream crossings for secondary haul roads within the Mine DE. Indicative locations of the secondary haul road crossings for streams are presented in Figure 1-4 (Myara North), Figure 1-5 (Holyoake) and Figure 1-6 (O'Neil).

River and stream crossing construction will involve clearing of vegetation and placement of earth fill to create an embankment over the valley floor, which is not expected to disturb ASS if occurring in the valley floor sediments. Excavation of sediments within valley floors will be limited to the immediate vicinity of the river/stream channel to create footings for culverts, including removal of low strength material (i.e. sediment), compaction of the sub-base and laying crushed rock as a footing material. The depth of low strength material (i.e. sediment) to be removed will depend on geotechnical investigation but is typically about one metre. The volume of sediment that may be removed is expected to be up to 500 m³ for a river crossing and less for a stream crossing, subject to confirmed final geotechnical design requirements. Apart from culvert footings, no trenches or other excavations will occur within the valley floors for river or stream crossings.

The shallow excavation of valley floor sediments for culvert footings may disturb ASS, if present in the sediments. Disturbance to ASS, if present, may cause oxidation of ASS and generation of acid and metalliferous leachate. All river and stream crossings will be subject to geotechnical survey, including sampling for ASS. If ASS are identified as present in the sediments to be removed, then management will be undertaken in accordance with national guidelines to minimise disturbance to and impacts from ASS (see Section 7.5).

7.4.2.3 Erosion of post-mining landforms

The mine development stage involves stripping and stockpiling the superficial soils and blasting or ripping the caprock layer. Mining then involves removing the bauxite caprock and friable fragmental layers, which are transported to stockpiles, then crushed and conveyed to Pinjarra Alumina Refinery.

The pit floor remaining after mining contains a diverse range of lateritic regolith materials from the lower mottled, pallid clay and saprolite layers, which mostly comprise sandy loams and clays (Mengler *et al* 2005). In areas where the regolith is thin and has been mostly removed by mining, the mine floor may contain partly weathered material that retains the texture of the original bedrock. Other areas of the regolith have existing root channels, adequate structure and stable aggregates that support root exploration and plant re-establishment. The majority of pit floors require ripping to create macrostructure and alleviate high strength and high bulk density (Mengler *et al* 2005). Soils derived from dolerite dykes (about 15 per cent of bedrock) tend to be more clay-rich and have more pedal structure, whereas soils derived from granite typically contain macropores (Raper and Croton 1996).

Following the completion of mining, rehabilitation is undertaken including pre-ripping of compacted floors to at least 1.2 m, landscaping batters, spreading overburden and topsoil (typically 300 mm combined depth), and then contour ripping to create a furrowed surface.

The net effect of bauxite mining of Jarrah forest soils is the removal of an approximately 4-6 m thick layer of caprock and friable fragmental material. The resulting void is then filled with seed rich topsoil and overburden, and placed over a ripped, friable substrate of sandy loams and clays. The total depth of friable material created is about 1.5 m, including topsoil, overburden and ripped substrate.

Vegetation use of Jarrah forest soils

The Leaf Area Index (LAI) of Jarrah forest vegetation is dominated by the predominant canopy tree Jarrah (*Eucalyptus marginata*), which comprises about 60 per cent to 80 per cent of the LAI depending on the presence of other trees (Crombie 1992). Shallow rooted vegetation (i.e. small shrubs and groundcovers with roots confined to shallow soils above the caprock) is estimated to comprise less than 10 per cent of LAI and medium rooted vegetation (i.e. larger shrubs with roots that penetrate the caprock but not far into the underlying clays) approximately 10 per cent of LAI (Crombie 1992).

Jarrah has a dimorphic root system, comprising dense lateral roots in the topsoil and overburden above the caprock, from which 'sinker' roots extend vertically to penetrate cracks and fissures in the caprock and gain access to moisture bearing clay through ancient root channels (Dell *et al* 1983, Farrington *et al* 1996). Dell *et al* (1983) suggest that each tree may access 100-200 ancient root channels of up to 40 m from the surface. The root channels are permanent features of the profile and are occupied by successive generations of trees (Dell *et al* 1983).

