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ENVIRONMENTAL SCIENCES

Environmental desktop review and survey scoping for the Carnegie Project

Prepared for Kalium Lakes Ltd

May 2017

Final Report

Environmental desktop review and survey scoping for the Carnegie Project

Prepared for Kalium Lakes Ltd

Draft Report

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1 INTRODUCTION

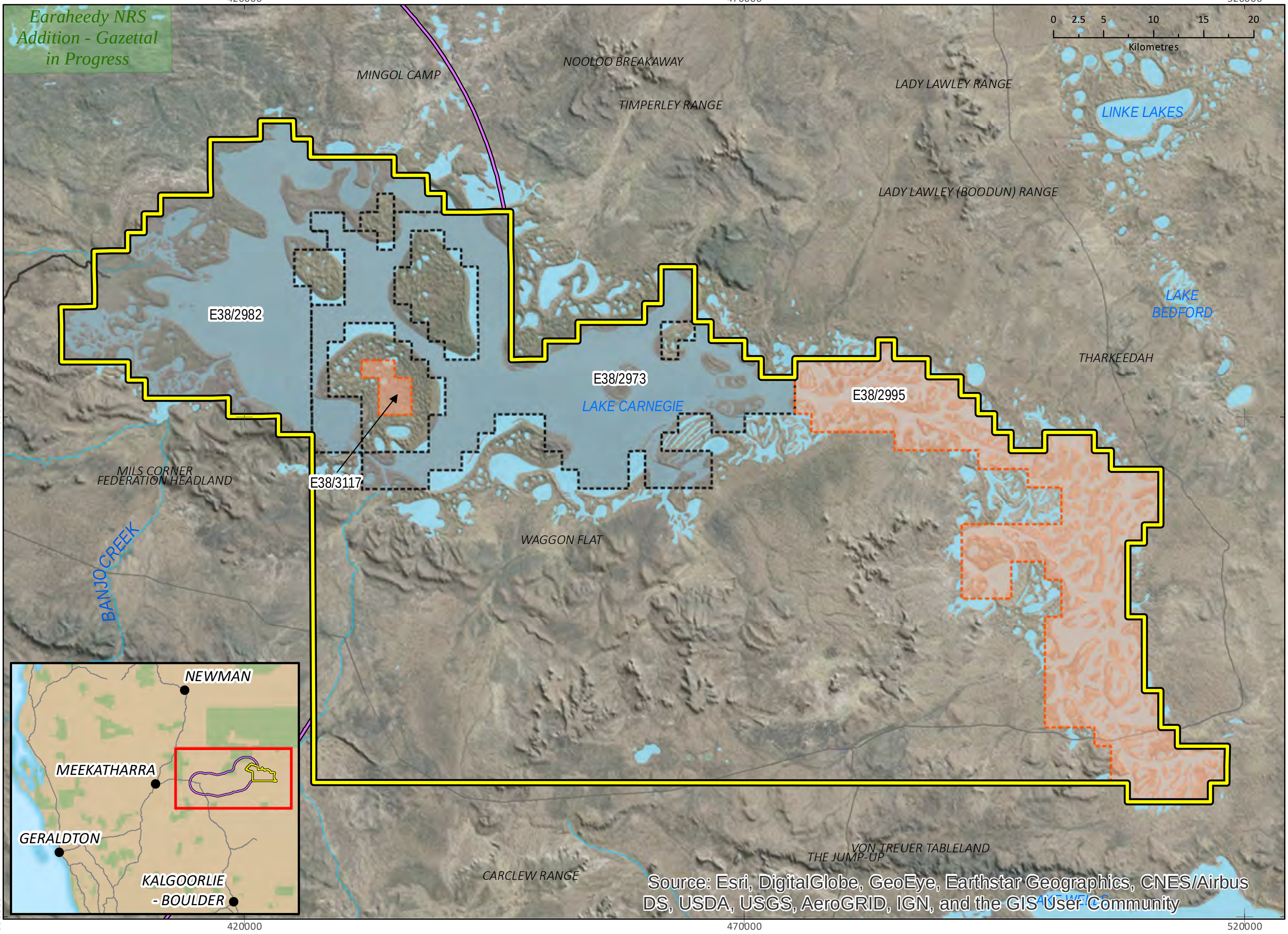
Kalium Lakes Ltd and BC Iron Ltd are joint venture (JV) partners (Carnegie JV) for the development of the Carnegie Project (the Project). The Project is a potash exploration project located at Lake Carnegie, approximately 220 km north-east of Wiluna townsite, within the Shire of Wiluna, Western Australia (Figure 1-1).

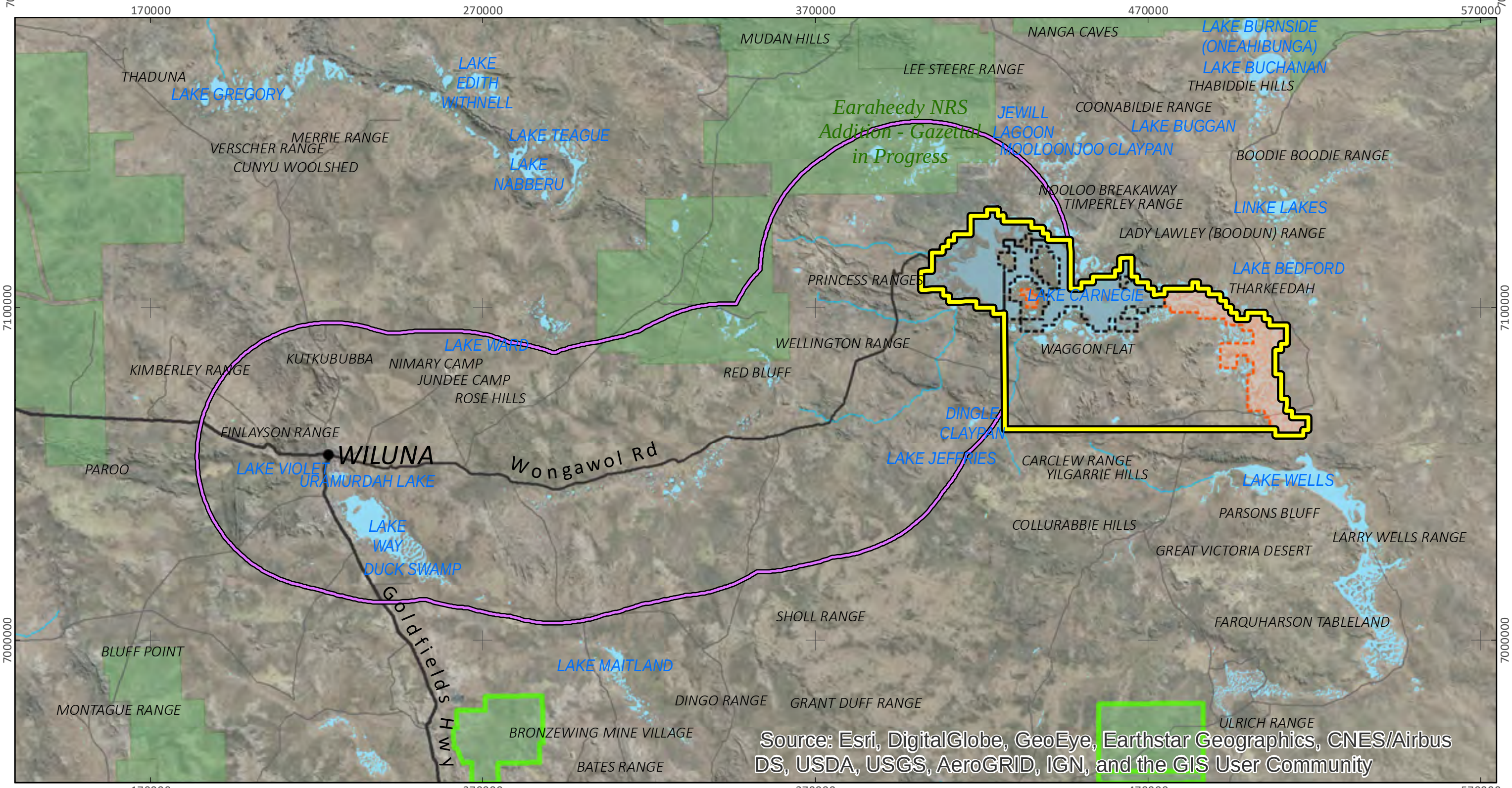
The granted tenement relevant to the Project is E38/2995. Additional tenements (E38/2982 and E38/2973) are pending (Figure 1-1). Should a project be developed to produce sulphate of potash, it would need to connect to the Goldfields Gas Pipeline, source fresh water supply (source to be determined) and run a fibre optic cable. The product would be trucked out via Wiluna to Geraldton or Perth.

Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Kalium Lakes Ltd (Kalium Lakes) to undertake the following for the Project:

- environmental desktop study to define the potential environmental values present within the project area
- based on the desktop study, prepare a survey program suitable to inform project approvals and provide an indicative costing to implement the survey program.

The desktop study and survey program will feed into overall project approvals planning to be undertaken by Preston Consulting.





Kalium Lakes Ltd
Carnegie Potash Project JV

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Map author	KC

0 10 20 40 60 80
Kilometres

1:2,250,000 (at A4) GDA 1994 MGA Zone 51

Lake study
Road study
Tenements within study area
Live
Pending
Protected areas
DPAW Managed Lands and Waters
Nature

Figure 1-1
Project location and study area

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2 Scope of work

A desktop study was undertaken for six environmental factors, in accordance with the Environmental Protection Authority's (EPA's) Environmental Impact Assessment guidance framework for environmental factors (EPA 2016g) (Table 2-1). The remaining environmental factors per (EPA 2016g) are being investigated by Preston Consulting.

Table 2-1 Environmental factors included in desktop review

Theme	Factor	Scope/information sources
Land	Flora and vegetation	Desktop study in accordance with (EPA 2016h). Full desktop review, including relevant database searches and literature review.
	Landforms	Directory of important wetlands. Literature review for Lake Carnegie system to determine if it is considered a significant landform in accordance with EPA (2016b)
	Subterranean fauna	Preliminary desktop risk assessment in accordance with EPA (2016i)
	Terrestrial fauna	Desktop study in accordance with EPA (2016h). Full desktop review, including relevant database searches and literature review.
Water	Hydrological processes	Desktop study for environmentally significant water dependent ecosystems and extractive values in accordance with EPA (2016e). Preston to review surface water data and references.
	Inland waters environmental quality	Desktop study for environmentally significant ecosystems and beneficial uses in accordance with EPA (2016f). Preston to review water data sets and references

3 Study area

The study area for the desktop review comprised:

- tenements E38/2995 (granted), tenement E38/2982 (pending), tenement E 38/2973 (pending) and an area directly south of the tenements for potential infrastructure placement – collectively referred to as the 'lake study area' (Figure 1-1)
- indicative access track of approximately 18 km length from tenement E38/29823 to Wongawol Road with 40 km buffer and approximately 240 km along Wongawol Road from access track to Wiluna with 40 km buffer – collectively referred to as the 'road study area' (Figure 1-1).

4 METHODS

4.1 FLORA AND VEGETATION

For the purposes of EIA, flora is defined as *native vascular plants* and vegetation is defined as *groupings of different flora patterned across the landscape that occur in response to environmental conditions* (EPA 2016a). The EPA's objective for the factor Flora and Vegetation is: *to protect flora and vegetation so that biological diversity and ecological integrity are maintained* (EPA 2016a)(EPA 2016a).

