9 EXISTING ENVIRONMENT

9.1 Flora and vegetation

The proposed development envelope is located in the Coolgardie Interim Biogeographic Regionalisation of Australia (IBRA) Bioregion which covers the interzone between mulga and spinifex country and eucalypt environments over an area of approximately 12,912,204 ha (DoE, 2015b, DPAW, 2014).

Within the Coolgardie IBRA Bioregion, the proposed development envelope is located in the Southern Cross subregion that is 6,010,832 ha in size (DoE, 2015b and DPAW, 2014). DPAW (2014) estimates approximately 5,773,838 ha of the current extent of pre-European vegetation remains in the sub-region.

The Southern Cross subregion comprises the western section of the Yilgarn Craton and is characterised as gently undulating uplands dissected by broad valleys with bands of low greenstone hills (Cowan *et al*., 2001). The granite strata of the Yilgarn Craton are interrupted by parallel intrusions of Archaean Greenstone.

Diverse Eucalyptus woodlands that include species such as *Eucalyptus salmonophloia, Eucalyptus salubris, Eucalyptus transcontinentalis* and *Eucalyptus longicornis* are common in the region. Granite basement outcrops occur at mid-levels in the landscape and support grasslands of *Borya constricta*, intermixed with stands of *Acacia acuminata* and *Eucalyptus loxophleba*. Areas with a slightly higher elevation in the landscape include the eroded remnants of yellow sandplains, gravelly sandplains and laterite breakaways. Mallees including *Eucalyptus leptopoda*, *Eucalyptus platycorys* and *Eucalyptus scyphocalyx* and scrub heaths (*Allocasuarina corniculata, Callitris preissii, Melaleuca uncinata* and *Acacia beauverdiana*) occur on these uplands (Cowan *et al.*, 2001).

9.1.1 Vegetation associations

Most of the vegetation within the proposed development envelope belongs to Beard vegetation association 437 'Shrublands; mixed acacia thicket on sandplain'. The south-western area (along the proposed water pipeline route and access road) belongs to Beard vegetation association 141 'Medium woodland; York gum, salmon gum and gimlet'.

Vegetation in the water pipeline route and access road areas are mostly Beard vegetation association 437 with some 141. The south-western end of the water pipeline route also contains Beard vegetation association 538 '*Eucalyptus* open woodland/*Triodia* open hummock grassland' and a small area of 435 '*Acacia* sparse shrubland/*Cryptandra* mixed sparse heath'. All of these vegetation associations have a low reservation priority for ecosystems.

Vegetation associations within the proposed development envelope and vicinity are shown on Figure 9-1.

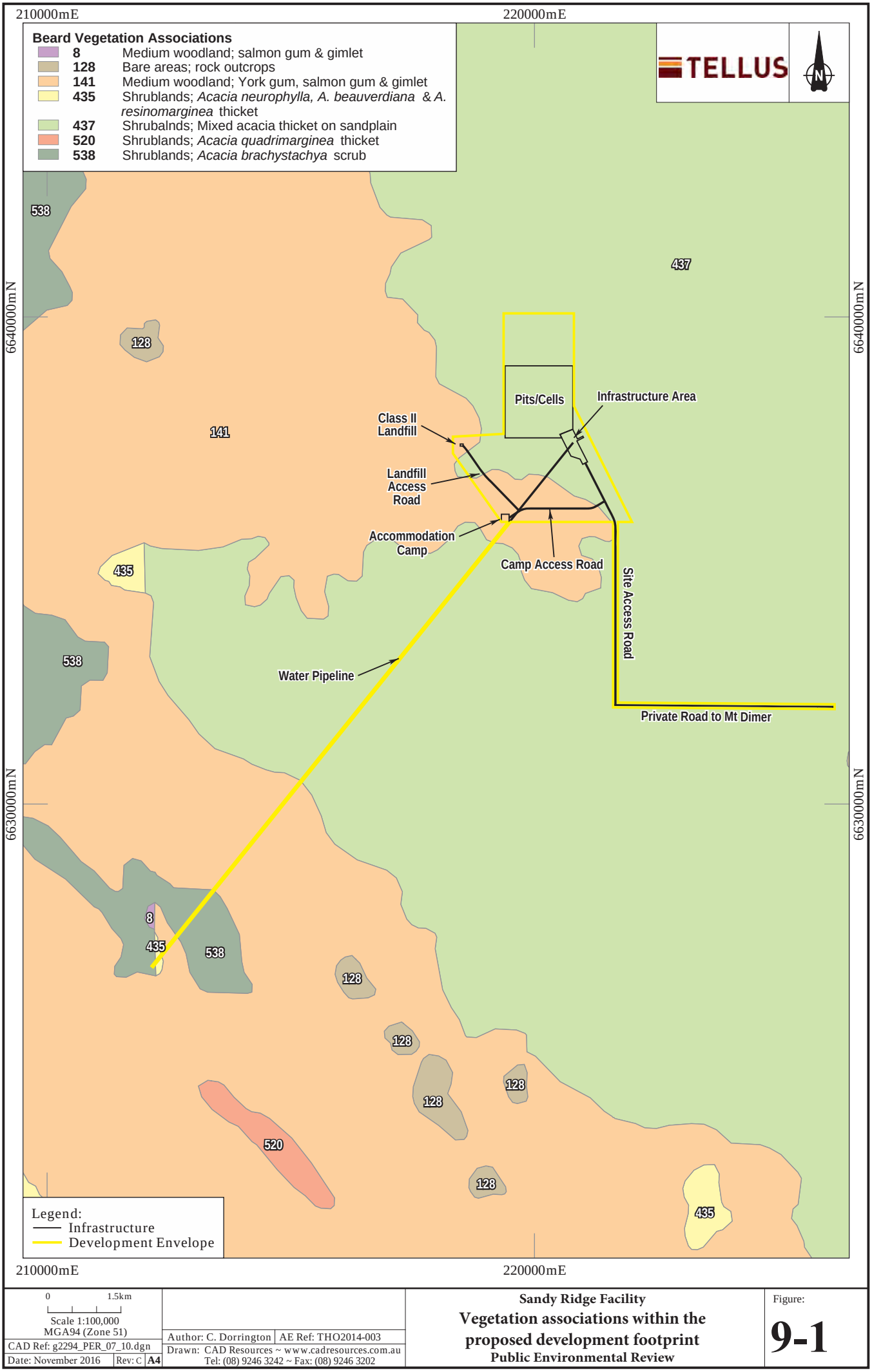
9.1.2 Vegetation types

A range of different vegetation types were described and mapped within the proposed development envelope (refer to Figure 9-2a and Figure 9-2b). Many of the vegetation types intergrade and could be considered variations of the main types. All of the vegetation types are considered common and widespread within the wider region. A description of the vegetation types including their assigned codes are provided below. A flora species list is provided in Appendix A.3.

Acacia resinimarginea Open Heath (Ar)

This is one of the most dominant vegetation types within the proposed development envelope. *Acacia resinimarginea* is consistently 1–1.2 m high and 40–50% cover (refer to Plate 9-1). Other common species include *Phebalium filifolium*, *Phebalium canaliculatum*, *Homalocalyx thryptomenoides*, *Melaleuca uncinata* and *Callitris preissii*. The *Callitris preissii* plants are small seedlings approximately 0.2–0.3 m high that are regenerating after a fire that occurred several years ago in the area. Spinifex (*Triodia scariosa*) is also common but at a low density. The soils are light yellow to orange-brown loamy sands.

Plate 9-1 *Acacia resinimarginea* Open Heath



0 1.5km
Scale 1:100,000
MGA94 (Zone 51)

CAD Ref: g2294_PER_07_10.dgn
Date: November 2016 | Rev: C | A4

Author: C. Dorrington | AE Ref: THO2014-003
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Vegetation associations within the proposed development footprint

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Figure: **9-1**

218000mE 220000mE 222000mE

6640000mN

6638000mN

6636000mN

TELLUS

N

Vegetation Types

Ar
Acacia resinimarginea Open Heath

ArAa
Acacia resinimarginea/Allocasuarina acutivalvis Open Heath

CpAr
Callitris preissii/Acacia resinimarginea Tall Shrubland

ArMu
Acacia resinimarginea/*Melaleuca uncinata* Open Low Heath

Lr
Leptospermum roei Open Heath

ArEpTs
Acacia resinimarginea Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Grassland

Eg
Eucalyptus gracilis Shrub Mallee over *Acacia nigripilosa* subsp. *nigripilosa/Acacia burkittii* Low Shrubland

EgAaEo
Eucalyptus gracilis Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland

Ab
Acacia burkittii Tall Shrubland

EpMuTs
Eucalyptus pileata Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland

ErMuAa
Eucalyptus ?rigidula . Very Open Shrub Mallee over *Melaleuca uncinata/Acacia acuminata* Open Low Heath

EcAt
Eucalyptus corrugata Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland

EsAt
Eucalyptus salmonophloia Woodland over *Acacia tetragonophylla* Tall Open Shrubland

EsEo
Eucalyptus salmonophloia Woodland over *Eremophila oppositifolia* Open Heath

EsalMu
Eucalyptus salubris var. *salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland

ArEpTs
Eg
ArAa
SR1
SR2
SR2.1
Eg
Calytrix creswelli (P3) SR3
Pits/Cells
Ar
SR4
Lepidosperma sp. SR5
Lepidosperma sp.
ArEpTs
SR6
Class II Landfill
SR10
EcAt
Landfill Access Road
Infrastructure Area
SR10A
Eg
Ar
SR8
SR7
SR9
SR11
EpMuTs
Ar
SR12
SR13
SR14 *Lepidosperma sp.*
CpAr
Lr
CpAr
Eg
EcAt
Lr
Camp Access Road
EcAt
Ar
SR16
Accommodation Camp
SR17
EsAt
Water Pipeline
EsAt
ArEpTs
Site Access Road

Legend:
- Priority Flora
- Potentially Conservation Significant
- Quadrat
- Infrastructure
- Development Envelope
- Proposed Mining Tenement
- Proposed Miscellaneous Licence

218000mE 220000mE 222000mE

0 400m

Scale 1:25,000
MGA94 (Zone 51)

CAD Ref: g2294_PER_07_11.dgn

Date: November 2016 | Rev: C | A4

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Vegetation types within the proposed development envelope

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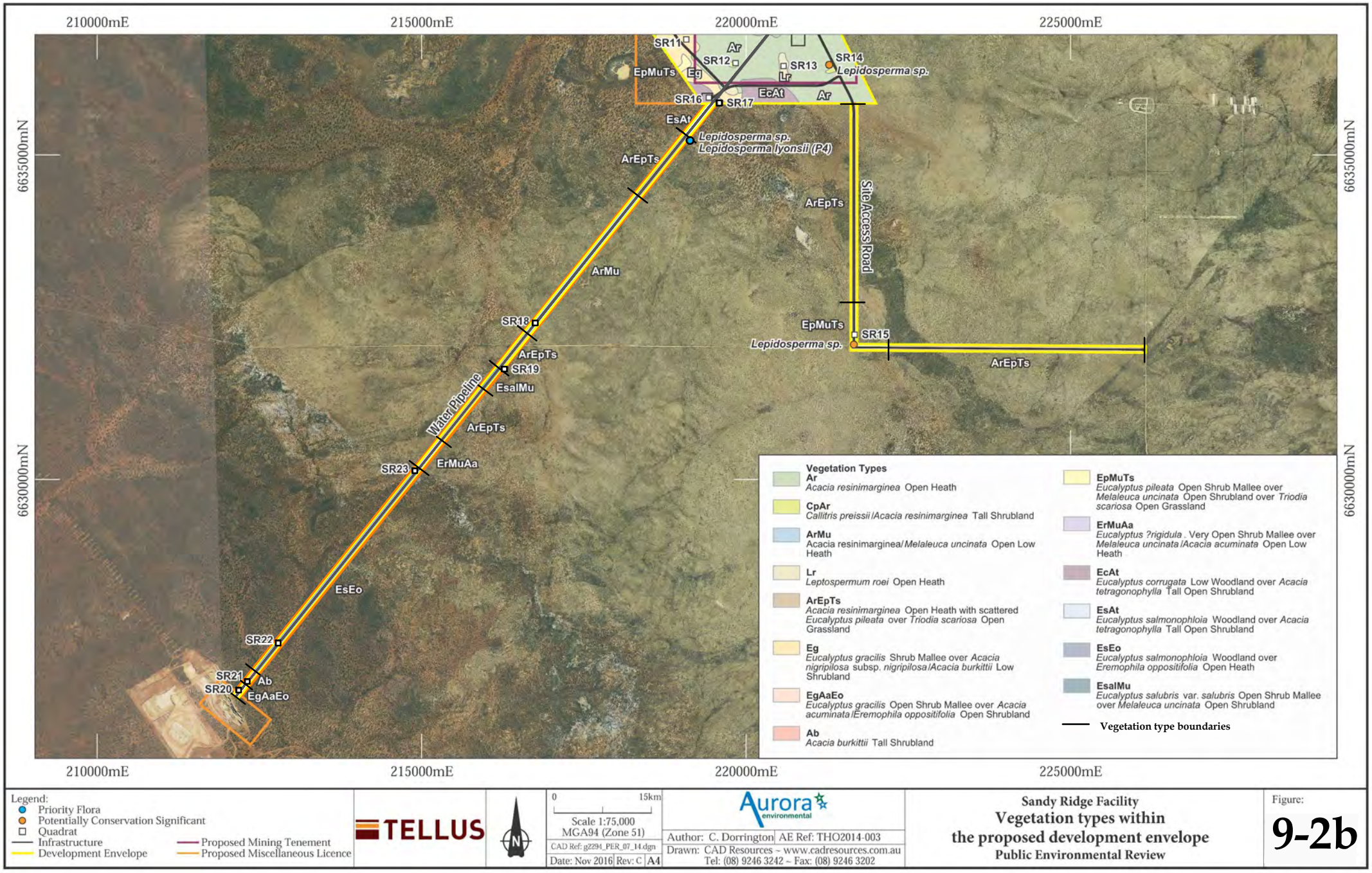
Figure:

9-2a



Legend:
- Priority Flora
- Potentially Conservation Significant
- Quadrat
- Infrastructure
- Development Envelope
- Proposed Mining Tenement
- Proposed Miscellaneous Licence

TELLUS

N

0 15km

Scale 1:75,000
MGA94 (Zone 51)

CAD Ref: g2294_PER_07_H.dgn
Date: Nov 2016 | Rev: C | A4

Aurora environmental

Author: C. Dorrington | AE Ref: THO2014-003
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Vegetation types within the proposed development envelope

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Figure:

9-2b

Callitris preissii/Acacia resinimarginea Tall Shrubland (CpAr)

This vegetation type is essentially a variety of the *Acacia resinimarginea* Open Heath (Ar) vegetation type that escaped a fire that occurred several years ago in the area. It is located in two pockets within the southern portion of the proposed development envelope (refer to Plate 9-2). The *Callitris preissii* trees are up to 3-4 m high and the *Acacia resinimarginea* and *Melaleuca uncinata* up to 2-2.5 m high. *Homalocalyx thryptomenoides* is a common small shrub. The soils are light yellow-brown loamy sands.

Plate 9-2 *Callitris preissii/Acacia resinimarginea* Tall Shrubland

Acacia resinimarginea/Allocasuarina acutivalvis Open Heath (ArAa)

A small pocket (approximately 20 m by 20 m) of this vegetation type occurs at the northern end of the proposed cell. It is very similar in structure and composition to the *Acacia resinimarginea* Open Heath (Ar) vegetation type but contains *Allocasuarina acutivalvis* which is virtually absent from the *Acacia resinimarginea* Open Heath (Ar) vegetation type (refer to Plate 9-3). The presence of ironstone pebbles at the surface of the loamy sand may be a reason for the occurrence of *Allocasuarina acutivalvis* in this area.

Plate 9-3 *Acacia resinimarginea/Allocasuarina acutivalvis* Open Heath

Acacia resinimarginea/Melaleuca uncinata Open Low Heath (ArMu)

This vegetation type occurs on the water pipeline route just north of the existing road to Mount Dimer. *Acacia resinimarginea* and *Melaleuca uncinata* co-dominate at around 1 m in height and 20-25% cover each (refer to Plate 9-4). The vegetation is slightly more species rich than the *Acacia resinimarginea* Open Heath (Ar) vegetation and sub-units within the proposed development envelope. The soils are light orange-brown loamy sand with ironstone pebbles at the surface.

Plate 9-4 *Acacia resinimarginea/Melaleuca uncinata* Open Low Heath

Leptospermum roei Open Heath (Lr)

This vegetation type occurs in the southern portion of the proposed development envelope. *Leptospermum roei* dominates this vegetation type, growing up to around 1.8 m in height with 50% cover. There is little to no *Acacia resinimarginea* present (refer to Plate 9-5). The composition of the smaller shrubs is similar to the *Acacia resinimarginea* Open Heath (Ar) vegetation type with *Homalocalyx thryptomenoides* common. The soils are yellow loamy sand.