Carbon *et al* (1980) report that the bulk of Jarrah roots are in shallow soils (topsoil and overburden) above the caprock, which has the greatest potential to supply water in winter but dries over the summer and autumn. Measurements by Carbon *et al* (1980) indicate that the shallow soils have root density (root depth per area of ground surface) about an order of magnitude greater than the deeper sandy loam and clay layers.

While trees have deeper roots, substantial groundwater use is limited to shallower depths, being recorded in Jarrah forest at sites with depths of 6 mbgl, but not at 14 mbgl or 30 mbgl (Farrington *et al* 1996). Deeper rooted vegetation such as Jarrah and large shrubs can maintain higher photosynthetic activity into summer and autumn compared to shallow rooted vegetation (Crombie 1992). However, both deep and shallow rooted vegetation exhibit daily cycling of water potentials and stomatal conductance and a rapid response following rainfall during summer (Crombie 1992). This suggests that Jarrah forest vegetation remains physiologically active during summer and is tolerant of low water potentials, which would be necessary to enable deeper rooted vegetation to use water held in clayey subsoils (Crombie 1992).

The establishment of a 1.5 m thick friable layer of topsoil, overburden and ripped substrate provides a comparable, though generally thicker, stratum than the topsoil and overburden present above the caprock prior to mining. The overburden occurring over the Myara North and Holyoake mine regions ranges from 0.1 m to 1.7 m thick and averages about 0.75 m (see Section 7.3.1.3).

The friable layer enables the development of a dense root structure of Jarrah forest vegetation as occurs in the topsoil and overburden present prior to mining. Deeper rooted vegetation establishing within the friable layer is expected to re-colonise ancient root channels present in the underlying regolith materials, as have been used by successive generations of trees prior to mining (Dell *et al* 1983). There is expected to be a partial loss of soil water capacity, due to the removal of the bauxite friable fragmental layer, which comprised about 2 m of loamy soils that previously were accessed by deep and medium rooted vegetation. Loss of this layer represents approximately 10 per cent of the regolith thickness, however the loamy layer may have had a higher plant available water than that of the underlying mottled and pallid clays. Loss of the bauxite caprock layer is not expected to substantially reduce the soil water capacity, as the layer was primarily cemented material that provided discrete pathways for water and roots to enter the underlying un-cemented layers.

Loss of the bauxite friable fragmental layer has not been observed to result in impaired growth or health of rehabilitation. Monitoring of rehabilitation has demonstrated the successful establishment and persistence of a LAI of 2-2.5, comparable to that of un-mined Jarrah forest (see Section 5.4.2.2). Monitoring has also indicated a floristic diversity of about 80 per cent to 100 per cent of un-mined Jarrah forest, declining weed cover and sustained understorey coverage (see Section 5.4.2.2).

During the 2010/11 drought and heat waves, Jarrah forest canopy die-off was observed at sites across the Northern Jarrah Forest, including un-mined forest and some areas of rehabilitation (see Section 5.4.2.2). Widespread die-off of rehabilitation did not occur nor was rehabilitation affected in greater proportion than un-mined forest. Browsers *et al* (2012) report that canopy die-off was more frequent on:

- rocky soils with low water holding capacity
- sites that were close to rock outcrops
- areas that received a slightly higher amount of annual rainfall compared to the surrounding landscape
- sites at high elevations or on steep slopes
- in areas that were generally slightly warmer than their surroundings.

The results of monitoring collectively demonstrate that Alcoa's rehabilitation establishes and persists, including during drought and heat wave events, indicating that the 1.5 m thick friable substrate over regolith containing ancient root channels is an effective growth medium. Accordingly, mine rehabilitation vegetation is expected to be sustained over the long-term, with resilience to climate change comparable to that of un-mined Jarrah forest. Mine rehabilitation is therefore expected to provide long-term protection of soils from erosion and associated sediment discharge to streams and reservoirs.