There are several considerations for EIA for the factor flora and vegetation (EPA 2016a); however, the focus of this desktop review was on identifying significant flora and vegetation that may be present in the study area (in particular threatened and priority flora and ecological communities), as well as current state of knowledge of flora and vegetation of the study area, to inform baseline survey scoping.

The following database searches were undertaken for the study area:

- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool for threatened flora and ecological communities listed as matters of NES under the EPBC Act
- Department of Parks and Wildlife (DPaW)/WA Museum NatureMap for threatened and priority flora records for the study area
- DPaW Threatened and Priority Flora Database
- DPaW Threatened and Priority Ecological Communities Database for TECs and PECs.

Search extent was typically the lake study area plus 40 km buffer and road study area (no buffer as this was already applied). The selection of the buffer for the searches was notional and does not represent any particular interest of Kalium Lakes.

4.2 LANDFORMS

For the purpose of EIA, the EPA (2016b) defines a landform as *a distinctive, recognisable physical feature of the earth's surface having a characteristic shape produced by natural processes*. The EPA's environmental objective for the factor landforms is: *to maintain the variety and integrity of distinctive physical landforms so that environmental values are protected* (EPA 2016b)(EPA 2016b)

The EPA considers the defining feature of a landform to be the combination of its geology (composition) and morphology (form).

In WA, types of landforms that may be significant in EIA include but may not be limited to:

- banded ironstone formations within the Yilgarn Craton geological formation
- dunes and dune systems
- caves and cave systems.

Geology and morphology of the study area were reviewed against EPA guidance (EPA 2016b) on defining significant landforms for the purpose of EIA – landform variety, integrity, ecological importance, scientific importance, rarity and social importance. Previous assessments that the EPA has identified Landforms as a factor were reviewed.

4.3 TERRESTRIAL FAUNA

For the purposes of EIA, terrestrial fauna includes vertebrate and invertebrate groups. Fauna habitat is defined as *the natural environment of an animal or assemblage of animals, including biotic and abiotic elements, that provides a suitable place for them to breed, forage, roost or seek refuge* (EPA 2016d). The EPA's objective for the factor Terrestrial Fauna is: *to protect terrestrial fauna so that biological diversity and ecological integrity are maintained* (EPA 2016d).

There are several considerations for EIA for the factor terrestrial fauna (EPA 2016d); however, the focus of this desktop review was on identifying significant fauna and fauna habitat (particularly threatened and priority fauna and species listed as migratory under international agreements) that may be present in the study area to inform baseline survey scoping.

The following database searches were undertaken for the study area:

- EPBC Act Protected Matters Search Tool for threatened fauna listed as matters of NES under the EPBC Act
- DPaW/WA Museum NatureMap for threatened and priority fauna records for the study area
- DPaW Threatened and Priority Fauna Database
- WAM Arachnology/Myriapodology, Crustacea and Mollusca databases
- Phoenix invertebrate database.

Search extent was typically the lake study area plus 40 km buffer and road study area (no buffer as this was already applied). The WAM and Phoenix database searches where conducted with a buffer of about 100 km consistent with the nominal range of short-range endemic species (SREs) (Harvey 2002).

4.4 SUBTERRANEAN FAUNA

For the purposes of EIA, the EPA (EPA 2016c) defines subterranean fauna as: *fauna which live their entire lives (obligate) below the surface of the earth*. They include stygofauna (aquatic and living in ground water) and troglofauna (air-breathing and living in caves and voids). The EPA's objective with respect to subterranean fauna is *its protection so that biological diversity and ecological integrity are maintained*.

The obligate underground existence with of subterranean fauna greatly increases the likelihood of short range endemism and the possibility that a species' conservation status may be impacted as a result of the implementation of a proposal. Subterranean fauna species may therefore be considered to be significant due to being identified as threatened or priority species, locally endemic, potentially new species, occupying restricted habitats and/or forming part of a Threatened of Priority Ecological Community (EPA 2016c).

The following database searches were undertaken for the study area:

- EPBC Act Protected Matters Search Tool for threatened fauna listed as matters of NES under the EPBC Act
- DPaW/WA Museum NatureMap for threatened and priority fauna records for the study area
- DPaW Threatened and Priority Fauna Database
- DPaW Threatened and Priority Ecological Communities Database for TECs and PECs.
- WAM Arachnology/Myriapodology, Crustacea and Mollusca databases

- Phoenix invertebrate database.

Search extent was typically the lake study area plus 40 km buffer and road study area (no buffer as this was already applied). The WAM and Phoenix database searches where conducted with a buffer of about 100 km consistent with the nominal range of short-range endemic species (SREs) (Harvey 2002).

A number of studies on the geology and hydrology around Lake Carnegie are available to assess the suitability for subterranean fauna, including the interpretations of the 1:250,000 geological maps – Stanley (SG51-6) (Commander *et al.* 1982), Kingston (SG51-10) (Bunting 1980) and Robert (SG51-11) (Jackson 1978). Updates to these studies were, for example, provided by Beard (2002) and Jones *et al.* (2001).

Some subterranean data are not available through database searches, but require screening of published literature, for example a recent study on troglobitic slaters in central Western Australian calcretes (Javidkar *et al.* 2016).

4.5 HYDROLOGICAL PROCESSES

For the purposes of EIA, the EPA (EPA 2016e) defines the factor Hydrological Processes as *the occurrence, distribution, connectivity, movement, and quantity of water*. The EPA's objective of the factor Hydrological Processes is: *to maintain the hydrological regimes of groundwater and surface water so that environmental values are protected*.

Environmental values related to hydrological processes include ecosystem health values and beneficial uses (EPA 2016e). For the purposes of EIA, these are considered as either in-situ or extractive values, i.e.:

- in-situ values are water dependent ecosystems and their associated recreational, cultural and aesthetic values – the EPA is focussed here on environmentally significant water dependent ecosystems
- extractive values are consumptive use for public water supply, agriculture, and industry – the EPA is focused here on impacts to significant current or potential water supplies, such as regional scale aquifers, and fresh, high order surface water systems.

Environmentally significant water dependent ecosystems include, but are not limited to:

- wetlands which are Ramsar listed, Conservation Category, or listed in the Directory of Important Wetlands in Australia
- wild and scenic rivers
- wetland types which may be poorly represented
- natural springs and pools, particularly in arid areas
- ecosystems which support conservation significant flora/vegetation and fauna species or communities, including migratory waterbirds, bats, and subterranean fauna
- ecosystems which support significant amenity, recreation and cultural values.

The desktop review for hydrological processes focussed on identifying if any of the in-situ or extractive values listed above are present in the study area.

4.6 INLAND WATERS ENVIRONMENTAL QUALITY

For the purposes of EIA, the EPA (EPA 2016f) defines the factor Inland Waters Environmental Quality as: *the chemical, physical, biological and aesthetic characteristics of inland waters*. Inland waters include groundwater, waterways, wetlands and estuaries. The EPA's objective for Inland Waters Environmental Quality is: *to maintain the quality of groundwater and surface water so that environmental values are protected*.

The focus of this factor and its associated objective is:

- how the discharge of waste is minimised
- how any discharge of waste or use of land or water will significantly impact on water quality and the environmental values it supports.

The focus of the desktop review for this factor was therefore on defining the groundwater and surface water systems of the study area (particularly the lake study area) to enable an assessment of potential activities associated with the Project that may impact on the inland water quality values.

The EPA (2016e) identifies several activities that may have the potential to impact on inland water quality:

- direct discharge of waste to surface water systems
- discharge of waste to groundwater aquifers via infiltration or aquifer injection
- injection of chemicals to groundwater associated with hydraulic fracturing
- discharge of wastes to storage or evaporative basins, where there is potential for overflow or leakage
- dewatering discharges where the water quality (temperature, heavy metals, carbonates) is a concern
- new or changed land uses which lead to offsite discharge of wastes, such as nutrient generating activities on low nutrient retentive soils
- irrigated agriculture – salinisation, and/or contamination by pesticides/herbicides
- the creation of pit lakes after the completion of mining
- any activity which alters the land surface or dewaters aquifers and exposes acid sulfate soils or creates acid rock drainage
- any drainage construction directly impacting on waterways or which leads to the discharge of drainage water to waterways.

5 RESULTS

5.1 EXISTING ENVIRONMENT

The lake study area is located in the Carnegie subregion of the Gascoyne bioregion (Figure 5-1). The road study area intersects the Carnegie subregion and the Eastern Murchison subregion of the Murchison bioregion (Figure 5-1). The Carnegie subregion is described as (Cowan 2001a):

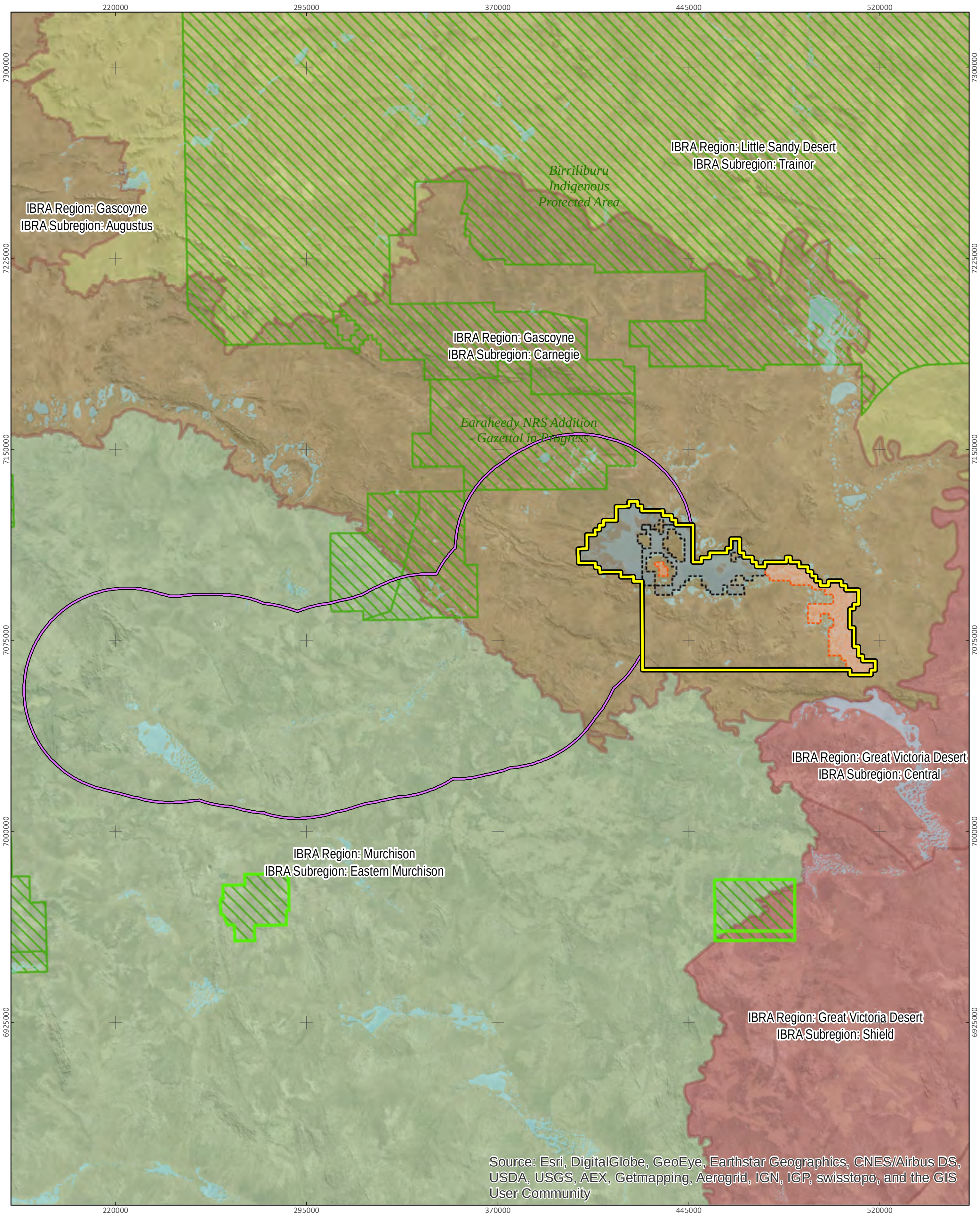
> Underlain by the Earaheedy Basin of the Capricorn Orogen (Proterozoic) and the south-eastern extension of the Bangemall Basin. Rugged low Proterozoic sedimentary and granite ranges divided by broad flat valleys. Shallow earthy loams over hardpan on the plains and shallow stony loams associated with the ranges. Extensive salt lake systems. Low Mulga communities occur on hills and plains. Samphire and saltbush steppes are associated with salt lakes while ranges are dominated by mulga scrub and *Eremophila* shrublands.