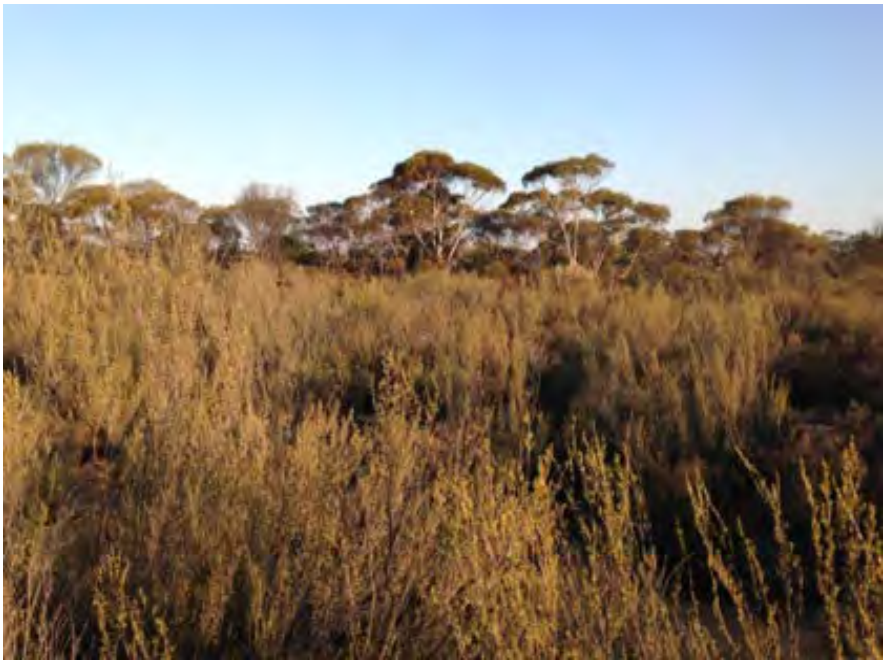


Plate 9-5 *Leptospermum roei* Open Heath

Acacia resinimarginea Open Heath with scattered Eucalyptus pileata over Triodia scariosa Open Grassland (ArEpTs)

This is another widespread vegetation type occurring on the yellow loamy sand soils, particularly in the central and northern parts of the proposed development envelope. The shrub cover is less dense at 25-40% which has allowed the Spinifex (*T. scariosa*) to grow in higher densities, around 20–25% cover. The Small Mallee (*Eucalyptus pileata*) occurs sporadically throughout this vegetation type. Other common species include *Phebalium filifolium, Homalocalyx thryptomenoides* and *Keraudrenia integrifolia.* At the time of the field survey*, Callitris preissii* was present as seedlings in some areas but only occurred as old dead plants with no seedlings evident in large areas (refer to Plate 9-6). The soils are light orange-brown loamy sand.

Plate 9-6 *Acacia resinimarginea* Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Gr

Eucalyptus pileata Open Shrub Mallee over Melaleuca uncinata Open Shrubland over Triodia scariosa Open Grassland (EpMuTs)

This vegetation type is located in the south-east portion of the proposed development envelope and is similar to the *Acacia resinimarginea* Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Grassland (ArEpTs) with the exception that *Acacia neurophylla* is the dominant *Acacia. S*everal other species not commonly recorded elsewhere in the proposed development envelope such as *Melaleuca eleuterostachya, Hakea francisiana* and *Podolepis capillaris* were present and indicated a transition from the vegetation within the proposed development envelope to that further east (refer to Plate 9-7). The soils are light orange-red sand.

Plate 9-7 *Eucalyptus pileata* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland

Eucalyptus gracilis Shrub Mallee over Acacia nigripilosa subsp. nigripilosa/Acacia burkittii Low Shrubland (Eg)

This vegetation type occurs on harder sandy loam soils on slightly more elevated land in the western and northern portions of the proposed development envelope. *Eucalyptus gracilis* is the main tree or mallee species present in densities around 10-40% (refer to Plate 9-8). *Acacia* species including *A. burkittii* and *A. nigripilosa* subsp. *nigripilosa* are common shrubs as is *Melaleuca uncinata, Alyxia buxifolia, Olearia muelleri* and *Scaevola spinescens.* There is a large percentage of bare ground present within this vegetation type, as shown in Plate 9-8. The soils are hard, red-orange sandy loam.

Plate 9-8 *Eucalyptus gracilis* Shrub Mallee over *Acacia nigripilosa* subsp. *nigripilosa/Acacia burkittii* Low Shrubland

Eucalyptus gracilis Open Shrub Mallee over Acacia acuminata/Eremophila oppositifolia Open Shrubland (EgAaEo)

This vegetation type occurs at the southern end of the water pipeline route close to the Carina Pit. The vegetation is located in a slight depression which may lead to slightly moister surface soils after rain. The shrub mallees are up to 4 m high and open over an open shrub layer consisting of *Acacia acuminata* and *A. tetragonophylla* as well as *Eremophila oppositifolia, E. maculata* and *Senna artemisioides* (refer to Plate 9-9). The soils are orange-red sandy loam with ironstone pebbles with a large percentage of bare ground.

Plate 9-9 *Eucalyptus gracilis* Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland

Acacia burkittii Tall Shrubland (Ab)

A small band of this vegetation type occurs near the southern end of the water pipeline route in a low valley. *Acacia burkittii* is the dominant taller shrub up to 3 m high and averaging 20% although it can be denser in places (refer to Plate 9-10). *Grevillea eriostachya* up to 1.3 m is also present. Common smaller shrubs include *Leucopogon* sp. Clyde Hill and *Homalocalyx thryptomenoides*. The soils are orange-red sandy loam with ironstone pebbles at the surface.

Plate 9-10 *Acacia burkittii* Tall Shrubland

Eucalyptus rigidula Very Open Shrub Mallee over Melaleuca uncinata/Acacia acuminata Open Low Heath (ErMuAa)

This vegetation type occurs on top of a small rise on perhaps the highest part of the water pipeline route between the Carina Pit and existing road to Mount Dimer. *Eucalyptus rigidula* (no buds or fruit) commonly occurs as a shrub mallee in very low densities. The shrub layer is dominated by *Melaleuca uncinata* with *Acacia acuminata* and *Senna artemisioides* common (refer to Plate 9-11). The soils are orange-red sandy loam.

Plate 9-11 *Eucalyptus rigidula* Very Open Shrub Mallee over *Melaleuca uncinata*/*Acacia acuminata* Open Low Heath

Eucalyptus corrugata Low Woodland over Acacia tetragonophylla Tall Open Shrubland (EcAt)

This vegetation type is located in the south-western portion of the proposed development envelope and consists of large tracts of typical Goldfields Eucalypt Woodland with *Eucalyptus corrugata* the dominant species up to 8 m high and with an open canopy cover of 10-25% (refer to Plate 9-12). Common understorey species include *Acacia tetragonophylla, Santalum acuminatum, Exocarpos aphyllus, Scaevola spinescens, Acacia colletioides, Phebalium filifolium* and *Austrostipa nitida.* The soils are orange-brown loamy sand.

Plate 9-12 *Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland

Eucalyptus salmonophloia Woodland over Acacia tetragonophylla Tall Open Shrubland (EsAt)

This vegetation type also occurs in the south-western part of the proposed development envelope mixed in with the *Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland (EcAt). Salmon Gum *(E. salmonophloia)* is sparse and up to 12 m high over a tall open shrubland containing similar common species to the EcAt vegetation type such as *Acacia tetragonophylla, Acacia colletioides, Scaevola spinescens* and *Olearia muelleri* (refer to Plate 9-13). The soils are orange-red sandy loam.

Plate 9-13 *Eucalyptus salmonophloia* Woodland over *Acacia tetragonophylla* Tall Open Shrubland

Eucalyptus salmonophloia Woodland over Eremophila oppositifolia Open Heath (EsEo)

This species is common along the southern portion of the water pipeline route. Superficially this vegetation type looks structurally the same as the *Eucalyptus salmonophloia* Woodland over *Acacia tetragonophylla* Tall Open Shrubland (EsAt) with Salmon Gum the main species present up to 12 m high and 20% cover over an open understorey. However, the understorey composition is quite different and contains Chenopod species *(Atriplex vesicaria, Maireana georgei, Sclerolaena densiflora)* that are absent from the proposed development envelope. *Eremophila* species *(E. oppositifolia, E. pantonii)* are common in the understorey (refer to Plate 9-14)**.** The soils are orange-red sandy loam.

Plate 9-14 *Eucalyptus salmonophloia* Woodland over *Eremophila oppositifolia* Open Heath

Eucalyptus salubris var. salubris Open Shrub Mallee over Melaleuca uncinata Open Shrubland (EsalMu)

A small stand of Gimlet *(Eucalyptus salubris* var. *salubris)* occurs on the water pipeline route south of the road to Mount Dimer. The Gimlet mallees are up to 5 m high and in low density. *Melaleuca uncinata*, *Senna artemisioides* and *Acacia resinimarginea* are common shrub species and the native grasses *Aristida contorta* and *Austrostipa nitida* occur together. Grass species were very sparse throughout the survey area (refer to Plate 9-15).

Plate 9-15 *Eucalyptus salubris* var. *salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland

The area of each vegetation type within the proposed development envelope is provided in Table 9-1.

Table 9-1 Area and percentage of vegetation types within the proposed development envelope

Vegetation type code	Vegetation type name	Area within proposed development envelope (ha)	Percentage within proposed development envelope (%)
Ab	*Acacia burkittii* Tall Shrubland	0.98	0.10
Ar	*Acacia resinimarginea* Open Heath	434.18	43.24
ArAa	*Acacia resinimarginea/Allocasuarina acutivalvis* Open Heath	0.04	<0.01
ArEpTs	*Acacia resinimarginea* Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Grassland	295.57	29.43
ArMu	*Acacia resinimarginea/Melaleuca uncinata* Open Low Heath	10.91	1.09
CpAr	*Callitris preissii/Acacia resinimarginea* Tall Shrubland	2.19	0.22
EcAt	*Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland	60.44	6.02
Eg	*Eucalyptus gracilis* Shrub Mallee over *Acacia nigripilosa* subsp. *nigripilosa/Acacia burkittii* Low Shrubland	150.86	15.02
EgAaEo	*Eucalyptus gracilis* Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland	0.91	0.09
EpMuTs	*Eucalyptus pileata* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland	15.59	1.55
ErMuAa	*Eucalyptus rigidula* Very Open Shrub Mallee over *Melaleuca uncinata/Acacia acuminata* Open Low Heath	2.22	0.22
EsalMu	*Eucalyptus salubris* var. *salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland	1.62	0.16
EsAt	*Eucalyptus salmonophloia* Woodland over *Acacia tetragonophylla* Tall Open Shrubland	4.42	0.44
EsEo	*Eucalyptus salmonophloia* Woodland over *Eremophila oppositifolia* Open Heath	16.11	1.60
Lr	*Leptospermum roei* Open Heath	8.16	0.81
Total		**1004.2**	**100%**

9.1.3 Vegetation condition

Using the vegetation condition rating scale devised by Keighery (1994) and described in Bush Forever (Government of Western Australia, 2000) (Table 9-2) most of the vegetation within the proposed development envelope is considered to be in ‘excellent’ condition.

Table 9-2 Vegetation condition rating scale

Condition	Description
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very good	Vegetation structure altered obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species.

9.1.4 Vegetation of conservation significance

Three Priority Ecological Communities (listed as Priority 1 by DPAW) were identified as potentially occurring within the vicinity of the proposed development envelope. These include:

- Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation).
- Hunt Range vegetation complexes (banded ironstone formation).
- Lake Giles vegetation complexes (banded ironstone formation).

These communities are all associated with the banded iron formation which does not occur within the proposed development envelope. Additionally, the interpreted vegetation types recorded within the proposed development envelope are not representative of these Priority Ecological Communities.

There are no Threatened or Endangered Ecological Communities listed under the WC Act or Threatened or Endangered Ecological Communities listed under the EPBC Act within the proposed development envelope.

9.1.5 Flora species of conservation significance

Fifty flora species listed under the WC Act and/or EPBC Act or by DPAW have been recorded or are predicted to occur within the proposed development envelope or within the locality (refer to Table 9-3). Thirty-two of these species were considered as possibly occurring within the proposed development envelope. The remaining species were considered unlikely to occur due to a lack of suitable habitat and, therefore, would not be affected by the Proposal.

Two of the 32 species considered as possibly occurring within the proposed development envelope were recorded during the field surveys. These were *Calytrix creswellii* and *Lepidosperma lyonsii* (both listed as Priority 3 by DPAW). These species are discussed further below. The remaining 30 species considered as possibly occurring within the proposed development envelope were not recorded during the field surveys, and therefore would not be affected by the Proposal.

An undescribed sedge species was also recorded within the proposed development envelope – *Lepidosperma* sp. This species is currently undescribed and may have some conservation value. This species is also discussed below.

Calytrix creswellii

Calytrix creswellii was recorded at one location in *Acacia resinimarginea* Open Heath (Ar) in the middle of the proposed cells (refer to Plate 9-10 and Figure 9-2a). *Calytrix creswellii* is currently known to occur within the Coolgardie and Murchison bioregions of the Eremaean Province (DPAW, 2015). It has previously been recorded on nearby sites including the Mount Walton East IWDF (Ecologia Environmental Consultants, 1997), the IWDF Access Road (Mattiske Consulting Pty Ltd, 2012) and on the site of the Carina Iron Ore Project (Recon Environmental, 2010). The Mattiske Consulting Pty Ltd (2012) survey recorded many separate populations of the species with population sizes greater than 50.

Lepidosperma lyonsii

Lepidosperma lyonsii was recorded on the proposed water pipeline route between the existing road to Mount Dimer and the Proposal surface infrastructure area (refer to Plate 9-11 and Figure 9-2b). *Lepidosperma lyonsii* is known to occur in several locations in the Coolgardie Botanical District and has previously been recorded on the site of the Carina Iron Ore Project (Recon Environmental, 2010) and the IWDF Access Road (Mattiske Consulting Pty Ltd, 2012).

Lepidosperma sp.

An undescribed sedge species was recorded within the proposed development envelope – *Lepidosperma* sp. The species was not considered to be any of the conservation significant species previously recorded in the vicinity of the proposed development envelope (as listed in Table 9-3). Five populations of this species were recorded in vegetation dominated by *Acacia resinimarginea* (refer to Figure 9-2a and Figure 9-2b). The species is likely to be more widespread within the proposed development envelope than the populations recorded. In their survey of the yellow sandplain vegetation on the Mt Walton Road to the south of the proposed development envelope, Mattiske Consulting Pty Ltd (2012) recorded 13 species of *Lepidosperma* which were not able to be identified to species level mostly due to the species being undescribed. The taxonomy of the *Lepidosperma* sp. is currently being reviewed by the WA Herbarium. Until those results are published, the *Lepidosperma* sp. recorded within the proposed development envelope has been treated as potentially having some conservation value.