Erosion during rehabilitation establishment

Mengler *et al* (2006b) surveyed topsoil and overburden samples in rehabilitated mine pits at the Huntly Mine. The survey indicated predominantly sandy gravel texture, comprising an average of 60 per cent gravel (>2 mm diameter, range 38 per cent-78 per cent), 38 per cent sand (2-0.02 mm diameter, range 24 per cent-65 per cent) and 3 per cent silt and clay (<0.02mm diameter, range 0-6 per cent) for Huntly Mine. Due to the predominant sandy gravel texture, the soils had calculated low erodibility coefficients (RUSLE equation K factors) averaging 0.009 (range 0.000-0.019).

The skeletal topsoil and overburden materials are distinct to most agricultural soils and mining waste, due to the low combined clay and silt contents and very high gravel contents, which develop with time a protective surface layer of gravel covering 70-80 per cent of the land surface. The high porosity and coarse texture also enable rapid infiltration of rainfall within the topsoil, overburden and ripped regolith material. However, thinly applied topsoil and overburden can be mixed with finer grained pit floor materials during contour ripping, which can introduce more erodible (and potential dispersive) clayey material into the shallow subsurface surface. The regolith beneath the ripped zone generally comprises lower permeability sandy loams and clays, therefore rainfall infiltration is limited to the water storage in the overburden and ripped zoned, accordingly surface runoff occurs following extended rainfall periods that fill up the permeable materials.

Gullies form in the rehabilitated landform through an erosion sequence (Mengler *et al* 2006). The fine-grained content is displaced from the coarser topsoil/overburden, depositing within the furrows and filling their volume such that surface water overflows and erodes through the fine-grained materials in downslope furrows. The gully that is initially created in the fine-grained materials concentrates flow and creates knickpoints that enable erosion of the coarser topsoil/overburden and underlying ripped regolith materials.

Analysis of gully erosion at the Huntly, Willowdale and Boddington bauxite mines suggested a minimum catchment of 0.3 ha for gully development, with gully volumes typically remaining small (20-100 m³) but potentially increasing for higher slopes (> 10 degrees for Huntly Mine, or > 17.6 per cent) and shallower topsoil/overburden placement (< 200 mm). Erosion was highest in the first two to three years following rehabilitation completion until rehabilitation establishes, though there was a lack of long-term data with which to compare the erodibility of rehabilitation to that of un-mined Jarrah forest (Mengler *et al* 2006). For the period at higher risk of erosion, the major triggers for gully erosion were identified as:

- directing excessive off-site runoff into the rehabilitation

- poor surface completion (e.g. ripping that does not adhere to contours) that concentrates flow or impairs infiltration
- insufficient depth of returned topsoil and overburden (< 200 mm combined).

As presented in Section 7.3.1.3, exploration drilling indicates that overburden occurs at a thickness of more than 200 mm over 90 per cent of drill sites in the Myara North, Holyoake, and O'Neil mine regions. This suggests that the majority of mine pits will have sufficient overburden to supply at least 200 mm depth on rehabilitation.

Chart 7-1, previously presented in Section 7.3.1.2, illustrates slope analysis based on LiDAR within Mine disturbance areas, including historic mine regions, the current Myara mine region and proposed Myara North and Holyoake DEs, and previously mined O'Neil DE. It is noted that the Myara North and Holyoake DE slopes are currently un-mined, whereas the Myara and historic regions reflect the topographic effect of mining. The analysis indicates that approximately 85 per cent of the disturbance areas (historic, current and proposed) within Huntly Mine have slope less than 16 per cent rise and are therefore likely to be subject to small volumes of gully erosion. The remaining 15 per cent of disturbance areas may potentially be subject to higher gully volumes, based on the findings of Mengler *et al* (2006).

The Huntly Mine Closure Plan included in Appendix D1, provides a detailed description of the practices and procedures for minimising erosion of the post-mining landscape and creating safe, stable post-mining landforms.

7.4.2.4 Contamination from spills and/or leaks from storage and handling of hazardous materials and waste

Use of hazardous materials – operations

Diesel is the predominant hazardous material used at the Huntly Mine, and to a lesser extent hydraulic and lubricating oils. Minor quantities of other hazardous materials including solvents, adhesives and other chemicals are used for vehicle and equipment maintenance or water treatment.