The Eastern Murchison subregion is described as (Cowan 2001b):

> The northern parts of the 'Southern Cross' and 'Eastern Goldfields' Terrains of the Yilgarn Craton. Characterised by its internal drainage, and extensive areas of elevated red desert sandplains with minimal dune development. Salt lake systems associated with the occluded palaeodrainage system. Broad plains of red-brown soils and breakaway complexes as well as red sandplains. Vegetation is dominated by Mulga Woodlands often rich in ephemerals; hummock grasslands, saltbush shrublands and *Halosarcia* shrublands.

The Carnegie subregion experiences a desert climate with bimodal rainfall (Cowan 2001a). The Eastern Murchison subregion is described (Cowan 2001b) as having an arid climate, with mainly winter rainfall (200 mm).

The study area intersects 62 land systems, as mapped by the Department of Agriculture and Food Western Australia (DAFWA) (Figure 5-2). The lake study area intersects 26 of these and the road study area intersects 57 reflecting the broad extent of this part of the study area (Table 5-1). Lake Carnegie is represented by the Carnegie land system which is described as salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic shrublands and acacia tall shrublands (Pringle *et al.* 1994).



Kalium Lakes Ltd
Carnegie Potash Project JV

Project No	1152
Date	24-May-17
Drawn by	KW
Map author	KC

0 12.5 25 50 75
Kilometres

1:1,900,000 (at A4) GDA 1994 MGA Zone 51

Lake study area
Road study area
Tenements within study area
Live tenement
Pending tenement
DPAW Managed Lands and Waters
Nature Reserve
Protected areas (CAPAD)
IBRA Regions
Gascoyne
Great Victoria Desert
Little Sandy Desert
Murchison

Figure 5-1

IBRA regions of the study area

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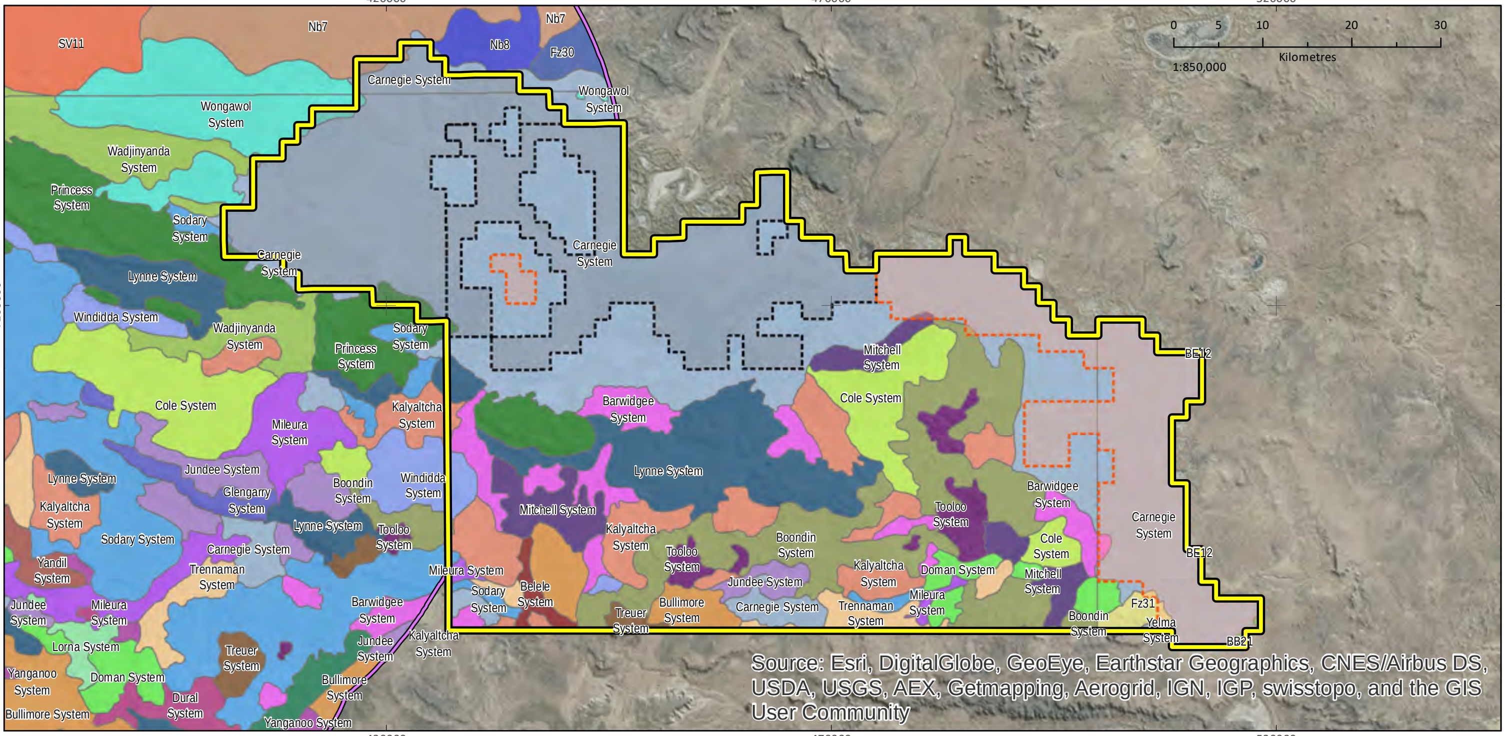

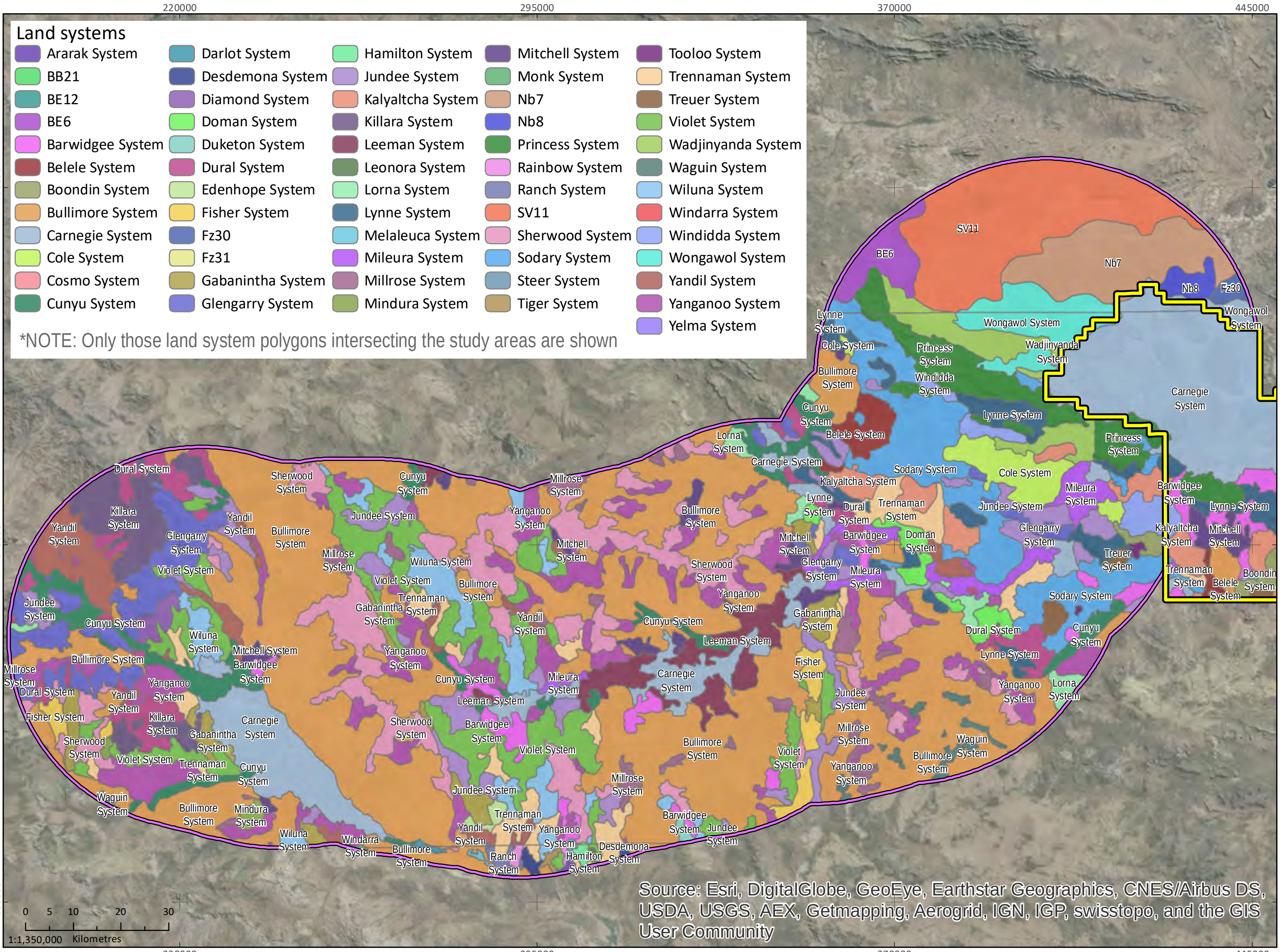

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GDA 1994 MGA Zone 51

Lake study area
Road study area
Tenements within study area
Live tenement
Pending tenement

Figure 5-2

Land systems of the study area

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Table 5-1 Description of land systems intersecting the study area