Table 9-3 Conservation significant flora known to occur near the proposed development envelope and likelihood of it occurring within the proposed development envelope

Species	WA status[19]	Status under EPBC Act 1999[20]	Habitat	Likelihood of occurring within the proposed development envelope
Myriophyllum lapidicola **Chiddarcooping Myriophyllum**	Threatened	Endangered	Ephemeral pools 20 cm to 50 cm deep on granite outcrops.[+]	Unlikely
Ricinocarpos brevis	Threatened	Endangered	Shallow sandy soils on rocky banded ironstone outcrops.[®]	Unlikely
Tetratheca paynterae **Paynter's Tetratheca**	Threatened	Endangered	Rock crevices, in shallow pockets of soil of rich red loam.[®]	Unlikely
Cryptandra polyclada subsp. aequabilis	Priority 1	-	Sand.	Possible
Cyathostemon sp. Mt Dimer **(C. McChesney TRL 4/72) PN**	Priority 1	-	Yellow sand.	Possible
Dampiera sp. Jaurdi **(D. Angus DA 268) PN**	Priority 1	-	Associated species: *Allocasuarina corniculata*, *Gyrostemon racemiger*, *Acacia sibina*, *Eucalyptus leptopoda* subsp. *subluta*, *Calytrix creswellii* ~ Interpreted habitat: Yellow sand, gravel, sandplains.	Possible
Lepidosperma sp. Parker Range **(N. Gibson & M. Lyons 2094)**	Priority 1	-	Recorded on ridge/slope. Well-drained. Dry brown clay loam over granite. 10–30% of loose rock on soil surface.[#]	Unlikely
Leucopogon sp. Yellowdine **(M. Hislop & F. Hort MH**	Priority 1	-	Recorded on Flat. Moist yellow sand. Burnt >5 years.^	Unlikely
Phebalium appressum	Priority 1	-	Yellow sandplain.	Possible
Tecticornia flabelliformis	Priority 1	-	Clay. Saline flats.	Highly unlikely

[19] Priority species are listed by the DPAW. Threatened species listed under the *Wildlife Conservation Act 1950* (WA)
[20] *Environment Protection and Biodiversity Conservation Act 1999* (Cth)

Species	WA status[19]	Status under EPBC Act 1999[20]	Habitat	Likelihood of occurring within the proposed development envelope
Xanthoparmelia fumigata	Priority 1	-	Recorded on ridge with bare to littered, stoney crusted brown clayey sand.[<]	Unlikely
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)	Priority 2	-	Light brown-yellow sand. Sandplains.	Possible
Daviesia sarissa subsp. redacta	Priority 2	-	Yellow sand. Plains.	Possible
Elachanthus pusillus	Priority 2	-	Open depression in plain system. Sandy clay loam.[&]	Unlikely
Goodenia jaurdiensis	Priority 2	-	Red clayey loam with laterite or banded ironstone gravel or quartz pebbles. Low-lying plains and lower slopes.	Possible
Hakea rigida	Priority 2	-	Sandy soils, yellow sand.	Possible
Hemigenia tenelliflora	Priority 2	-	Sandplain.[@]	Possible
Lissanthe scabra	Priority 2	-	Dry, white to orange-brown clay, sandy gravel loams, granite. Breakaways, uplands.	Unlikely
Malleostemon sp. Adelong (G.J. Keighery 11825)	Priority 2	-	Red sand.	Unlikely
Acacia cylindrica	Priority 3	-	Yellow/brown sand, gravelly soils. Undulating plains, flats.	Possible
Acacia desertorum var. nudipes	Priority 3	-	Yellow sand, lateritic gravel. Sandplains, flats.	Possible
***Austrostipa blackii* Crested Spear-grass**	Priority 3	-	Recorded on a gentle upper North slope. Brown loam over red loam with granite fragments at 5 cm.[%]	Unlikely
Banksia lullfitzii	Priority 3	-	Yellow sand. Sandplains.	Possible
Bossiaea celata	Priority 3	-	Deep sand. Open mallee.	Possible

Species	WA status[19]	Status under EPBC Act 1999[20]	Habitat	Likelihood of occurring within the proposed development envelope
Calytrix creswellii	Priority 3	-	Yellow sand, sometimes with lateritic gravel. Sandplains.	Possible (subsequently recorded during field surveys)
Cyathostemon verrucosus	Priority 3	-	Flat yellow sandy clay plain.>	Unlikely
Eucalyptus exigua	Priority 3	-	Sandy loam, white sand. Sandplains.	Possible
Eutaxia actinophylla	Priority 3	-	Red-brown clay loam, red clay loam over granite, gravel. Small depressions.	Unlikely
Gastrolobium semiteres	Priority 3	-	Deep yellow sand, yellow to brown sandy clay, gravel, granite. Broad sand dunes, around rocks, undulating plains.	Possible
Gnephosis intonsa **Shaggy Gnephosis**	Priority 3	-	Red/brown clay, stony saline loam.	Unlikely
Gnephosis sp. Norseman **(K.R. Newbey 8096)**	Priority 3	-	Sub-saline loam. Moderately exposed flat.	Unlikely
Gompholobium cinereum	Priority 3	-	Yellow sand, clayey sand, brown loam, sandy gravel, laterite. Well-drained open sites, slopes, plains, roadsides.	Possible
Grevillea georgeana	Priority 3	-	Stony loam/clay. Ironstone hilltops and slopes.	Possible
Hibbertia lepidocalyx **subsp.** ***tuberculata***	Priority 3	-	Yellow-orange loam, ironstone gravel.	Possible
Homalocalyx grandiflorus	Priority 3	-	Yellow sand. Sandplains.	Possible

Species	WA status[19]	Status under EPBC Act 1999[20]	Habitat	Likelihood of occurring within the proposed development envelope
Labichea eremaea	Priority 3	-	Red sand.	Unlikely
Lepidium genistoides	Priority 3	-	Sandy loam.	Possible
***Melichrus sp. Bungalbin Hill* (F.H. & M.P. Mollemans 3069)**	Priority 3	-	Yellow sandplain.=	Possible
Mirbelia ferricola	Priority 3	-	Recorded on skeletal red loam soils on massive banded iron formation.“	Possible
Stenanthemum newbeyi	Priority 3	-	Clayey sand, clay or loam over laterite or ironstone. Hillslopes.	Possible
***Stylidium choreanthum* Dancing Triggerplant**	Priority 3	-	White/yellow or red sand. Plains.	Possible
Verticordia mitodes	Priority 3	-	Yellow sand. Undulating plains.	Possible
Verticordia stenopetala	Priority 3	-	Yellow sand, sometimes with gravel. Undulating plains.	Possible
Lepidosperma lyonsii	Priority 3	-	Orange skeletal sandy loam with banded ironstone gravel and rock, well-drained shallow stony loamy with quartz. Gentle hill slopes, upper slopes of large hill.	Possible (subsequently recorded during field surveys)
***Banksia arborea* Yilgarn Dryandra**	Priority 4	-	Stony loam. Ironstone hills.	Possible

Species	WA status[19]	Status under EPBC Act 1999[20]	Habitat	Likelihood of occurring within the proposed development envelope
Eremophila caerulea subsp. merrallii	Priority 4	-	Sand, clay or loam. Undulating plains.	Possible
Eucalyptus formanii	Priority 4	-	Red sand. Ironstone slopes.	Possible
Grevillea erectiloba	Priority 4	-	Gravelly loam. Lateritic ridges.	Unlikely
Haegiela tatei	Priority 4	-	Clay, sandy loam, gypsum. Saline habitats.	Unlikely
Sowerbaea multicaulis **Many Stemmed Lily**	Priority 4	-	Yellow-brown sand.	Possible

** Sourced from Florabase (DPAW, 2015) unless otherwise annotated as per the list below*
® DoE SPRAT Database (DoE, 2015c)
+ Patten and Brown (2004)
~ Western Australian Herbarium (2015a)
 # Western Australian Herbarium (2015b)
^ Western Australian Herbarium (2015c)
< Western Australian Herbarium (2015d)
& State Herbarium of South Australia (2015a)
@ Western Australian Herbarium (2015e)
% State Herbarium of South Australia (2015b)
> Australian National Herbarium (2015)
= Western Australian Herbarium (2015e)
"National Herbarium of New South Wales (2015)

9.2 Terrestrial environmental quality

This section discusses climate, rainfall, temperature, evaporation and evapotranspiration, wind speed and direction, land use, topography, geology and soils within the proposed development envelope.

9.2.1 Climate

The proposed development envelope is located within a 'semi desert Mediterranean' climate and averages approximately 250 mm of rainfall per annum (Beard, 1990). The closest BoM weather station to the proposed development envelope is located at Menzies, approximately 110 km to the northeast.

An Automated Weather Station (AWS) was setup within the proposed development envelope in May 2015 (refer to Plate 9-16). It has recorded hourly average data since 8 May, 2015. The AWS collects the following data on a continuous basis:

- Wind speed at 10 m.
- Wind direction at 10 m.
- Relative humidity at 2 m.
- Air temperature at 2 m.
- Precipitation.

The climatic pattern during the warmer months of November to April is influenced by anticyclonic systems to the south-east. This means the proposed site is subjected mostly to easterly winds, clear skies and hot days. Occasionally during the above months, the southern extension of the Intertropic Convergence Zone may bring thunderstorm activity with impressive lightning displays and some rain (Pringle et al., 1994).

Plate 9-16 The Sandy Ridge automated weather station

Sporadic high intensity rainfall can also occur in the summer months as a result of remnant tropical cyclones that cross the coast between Carnarvon and Port Hedland. These track south-easterly, weakening to rain-bearing troughs or depressions between the usual anticyclone patterns (Pringle *et al*., 1994). Strong wind gusts can be associated with these depressions.

Maximum temperatures during these summer months often exceed 40°C and evaporation levels average over 2000 mm per annum (BoM, 2015a). Humidity levels are generally low and dews are rare (Pringle et al., 1994).

The climatic pattern during the cooler months (May to October) is still predominantly influenced by anticyclone systems. These tend to be centred further to the south and reach their northern extent over WA. As a result, the area is characterised to a large extent by cooler temperatures, cloudless skies and light south to south-easterly winds. This pattern is periodically interrupted by the passage of low pressure systems moving in from the west or south-west which result in bursts of north-westerly or westerly winds. These depressions often bring rain and are the main source of rain for south-western Australia.

The proposed development envelope is located sufficiently far enough to the north and east from the coast that these rainfall events are seldom intense. This synoptic pattern generally results in mild daytime temperatures and cold nights in the region.

Minimum temperatures during these months can drop below 0°C, although the mean is generally around 7°C. Evaporation levels are greatly reduced during the wetter months of May and June and humidity is generally highest in June and July.

9.2.2 Rainfall

The average annual rainfall for Menzies is 250 mm and the annual median rainfall is 244.4 mm. Rainfall is irregular and there may be extensive periods with no significant falls of rain. On average, rain falls most in February (probably as a result of remnant cyclones), with the next highest falls on average occurring in June, March and May respectively. On average, there about 32 rain days per year with June and July having the highest number of rain days at about four.

October has the least number of rain days at about two, so there is little variation in the number of rain days per month (BoM, 2015a). Slightly more rain falls on average (53%) in the summer months than in the winter months (47%).

The AWS recorded a total of 304.2 mm of rainfall from May 2015 to April 2016, with the highest fall recorded in January, and the next highest falls in February, March and August. This is consistent with long-term trends from the Menzies weather station to the north-east. Less than 1 mm of rain was recorded in May and September.

During the 2015-16 recording period, more rainfall occurred in the summer months (132.2 mm) than the winter months (76.2 mm). The distribution of rainfall is presented in Figure 9-3. The distribution of rainfall at Sandy Ridge is presented in Table 9-4. Maximum daily rainfall of 53.8 mm was observed during the summer, with the average rainfall during the summer months being the highest of all seasons. Lowest maximum and daily average rainfall was observed during the spring months at the Proposal site.

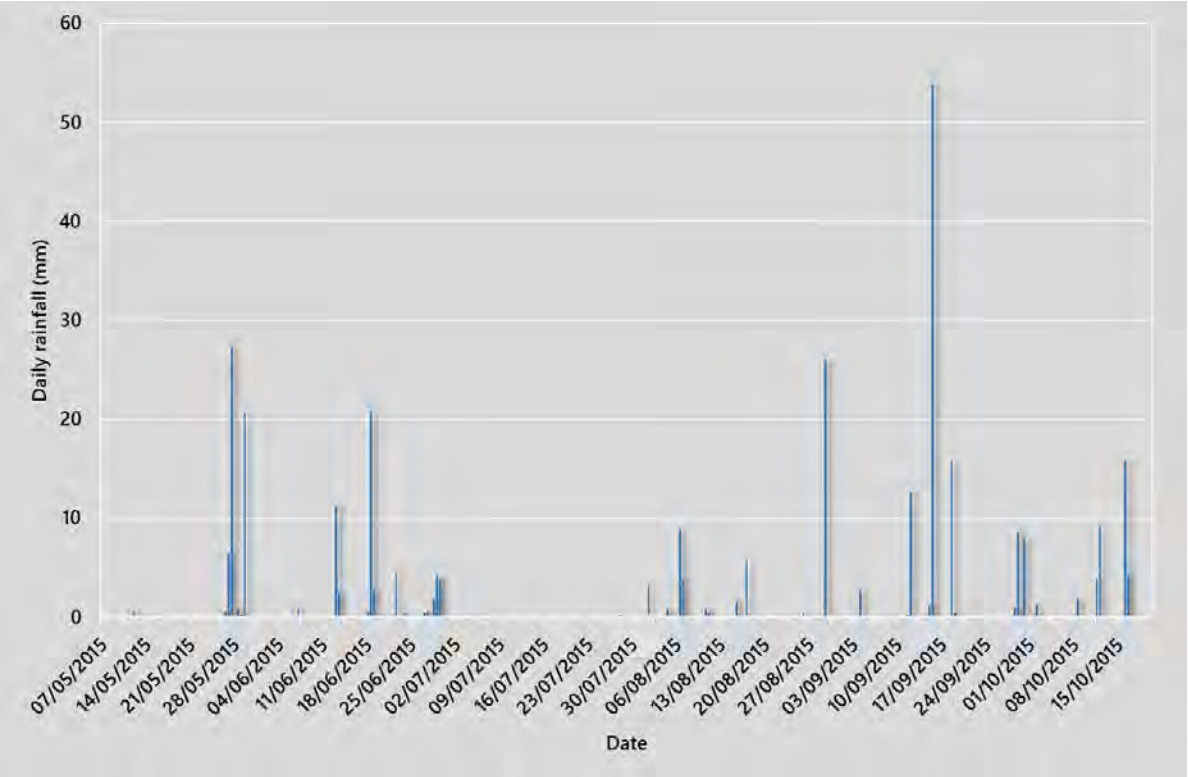


Figure 9-3 Daily average rainfall recorded at Sandy Ridge

Table 9-4 Seasonal rainfall recorded at Sandy Ridge between May 2015 and April 2016

Season	Daily rainfall (mm)		
	Maximum	Average	Minimum
Annual	**53.8**	**0.9**	**0.0**
Spring	8.8	0.3	0.0
Summer	53.8	1.8	0.0
Autumn	15.8	0.6	0.0
Winter	27.2	1.2	0.0

9.2.3 Temperature

Air temperatures measured at the proposed site between 7 May 2015 and 4 April 2016 varied between a minimum of 0.4 °C and a maximum of 42.1 °C. The average temperature measured over the monitoring period was 19.0 °C. Average maximum and minimum hourly temperatures measured during each season at the Proposal site are presented in Table 9-5.

Table 9-5 Observed temperatures at Sandy Ridge between May 2015 and April 2016

Season	Temperature (° C)		
	Maximum	Average	Minimum
Annual	**42.1**	**19.0**	**0.4**
Spring	39.7	20.3	0.8
Summer	42.1	25.1	9.7
Autumn	38.5	18.4	1.0
Winter	28.3	11.7	0.4

The daily average temperature calculated between 7 May 2015 and 4 April 2016 is presented in Figure 9-4 along with the observed range in daily temperature. As expected, maximum daily average and maximum temperatures occur during the summer months with a daily average temperature of 25.1 °C observed. Average air temperatures during the winter months is 11.7 °C but during the daytime hours have reached up to 28.3 °C during the year of measurement. The coldest temperature observed over the period was 0.4 °C in winter 2015.

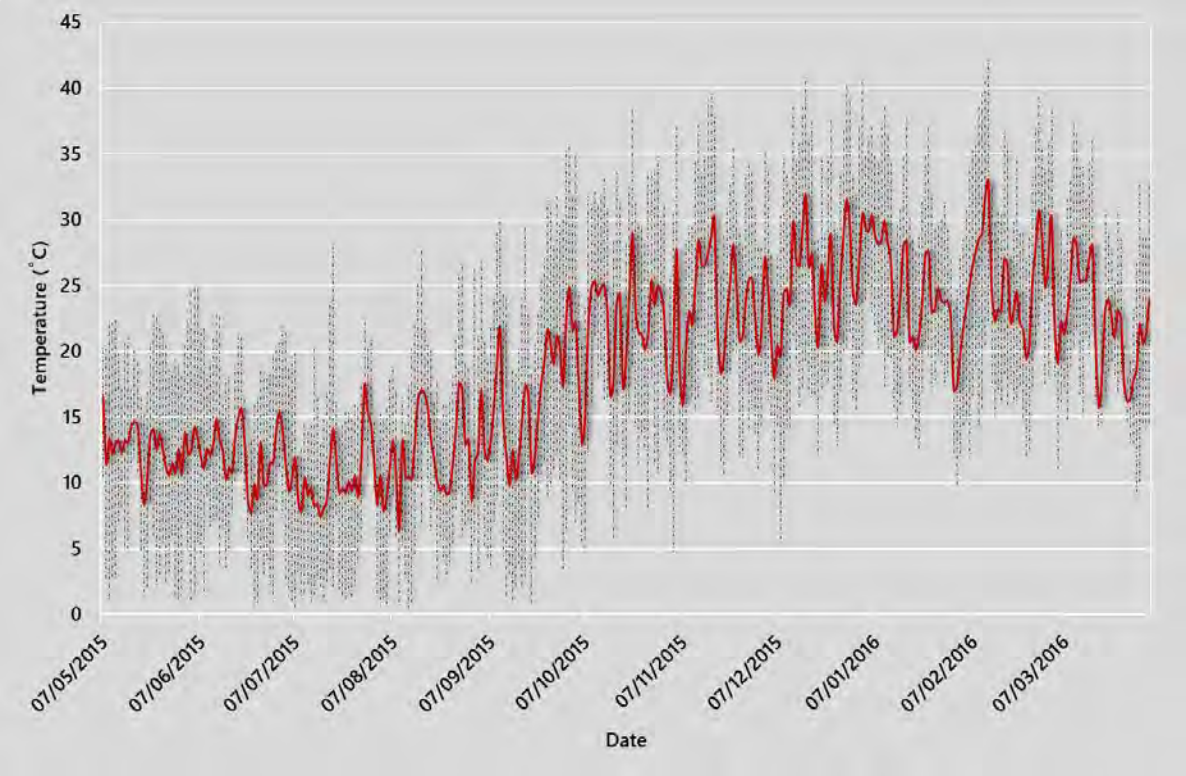


Figure 9-4 Daily average air temperatures at Sandy Ridge recorded between May 2015 and April 2016

9.2.4 Evaporation and evapotranspiration

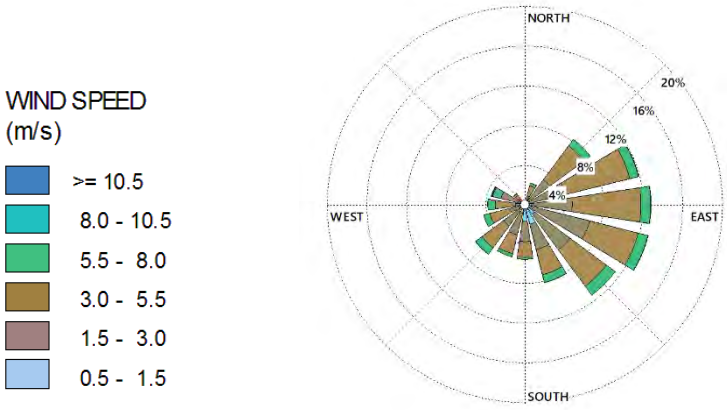
Average evaporation at the proposed development envelope is between 2400 mm and 2800 mm per annum, based on 10 years of records from 1975 to 2005 (BoM, 2015b). Pan Evaporation is based on the amount of water evaporating from bare ground. Evaporation from land surfaces covered by vegetation is better estimated by evapotranspiration. Average areal actual evapotranspiration at the site is 300 mm per annum, based on 30 years of data from 1961 to 1990 (BoM, 2015c). Both

evaporation and evapotranspiration averages per annum exceed the annual rainfall received at the site by approximately eight times, demonstrating it is a very dry environment.