The Huntly Mine predominantly uses diesel as fuel for haul trucks, excavators and other large earthmoving equipment, and to a lesser extent for light vehicles. Diesel may also be used for on-site power supplies and mobile lighting towers. Very minor quantities of unleaded petrol are used in gardening equipment to maintain areas surrounding the mine facilities and on-site offices. The storage and handling of diesel, oils and other chemicals creates the potential for spills and/or leaks that cause soil contamination.

Haul trucks, some wheeled earthmoving equipment and light vehicles are refuelled at fuel bays. Planned maintenance of haul trucks, light vehicles and some earthmoving equipment is undertaken at workshops. The fuel bay and workshop buildings are located at mine facilities and have roofs and sealed floors, which are expected to capture spills or leaks during refuelling or maintenance. Diesel and oil storage tanks are located at mine facilities and are double-lined and above ground to minimise and detect leaks. Smaller quantities of hazardous materials stored at mine facilities are inside buildings or on sealed floors. Due to the high volume and frequency of storage and handling of diesel, oils and other chemicals at the mine facilities, there is potential for localised soil contamination to occur that requires remediation when a facility is decommissioned.

Excavators, bulldozers and other earthmoving equipment will be refuelled and maintained in the field. Refuelling and maintenance in the field have the potential to cause spills and leaks that contaminate soils. There is also potential for ongoing, small volumes of oil leaks from vehicles and equipment, and rare collisions that result in fuel or oil spills.

The majority of spills and leaks in the field, particularly those from major incidents and involving large volumes, are expected to be identified quickly and the contaminated soils excavated and disposed of off-site at a licensed waste facility. Smaller spills and leaks may potentially be missed, but these are anticipated to mostly adsorb to soil particles beneath the spill site. Diesel and particularly oils contain longer chain hydrocarbons that are weakly water soluble and readily adsorb to soils with organic matter and clay content. Small volumes of diesel and oil that escape detection and remediation are therefore expected to remain as in-situ soil contamination rather than migrate to sensitive areas such as streams. All mine pits and haul roads will be rehabilitated post mining, and any identified minor soil contamination arising from small spills and leaks will be overlaid with overburden, topsoil and establishing native vegetation (see Section 5.5.3). Pockets of soil contamination remaining in the rehabilitation are expected to biodegrade over time and may result in localised impact to vegetation condition in the rehabilitation.

Use of hazardous materials – construction

Use of hazardous materials during construction is expected to be similar to operations and predominantly involve diesel and to a lesser extent oils for construction equipment, vehicles and generators. Fuel, oil and other chemicals will be stored at a designated construction compound which will be located at the proposed mine facilities area. Fuel and oil storage tanks will be double lined and above ground, and smaller quantities of hazardous materials will be stored on bunded pallets or inside temporary buildings.

Earthmoving equipment will be refuelled and maintained in the field, which has potential to cause spills and leaks that contaminate soils. The majority of spills and leaks in the field are expected to be identified and contaminated soils disposed off-site at a licensed waste facility. Smaller spills or leaks that escape detection are expected to cause pockets of soil contamination that remain in-situ. All construction areas will either become footprints for mine facilities and infrastructure and/or will be subject to mining. These will ultimately be rehabilitated either progressively or at the end of life for the mine region. Minor soil contamination arising from construction in the field will therefore be overlaid with overburden, topsoil and establishing native vegetation. The construction compound will form part of the mine facilities footprint and therefore soil contamination that occurs there may require remediation when the facility is decommissioned.

Waste generation and disposal

All operational and construction wastes will be transported off-site for recycling or disposal at licensed waste facilities. Operational and construction wastes will be temporarily stored at the mine facilities and construction compound, respectively, in designated containers. Liquid wastes (e.g. waste oils) will be stored in double-walled above-ground tanks or other secondary containment systems (e.g. drums on banded pallets). Construction and mine operations in the field will use 'portaloo's or demountable ablution blocks that are zero discharge systems and are pumped out by tanker or transported off-site, with the sewage disposed at an off-site licensed waste facility.