Land system name	Land system description
Ararak System	Broad plains with mantles of ironstone gravel supporting Mulga shrublands with wanderrie grasses.
Barwidgee System	Alluvial plains with channeled zones and small sand banks, supporting bluebush shrublands.
BB21	Valley plains with a variety of soils
BE12	Broad gently undulating plateau ridges and pediments with extensive gravel pavements, some small sandy plains, and small tracts of longitudinal dunes
BE6	Extensive flat and gently sloping plains, which sometimes have a surface cover of gravels and on which red-brown hardpan frequently outcrops
Belele System	Hardpan wash plains with acacia tall shrublands, and low sandy banks supporting shrublands with wanderrie grasses.
Boondin System	Summits, uplands, hillslopes and drainage floors, supporting Mulga and other acacia tall shrublands with spinifex, also chenopod shrublands.
Bullimore System	Gently undulating sandplain with occasional linear dunes and stripped surfaces supporting spinifex grasslands with mallees and acacia shrubs.
Carnegie System	Salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic shrublands and acacia tall shrublands.
Cole System	Hardpan wash plains with reticulate patterns of wanderrie banks and Mulga groves and more concentrated drainage tracts, supporting mixed Mulga and wanderrie shrublands.
Cosmo System	Calcreted drainage tracts through sandplain with spinifex hummock grasslands and occasional black oak or Mulga open woodlands.
Cunyu System	Calcrete platforms, intervening drainage floors and channels and minor alluvial plains, supporting acacia shrublands, occasional casuarina woodlands and minor halophytic shrublands.
Darlot System	Salt lakes, fringing saline alluvial plains, regularly arranged sandy banks and numerous claypans and swamps, supporting halophytic shrublands and spinifex and wanderrie grasslands.
Desdemona System	Plains with deep sandy or loamy soils supporting Mulga tall shrublands and wanderrie grasses.
Diamond System	Gently undulating plains supporting sometimes groved Mulga tall shrublands with dense low shrubs.
Doman System	Low stony uplands and gentle slopes supporting open Mulga shrublands with low shrubs and wanderrie grasses.
Duketon System	Stony wash plains and sandy banks supporting Mulga shrublands and wanderrie grasses.
Dural System	Strongly undulating terrain on weathered mudstone and basalt supporting open Mulga shrublands with mallee and spinifex.
Edenhope System	Low rounded hills and undulating stony plains supporting open or thinly groved Mulga and other acacia shrublands with sparse undershrubs.
Fisher System	Undulating terrain with low ridges and crests, shallow valleys and alluvial fans supporting Mulga shrublands with spinifex and groved Mulga and other acacia shrublands.
Fz30	Undulating pediments on sandstone, shale, and dolomite with some dolerite dykes; much rock outcrop; stony and gravelly pavements are common

Land system name	Land system description
Fz31	Undulating pediments characterized by silcrete-capped cuestas, and hilly ridges on tillite and shale; much rock outcrop; stony pavements are common
Gabanintha System	Greenstone ridges, hills and footslopes supporting sparse acacia and other mainly non-halophytic shrublands.
Glengarry System	Sandstone plateaux, summits and hillslopes supporting mainly dense Mulga and other acacia shrublands, spinifex, and numerous low shrubs.
Hamilton System	Hardpan plains, stony plains and incised drainage lines supporting Mulga tall shrublands.
Jundee System	Hardpan plains with variable gravelly mantles and minor sandy banks supporting weakly groved Mulga shrublands.
Kalyaltcha System	Stony erosional plains, alluvial plains and drainage floors supporting open Mulga shrublands with undershrubs including blue bush.
Killara System	Basalt hills supporting open Mulga shrublands with patchy spinifex.
Leeman System	Sandy tracts and banks, saline alluvial plains and lake margins supporting shrubby spinifex grasslands, Mulga and blue bush shrublands and samphire low shrublands.
Leonora System	Low greenstone hills and stony plains supporting mixed chenopod shrublands.
Lorna System	Gently undulating sandy plains supporting Mulga shrublands and spinifex.
Lynne System	Stony plateaux, summits and hillslopes with minor flood plains and drainage floors supporting open Mulga and other acacia shrublands and minor saltbush and bluebush shrublands.
Melaleuca System	Sandy-surfaced plains and calcareous plains supporting spinifex or Mulga shrublands with wanderrie grasses.
Mileura System	Saline and non-saline calcreted river plains with flood plains and calcrete platforms supporting variable tall shrublands, mixed halophytic shrublands and shrubby grasslands.
Millrose System	Level or very gently undulating stony plains on hardpan and granite with irregularly distributed sandy banks supporting mostly scattered Mulga shrublands with minor grasses.
Mindura System	Low hills, ridges and outcrops of granite, gneiss and quartz above convex, quartz-strewn interfluves and lower plains supporting sparse acacia shrublands becoming more dense in drainage floors.
Mitchell System	Sandplains, wanderrie banks and salt flats, supporting Mulga and mallee shrublands with wanderrie grasses and spinifex, chenopod shrublands on saline plains.
Monk System	Hardpan plains with occasional sandy banks supporting Mulga tall shrublands and wanderrie grasses.
Nb7	Uneven and broken plains with gravel and stone pavements, scald patches, and clay pans and traversed by low narrow ridges and knolls of bare rock including shales, limestones, sandstones, and quartzites; some laterite and silcrete cappings
Nb8	Alluvial plains with sand banks and dunes, pans, channels, and scalded areas
Princess System	Rocky sandstone ranges, summits, footslopes and minor drainage floors; supporting dense Mulga and other acacia shrublands, occasional mallees, understorey low shrubs and spinifex.
Rainbow System	Hardpan plains supporting Mulga tall shrublands.
Ranch System	Hardpan plains and prominent broad drainage tracts supporting dense Mulga tall shrublands.
Sherwood	Breakaways, kaolinised footslopes and extensive gently sloping plains on granite supporting

Land system name	Land system description
System	Mulga shrublands and minor halophytic shrublands.
Sodary System	Stony uplands and plains on shale supporting Mulga shrublands with sparse chenopod and other shrub understoreys.
Steer System	Gravelly alluvial plains supporting chenopod shrublands.
SV11	Plains studded with lakes, clay pans, and salt pans
Tiger System	Gravelly hardpan plains and sandy banks with Mulga shrublands and wanderrie grasses.
Tooloo System	Breakaways on sedimentary rocks with saline footslopes and extensive stony lower plains, supporting Mulga shrublands and minor halophytic shrublands.
Trennaman System	Sandy hardpan plains and broad drainage zones supporting groved Mulga shrublands and wanderrie grasses.
Treuer System	Tablelands, lower slopes, plains and drainage floors, supporting Mulga and other acacia tall shrublands and numerous low shrubs.
Violet System	Gently undulating gravelly plains on greenstone, laterite and hardpan, with low stony rises and minor saline plains; supporting groved Mulga and Bowgada shrublands and occasionally chenopod shrublands.
Wadjinyanda System	Alluvial plains, active flood-plains, sandy banks and channels, supporting sparse Mulga and other acacia shrublands.
Waguin System	Sandplains and stripped granite or laterite surfaces with low fringing breakaways and lower plains; supports Bowgada and Mulga shrublands with wanderrie grasses and minor halophytic shrublands.
Wiluna System	Low greenstone hills with occasional lateritic breakaways and broad stony slopes, lower saline stony plains and broad drainage tracts; supporting sparse Mulga and other acacia shrublands with patches of halophytic shrubs.
Windarra System	Gently undulating stony plains and low rises with quartz mantles on granite, supporting *Acacia-Eremophila* shrublands.
Windidda System	Plains on shale and dolomitic limestone, supporting groved Mulga shrublands and scattered bluebush shrublands.
Wongawol System	Sandstone plateaux, low dolerite ridges and flood-plains; supporting sparse Mulga and Curara shrublands.
Yandil System	Flat hardpan wash plains with mantles of small pebbles and gravels; supporting groved Mulga shrublands and occasional wanderrie grasses.
Yanganoo System	Almost flat hardpan wash plains, with or without small wanderrie banks and weak groving; supporting Mulga shrublands and wanderrie grasses on banks.
Yelma System	Sandplains, minor stripped surfaces and drainage floors, supporting spinifex grasslands with scattered mallees and Mulga and groved Mulga shrublands.

5.1.1 Geology

Both geological and hydrological conditions are of little relevance for the proposed development in the road study area and therefore the geological and hydrological sections concentrate on the lake study area.

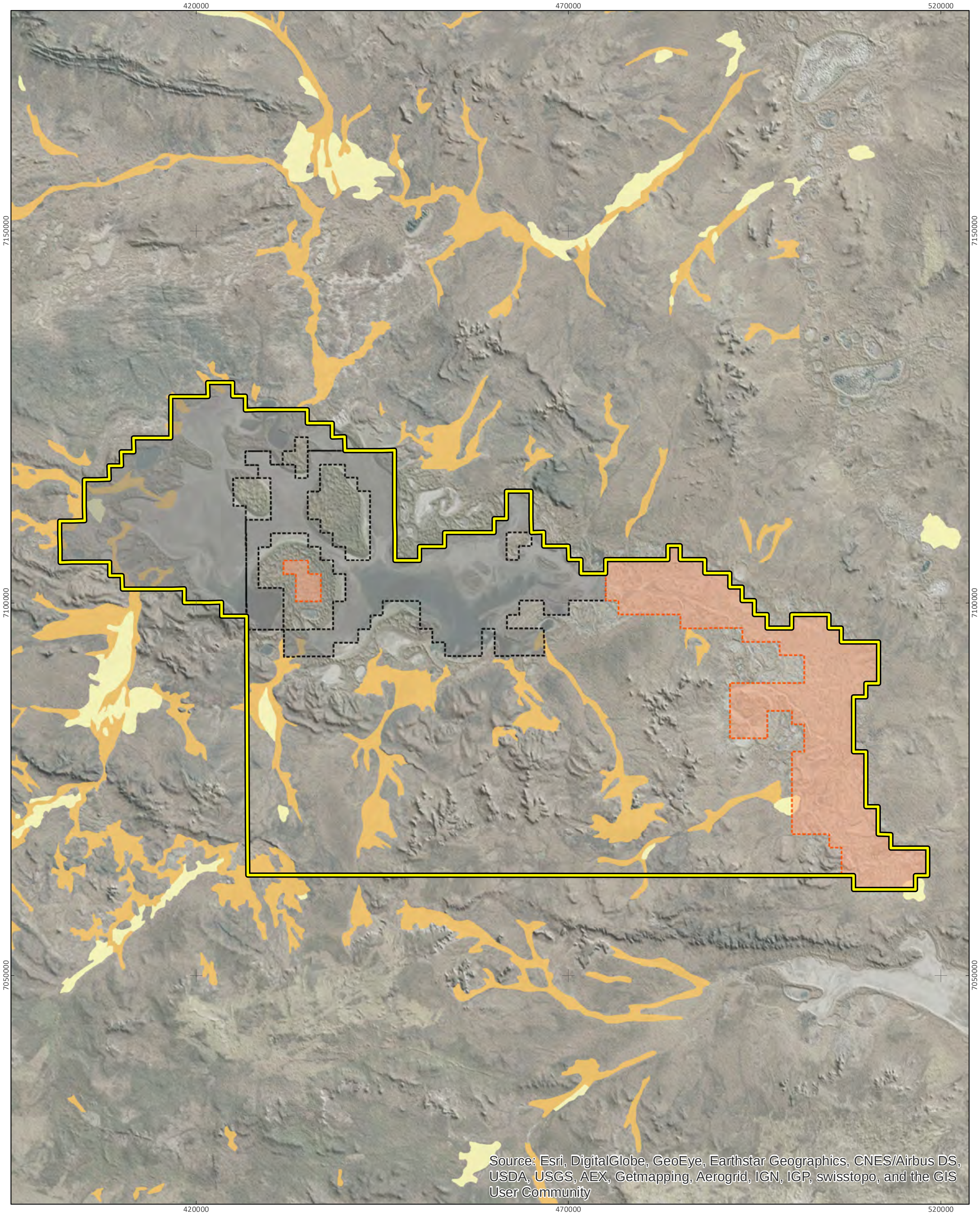
The lake study area is situated over the Nabberu Basin and is characterised by generally low relief with elevation rising from about 440 m in the low-lying areas around Lake Carnegie to about 600 m in some of the ranges to the west (Bunting 1986). The Nabberu Basin contains two sub-basins, namely the Glengarry sub-basin in the west and the Earaheedy sub-basin in the east (Bunting 1986). The lake study area belongs to the Earaheedy sub-basin which represents the southern portion of a passive continental margin on the north-eastern edge of the Yilgarn Craton (Jones *et al.* 2001).