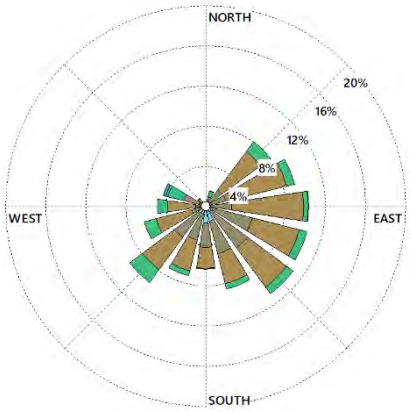
9.2.5 Wind speed and direction

Annual and seasonal wind roses for wind data collected from the AWS between 7 May 2015 and 4 April 2016 are presented in Figure 9-5. The distributions of wind speed in a number of categories, including calm winds are presented in Figure 9-6. The wind roses indicate that over the course of the year, winds were predominantly observed from the east/north-east to south-easterly directions. The majority of wind speeds experienced at the development envelope generally ranged from 1.5 metres per second (m/s) to 8.0 m/s (frequency of 78% combined) with the highest wind speeds (>10.5 m/s) occurring from a west and west-north-westerly direction. Winds of this speed were rare and occurred for approximately 0.1% of hours across the year (eight hours). Calm winds (<0.5 m/s) occurred during 1.8% of the observed hours during the year. The wind roses show seasonality in wind speeds and direction as described below:

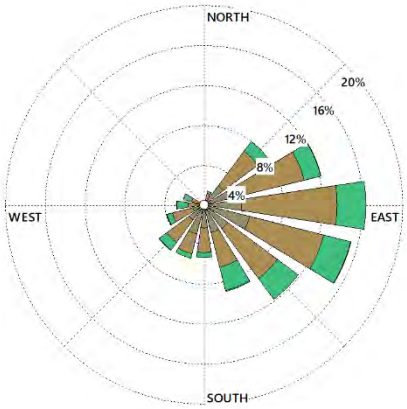
- **Spring** – Winds were predominantly experienced from the north-east to south-east directions. Wind speeds were typically in the range of 3.0 m/s to 8.0 m/s (frequency of 48.6%) and 1.5 m/s to 3.0 m/s categories (frequency of 30%). High wind speeds (8.0 m/s to > 10.5 m/s) occurred for a frequency of 0.6% of the year (13 hours in total) with the strongest winds (>10.5 m/s) occurring for 0.3% of the season (6.5 hours in total). Calm winds were experienced for 1.3% of observed hours.
- **Summer** – There was an observed decrease in the frequency of lighter winds (0.5 m/s to 3 0 m/s), and an increase in the frequency of wind speeds > 3.0 m/s to 8.0 m/s when compared to other seasons. The strongest winds (> 8.0 m/s) did not increase in frequency however the frequency of these wind speed categories were comparable to those experienced in all other seasons. Wind directions in the summer months were predominantly from easterly directions. The incidence of generally higher wind speeds in summer months was reflected in the low incidence of calm wind speeds (0.2%).
- **Autumn** – there was an observed increase in wind speeds in the 1.5 m/s to 3.0 m/s categories when compared with all other seasons, with a combined frequency of 84%. Distribution of wind directions is similar to those observed during summer months, although a higher frequency of winds from a south-easterly direction was experienced during the autumn. Calm winds were experienced for 1.1% of hours during the autumn months.
- **Winter** – a reduction in the frequency of winds originating from the east is observed during the winter months when compared to all other seasons. Lighter winds (1.5 m/s to 3.0 m/s) prevailed within the proposed development envelope in winter (43.9%). There was a reduction in the observation of higher wind speeds when compared with all other seasons, with no winds of greater than 8.0 m/s being recorded. An increase in calm wind speeds was also observed in winter months, with 4.4% of the recorded hours being less than 0.5 m/s (approximately 96 hours during the season).



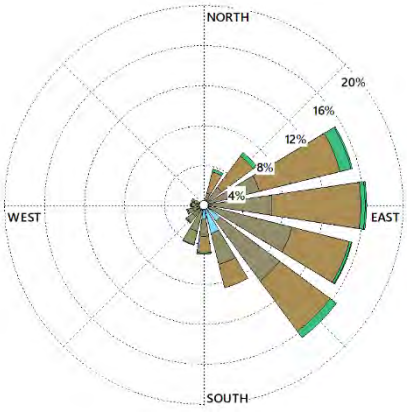
Annual – calms 1.8%



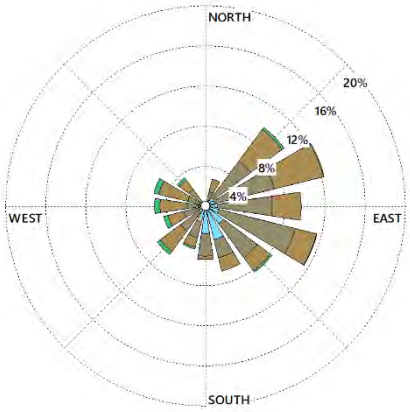
Spring – calms 1.3%



Summer – calms 0.2%



Autumn – 1.1%



Winter – calms 4.4%

Figure 9-5 Annual and seasonal wind roses recorded at Sandy Ridge between May 2015 and April 2016

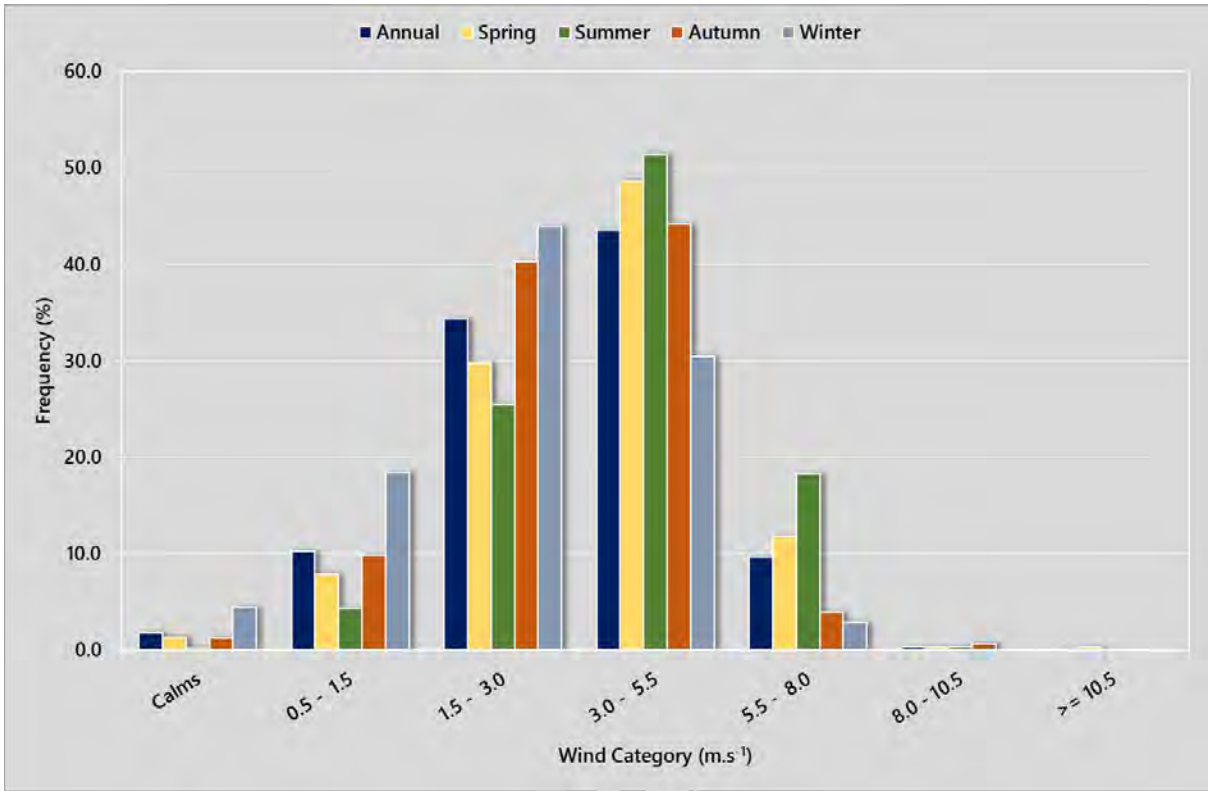


Figure 9-6 Annual and seasonal wind distribution at Sandy Ridge between May 2015 and April 2016

9.2.6 Land use

The land within the proposed development envelope is currently vacant, undisturbed Crown land. The water pipeline route would traverse a portion of the former Jaurdi Pastoral Lease, managed by the DPAW. There are several DPAW managed lands which are located within the vicinity of the proposed development envelope, as shown on Figure 9-7. These are:

- Mount Manning Range Nature Reserve, located approximately 9.8 km to the north-west.
- Mount Manning – Helena and Aurora Ranges Conservation Park, located approximately 19.8 km to the west.
- Boorabbin National Park, located approximately 100 km to the south.

The location of the proposed development envelope is remote. The nearest permanent residents are tourists staying at the Jaurdi Homestead (approximately 51 km away) and residents of the Carina Iron Ore Mine Accommodation Village (approximately 52 km away). Residents at the Carina Iron Ore Mine Accommodation Village are only present whilst the mine is operational.

An area to the east of the proposed development envelope, known as File Notation Area (FNA) 667, was set aside for the expansion of the IWDF. The FNA boundary is shown on Figure 9-7. Establishment of infrastructure such as a camp, works area or fuelling depot in the FNA area is prohibited unless permission is granted by the DMP and Department of Finance (Building Management and Works).

Two additional FNA areas; FNA 275 and FNA 668, are 15 km (radius) buffers from the IWDF, which have similar restrictions on land use to FNA 667. However, permission has been granted from the Department of Finance (Building Management and Works) that components of the Proposal could be established in these areas (approval letter dated 9 December 2015 can be provided on request).

9.2.7 Topography

The proposed development envelope has very low relief. It consists of flat to gently undulating plains and low rises and is typical of landscape which occurs over deeply weathered granite rocks. The topography ranges from about 460 m above sea level to 490 m above sea level and generally rises slightly from west to east (refer to Figure 9-7).

The proposed development envelope falls within the Kalgoorlie Province defined by Tille (2006). The Kalgoorlie Province is described as consisting of an extensive plateau of low relief that includes:

- Flat to undulating plains with small valleys (occasionally broken by low narrow rocky hills, ridges, tors and bosses) most commonly found on granitic terrain.
- Broad, flat to undulating, shallow valley plains are below these undulating plains and are formed on Quaternary alluvium and colluvium.
- Gently sloping to undulating plateau areas on granites and gneisses are situated higher in the landscape. These have long gentle slopes and, in places, abrupt erosional scarps.
- Rocky ranges, hills and ridges on the greenstone, along with some undulating to low hilly country.
- Level to gently undulating sandplains and gravelly sandplains are mostly found over lateritic residuals and granitic basement.
- The Yendilberin Hills which fall within the rocky ranges, hills and ridges of the greenstone category comprise a narrow, approximately north-west to south-west-trending rocky ridge to the west of the proposed development envelope, with a maximum elevation of 523 m AHD at Mount Walton (approximately 16 km south of the proposed development envelope (i.e. mining tenement), and approximately 8 km southeast of the Carina Pit and water pipeline route.

The proposed development envelope predominantly consists of flat to gently undulating sand plains and over weathered granite. There are no salt lakes in the proposed development envelope and the southern end of the water pipeline route near Carina Pit enters the Yendilberin Hills.

9.2.8 Regional geology

The proposed development envelope lies within the Archean Yilgarn Craton that comprises an area of approximately 657,000 km^2 and forms one of the largest intact segments of the Archean crust on Earth (CRM, 2016). The bulk of the craton is thought to have formed between 3,000 and 2,600 million years ago, with some gneissic terranes exceeding 3,000 million years in age (Anand and Butt, 2010).

The surface of the Yilgarn Craton, the Yilgarn Plateau, has low relief and, on a regional scale, probably represents a Proterozoic[21] erosion surface. This extremely old surface has subsequently been modified by weathering, partial erosion, and sedimentation, resulting in a complex regolith[22] (Anand and Butt, 2010). Broad landforms have been in place for about 250 million years and the Yilgarn Craton has been tectonically stable for approximately 2,500 million years.

The geological history of the proposed development envelope involved the emplacement of a granitic body within the earth's crust about 2,700 million years ago (Nelson, 2002). Over the next 2000 million years the overlying rocks were eroded, resulting in a relatively flat landscape, which has been above sea level for at least the last 540 million years, during which time it has been subject to various weathering events as it has undergone different climatic regimes (CRM, 2016).

The Yilgarn Craton can be subdivided into four provinces (Gee *et al*.,1981); the Western Gneiss Terrane, the Murchison Province, the Southern Cross Province and the Eastern Goldfields Province. The proposed development envelope lies in the Southern Cross Province, but is very close to the western boundary of the Eastern Goldfields Province (Geological Survey of Western Australia, 1990).