Sewage from the mine facilities workforce will be treated at an on-site sewage treatment plant (STP), which comprises an aerated treatment system with disinfection. Treated sewage effluent from the STP will be disposed at the mine facilities at an effluent irrigation area. There is potential for soil contamination to accumulate at the effluent irrigation area, including nutrients and metals, which may require remediation when a facility is decommissioned.

Use of per- and poly- fluoroalkyl substances (PFAS)

Alcoa has committed to using PFAS-free fire-fighting foams for the Myara North, Holyoake, and O'Neil mine regions. All water supplies to construction and operations in the Myara North and Holyoake DEs will be sourced from public drinking water sources, captured on-site stormwater or from licensed on-site water treatment facilities, where approved for reuse on the Mine. PFAS would be limited to minor quantities in materials such as workforce clothing, paper packaging, carpets or wire insulation, which are unlikely to be discharged to the environment as all wastes will be recycled or disposed off-site at licensed waste facilities. Accordingly, the direct discharge of PFAS from construction and mining is unlikely to occur and less likely to cause significant soil contamination.

7.5 Mitigation

Mitigation measures associated with Terrestrial Environmental Quality impacts are detailed in Table 7.6. Objectives, triggers and contingency actions are presented in Table 7.7. As presented, the mitigation measures are typically established practice, best practice or industry standard and have a high certainty of effectiveness. Mitigation measures with a moderate certainty of effectiveness relate to the timing of rehabilitation and avoidance of swamp and streamzones, which will be undertaken as practicable.

Table 7.6 Avoidance and minimisation of potential impacts to terrestrial environmental quality

Mine Development Envelope		
No.	Soil salinisation as a result of mining	Industry standard, best practice and certainty of effectiveness
	Minimise	
7-1	Where salinity risk has been identified through previous data, rehabilitation will be completed as soon as practicable after mining has been completed.	Established practice at Huntly Mine, commencement timeframes may vary due to a range of factors, moderate certainty
7-2	Rehabilitation within the Mine Development Envelope will be undertaken as presented in Section 5.4.7.	Established practice at Huntly Mine, high certainty
	Disturbance of potential acid sulfate soils	Industry standard, best practice and certainty of effectiveness
	Minimise	
7-3	Haul roads, conveyors, and other infrastructure within the Mine Development Envelope are planned to limit crossing of mapped swamp and stream zones, to the minimum required for safe mining, as far as practicable. If disturbance to mapped swamp and stream zone cannot be avoided, minimise disturbance within swamp and stream zones, as far as practicable.	Best practice, moderate certainty
7-4	Where excavation of 100 m ³ or more or dewatering of swamp sediments is required in an identified high to moderate ASS risk mapped area, ASS investigation will be undertaken in accordance with the national guideline requirements for acid sulfate soils (waterquality.gov.au).	Industry standard, high certainty
7-5	Where ASS is confirmed as present within the excavation or groundwater drawdown area, construction will be reviewed to avoid disturbance as far as practicable. Where ASS disturbance is not avoidable, an ASS management plan	Industry standard, high certainty

	(ASSMP) will be prepared in accordance with <i>the national guideline requirements for acid sulfate soils (waterquality.gov.au)</i> .	
7-6	Monitoring and validation will be undertaken in accordance with the approved ASSMP.	Industry standard, high certainty
	Erosion of post-mining landform	Industry standard, best practice and certainty of effectiveness
	Minimise	
7-7	Rehabilitation within the Mine Development Envelope will be undertaken as presented in Section 2.4.	Established practice at Huntly Mine, high certainty
7-8	Rehabilitation will meet the closure criteria set out in the Huntly Mine Closure Plan (Appendix D1).	Established practice at Huntly Mine, high certainty
7-9	Rehabilitation will be monitored as presented in Section 2.4.	Established practice at Huntly Mine, high certainty
7-10	Visual inspections of rehabilitated areas for stability, as per Huntly Mine Closure Plan (Appendix D1).	Established practice at Huntly Mine, high certainty
	Contamination from spills and/or leaks from storage and handling of hazardous materials and wastes	Industry standard, best practice and certainty of effectiveness
	Avoid	
7-11	Construction and operational vehicles and equipment will use PFAS-free fire-fighting foams.	Best practice, alternatives available, high certainty
7-12	All wastes apart from treated sewage effluent will be transported off-site for recycling or disposal at a licensed waste facility.	Established practice at Huntly Mine, high certainty