The sedimentary features in the Proterozoic Earaheedy Group indicate deposition in a shallow-marine to coastal environment (Jones *et al.* 2001). Surface expressions of the Earaheedy Group are in particular evident around the north-east of Lake Carnegie (Princess Ranges, Timberly Range), but also scattered along its southern edge. These largely constitute outcrops of the Wongawol formation (fine arkosic sandstone grinding upwards into mudstone and carbonate), Princess Ranges Quartzite (clean white quartz arenite, minor clayey sandstone and siltstone forming rugged hills), Windiwarra Formation (fine to coarse grained quartz sandstone and shale), and Windidda Formation (limestone, shale, stromatolitic in part) (Bunting 1980; Commander *et al.* 1982). Scattered surface expressions of the early Permian (Palaeozoic) Paterson Formation are evident around the lake, which constitute poorly sorted sandstone, siltstone claystone and conglomerate. This formation is exposed in breakaways where it is seen to be flat-lying and undeformed; only rarely is there a measurable dip (Bunting 1980).

The surface geology of the lake study area itself is dominated by the Quaternary lacustrine deposits of Lake Carnegie, which consists of saline and gypsiferous clay, silts and sand (Bunting 1980; Jackson 1978). These represent the sedimentary infill deposits of the former Carnegie palaeoriver. Cainozoic alluvial and colluvial deposits dominate the lower lying parts of the landscape around Lake Carnegie (Bunting 1980; Commander *et al.* 1982; Jackson 1978). Colluvial deposits, which consist of unconsolidated rock and quartz fragments in loam, form a blanket of debris extending from scree slopes below outcrops, through gently sloping pediments, to extensive, flat, low-lying plains (Bunting 1980). Alluvium occurs in broad, ill-defined drainage lines ranging from small creeks with thick Mulga growth, to wide flood plains in the lower reaches of the drainage systems. The deposits are poorly sorted and contain material ranging from clay to pebble size. Extensive sandplains of Quaternary Aeolian sand dominate the landscape and form a distinctive geomorphological unit between the high bedrock outcrops and the regional drainage lines (Sanders & Harley 1971).

The main drainage valleys have rubbly calcrete overlaying fluviatile material (Sanders & Harley 1971). Calcrete is a deposit of limestone and opaline silica, formed by partial replacement of soil material in major drainages. It formed after the trunk valleys of the palaeodrainage system had been filled, probably in the late Tertiary, and is now being eroded in those drainage lines which are still active (e.g. Banjo Creek). The calcrete may be nodular, massive or laminated and is typically cavernous. In the east of Lake Carnegie, calcrete may be up to 40 m thick (Jackson 1978), but most of the calcretes around the east of the lake are probably under 10 m thick (Bunting 1980).

Within the scope of this assessment, the considerable extent of Quaternary alluvial deposits and calcretes around the study area (Figure 5-3) are significant, as they provide the geological and hydrological conditions for subterranean fauna to occur.



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Kilometres

1:650,000 (at A4) GDA 1994 MGA Zone 51

Lake study area
Tenements within study area
Live tenement
Pending tenement
Surface geology
Quaternary Alluvium (Qa)
Calcrete (Czk)

Figure 5-3

Surface geology

(with particular respect to Quarternary alluvial deposits and calcretes)

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5.1.2 Hydrology

5.1.2.1 Groundwater

Groundwater is common around the lake study area and is shallowest and freshest in the alluvial deposits and the fine gravel and calcrete of the valley fills, although some may be obtained from the fractured sandstone, shales and dolomites (Sanders & Harley 1971). The water table is generally between 3–15 m below the surface, although it may be as deep as 35 m in zones of fractured or weathered bedrock of Archaean or Proterozoic origin (Sanders & Harley 1971).

The Permian fluvio-glacial deposits are not extensive enough to provide a catchment area. The Proterozoic and Archaean rocks are generally too impervious to make suitable aquifers, although small amounts of water may be obtained from joints and fracture systems (Bunting 1980).

The groundwater in the alluvial deposits and calcretes is comparatively fresh. Salinities measured at Wongawol, Carnegie, Lorna Glen and Windidda ranged from 400 ppm total dissolved solids (TDS) to about 7,800 ppm TDS (Sanders & Harley 1971). To the north of Lake Carnegie, areas of bedrock and colluvium away from the trunk drainages tend to have fresh to brackish groundwater in the salinity range 400-4,000 mg/l. Salinities tend to rise downstream, and towards the centres of the drainages, to over 10,000 mg/l in the alluvium/sheetwash and salt lake areas (Commander *et al.* 1982). Generally, salinity in calcretes increases rapidly away from the intake (Sanders & Harley 1971). However, the hydrological conditions in inland calcrete aquifers are complex, and characterised by high spatial and temporal variability; they likely resemble coastal anchialine systems, where freshwater overlays a heavier saline layer with a temporal vertical shift during and after rainfall events (Humphreys *et al.* 2009). Salinity in the groundwater under Lake Carnegie and some saline drainages is assumed high (Bunting 1980).

Groundwater replenishment occurs entirely from rainfall during major storms. Approximately 3% of the mean annual rainfall infiltrates to the water table within the region (Sanders & Harley 1971).

The groundwater flow in the study area likely follows the ancient palaeodrainage system. During initial mapping of the Carnegie palaeoriver, that also includes Lake Wells, it remained unclear if this system drained to the north (into Lake Disappointment) or to the south-east (into the Throssell palaeodrainage system), although the current understanding is that the Carnegie palaeorivers drained into the south-east (Beard 2002). However, the Carnegie system was ultimately cut off in the south and formed into a basin of interior drainage with little groundwater flow. Lake Carnegie and Lake Wells today represent separate groundwater sinks as the palaeochannel connecting both is now divided by a watershed (Beard 2002). Details of the Cainozoic stratigraphy of the Carnegie palaeochannel are not well understood, unlike, for example, other ancient drainage systems, e.g. the Roe palaeosystem near Kalgoorlie (Kern & Commander 1993).

5.1.2.2 Surface water

There is no permanent surface water around Lake Carnegie. Drainage lines in the southern part of the area are now inactive, and, together with the major salt-lake systems, they form part of the palaeodrainage system which ceased significant flow in the middle Miocene (Bunting *et al.* 1973). The active drainages, which flow only after heavy rain, occur on a more recent erosion surface. Larger creeks have incised channels up to 4 m deep and 30 m wide which are flanked by extensive flood plains (e.g. Wongawol Creek), and which are mainly confined to areas underlain by the Earaheedy Group (Bunting 1980).

5.1.3 Conservation reserves and environmentally sensitive areas

The study area does not intersect any conservation reserves. The closest reserves to the lake study area are (Figure 1-1):

- Lorna Glen (Matuwa) – 44 km W
- Earaheedy (Kurrara Kurrara) – 8 km NW.

The road study area intersects Lorna Glen and Earaheedy (Figure 1-1).

Much of the lake study area is designated an environmentally sensitive area (ESA) as declared by the Minister for Environment under section 51B of the *Environmental Protection Act 1986* (EP Act) for its wetland values.

5.2 Environmental factor – Flora and vegetation

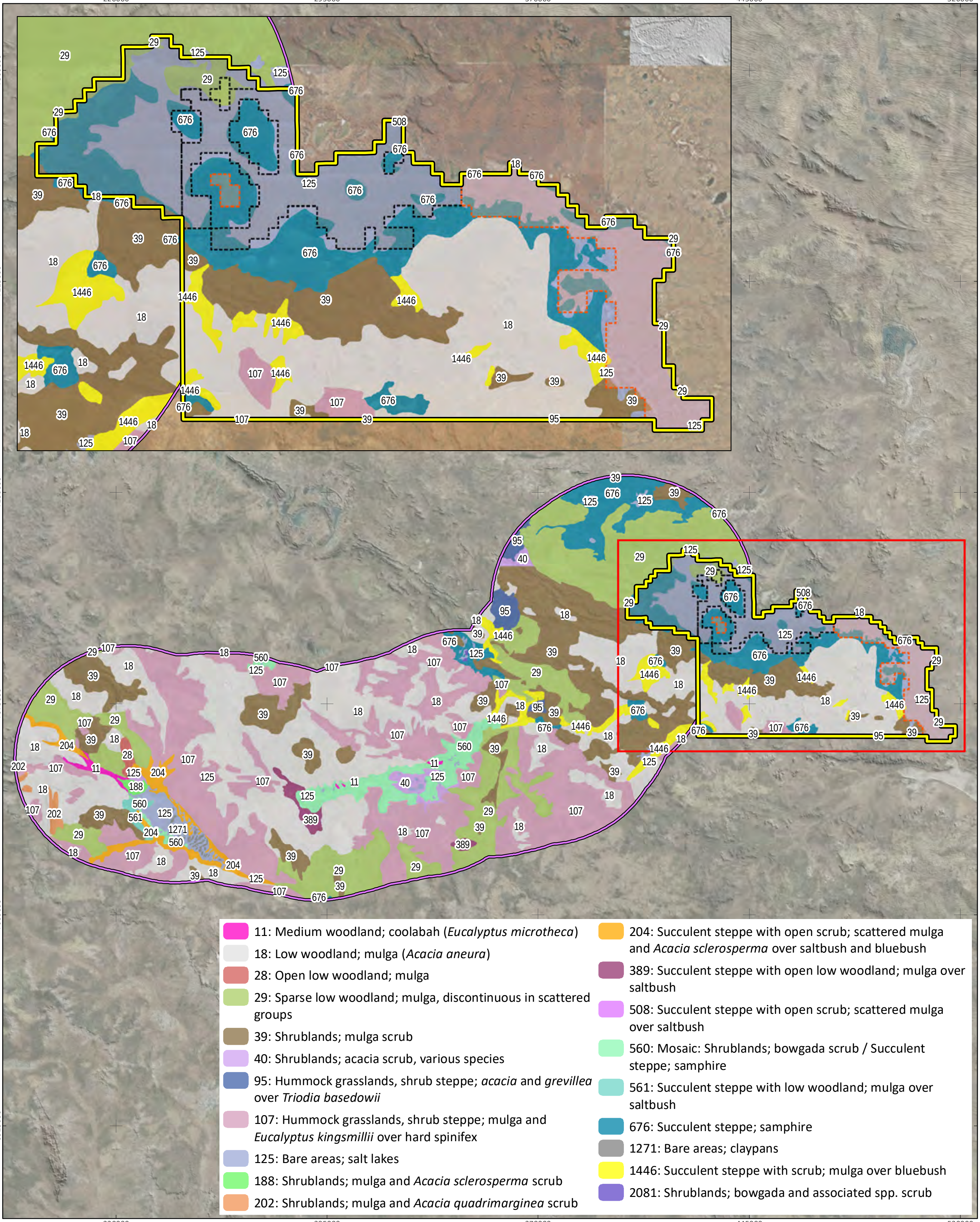
5.2.1 Vegetation

5.2.1.1 Native vegetation extent and status

The study area is located within the Eremaean Botanical Province (EPA 2016h). Broad scale vegetation mapping of the area (Shepherd *et al.* 2002) identifies nine vegetation associations represented within the lake study area (Figure 5-4). Lake Carnegie is predominantly mapped as association 676 *Succulent steppe; samphire* and 125 *Bare areas; salt lakes*.