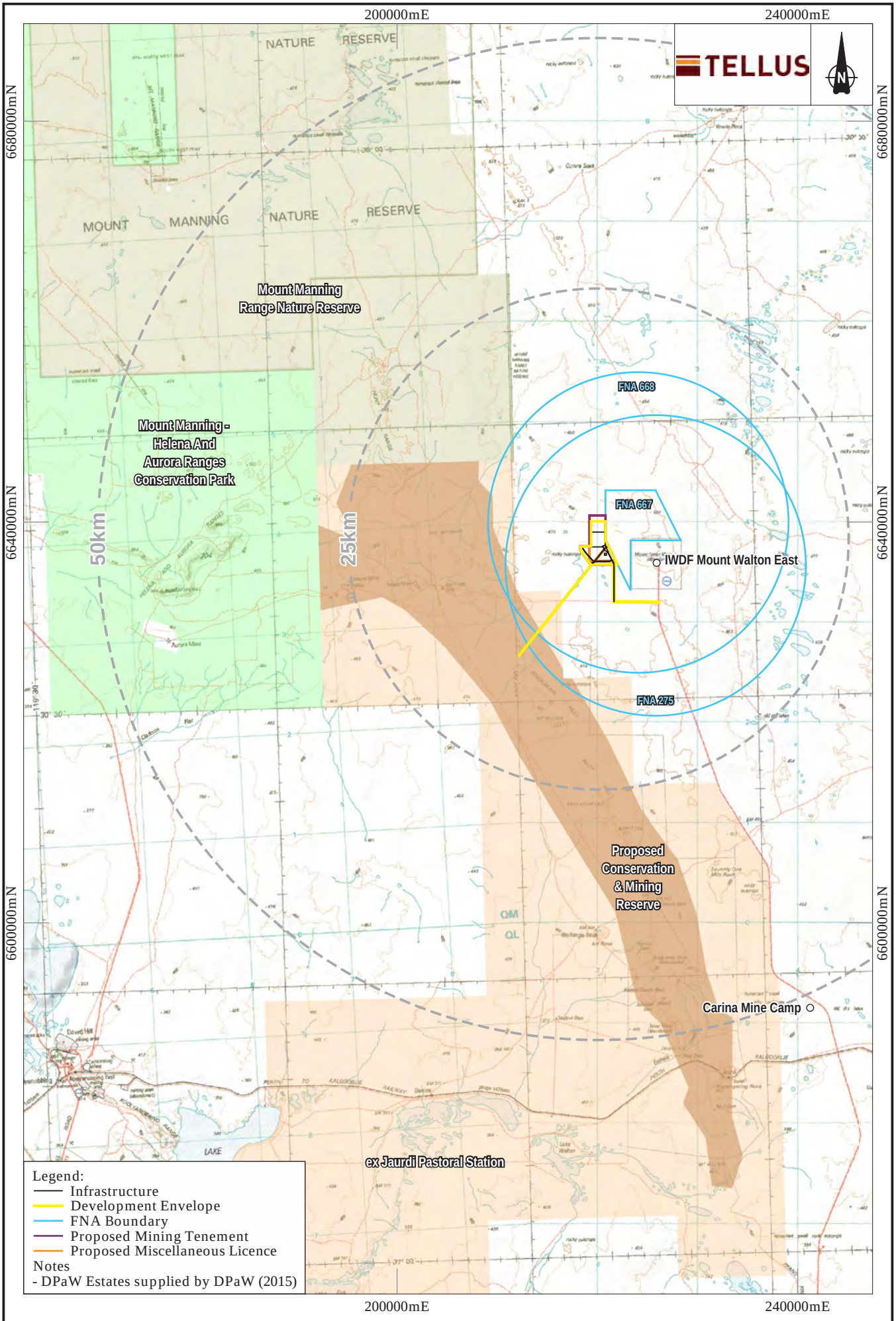
9.2.9 Local geology

The geology underlying the proposed development envelope is shown on Figure 9-8 which displays interpreted bedrock geology. Table 9-6 shows the drilling history in and around the proposed Sandy Ridge site.

The data within Table 9-6 shows that since the granting of an exploration licence, 202 holes have been drilled across the proposed development envelope between 2014 and 2016. This equates to 5,607 m of geological data which has been used to infer physical and chemical characteristics of the kaolin, and to prove the site lacks groundwater.

The proposed development envelope is located in the centre of a 160 km long and 20 km wide north-north-west trending granitic body, which intruded older granitic and volcanic rocks (CRM, 2016).

[21] The Proterozoic is that period of time between approximately 2500 and 540 million years ago.
[22] The regolith is the combination of weathered rock, soil, and other unconsolidated or cemented material that forms a younger blanket over unweathered bedrock.



0 8km

Scale 1:500,000
MGA94 (Zone 51)

CAD Ref: g2294_PER_07_01.dgn

Date: November 2016 | Rev: J | A4

Aurora environmental

Author: C. Dorrington | AE Ref: THO2014-003

Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

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Landuse

Public Environmental Review

Figure:

9-7

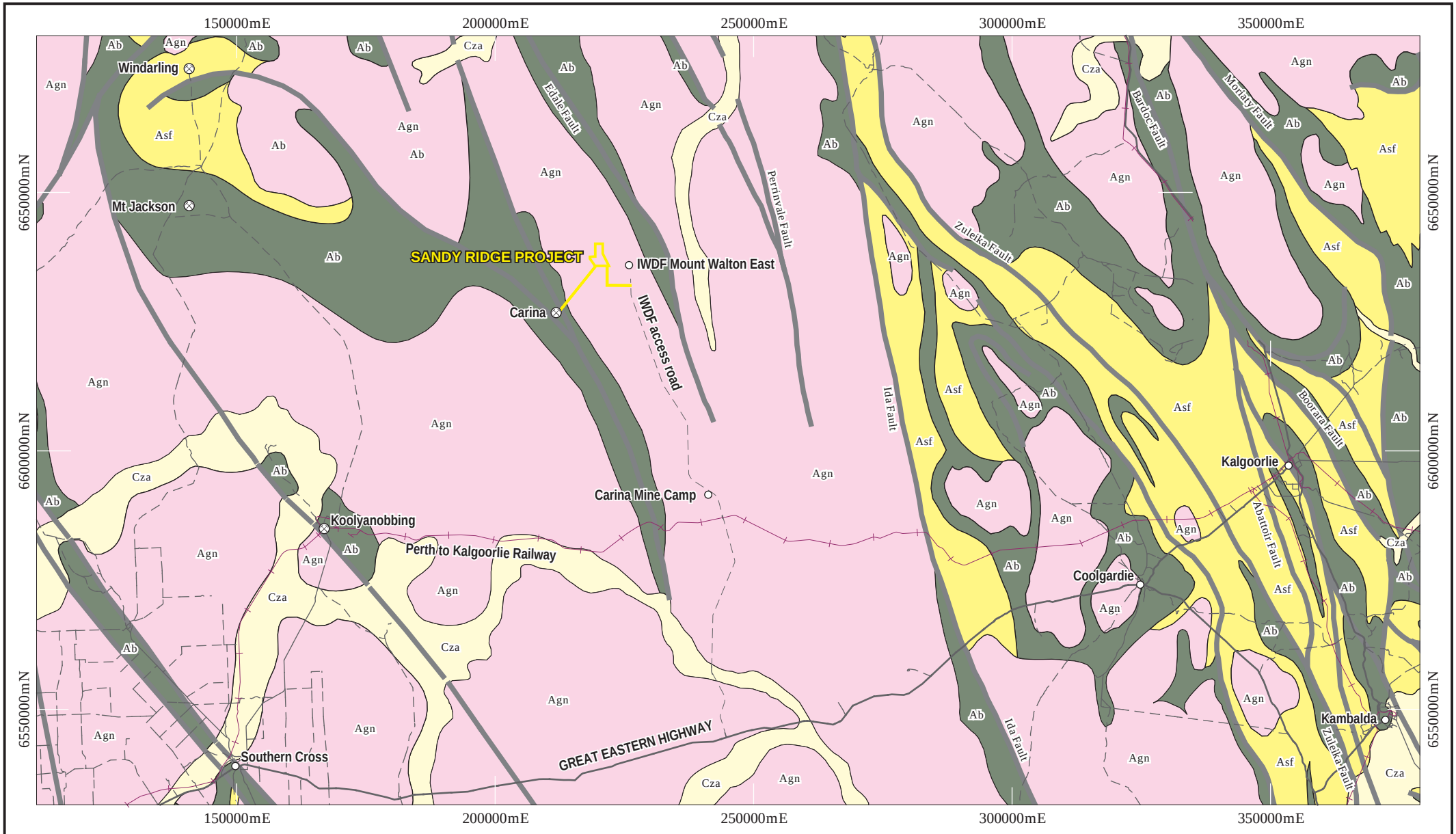
Table 9-6 Drilling history in and around Sandy Ridge

Activity	Drill holes	Metres
IWDF drilling (1995)	53	1,397
IWDF drilling (1995) within E16/440	10	337
IWDF monitoring bore drilling (1995)	2	39
E16/440 resource drilling (2014)	61	1,864
E16/440 resource drilling (2015)	51	1,355
E16/440 bulk sample drilling (2015)	88	2,162
E16/440 monitoring bore drilling (2015)	7	226
TOTAL	**272**	**7,380**

The local geology is well understood due to mineral exploration drilling across the exploration tenement. In geological terms the proposed development envelope is a deeply weathered granitoid terrane that generally comprises four main lithologies. From the surface these are:

- **Colluvial sand and gravel with mottled zone laterite** – this comprises mostly yellow brown quartz sand overlying pisolitic-ironstone gravel and/or nodular red-brown clayey sand (lateritic mottled zone).
- **Silcrete** – comprises kaolinitic clay and silica to form a hard cap over underlying lithologies. This layer is essentially as hard as granite. It has a sharply defined upper surface that undulates quite sharply at times with numerous protrusions; it exhibits peaks and troughs that have amplitudes up to 1 m. The silcrete does not display much fracturing, but some parts near the surface may be disrupted by tree roots. The base of the silcrete generally merges gradationally into the underlying kaolinitic clay profile and as a result the silcrete can be quite variable in terms of overall thickness. The silcrete has most likely been hardened as the result of a secondary chemical process that effectively has re-cemented the kaolinitic clay profile from its upper surface.
- **Kaolinitic clay** – comprises soft white kaolin weathered from pre-existing granitoids. As a result, the clays contain relict quartz phenocrysts. This clay profile may be absent in some areas where silcrete stretches to the granitoid basement, but generally is more than 15 m thick and up to a maximum of nearly 40 m thick. The clay is quite uniformly white with little fracturing and only exhibits minor iron staining in the few fracture zones present.
- **Granitoid basement** – comprises a fine to medium grained light coloured granite containing pegmatite and quartz veins. The basement topography varies widely to less than 5 m from the surface to greater than 45 m below the surface.

Plate 9-17 shows a typical lithological profile through the weathered granite profile (extracted from CRM, 2015). The profile commences with sand/laterite (bottom tray in Plate 9-17) and grades into silcrete, mottled kaolin and white kaolin. Below the white kaolin is a saprock zone, the top of which represents the base of complete oxidation underlain by the fresh granite (CRM, 2016). The formation of the profile is described in Appendix A.4.



Legend:
- Iron Ore Mine
- Rail
- Major Road
- Minor Road
- Faults

- Ab Metamorphosed basic and ultrabasic volcanic and intrusive rocks
- Agn Granite and Gneiss
- Asf Metamorphosed sedimentary and acid volcanic rocks
- Cza Alluvial, shoreline, & eolian deposits

*Geology: DMP Generalised Geology of WA 1999

TELLUS

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Date: Nov 2016 | Rev: H | A4

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Figure: **9-8**

Plate 9-17 Lithological profile

9.2.10 Earthquakes

A search of Geoscience Australia's Earthquake Database (Geoscience Australia, 2015a) for information on past earthquakes indicates two earthquakes of similar magnitudes have occurred within 25 km of the proposed development envelope:

- 3 March 2014 – magnitude 2.4 west of the Carina Iron Ore Mine, approximately 22 km south west from the Proposal.
- 4 February 2014 – magnitude 2.5 north of the Mount Walton East IWDF, approximately 17.5 km north east from the Proposal.

No earthquakes have occurred at the proposed location of the cells. Australia is located on the Indo-Australian Plate, and there are no plate boundaries on the continent, therefore tectonic plate activity is not experienced in WA. There are no active or dormant volcanoes in WA.

9.2.11 Tectonic plate movement

The proposed development envelope is situated on the Archaean Yilgarn Shield, within the central portion of the eastern section of the Indo-Australian Plate. This eastern section is, in general, moving north-east at around 5.6 cm per year (Hammonds, 2012).

This rate of movement and the location of the proposed development envelope within a seismically quiet portion of a stable shield is very unlikely to cause any significant tectonic activity (uplift, subsidence, or fracturing) in any timeframe relevant to the Proposal. However, if the present movement continues at the same rate, the proposed development envelope could be expected to approach the present position of the seismically active section of New Guinea in about 60 million years (CRM, 2016).

9.2.12 Volcanic activity

No igneous activity has occurred in the region for over 1,000 million years. The Archaean granite that constitutes the bedrock in the proposed development envelope has been dated at around 2700 million years (Nelson, 2002). A Proterozoic age east-west trending dyke intruded the granitic basement about 20 km south of the proposed development envelope. Similar dykes within the Yilgarn Craton have been dated at circa 2,420 million years (Nemchin and Pidgeon, 1998) and at circa 1210 million years (Pidgeon and Nemchin, 2001).

There is no reason to expect that there would be any sub-surface or surface volcanic activity within this part of the stable craton for at least 50 million years (CRM, 2016).

9.2.13 Weathering, erosion and stability

Current weathering and erosion in the area is extremely slow. The present semi-arid climate, with a median annual rainfall of about 250 mm and an annual evaporation rate over 2,000 mm is not conducive to chemical weathering, which is active in humid temperate to tropical climates, but much less active in semi-arid and arid climates (CRM, 2016).

The present surface has not changed for at least the past 2.6 million years (CRM, 2016) except for the addition of wind-blown sand, and possible minor redistribution of lateritic pebbles. The site has a large amount of silcrete and laterite. The presence of these rock types is a good indication that the site lacks erosion.

The proposed development envelope is situated at an elevation of between 460 m and 490 m in an area of low relief. It contains no active stream channels and no known paleo-channels, and is distant from any major drainage system. The near horizontal sandy surface and lack of stream channels results in rain water being absorbed into this surface unit, rather than running off with resulting water erosion. Wind erosion is very limited, as the sandplain is well covered with native vegetation and average wind speeds are low for the majority of the year (refer to Figure 9-5).

It is the combination of a virtually flat plateau, cemented surface layers, and semi-arid conditions that creates the stable geomorphology of the proposed development envelope (CRM, 2016).

9.2.14 Glaciation

There is no evidence that the central portion of the Yilgarn Plateau has been subject to glaciation, even during the most recent Ice Ages of the last 70,000 years, when the only areas in Australia where glaciers were present were the Snowy Mountains and Tasmania (Barrows and Fifield, 2016).

The present north-easterly movement of the Australian continent towards the tropics and away from the South Pole suggests that there is no likelihood of a future glaciation of the area, at least in the next 60 million years (CRM, 2016).

9.2.15 Soils

The proposed development envelope is located within the Norseman (266) soil landscape mapping zone, within the Kalgoorlie Province as defined by Tille (2006). The soils of the Norseman zone are described as calcareous loamy earths, yellow sandy and loamy earths, red loamy earths, red deep sands and salt lake soils.

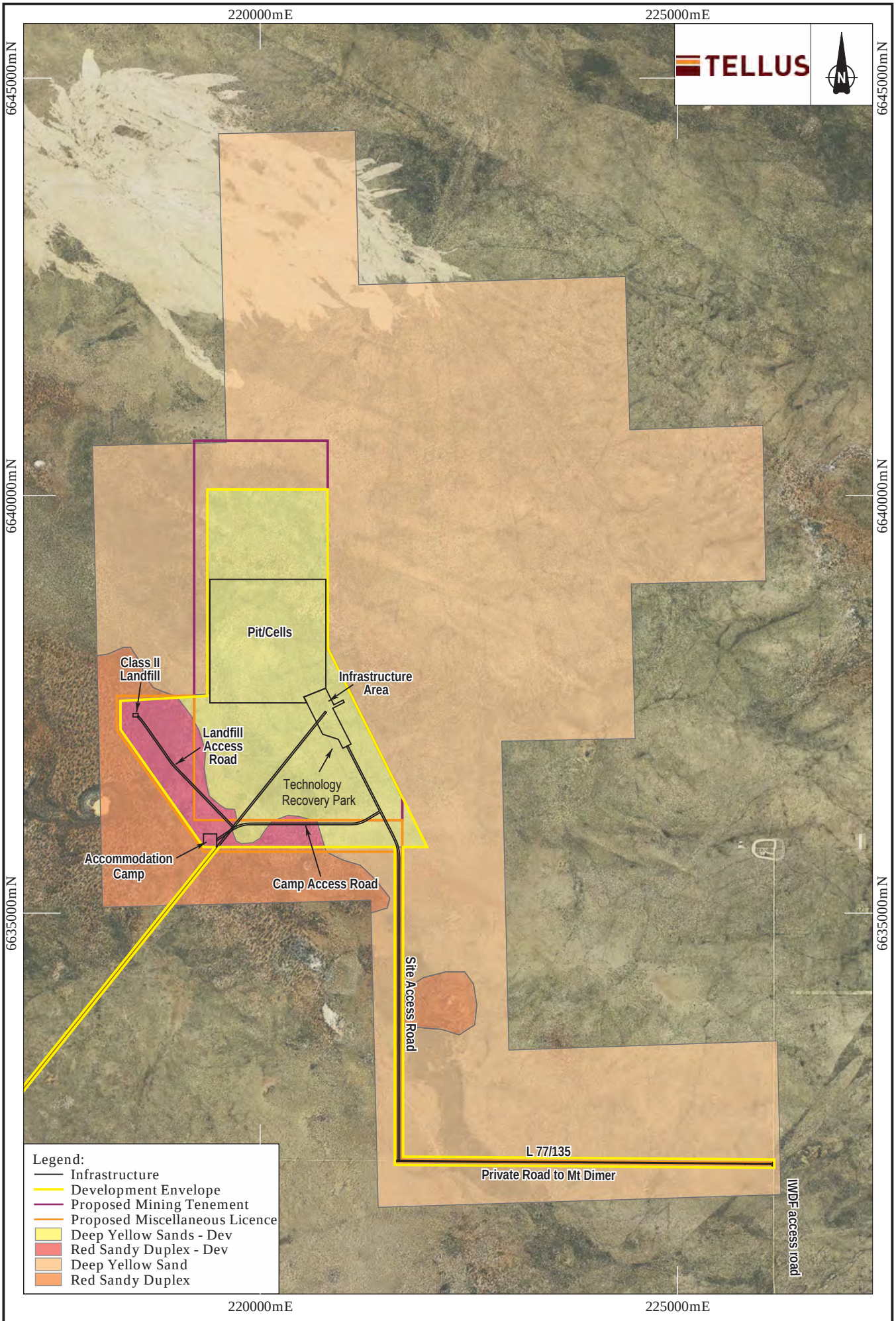
The field assessment identified two soil types within the proposed development envelope; Deep Yellow Sand and Red Sandy Duplexes (refer to Figure 9-9). The Deep Yellow Sand is associated with the higher relief areas of low sandy dune systems of the proposed development envelope. The pH of the Deep Yellow Sand was strongly acidic, with pH ranging from 4.2 to 4.9.