	Minimise	
7-13	Haul trucks, heavy vehicles and light vehicles will be refuelled as far as practicable at designated fuel bays.	Established practice at Huntly Mine, high certainty
7-14	Mobile fuel tankers that service heavy equipment in the field will be limited to 15 m ³ capacity.	Established practice at Huntly Mine, high certainty
7-15	Storage of all hydrocarbon and chemicals within the Mine Development Envelope will be undertaken within appropriately sized secondary containment in accordance with <i>Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007</i> as applicable to specific materials. Storage will take into consideration the requirements of WQPN 56 Tanks for fuel and chemical storage near sensitive water resources (DWER 2018).	Industry standard, high certainty
7-16	Planned maintenance of operations and construction vehicles and equipment will occur within workshops, as far as practicable.	Established practice at Huntly Mine, high certainty
7-17	Hazardous materials and wastes will be stored at designated construction compounds or other storage facilities in accordance with <i>Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007</i> as applicable to the specific materials. Storage will take into consideration the requirements of WQPN 56 Tanks for fuel and chemical storage near sensitive water resources (DWER 2018) and WQPN 65 Toxic and hazardous substances (DoW 2015).	Industry standard, high certainty
7-18	All wastes will be temporarily stored in designated containers and compounds prior to transport off-site for recycling or disposal at a licensed waste facility.	Established practice at Huntly Mine, high certainty
7-19	Construction and operations will have an emergency response plan that includes the requirements of WQPN 10 <i>Containment spills – emergency response plan</i> (DWER 2020).	Industry standard, high certainty
7-20	Spill response equipment will be maintained at the designated construction compound during construction, or mine facilities during operations in accordance with the Huntly Mine Emergency Response Plan.	Established practice at Huntly Mine, high certainty
7-21	Staff will be trained in spill response and clean up to enable effective and efficient clean-up of any spills that may occur.	Established practice at Huntly Mine, high certainty
7-22	All spills or leaks will be reported and remediated as soon as practicable, in accordance with Alcoa procedures.	Established practice at Huntly Mine, high certainty

7-23	Incident reporting and investigation will be conducted in accordance with Alcoa's procedures to reduce the likelihood of similar incidents occurring.	Established practice at Huntly Mine, high certainty
7-24	Contaminated areas within the Huntly Mine will be identified at closure and remediated in accordance with the Huntly Mine Closure Plan (Appendix D1).	Best practice, high certainty
7-25	Inspection of spill locations after clean-up is completed to ensure all contaminated soil is removed and managed accordingly.	Established practice at Huntly Mine, high certainty

Table 7.7 Objectives, triggers and contingency actions for terrestrial environmental quality – Huntly Mine

Potential Impact	Objective	Trigger	Contingency action
Soil salinisation as a result of clearing for mining	Where salinity risk has been identified through previous data, rehabilitation is completed as soon as practicable after clearing.	Rehabilitation of a mine pit has not commenced within three years of clearing.	<ul style="list-style-type: none"> Review remaining mining activities scheduled for mine pit and coordinate mining completion as soon as practicable. Coordinate rehabilitation resources to prioritise the commencement of rehabilitation in the mine pit as soon as practicable.
Disturbance of potential ASS	Avoid disturbance of potential ASS where practicable	Excavation of more than 100 m ³ of soils or dewatering within swamp deposits for an infrastructure crossing.	ASS investigation in accordance with DER (2015a) guidance.
	Manage ASS disturbance in accordance with approved ASSMP.	ASS investigation confirms the presence of ASS in swamp deposits to be excavated or dewatered.	ASSMP in accordance with DER (2015b) guidance
Erosion of post-mining land	The mine pit areas are landscaped to be stable and to blend in with the surrounding forest.	<ul style="list-style-type: none"> Visual inspection identifies erosion features (rills, gullies, tunnelling, etc) on post-mining landforms. Visual inspection identifies inadequate vegetation establishment to stabilise the post-mining landforms. 	<ul style="list-style-type: none"> Alcoa to provide documentation and advice to DBCA, where self-certification has resulted in non-standard outcomes. If DBCA finds that any rework is required based on occasional inspection, then they will state this in writing to Alcoa within three months of the completed inspection. Alcoa will undertake and monitor remedial works to ensure areas meet the landscape design standard.
Contamination from spills and/or leaks from storage and handling of hazardous materials and wastes	No contamination of soils from the storage and handling of hazardous materials or waste.	Spill or leak of hazardous material or waste to soils.	<ul style="list-style-type: none"> All spills or leaks will be reported and remediated as soon as possible. All contaminated soil identified at the spill or leak site will be excavated and the site assessed as clean, visually for minor spills or through soil testing where required. All contaminated soil from spill or leak sites will be transported off-site for treatment or disposal at a licensed waste facility.