Within the road study area, 19 vegetation associations are mapping representing mostly low mulga woodlands, mulga scrub shrublands and hummock grasslands (Figure 5-4).

The Directory of Important Wetlands (DIW) listing for Lake Carnegie (Department of the Environment and Energy 1995) describes the lake bed as bare of vegetation; the islands and lake margins as supporting low shrubland (saltbush and samphire); and low open-woodland with a low shrubland understorey fringing the northern boundary of the lake.



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Drawn by	KW
Map author	KC

0 10 20 40 60
Kilometres

1:1,750,000 (at A4) GDA 1994 MGA Zone 51

Lake study area
Road study area
Tenements within study area
Live tenement
Pending tenement

Figure 5-4

Vegetation associations of the study area (Shepherd *et al.* 2002)

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5.2.1.2 Threatened and priority ecological communities

No TECs listed under the EPBC Act or WC Act were returned in the database search results.

Fourteen PECs were identified within the area of the desktop review, with 12 of these representing stygofaunal communities associated with confined palaeodrainage systems, also referred to as calcrete groundwater assemblages (CGAs; refer to section 5.5). Two PECs associated with BIFs were identified, one located north of the lake study area and the other west of Wiluna (Table 5-2; Figure 5-5). Neither of these PECs are likely to be relevant to the current study area.

Table 5-2 Vegetation related priority ecological communities in vicinity of study area

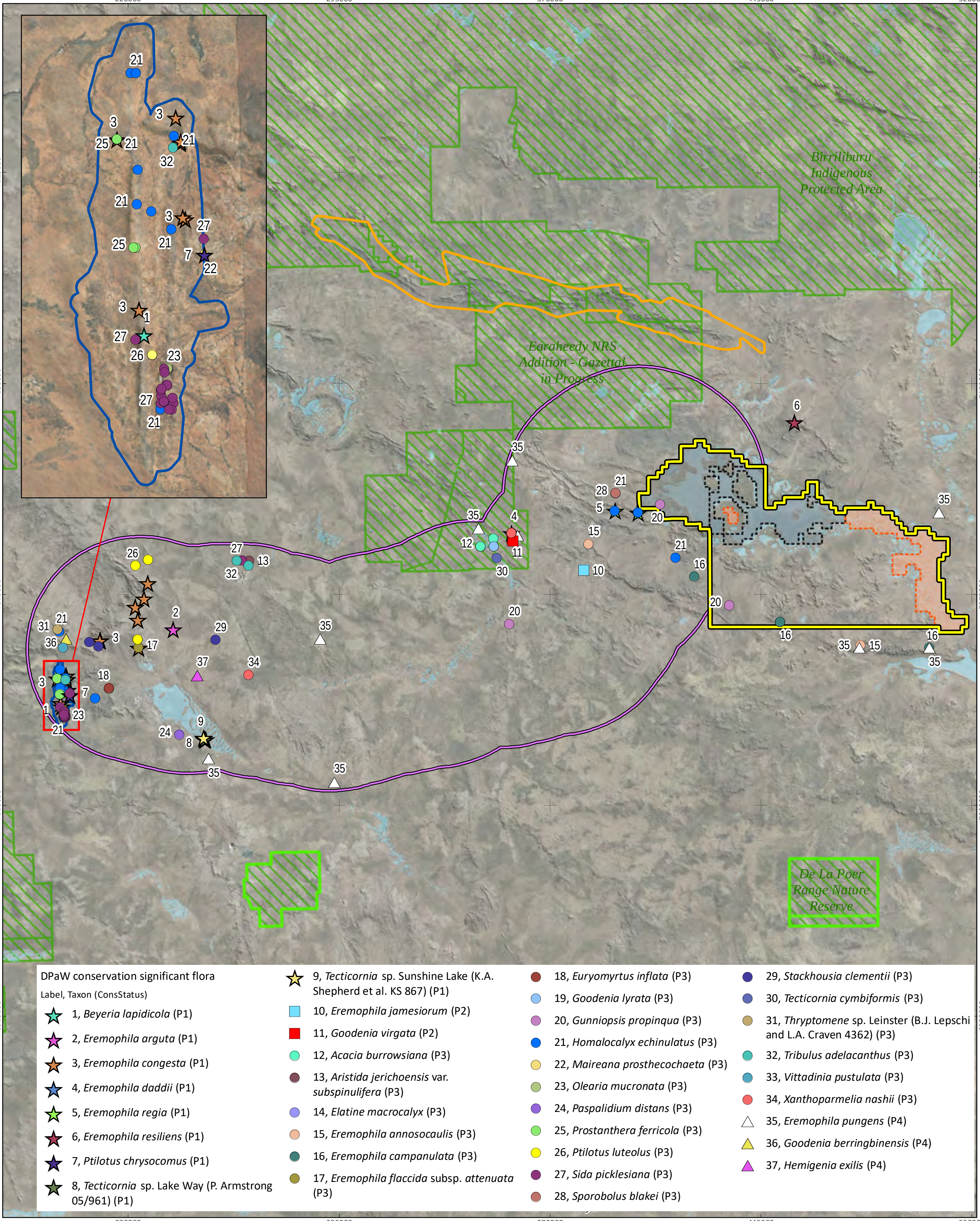
Community ID	Community name	Conservation status	Buffer (km)	Proximity to study area
Lee Steere Range BIF	Lee Steere Range vegetation complexes (banded ironstone formation)	Priority 1	1	36 km N of lake study area
Wiluna West BIF	Wiluna West vegetation complexes (banded ironstone formation)	Priority 1	0.5	30 km W of Wiluna end of Wongawol Road

5.2.2 Flora

The desktop study identified 597 records of flora species within the area of the desktop review. The list comprised species from 62 families and 208 genera. A total of 21 species are introduced, including one species listed as a weed of national significance.

No threatened flora listed under the EPBC Act or the WC Act were identified in the desktop study.

The database searches returned 38 priority flora species within the area of the desktop review (Table 5-3). There are records for two species, *Gunniopsis propinqua* (P3) and *Eremophila campanulata* (P3), within the lake study area and a large number of priority flora records within the road study area (Figure 5-5).



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0 10 20 40 60
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DPaW TEC/PEC search results

- Lee Steere Range vegetation complexes (banded ironstone formation) (P1)
- Wiluna West vegetation complexes (banded ironstone formation) (P1)
- Lake study area
- Road study area

Tenements within study area

- Live tenement
- Pending tenement
- Nature Reserve
- Protected areas (CAPAD)

Figure 5-4

Desktop records of conservation significant flora and ecological communities

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Table 5-3 Conservation significant flora records in the vicinity of the study area

Family	Name	Cons. status	Description (Florabase)
Aizoaceae	*Gunniopsis propinqua*	P3	Prostrate annual or perennial, herb, 0.03-0.1 m high. Fl. white/pink, Aug to Sep. Stony sandy loam. Lateritic outcrops, winter-wet sites.
Amaranthaceae	*Ptilotus chrysocomus*	P1	Compact, perennial, woody shrub, to 1 m high, leaves bunched at shoots, oblanceolate, 3-10 mm long, 0.5-1 mm long; spikes yellow, ovoid-orbicular, 6-12 mm long, 6-10 mm wide; bracts 0.8-1 mm long; bracteoles 1.8-2.2 mm long; tepals 3.4-4 mm long; 5 fertile stamens; ovary glabrous, style 1.4-1.8 mm long, sigmoid, centrally fixed to ovary. Fl. yellow, Aug to Sep. Brown sandy clays. Bases of breakaways, rocky scree slopes.
Amaranthaceae	*Ptilotus luteolus*	P3	
Asteraceae	*Olearia mucronata*	P3	Densely branched, unpleasantly aromatic shrub, 0.6-1 m high. Fl. white & yellow, Aug to Dec or Jan. Schistose hills, along drainage channels.
Asteraceae	*Vittadinia pustulata*	P3	Low annual, herb (sometimes persisting as an under-shrub), 0.1-0.3 m high. Fl. Sep.
Celastraceae	*Stackhousia clementii*	P3	Dense broom-like perennial, herb, to 0.45 m high. Fl. green/yellow/brown. Skeletal soils. Sandstone hills.
Chenopodiaceae	*Maireana prosthecochaeta*	P3	Open, densely-leaved shrub, 0.3-0.6 m high. Laterite. Hills, salty places.
Chenopodiaceae	*Tecticornia cymbiformis*	P3	Erect, perennial shrub, 0.3-0.5 m high. Saline soils. Along the edge of creeklines.
Chenopodiaceae	*Tecticornia* sp. Lake Way (P. Armstrong 05/961)	P1	
Chenopodiaceae	*Tecticornia* sp. Sunshine Lake (K.A. Shepherd et al. KS 867)	P1	
Elatinaceae	*Elatine macrocalyx*	P3	Prostrate, glabrous, mat-forming annual, herb, sepals 2-3mm long, fruit indehiscent. Fl. white, May to Oct (probably opportunistic). Shallow sands over clay. Margins of playa lakes and clay pans.
Euphorbiaceae	*Beyeria lapidicola*	P1	
Fabaceae	*Acacia burrowsiana*	P3	Stout shrub or tree, to 5 m high, bark grey, fibrous, fissured, smooth on upper branches; phyllodes sub-rigid, sub-glaucous, erect, coarsely pungent. Red-brown loams with ironstone rubble on surface, calcrete soils, laterite, quartz. Flats adjacent to watercourses, crests of low rises, breakaways.

Family	Name	Cons. status	Description (Florabase)
Goodeniaceae	*Goodenia berringbinensis*	P4	Ascending annual, herb, 0.1-0.3 m high. Fl. yellow, Oct. Red sandy loam. Along watercourses.
Goodeniaceae	*Goodenia lyrata*	P3	Prostrate herb, with lyrate leaves. Fl. yellow, Aug. Red sandy loam. Near claypan.
Goodeniaceae	*Goodenia virgata*	P2	Ascending to erect, virgate perennial, herb, to 0.4 m high. Fl. yellow, Jul. Red sandy loam. Near salt pans.
Lamiaceae	*Hemigenia exilis*	P4	Erect, multi-stemmed shrub, 0.5-2 m high. Fl. blue-purple/white, Apr or Sep to Nov. Laterite. Breakaways, slopes.
Lamiaceae	*Prostanthera ferricola*	P3	Erect, openly-branched shrub, 0.3-1 m high. Shallow red-brown skeletal sandy loam on banded ironstone, laterite, basalt or quartz. Gently inclined mid to upper slopes of hills, rocky crests, outcrops.
Malvaceae	*Sida picklesiana*	P3	Herb or shrub. Stems glabrous. Leaves 10-45 mm long, 10-34 mm wide, not lobed; Flowering time April, August or November. There is a detailed scientific description of this species on Florabase
Myrtaceae	*Euryomyrtus inflata*	P3	Shrub, 0.3-0.7 m high, leaves dull green, fruits erect. Fl. white-pink, Jun to Jul. Deep red sand. Flat plain.
Myrtaceae	*Homalocalyx echinulatus*	P3	Shrub, 0.45-1 m high. Fl. pink, Jun to Sep. Laterite. Breakaways, sandstone hills.
Myrtaceae	*Thryptomene* sp. Leinster (B.J. Lepschi & L.A. Craven 4362)	P3	
Parmeliaceae	*Xanthoparmelia nashii*	P3	
Poaceae	*Aristida jerichoensis* var. *subspinulifera*	P3	Compactly tufted perennial, grass-like or herb, 0.3-0.8 m high, lemma groove muricate. Hardpan plains.
Poaceae	*Paspalidium distans*	P3	Rhizomatous, tufted perennial, grass-like or herb, 0.15-0.8 m high. Fl. green, Mar to Sep. Loam. River banks.
Poaceae	*Sporobolus blakei*	P3	Tufted perennial, grass-like or herb, 0.45-0.6 m high. Fl. green-purple, Mar or Jun to Jul. Red sandy clay, loam. Creeks.
Scrophulariaceae	*Eremophila annosocaulis*	P3	