The soil extents within the proposed development envelope are:

- Red Sandy Duplex – 8.26 ha.
- Deep Yellow Sands – 65.8 ha

The field assessment results correlated with the soil landscape mapping (Tille, 2006). The Red Sandy Duplex is associated with the lower-lying areas of the proposed development envelope, potentially broad areas of drainage, and consequently are areas of potential erosion.

The Red Sandy Duplexes were found at shallow depths (<0.3 m BGL) over a tightly packed laterite ferricrete. The pH of the Red Sandy Duplex was neutral at the surface (pH 7.0) to alkaline at depth (pH 8.9). Based on the number of Red Sandy Duplexes samples analysed the average pH was 7.6.



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Soils

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Figure:

9-9

9.3 Terrestrial fauna

This section discusses fauna and fauna habitat within the proposed development envelope. The presence of fauna of conservation significance is also discussed.

9.3.1 Terrestrial fauna habitat

The proposed development envelope is located in the Southern Cross IBRA Subregion. The Southern Cross IBRA Subregion is characterised as a weathered plain comprising gently undulating uplands dissected by broad valleys with bands of low greenstone hills. The subregion is characterised by a diverse eucalypt woodland and low heaths.

Two fauna habitats were recorded within the proposed development envelope. These included open woodland and shrublands as described in Table 9-7 and illustrated in Figure 9-10 and Figure 9-10 b. Fauna species potentially occurring within these habitats are detailed in Appendix A.8.

Table 9-7 Fauna habitats within the proposed development envelope

Broad fauna habitat type	Fauna habitat mapping	Condition
Open woodland	Open eucalypt woodland with an open understorey of shrubs over ephemeral grasses or scattered spinifex on red sandy clay soils.	Very good to excellent condition.
Shrubland	Moderately dense to dense sand plain shrubland varying in height from 0.5–1.8m on yellow sandy soils.	Very good to excellent condition.

Source: Terrestrial Ecosystems (2015)

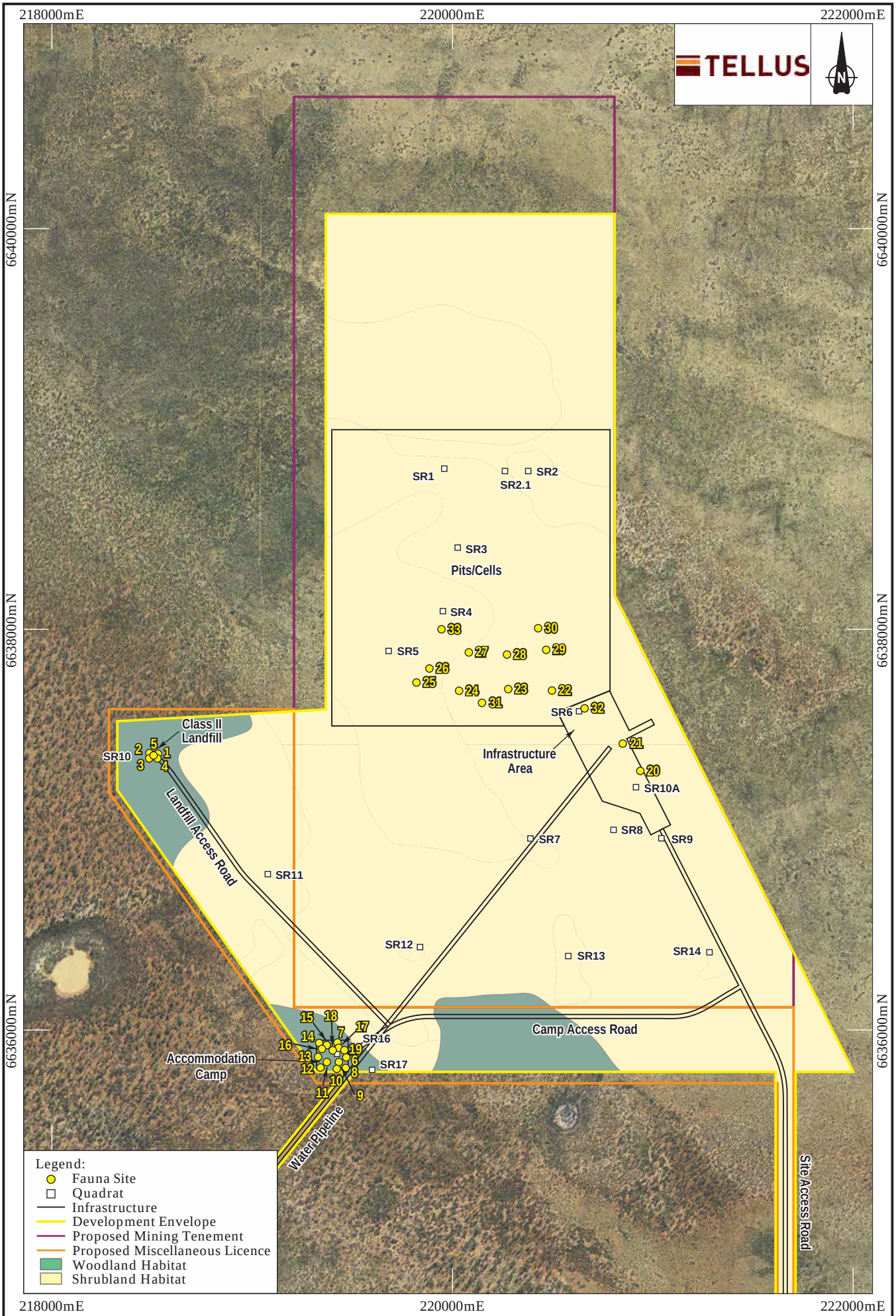
9.3.2 Ecological linkages

Ecological linkages are a series of (both contiguous and non-contiguous) patches of native vegetation which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape. The proposed development envelope currently does not provide any important ecological linkages or fauna movement corridors as it is part of a large and relatively undisturbed area.

9.3.3 Vertebrate fauna species of conservation significance

Fourteen fauna species listed under the WC Act and/or EPBC Act or by DPAW have been recorded or are predicted to occur within the proposed development envelope or within the locality (refer to Table 9-8). Evidence of two of these species was recorded within the proposed development envelope during the field surveys. These were Malleefowl (*Leipoa ocellata*) (listed as Vulnerable under the WC Act and the EPBC Act) and Rainbow Bee-eater (*Merops ornatus*) (listed as Migratory under the WC Act and the EPBC Act). These species are discussed further below.

An additional four listed species may possibly occur within the proposed development envelope. These species include sp. 1 Central Long-eared Bat (*Nyctophilus timoriensis*), Western Rosella (Mallee) (*Platycercus icterotis xanthogenys*), Fork-tailed Swift (*Apus pacificus*) and Peregrine Falcon (*Falco peregrinus*). The remaining species are considered unlikely to occur within the proposed development envelope due to a lack of suitable habitat and, therefore, would not be affected by the Proposal.



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Fauna habitats

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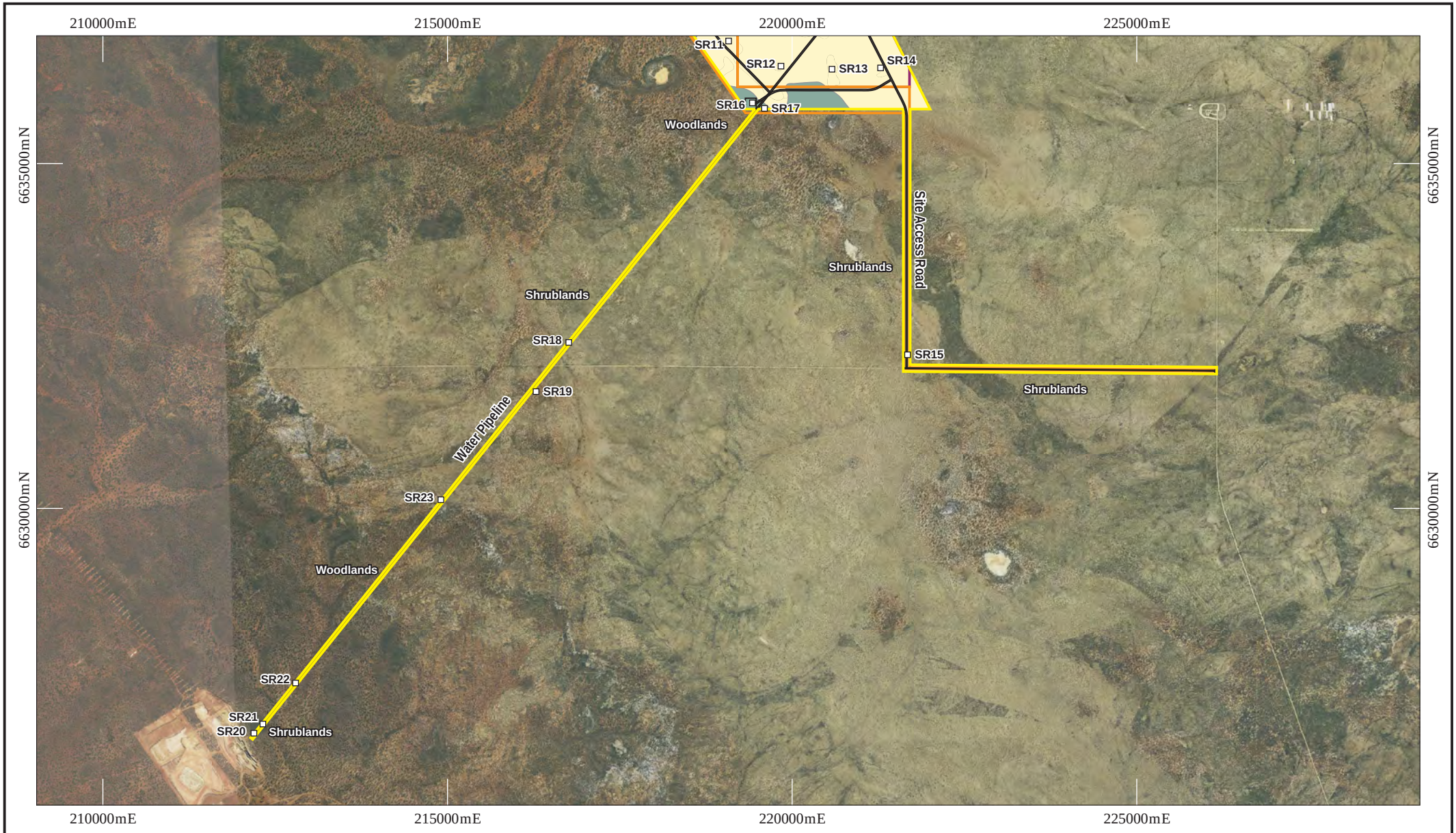
Figure:

9-10a



Legend:
- Quadrat
- Infrastructure
- Development Envelope
- Proposed Mining Tenement
- Proposed Miscellaneous Licence
- Woodland Habitat
- Shrubland Habitat

TELLUS

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Scale 1:75,000
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Fauna habitats - water pipeline and access road

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Figure:

9-10b

Malleefowl (Leipoa ocellata)

No Malleefowl or active breeding mounds were observed within the proposed development envelope during the targeted survey. Old mounds were evident, with 63 identified during the survey of various ages and in varying states of degradation. Most were little more than circular raised areas of gravel, potentially unused for decades or centuries (refer to Plate 9-18).

Five mounds were large (up to 9 m wide, 0.5 m high and 0.3 m deep) and distinctive although not recently used.

Mounds were found where the soils were a gravelly loam, with the mounds themselves being composed largely of lateritic gravel.

Malleefowl are likely to occur in the proposed development envelope only as an occasional visitor. Malleefowl can be expected to return to the proposed development envelope and surrounding areas as a breeding species at a low density when the vegetation has matured. It favours gravelly soils for mound construction and these lie mostly outside the proposed development envelope.

Plate 9-18 Malleefowl mound (very old); little more than a raised patch of gravel

Plate 9-19 Malleefowl mound with well-defined central depression.

Rainbow Bee-eater (Merops ornatus)

Two Rainbow Bee-eaters were observed during the field survey; however, as the nesting period had finished for the season, it was assumed the birds were just passing through. Sandy to sandy loam soils within the proposed development envelope would be suitable breeding habitat for this species, however no recently used burrows were observed. Therefore, Rainbow Bee-eaters may be present when transiting across the proposed development envelope.

Table 9-8 Potentially occurring conservation significant vertebrate fauna species

Species[23]	Conservation status		Habitat	Likelihood of occurrence
	EPBC Act	WA status[24]		
Mammals				
Numbat ***Myrmecobius fasciatus***	Vulnerable	Endangered	Current populations inhabit Jarrah forest, open Eucalypt woodland, *Banksia* woodland and tall closed shrubland. Habitats usually have an abundance of termites in the soil, hollow logs and branches for shelter (DEC, 2012).	Unlikely. Not recently recorded in the vicinity of the proposed development envelope.
Chuditch ***Dasyurus geoffroii***	Vulnerable	Vulnerable	Chuditch are known to have occupied a wide range of habitats from woodlands, dry sclerophyll (leafy) forests, riparian vegetation, beaches and deserts. Riparian vegetation appears to support higher densities of Chuditch, possibly because food supply is better or more reliable and better cover is offered by dense vegetation. The estimated home range of a male Chuditch is over 15 km^2 whilst that for females is 3–4 km^2 (Sorena and Soderquist, 1995).	Unlikely. The proposed development envelope is outside the normal distribution of this species. The species has not recently been recorded in the vicinity of the proposed development envelope.
Central Long-eared Bat ***Nyctophilus(timoriensis)*** **sp. 1**	-	Priority Fauna (P4)	The proposed development envelope is on the north-western boundary of its known distribution. It roosts in tree cavities, foliage and under loose bark (Terrestrial Ecosystems, 2015).	Possible. Within known distribution and suitable habitat present.
Western Brush Wallaby ***Macropus irma***	-	Priority Fauna (P4)	The species optimum habitat is open forest or woodland, particularly favouring open, seasonally wet flats with low grasses and open scrubby thickets. It is also found in some areas of mallee and heathland, and is uncommon in Karri forest (DEC, 2012).	Unlikely. Not recorded in recent surveys.
Western Mouse ***Pseudomys occidentalis***	-	Priority Fauna (P4)	Tall shrub land with mallee eucalypts and a heath understorey on a substrate of gravelly loam (Kitchener and Chapman, 1977).	Unlikely. Not recorded in recent surveys.