7.6 Assessment and significance of residual impact

Table 7.8 summarises the potential residual impacts on terrestrial environmental quality from the Mine component of the Proposal. As presented, the Proposal is not expected to cause significant residual impacts on terrestrial environmental quality.

Alcoa has proposed substantial avoidance, mitigation and rehabilitation to reduce the residual impacts to a low as reasonably practicable. This includes avoidance of PFAS in fire-fighting foams and water supplies. Soil contamination will be substantially mitigated through concentrating storage and handling at designated facilities within construction compounds and mine facilities. The water storage ponds will be provided with freeboard and a low permeability liner to minimise the likelihood of overflows or seepage, and monitoring will detect any substantial leakage at an early stage to enable contingency actions. The effectiveness of mine rehabilitation, including resilience during drought and heat waves, has been demonstrated through long-term research and monitoring, and is at a high level of confidence.

7.7 Environmental outcomes

Table 7.9 presents proposed environmental outcomes with respect to terrestrial environmental quality. The proposed environmental outcomes:

- reflect specific and measurable environmental states
- have a clear boundary, size, extent, or limit
- are consistent with the EPA's objective to maintain the quality of land and soils so that environmental values are protected.

Table 7.9 identifies where another statutory decision-making process can mitigate the potential environmental impacts of the Proposal on the environment to be consistent with the EPA's factor objective. As presented, amendments to existing Part V environmental licences for the Huntly Mine are expected to regulate outcomes relating to waste disposal, and requirements under the *Contaminated Sites Act 2003* are expected to regulate outcomes with respect to mine facilities contamination.

Table 7.8 Residual impacts to terrestrial environmental quality – Huntly Mine

Potential impact	Residual Impact	Likelihood of significant impact
Soil salinisation as a result of clearing for mining	<ul style="list-style-type: none"> • The Proposal is unlikely to result in widespread salinity impacts to soils. This is due to the predominantly freshwater quality of groundwater recorded in the Myara North and Holyoake mine regions. • There are pockets of saline groundwater that occur in the Mine DE. Groundwater mounding that is close to the surface, and may therefore impact soils, will be predominantly in valleys that have been subject to shallow groundwater in the past prior to the decline of groundwater levels with declining rainfall. Accordingly, the modest groundwater mounding expected near valleys that may result in shallow groundwater depths is likely to return soil salinity to past levels. • Rehabilitation will be completed as soon as practicable after clearing to minimise the potential for pockets of saline groundwater mounding. 	Unlikely
Disturbance of potential acid sulfate soils	<ul style="list-style-type: none"> • Mining is not expected to result in oxidation of ASS. Mining occurs above the groundwater table and no dewatering will be undertaken of mine pits. Any potential acid forming materials in the regolith are therefore expected to already be oxidized at the depths to which mining occurs. • ASS may potentially be presented in swamps, which will not be subject to mining. Swamps may be disturbed for infrastructure crossings such as haul roads and conveyors, which may cause localised oxidation in the event that ASS is present. • Disturbance to swamps will be minimised and where substantial excavation or dewatering is proposed, ASS investigation will be undertaken. Where ASS is confirmed as present, construction will be in accordance with an approved ASSMP which is expected to effectively mitigate the risk of soil contamination. • Small quantities of sediments may be excavated for culvert footings for river or stream crossings. The excavations, if required, will be shallow and localised to the river/stream channel and involve small volumes (typically up to 500 m³ per river crossing and less for stream crossing, depending on geotechnical detailed design requirements). All crossings will be subject to an ASS investigation. Where ASS is confirmed as present, construction will be in accordance with an approved ASSMP which is expected to effectively mitigate the risk of soil contamination. 	Unlikely
Erosion of post-mining landform	<ul style="list-style-type: none"> • The results of monitoring collectively demonstrate that Alcoa’s rehabilitation establishes and persists, including during drought and heat wave events, indicating that a 1.5 m thick friable substrate over regolith containing ancient root channels is an effective growth medium. Accordingly, mine rehabilitation vegetation is expected to be sustained over the long-term with resilience to climate change comparable to that of un-mined Jarrah forest. Mine rehabilitation is therefore expected to provide long-term protection of soils from erosion and associated sediment discharge to streams and reservoirs. 	Unlikely