Family	Name	Cons. status	Description (Florabase)
Scrophulariaceae	*Eremophila arachnoides* subsp. *arachnoides*	P3	Broom-like shrub, to 3 m high, branches with circular, discrete tubercles. Fl. white/blue-purple, Sep. Shallow loam over limestone.
Scrophulariaceae	*Eremophila arguta*	P1	Shrub.
Scrophulariaceae	*Eremophila campanulata*	P3	Low shrub, ca 0.3 m high, 0.4 m wide. Fl. purple-red, Sep. Stony red/brown clay.
Scrophulariaceae	*Eremophila congesta*	P1	Upright shrub, to 1.2 m high. Fl. purple-blue, Aug to Sep. Lateritic outcrops in greenstone hills, stony quartzite slopes.
Scrophulariaceae	*Eremophila daddii*	P1	
Scrophulariaceae	*Eremophila flaccida* subsp. *attenuata*	P3	Erect, compact shrub, ca 0.5 m high. Fl. pink & blue, May. Stony clay over quartzite. Hillslopes, ridges.
Scrophulariaceae	*Eremophila jamesiorum*	P2	
Scrophulariaceae	*Eremophila pungens*	P4	Erect, viscid shrub, 0.5-1.5 m high. Fl. purple-violet, Jun to Aug. Sandy loam, clayey sand over laterite. Plains, ridges, breakaways.
Scrophulariaceae	*Eremophila regia*	P1	
Scrophulariaceae	*Eremophila resiliens*	P1	
Zygophyllaceae	*Tribulus adelacanthus*	P3	Prostrate herb, plants villous; leaflet pairs 3-6; fruits 5-winged, lacking spines, 10-14 mm high.

5.3 Environmental factor – Landforms

EPA guidance for landforms (EPA 2016b) does not specifically mention salt lakes as representing potentially significant landforms for the purpose of EIA; however, Lake Carnegie fits the EPA's broad definition of a landform (see section 4.2) and the landform characteristics of the lake may trigger some criteria considered by the EPA (EPA 2016b) in the determination of significant landforms, as outlined in Table 5-4.

The Lake Carnegie landform is a megascale irregular sumpland with numerous microscale to macroscale islands (Department of the Environment and Energy 1995). At its south-east end the lake becomes a discontinuous series of microscale to macroscale sumplands. Lake Carnegie has formed in a largely infilled alluvial valley of a major palaeodrainage which is connected to Lake Wells and flowed south-east into the Throssell palaeodrainage system (Beard 2002). The lake bed is an expanse of lacustrine clay and silt with sand, salt and gypsum. Mixed Aeolian dunes of gypsum and quartz sand form numerous circular or crescentic islands and marginal lake deposits.

The lake study area does not intercept BIFs and is unlikely to intersect any dunal systems that may represent significant landforms.

Table 5-4 Considerations for determining significant landforms

Aspect	Description	Relevant to study area?
Variety	The landform is a particularly good or important example of its type. The landform is not well represented over the local, regional or national scale or differs from other examples at these scales.	Lake Carnegie is significant as a DIW wetland (criterion 1) because it is considered a good example of a large intermittent saline lake unusual in the Gascoyne bioregion (Department of the Environment and Energy 1995; see section 5.6).
Integrity	The landform is intact, being largely complete or whole and in good condition.	Likely.
Ecological importance	The landform has a distinctive or exclusive role in maintaining existing ecological and physical processes; for example, by providing a unique microclimate, source of water flow, or shade. The landform supports endemic or highly restricted plants or animals.	Possibly. Lake Carnegie is listed as a DIW under criterion 3: 'It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.' (Department of the Environment and Energy 1995; see section 5.6).
Scientific importance	The landform provides evidence of past ecological processes or is an important geomorphological or geological site. The landform is of recognised scientific interest as a reference site or an example of where important natural processes are operating.	Unknown, requires further investigation.
Rarity	The landform is rare or relatively rare, being one of the few of its type at a national, regional or local level.	Possibly. Lake Carnegie is noted as 'unusual in the Gascoyne bioregion'.
Social importance	The landform supports significant amenity, cultural or heritage values.	Unknown, requires further investigation.

5.4 ENVIRONMENTAL FACTOR – TERRESTRIAL FAUNA

5.4.1 Vertebrate fauna

Records for 297 terrestrial vertebrate fauna species and subspecies were identified in the area of the desktop review. This comprised of nine frogs, 87 reptiles, 152 birds (151 native and one introduced) and 48 mammals (37 native and 11 introduced).

A total of 39 species or subspecies of conservation significance were identified in the desktop review including 17 listed under the EPBC Act and/or WC Act as Threatened, Conservation Dependent or Specially Protected (Table 5-5). A further 16 species are listed as 'Migratory' under the EPBC Act and WC Act and eight species are listed as Priority species (Table 5-5). A record for one Migratory species, Wood Sandpiper (*Tringa glareola*) was identified within lake study area and numerous records for conservation significant species were returned within the boundary of the road study area (Figure 5-6).

Some species identified in the desktop review are considered regionally extinct in the vicinity of the study area and recent records of the species are only known from translocated populations to a fenced-off area on ex-Lorna Glen pastoral station (Table 5-5). Some of these species may possibly occur outside of the managed area and are therefore included as a species with the potential to occur within the study area in this report. One species, the Boodie (*Bettongia lesueuri*), comprises of three separate subspecies which formed part of a translocated population to Lorna Glen, of which the status of the subspecies is not well known; however, it is likely the three have intermixed following the translocation.

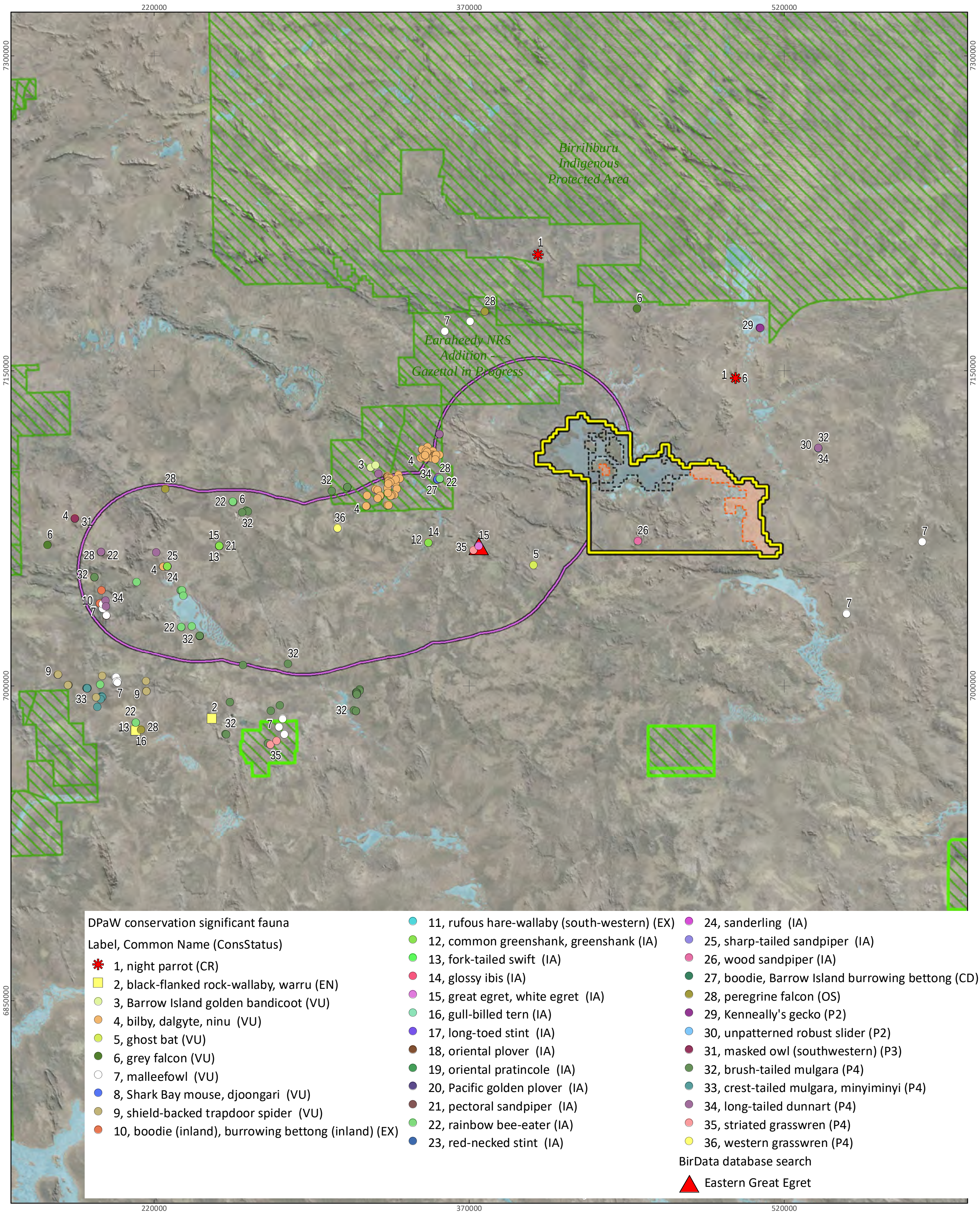
One species identified in the desktop review, the Greater Stick-nest Rat, is considered regionally extinct. It is only known on the Western Australian mainland from one translocated population which is managed by the Australian Wildlife Conservancy on the Mt Gibson Sanctuary located over 600 km southwest of the study area and should not be considered further.

Also of note, Lake Carnegie is listed as a major episodic breeding area for Black Swan *Cygnus atratus* and also a major habitat for other waterfowl (Department of the Environment and Energy 1995).