[23] *Species listed in Terrestrial Ecosystems (2015) which have since been deleted from the Wildlife Conservation (Specially Protection Fauna) Notice 2015 have been excluded from this table.*
[24] *Priority species are listed by DPAW. Endangered, vulnerable, migratory and specially protected fauna listed under the WC Act 1950 (WA).*

Species[23]	Conservation status		Habitat	Likelihood of occurrence
	EPBC Act	WA status[24]		
Quenda ***Isoodon obesulus fusciventer***	-	Priority Fauna (P4)	Dense scrubby, often swampy, vegetation with dense cover up to one metre high, often feeds in adjacent forest and woodland that is burnt on a regular basis and in areas of pasture and cropland lying close to dense cover. Populations inhabiting jarrah and Wandoo forests are usually associated with watercourses. Quendas can thrive in more open habitat subject to exotic predator control (DEC, 2012).	Unlikely.
Reptiles				
Southern Death Adder ***Acanthophis antareticus***	-	Priority Fauna (P3)	The Southern Death Adder is a very cryptic snake that is found from the Darling Range, central Wheatbelt and from Esperance across the Nullarbor Plain to the South Australian border (Cogger, 2014). It is rarely caught in fauna surveys and only opportunistically encountered on roads and in undisturbed bushland.	Unlikely. Rarely encountered in the Southern Cross IBRA subregion.
Birds				
Carnaby's Black Cockatoo ***Calyptorhynchus latirostris***	Endangered	Endangered	Forests, woodlands, heathlands, farms; feeds on *Banksia*, *Hakea* and Marri. Carnaby's Black-Cockatoo has specific nesting site requirements. Nests are mostly in smoothed-barked eucalypts with the nest hollows ranging from 2.5–12 m above the ground, an entrance from 23–30 cm diameter and a depth of 0.1–2.5 m (Johnstone and Storr, 1998).	Unlikely. The proposed development envelope is outside the normal distribution of this species. The species has not been recently recorded in the vicinity.
Malleefowl ***Leipoa ocellata***	Vulnerable	Vulnerable	Mainly scrubs and thickets of mallee *Eucalyptus* sp., boree *Melaleuca lanceolata* and bowgada *Acacia linophylla*, also dense litter forming shrublands (DEC, 2012).	Likely. Potentially in the general area and may be an occasional visitor to the proposed development envelope. No active mounds are present within the proposed development envelope; therefore, it is currently unlikely to use the proposed development

Species[23]	Conservation status EPBC Act	 WA status[24]	Habitat	Likelihood of occurrence
				envelope for nesting habitat. Evidence of this species was recorded within the proposed development envelope during the field surveys.
Western Rosella (mallee) Platycercus icterotis xanthogenys		Priority Fauna (P4)	The mallee form of the Western Rosella is found mostly in Eucalypt and *Casuarina* woodland and shrublands, especially Wandoo, Flooded Gums and Salmon Gums (Terrestrial Ecosystems, 2015).	Possible. This species could potentially occur in the eucalypt woodland, however the proposed development envelope is north of where it was previously recorded (McKenzie and Rolfe, 1995). Has not been recorded in recent surveys (BCE, 2016).
Fork-tailed Swift ***Apus pacificus***	Migratory	Schedule 5 (Migratory)	Low to very high airspace over varied habitat from rainforest to semi-desert (Morcombe, 2003).	Possible.
Rainbow Bee-eater ***Merops ornatus***	Migratory	Schedule 5 (Migratory)	Open country, woodlands, open forest, semi-arid scrub, grasslands, clearings in heavier forest, farmlands (Morcombe, 2003). Breeds underground in areas of suitable soft soil firm enough to support tunnel building.	Likely. This species could potentially occur within the proposed development envelope. This species could potentially breed in sandy areas if conditions were suitable. Evidence of this species was recorded within the proposed development envelope during the field surveys.
Peregrine Falcon ***Falco peregrinus***	-	Schedule 7 (Other specially	Diverse habitat from rainforest to arid shrublands, from coastal heath to alpine (Morcombe, 2003). Mainly about cliffs along coasts, rivers and ranges and about wooded watercourses and lakes (Johnstone and Storr, 1998). The species utilises ledges, cliff	Possible.

Species[23]	Conservation status		Habitat	Likelihood of occurrence
	EPBC Act	WA status[24]		
		protected fauna)	faces and large hollows/broken spouts of trees for nesting. It would also occasionally use the abandoned nests of other birds of prey.	
Hooded Plover ***Charadrius rubricollis***	Marine (as *Thinornis rubricollis*)	Priority Fauna (P4)	This species frequents the margins and shallows of salt lakes, and also along coastal beaches, where it forages for invertebrates (Johnstone and Storr, 1998).	Unlikely. Lack of suitable habitat.

9.4 Inland waters environmental quality

This section describes the hydrology and hydrogeology of the proposed development envelope.

9.4.1 Hydrology

No channels or creeks occur in the proposed development envelope (Rockwater, 2015). There are no major flow paths in the area of the proposed cells, and surface water runoff would only be generated from very infrequent high rainfall events (Rockwater, 2015). These flows would be from small local catchments which drain residual runoff after infiltration losses, to low–lying depressions. Generally surface water would only be retained for short periods in the depressions due to continual infiltration. In addition, there would be evaporation of water in clay pans, this would typically begin three days after a major rainfall event once clouds have lifted. Water may drain into the proposed cell area from the north and east because it has a slighter higher elevation but only in the event of infrequent, very high rainfall events.

Based on rainfall analysis the likely peak run-off for rainfall events between 1 in 2 and 1 in 2000 years ARI are listed in Table 9-9.

Table 9-9 Total rainfall including probable maximum precipitation

Duration (Hours)	ARI / total rainfall (mm)									
	2	5	10	20	50	100	200	500	1000	2000
24	40	57	70	87	113	136	155	180	201	222
48	47	68	83	104	135	163	186	216	241	266
72	50	72	89	111	146	176	200	232	258	285

In order to compare estimated total rainfall levels for a range of estimated ARI, the maximum recorded rainfalls from other weather stations in the vicinity of the proposed development envelope were reviewed.

The two largest recorded total rainfalls over 72 hours occurred in 1948 and 1995, at Menzies and Ora Banda, both of which are within 115 km of the proposed development envelope. The rainfall recorded was 211.6 mm and 280.8 mm at Menzies, and 254.0 mm and 189.8 mm at Ora Banda. The information in Table 9-9 indicates that the 1948 and 1995 rainfall events were extreme events. The volumes of rainfall recorded at the two locations equate to a 1 in 2000 ARI.

The total rainfall for a range of ARI and the maximum recorded rainfalls were compared against infiltration losses. Infiltration rates for sandy soils can be up to 720 mm/day and are typically about 500 mm/day for sandy, loamy soil.

The proposed development envelope has predominantly sandy soil; with some small clay pans where infiltration rates could be between 24 and 120 mm/day. During the highest recorded rainfalls, sandy loam soil should experience an infiltration loss within 12 hours, or soon after. This means the likelihood of widespread water pooling on the surface within the proposed development envelope is rare.

9.4.2 Surface water catchments and peak flows

Fourteen catchments were identified in the proposed development envelope and their flow paths are shown in Figure 9-11. If water does not infiltrate over the flow path, it would pool in a depression until it infiltrates or evaporates. Five depressions were identified in the vicinity of the proposed development envelope (refer to Figure 9-11). A further two depression occurred outside of the proposed development envelope.

The estimated peak flows over the access road range from approximately 10 m^3/s to 35 m^3/s for the 100 year ARI event and 40 m^3/s to 130 m^3/s for the probable maximum flood (2,000 year event). It must be noted the access road lacks vegetation which is likely to increase the speed of surface water flows.

Peak flows would typically occur approximately 20 minutes after the start of a rainfall event, and flow depth and widths would be the same speed with or without infiltration, but flow depths and widths would reduce by the end of a rainfall event.

Flow durations would be short. For example, peak flows in the vicinity of the proposed cell and infrastructure area range from approximately 1.6 m^3/s to 5.5 m^3/s and for the probable maximum flood 2,000 year event from 7 m^3/s to 20 m^3/s.

If surface water flows are generated within the proposed development envelope, they would likely follow the natural topography until they evaporate (within 12 hours) or infiltrate (at a rate of up to 500 mm/day).

The area and length of the 14 catchments for typical ARI up to the 100 year event and probable maximum flood (1 in 2000 years) are summarised in Table 9-10.

The table shows that the largest catchments (RA, RB, RD and RC and RD) are the largest of the 14 catchments. The remainder of catchments (A to K) are all under 1 km^2. The contributing catchments at the Sandy Ridge site are E, F, G and H. Cross sections for these catchments and the corresponding flows base don a 100 year ARI are shown in Table 9-11.

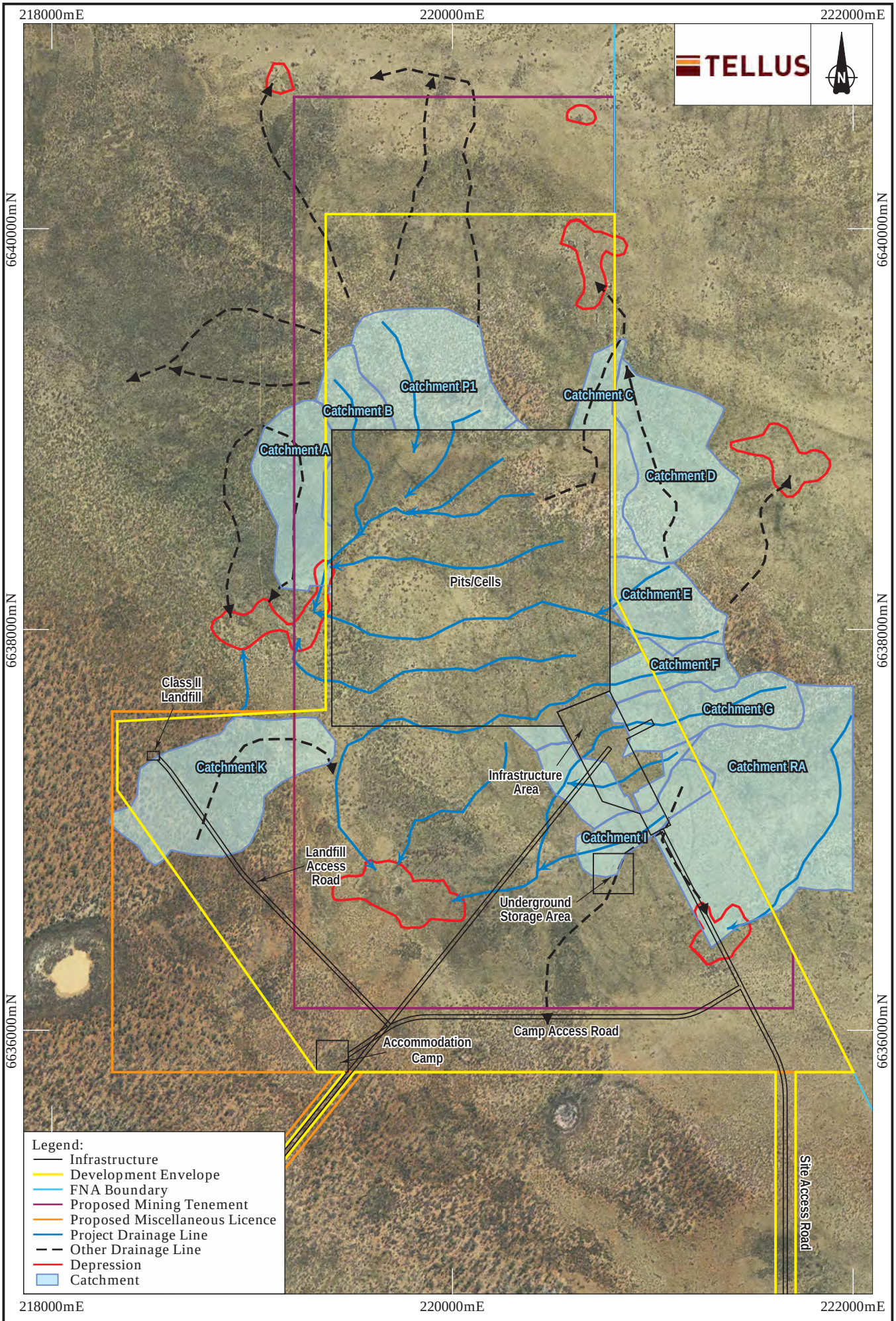
Table 9-10 Characteristics of catchments

Catchment	Area (km^2)	Length (km)
A	0.32	0.88
B	0.15	0.73
C	0.31	0.91
D	0.39	0.90
E	0.24	0.65
F	0.26	1.18
G	0.11	0.96
H	0.11	0.44
I	0.23	0.63
J	0.07	0.41
K	0.48	1.03
P1	0.41	0.75
P2	0.07	0.18
P3	0.50	1.06
RA	1.48	1.58
RB	2.80	2.37
RC	13.85	6.70
RD	15.22	5.65

Table 9-11 Contributing catchments in peak flows

Cross section	Contributing catchments	100 year ARI flows (m^3/s)
XS1	E	3.93
XS2	0.5 * F	1.63
XS3	F	3.25
XS4	G	1.84
XS5	H	2.56

The potential impacts of the above peak flows under a 1 in 100 year rainfall event are discussed in Section 10.5.3.



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Catchment surface water flows

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Figure:

9-11

9.4.3 Hydrogeology (desktop review)

The hydrogeology of the proposed development envelope is characterised as weathered granite rock with minor groundwater resources (Kern, 1994). With the exception of groundwater bores for monitoring purposes at the IWDF (approximately 5.5 km east of the proposed development envelope) and water supply bores at the Mount Dimer Gold Mine, greater than 23 km from the proposed development envelope, there are no other known registered users of groundwater in the vicinity of the Proposal.

A groundwater investigation of the Mount Walton north-east area in 1988 (excluding drilling, but including the area in which the IWDF and the proposed Sandy Ridge site are situated) considered both areas to be suitable for the permanent isolation of hazardous wastes (Hirschberg, 1988). The early investigations for the siting of the IWDF indicated a low likelihood of aquifers. Further investigation and subsequent drilling confirmed this because no aquifers were intersected.

Previous drilling investigations in the region (Soil & Rock Engineering, 1989 and ATA Environmental, 1995) comprising 21 drill holes did not detect a groundwater aquifer (see Figure 9-12 for locations of drill holes). Permeability tests conducted on four of the 21 holes gave approximate in situ soil permeability values for the weathered granite ranging from 2.5 x 10^{-8} m/s to 3.2 x 10^{-7} m/s. These values mean the kaolin is not permeable and is very dry.

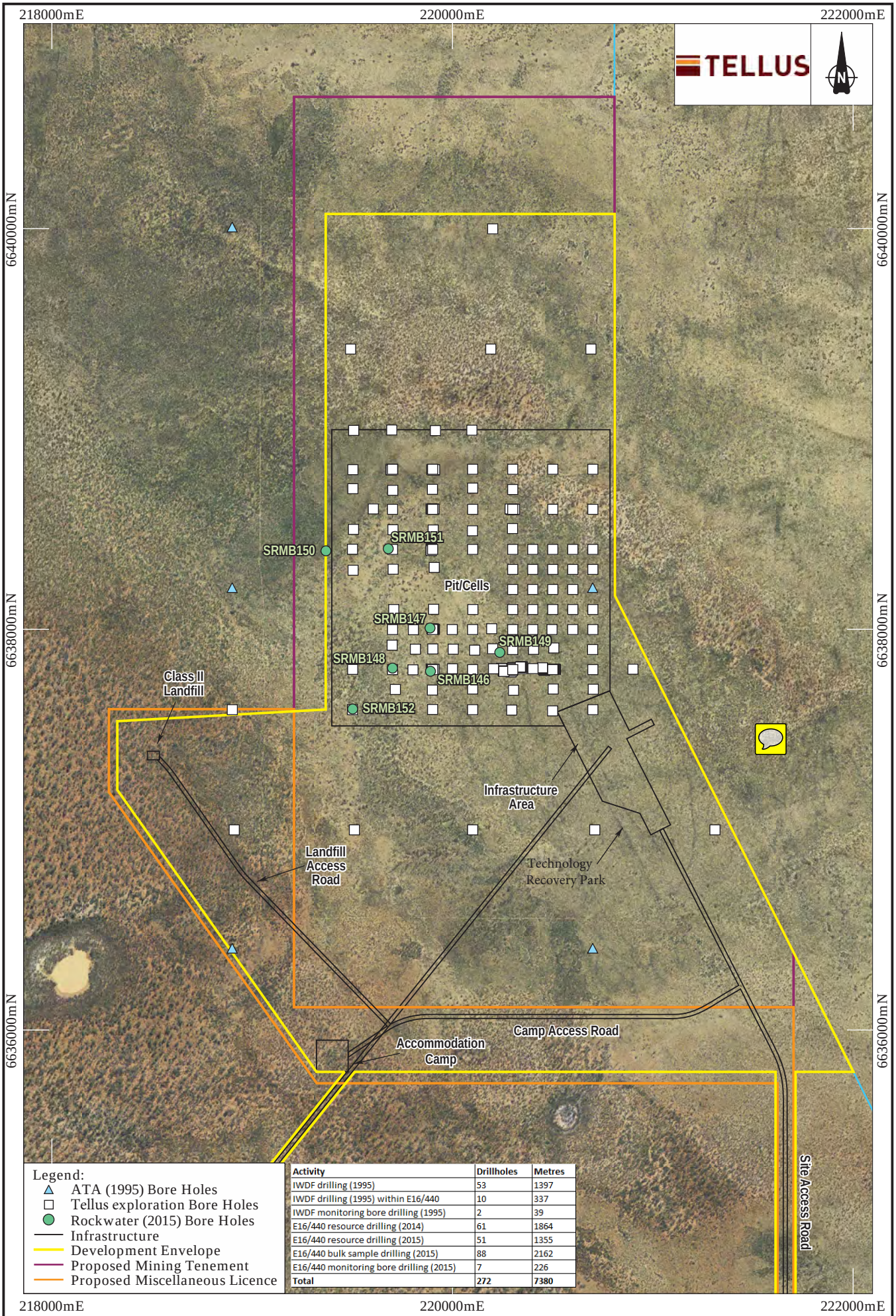
9.4.4 Hydrogeology (field investigation)

On 14 and 15 April 2015, seven investigation groundwater bores were drilled and constructed within the proposed development envelope (refer to Figure 9-12). The depth of the holes ranged from 21 m to 49 m BGL with drilling ceasing on refusal in weathered or fresh granite. The methodology and construction details of each bore are provided in Appendix A.11.