Potential impact	Residual Impact	Likelihood of significant impact
	<ul style="list-style-type: none"> • LiDAR analysis indicates that approximately 93 per cent of the disturbance areas within Mine DE have slope less than sixteen per cent and are likely to be subject to small volumes of gully erosion. The remaining 7 per cent of disturbance areas may potentially be subject to higher gully volumes during initial rehabilitation establishment. 	
Contamination from spills and/or leaks from storage and handling of hazardous materials and wastes	<ul style="list-style-type: none"> • The potential for soil contamination will be substantially mitigated through all storage and most of the handling of hazardous materials and wastes occurring at designated construction compounds and mine facilities. These will enable the provision of containment measures to prevent and contain spills and leaks. Mine facilities will be subject to site investigation and, if required, remediation of contamination upon decommissioning. • All wastes, apart from treated sewage effluent, will be transported off-site for recycling or disposal at licensed waste facilities. • The majority of spills and leaks in the field, particularly those from major incidents involving large volumes, are expected to be identified quickly and the contaminated soils excavated and disposed off-site at a licensed waste facility. Smaller spills and leaks that escape detection are expected to result in localised pockets of soil contamination. These pockets will be overlaid with rehabilitation overburden, topsoil and native vegetation. Pockets of soil contamination remaining in the rehabilitation are expected to biodegrade over time. • Construction and operational vehicles and equipment will use PFAS-free fire-fighting foams. Water supplied for construction and operations will come from public drinking water sources, captured on-site stormwater or from licensed on-site water treatment facilities, where approved for reuse on the Mine. Accordingly, construction and mining are unlikely to cause the discharge of PFAS and even less likely to result in significant soil contamination. 	Unlikely

Table 7.9 Proposed environmental outcomes – terrestrial environmental quality

Potential environmental impact	Environmental outcome	Other statutory approval that will ensure outcome	Monitoring of outcomes
Mine Development Envelope			
Soil salinisation as a result of clearing for mining	All cleared areas within the Mine Development Envelope rehabilitated to Jarrah Forest ecosystem to completion criteria.	n/a	Annual monitoring and reporting of rehabilitation extent and performance against completion criteria.
Erosion of post-mining landform	All cleared areas within the Mine Development Envelope rehabilitated to Jarrah forest ecosystem to completion criteria.	n/a	Annual monitoring and reporting of rehabilitation extent and performance against completion criteria.
Contamination from spills and/or leaks from storage and handling of hazardous materials and wastes	No construction or operational waste disposal areas located within the Mine Development Envelope, with the exception of mine facilities treated sewage effluent irrigation area.	Environmental licence under Part V of EP Act	Annual reporting of waste disposal.
	No soil or water contamination exceeding ecological or health guideline criteria within the mine facilities footprint following decommissioning.	<i>Contaminated Sites Act 2003</i>	Detailed site investigation, remediation action plan and validation report upon facilities decommissioning
Disturbance of potential acid sulfate soils (PASS)	PASS study is undertaken for any PASS areas and if required, management plans developed.	n/a	Implementation of management plan