All seven holes intersected typical granite weathering profiles. This comprises 2–3 m of surficial aeolian sand overlying up to 8 m of silcreted clay and/or laterite, then mottled and pallid zone clays/very deeply to completely weathered granite; with slightly weathered to fresh granite and from 26–31 m BGL in borehole SRMB146. Minor cavities were observed in the silcrete, clay, kaolinite and weathered granite.

No aquifer was intersected during the investigation. Salinity of the moisture abstracted within damp soils ranged between 6032 and 6565 mg/L TDS. This result means the water content within the soil is moderately saline. Permeability (hydraulic conductivity) testing was undertaken on all bores and the results are listed in Table 9-12.

The low/dry permeability show that the water-bearing zones contain small quantities of water and do not constitute an aquifer.



Activity	Drillholes	Metres
IWDF drilling (1995)	53	1397
IWDF drilling (1995) within E16/440	10	337
IWDF monitoring bore drilling (1995)	2	39
E16/440 resource drilling (2014)	61	1864
E16/440 resource drilling (2015)	51	1355
E16/440 bulk sample drilling (2015)	88	2162
E16/440 monitoring bore drilling (2015)	7	226
Total	**272**	**7380**

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Scale 1:25,000
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Figure:

9-12

Table 9-12 Results of permeability testing

Bore ID	Test number	Dry permeability (meters/day)	Dry permeability (meters/second)	Lithology of screened interval
SRMB146	1	0.14	1.62×10^{-6}	Kaolinite and deeply weathered granite.
	2	0.12	1.36×10^{-6}	
SRMB147	1	0.93	1.08×10^{-5}	Kaolinite (saprolite).
SRMB148	1	0.99	1.15×10^{-5}	Kaolinite (weathered granite).
SRMB149	1	0.39	4.51×10^{-6}	Weathered granite.
	2	0.22	2.55×10^{-6}	
SRMB150	1	0.03	3.47×10^{-7}	Weathered and fresh granite.
	2	0.02	2.31×10^{-7}	
SRMB151	1	0.33	3.82×10^{-6}	Moderately to slightly weathered granite.
SRMB152	1	0.19	2.20×10^{-6}	Weathered granite.
	2	0.18	2.08×10^{-6}	

Source: Rockwater Pty Ltd (2015a).

9.4.5 Conceptual hydrogeological information

Conceptual cross sections were prepared for the proposed cells (refer to Figure 9-13 and Figure 9-14). Drilling data shows a granite weathering profile consisting of the following hydrogeological units, which are described from the surface to depth:

- Typically, 2–3 m thick surficial aeolian yellow sand.
- Silcreted clay and/or laterite, approximately 8 m thick.
- Mottled and pallid zone clays/weathered granite (this is the kaolin resource) variable in thickness, but typically around 13 m thick.
- Slightly weathered to fresh granite at a depth of 31–36 m.

The following evidence suggests the absence of a groundwater aquifer within the granite weathering profile proposed to host waste cells:

- No groundwater aquifer has been intersected during the targeted groundwater investigation (Rockwater, 2015).
- No groundwater aquifer has been intersected during exploration drilling. This included 216 holes with depths ranging from 12.0–47.5 m BGL across the proposed development envelope as shown on Figure 9-12.
- Very small quantities of groundwater were airlifted from bores SRMB150 (0.03 L/s) and SRMB152 (<0.01 L/s). The low airlift yield and low permeability show that the water-bearing zones containing the groundwater do not constitute an aquifer (Rockwater, 2015). Water may exist in some pores within the weathered granite profile, but may not be present in all pores nor are all pores connected as is generally the case for a saturated aquifer. A possible explanation for the formation of these moist areas is suggested by CyMod (2016). If the silcrete is absent or more permeable (i.e. vuggy – containing macropores for preferential flow), and an extreme rainfall event occurs, water may infiltrate through macropores into

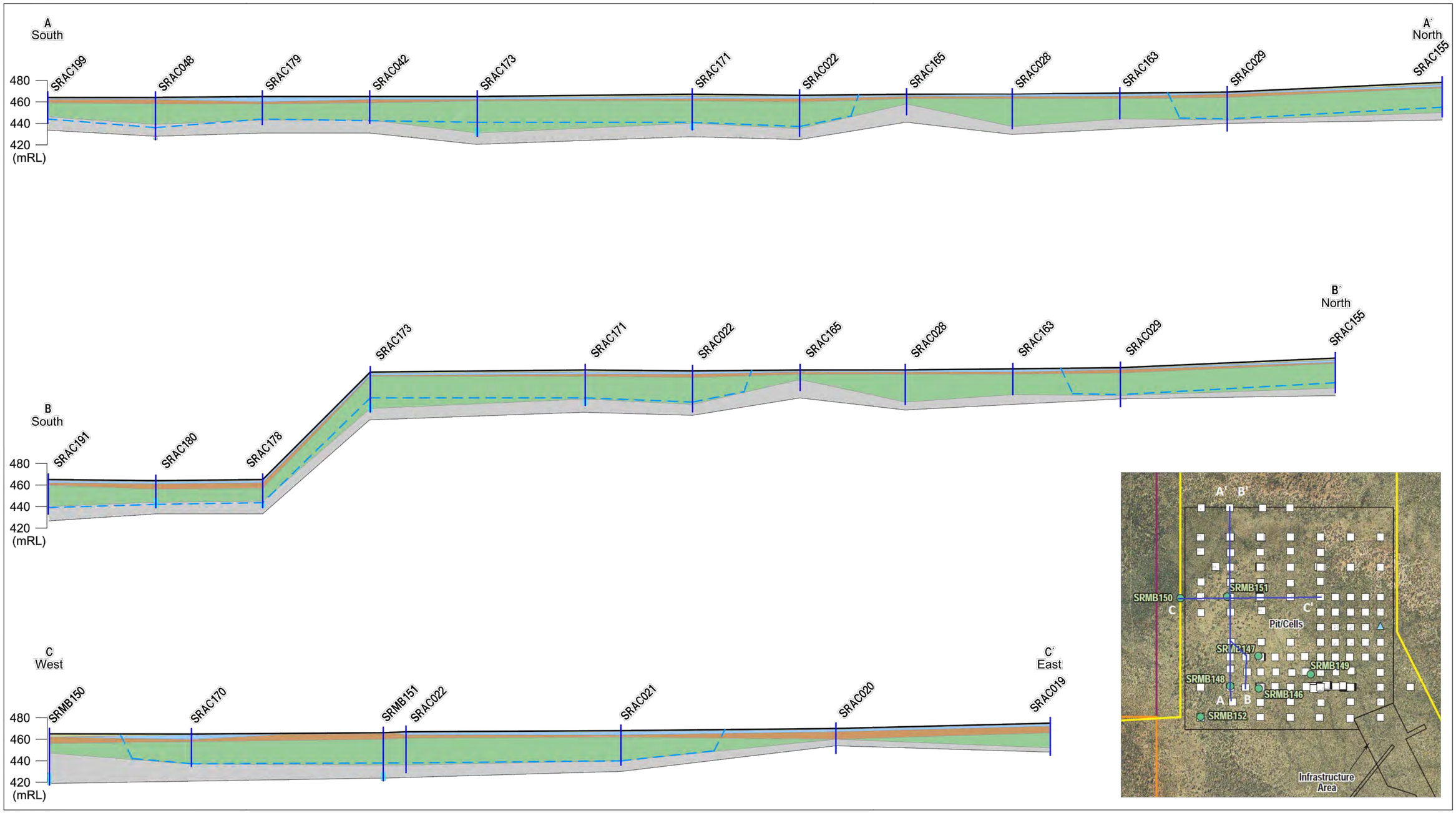
the weathered granite profile to form a damp to saturated zone lying on top of the fresh granite.

- Analysis of resource samples collected during mining exploration activities indicate that for weathered granite deeper than 6m BGL, moisture content is typically between 10% and 12% by weight. This suggests the soil is very dry, the area has limited recharge, the depth to the water table is inferred to be well below the weathered granite, and the material is free draining (i.e. water flows vertically under a unit gradient due to gravity) (CyMod, 2016).
- Since monitoring began in 1995, no groundwater has been detected in monitoring bores at the IWDF. The bores vary in depths of between 24 m and 41 m BGL, (Department of Finance, 2014).

Evidence shows absence of a groundwater aquifer in the weathered granite profile. The absence of a water table in the weathered kaolinised granite on top of the fresh granite suggests any deep water infiltration would subsequently migrate into very low permeability fresh granite and water stored in the fresh granite is to likely to form localised fractured rock aquifers. Hydraulic conductivity of fresh granite is typically in the range of $1x10^{-7}$ to $1x10^{-12}$ m/s, with a porosity of 0.1–1% (Cook, 2003 and CyMod, 2016).

There is no evidence of a shallow groundwater table (i.e. in soils above the silcrete and kaolin). This is expected given the climatic conditions experienced at the site; annual evaporation rate is greater than 2400 mm (BoM, 2015b) which far exceeds the average annual rainfall amount (250 mm). Under these conditions the sporadic rainfall events (which may be temporary but of high intensity) result in local runoff, and some infiltration of rainfall into the thin aeolian surface sand.

However, during subsequent dry periods, evaporation and evapotranspiration acts to remove this rainfall infiltration from the top few metres of soil, which results in little if any net recharge. In the absence of regular recharge, a groundwater table has not formed above the silcrete and kaolin.



Legend:
- Borehole
- Bottom of Kaolin Resource
- Clayey Sand
- Laterite
- Silcrete
- Kaolinised Granite
- Saprock
- Moist

TELLUS

CAD Ref: g2294_PER_07_08.dgn
Date: Nov 2016 | Rev: B | A4

Author: C. Dorrington | AE Ref: THO2014-003
Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

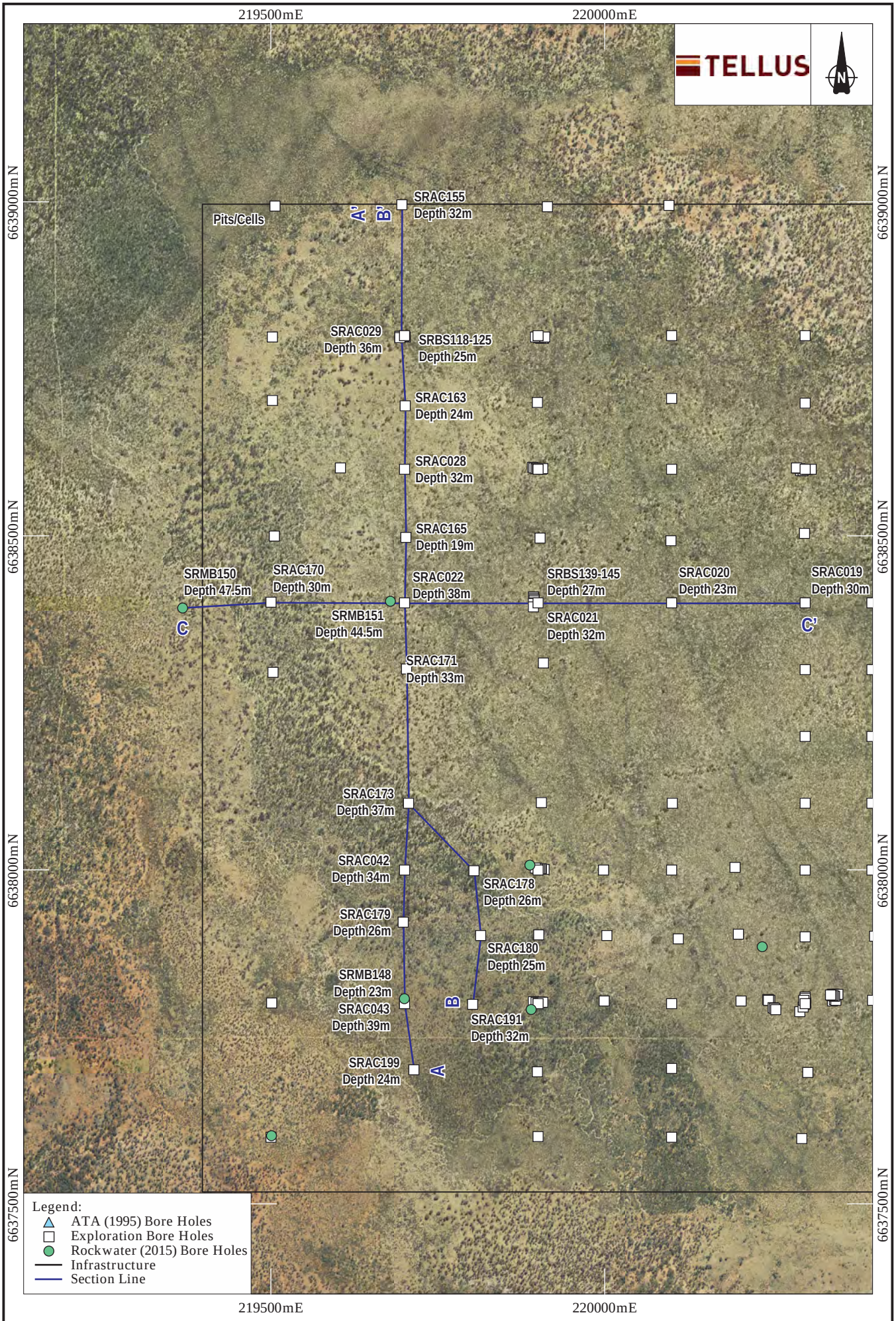
Sandy Ridge Facility

Interpreted hydrogeological cross section

Public Environmental Review

Figure:

9-13



0 150m

Scale 1:7,500
MGA94 (Zone 51)

CAD Ref: g2294_PER_07_09.dgn

Date: November 2016 | Rev: B | A4

Aurora environmental

Author: C. Dorrington | AE Ref: THO2014-003

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Sandy Ridge Facility

Interpreted hydrogeological cross section plan view

Public Environmental Review

Figure:

9-14

9.5 Human health

A desktop assessment of the radionuclides and metals likely to be present in the geology of the proposed development envelope was undertaken in February 2016 (refer to Appendix A.6). Regional radiometrics shows a low background of radiation present in the area. The geology in the area is considered unlikely to produce significant accumulations of uranium or thorium with potassium being the dominant radioactive species. The nearest uranium accumulations identified within the WA Department of Mines mineral occurrence database are calcrete uranium occurrences that form in saline paleochannels and playa lake sediments. The nearest is low level mineralisation, approximately 80 km away at Lake Eva.

There is no evidence of significant paleochannel development in the Sandy Ridge area.

There are no significant thorium accumulations in the region. Regional sampling of the granite shows the uranium content to be consistently at or below 11 ppm. This is considered too low to contribute to any significant secondary surficial uranium enrichment.

Naturally occurring radiation levels within the Proposal area are low (refer to Appendix A.6 for more detail).

9.6 Heritage

There are no known records of heritage items (Aboriginal or European) within or in close proximity to the proposed development envelope as confirmed via online database searches (WA Department of Aboriginal Affairs Site Register, State Heritage Register [inHerit], World Heritage Register, National Heritage Register, Commonwealth Heritage Register and the Australian Heritage Database). In addition, a search of the Land, Approvals and Native Title Unit indicated there are no registered native title claims over the proposed development envelope (Government of Western Australia, 2015).

Field surveys did not record any heritage items (registered or previously unrecorded) or ethnographic values within the proposed development envelope. The field surveys were conducted in consultation with representatives of the Kapam Native Title Group, Kelamaia Kabu(d)n and Widji Group.

9.7 Amenity

As discussed in Section 9.2.6, the land within the proposed development envelope is currently vacant and undisturbed Crown Land. The water pipeline route would traverse a portion of the former Jaurdi Pastoral Lease, managed by DPAW.

Land use in the vicinity of the proposed development envelope includes vacant and undisturbed Crown Land in addition to the Mount Walton East IWDF which is located approximately 6 km to the east of the proposed development envelope. There are several DPAW managed lands located within the vicinity of the proposed development envelope. These are:

- The Mount Manning Range Nature Reserve, located approximately 9.8 km to the northwest.

- The Mount Manning – Helena and Aurora Ranges Conservation Park, located approximately 19.8 km to the west.
- The Boorabbin National Park, located approximately 100 km to the south.

The location of the proposed development envelope is remote. The nearest permanent residents are tourists staying at the Jaurdi Homestead (approximately 51 km away) and residents of the Carina Iron Ore Mine Accommodation Village (approximately 52 km away). Residents at the Carina Iron Ore Mine Accommodation Village are only present while the mine is operational.