Table 5-5 Conservation significant fauna species identified in the desktop review

Species	Common name	Conservation status		
		EPBC Act	WC Act	DPaW
Reptiles				
Diplodactylus kenneallyi	Kenneally's Gecko			P2
Lerista macropisthopus remota	Unpatterned Robust Slider			P2
Birds				
Apus pacificus	Fork-tailed Swift	Mig.	Mig.	
Ardea modesta	Eastern Great Egret		Mig.	
Charadrius veredus	Oriental Plover		Mig.	
Pluvialis fulva	Pacific Golden Plover		Mig.	
Falco hypoleucos	Grey Falcon		VU	
Falco peregrinus	Peregrine Falcon		OS	
Glareola maldivarum	Oriental Pratincole		Mig.	
Amytornis striatus striatus	Striated Grasswren (inland)			P4

Species	Common name	Conservation status		
		EPBC Act	WC Act	DPaW
Leipoa ocellata	Malleefowl	VU	VU	
Merops ornatus	Rainbow Bee-eater	Mig.	Mig.	
Motacilla cinerea	Grey Wagtail		Mig.	
Motacilla flava	Yellow Wagtail		Mig.	
Pezoporus occidentalis	Night Parrot	EN	CR	
Polytelis alexandrae	Princess Parrot	VU		P4
Calidris acuminata	Sharp-tailed Sandpiper		Mig.	
Calidris alba	Sanderling		Mig.	
Calidris melanotos	Pectoral Sandpiper	Mig.	Mig.	
Calidris ruficollis	Red-necked Stint		Mig.	
Calidris subminuta	Long-toed Stint	Mig.	Mig.	
Tringa glareola	Wood Sandpiper		Mig.	
Tringa nebularia	Common Greenshank		Mig.	
Plegadis falcinellus	Glossy Ibis	Mig.	Mig.	
Tyto novaehollandiae novaehollandiae	Masked Owl (southern subsp)			P3
Mammals				
Dasycercus blythi	Brush-tailed Mulgara			P4
Dasycercus cristicauda	Crest-tailed Mulgara	VU		P4
Sminthopsis longicaudata	Long-tailed Dunnart			P4
Sminthopsis psammophila	Sandhill Dunnart	EN	EN	
Lagorchestes hirsutus hirsutus	Rufous Hare-wallaby	CD	EX	
Petrogale lateralis lateralis	Black-flanked Rock-wallaby	EN	EN	
Macroderma gigas	Ghost Bat	VU	VU	
Leporillus apicalis	Lesser Stick-nest Rat	CD	EX	
Pseudomys fieldi	Shark Bay Mouse	VU	VU	
Isoodon auratus barrowensis	Barrow Island Golden Bandicoot	VU	VU	
Bettongia lesueur subsp. (WAM M10733)	Barrow Island Boodie	VU	CD	
Bettongia lesueur graii	Boodie	CD	EX	
Bettongia lesueur lesueur	Shark Bay Boodie	VU	CD	
Macrotis lagotis	Bilby	VU	VU	



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Map author	KC

0 15 30 60 90
Kilometres

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Lake study area
Road study area
Tenements within study area
Live tenement
Pending tenement
Nature Reserve
Protected areas (CAPAD)

Figure 5-6

Desktop records of conservation significant vertebrate fauna

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5.4.2 Short-range endemic invertebrates

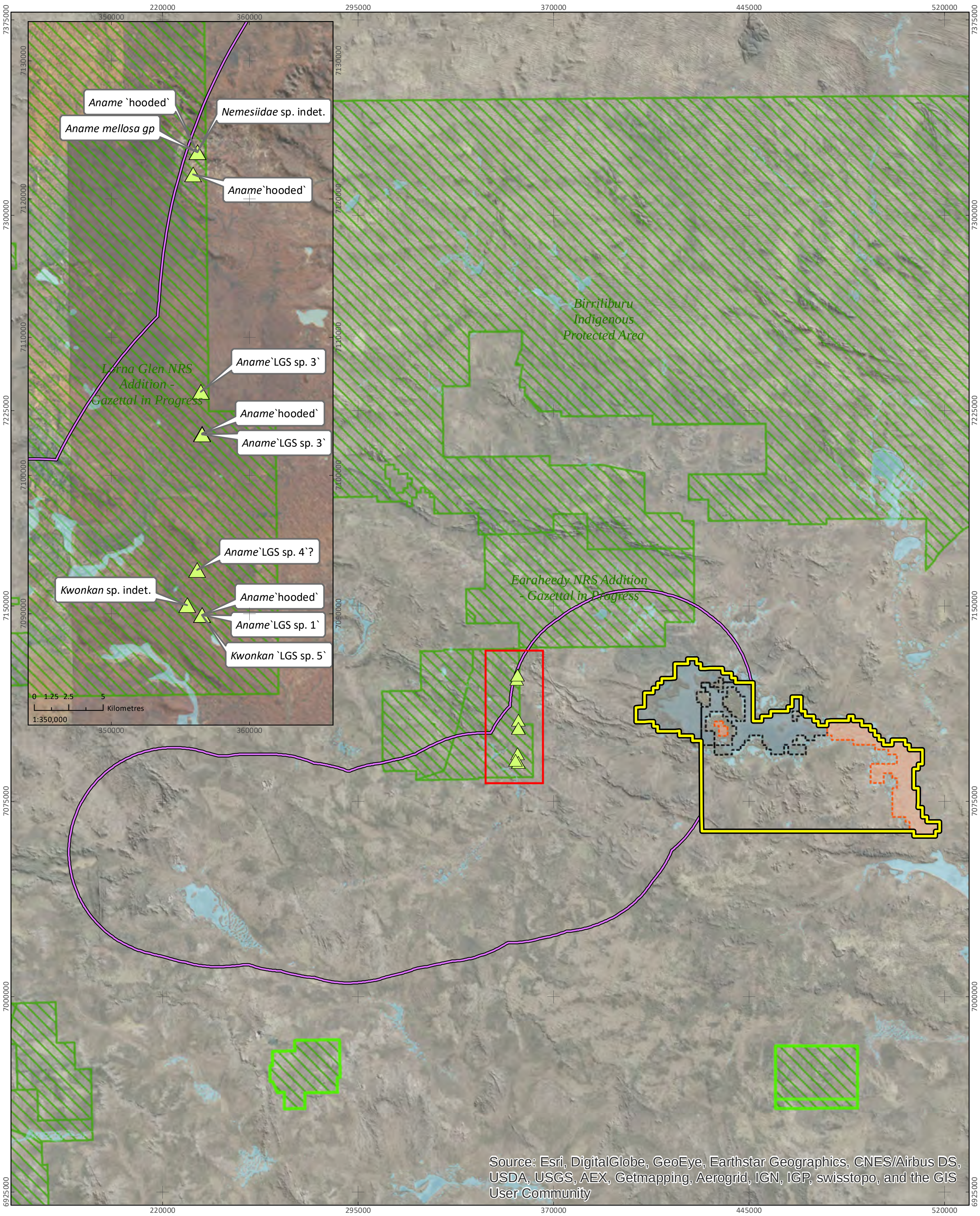
The WAM database searches returned a total of 260 records of terrestrial invertebrates (Arachnology/Myriapodology – 259; Crustacea – 0; Mollusca - 1) within approximately 100 km of the study area. These included a total of 12 potential SRES, all in the trapdoor spider family Nemesiidae (Table 5-6; Figure 5-7). All records were from surveys at Lorna Glen Station (Langlands *et al.* 2011; Langlands *et al.* 2012). There were no records from the lake study area. The invertebrate fauna in the region is too poorly known to confidently identify any of the species listed here as SREs.

Table 5-6 Potential short-range endemic invertebrates identified by the desktop review

WAM reg. no	Family	Genus and species	Location (as per WA Museum)	Latitude (GDA94)	Longitude (GDA94)
Araneae (spiders)					
T88654	Nemesiidae	*Aname* \`hooded\`	8.5 km S. of Lorna Glen Station	-26.3036	121.5628
T88669	Nemesiidae	*Aname* \`hooded\`	25.2 km N. of Lorna Glen Station	-26.0013	121.5633
T88660	Nemesiidae	*Aname* \`hooded\`	4.6 km N. of Lorna Glen Station	-26.1852	121.5644
T88655	Nemesiidae	*Aname* \`hooded\`	23.4 km N. of Lorna Glen Station	-26.0155	121.5600
T66399	Nemesiidae	*Aname* \`LGS sp. 1\`	Lorna Glen Station, quadrat 13	-26.3036	121.5628
T66461	Nemesiidae	*Aname* \`LGS sp. 3\`	Lorna Glen Station, quadrat 17	-26.1577	121.5639
T66458	Nemesiidae	Aname \`LGS sp. 3\`	Lorna Glen Station, quadrat 16	-26.1855	121.5644
T65329	Nemesiidae	*Aname* \`LGS sp. 4\`?	Lorna Glen Station, quadrat 15	-26.2741	121.5597
T88656	Nemesiidae	*Aname mellosa* gp	25.2 km N. of Lorna Glen Station	-26.0013	121.5633
T76094	Nemesiidae	*Kwonkan* \`LGS sp. 5\`	Lorna Glen Station, site LGS13	-26.3036	121.5628
T64718	Nemesiidae	*Kwonkan* sp. indet.	Lorna Glen Station, quadrat 14	-26.2972	121.5522
T65377	Nemesiidae	Nemesiidae sp. indet.	Lorna Glen Station, quadrat 19	-26.0013	121.5633

No terrestrial crustaceans (e.g. slaters) were identified from the WAM or Phoenix database searches in the study area.

The most prospective habitat for SREs in the study area and most likely impacted is the playa of Lake Carnegie and its riparian zone, including some islands within the lake. Salt lakes are known to harbour a number of SREs, particularly within wolf spiders (Framenau & Hudson 2017) and tiger beetles (López-López *et al.* 2016; Pons *et al.* 2006). A number of salt lake specialist invertebrates have been collected from Lake Wells, including wolf spiders, a buthid scorpion and tiger beetles (Phoenix invertebrate databases), but these records are situated outside the desktop search area and therefore not considered here in detail. However, as Lake Wells belongs to the same palaeodrainage system as Lake Carnegie, the records provide an important reference for future surveys at Lake Carnegie.



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Map author	KC

0 12.5 25 50 75 Kilometres

1:1,857,211 (at A4) GDA 1994 MGA Zone 51

- Lake study area
- Road study area
- Tenements within study area
- Live tenement
- Pending tenement
- SRE records
- Nature Reserve
- Protected areas (CAPAD)

Figure 5-7

Desktop records of short range endemic invertebrates

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5.5 ENVIRONMENTAL FACTOR – SUBTERRANEAN FAUNA

Considerable subterranean fauna communities have been identified from calcretes in the Western Australian Yilgarn region, often associated with salt lakes (Cooper *et al.* 2008; Guzik *et al.* 2008). Many of these communities have been listed as Threatened or Priority Ecological Communities. Twelve of these occur in proximity to the study areas; two of these near the lake study area (Windidda and Glenayle/Carnegie Calcretes), all others within or near the road study area (Table 5-7; Figure 5-8).

Table 5-7 Priority ecological communities (subterranean) in vicinity of study area

Community ID	Community name	Conservation status	Buffer (km)	Proximity to study area
Windidda Calcrete	Windidda calcrete groundwater assemblage type on Carnegie palaeodrainage on Windidda Station	Priority 1	2	<1 km S of lake study area
Glenayle/Carnegie Calcrete	Glenayle and Carnegie Downs calcrete groundwater assemblage type on Burnside palaeodrainage on Glenayle Station	Priority 1	2	30 km N of lake study area
Barwidgee Calcrete	Barwidgee calcrete groundwater assemblage type on Carey palaeodrainage on Barwidgee Station	Priority 1	2	44 km S of Wongawol Road
Hinkler Well Calcrete	Hinkler Well calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station	Priority 1	2	23 km S of Wongawol Road
Jundee Calcrete	Jundee Homestead calcrete groundwater assemblage type on Carnegie palaeodrainage on Jundee Station	Priority 1	2	30 km N of Wongawol Road
Jundee South Hill Calcrete	Jundee South Hill calcrete groundwater assemblage type on Carnegie palaeodrainage on Jundee Station	Priority 1	2	36 km N of Wongawol Road
Lake Violet Calcrete	Lake Violet south and Lake Violet calcrete groundwater assemblage types on Carey palaeodrainage on Millbillillie Station	Priority 1	2	5 km S of Wongawol Road
Lake Way South Calcrete	Lake Way South calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station	Priority 1	2	33 km S of Wongawol Road
Lorna Glen Calcrete	Lorna Glen calcrete groundwater assemblage type on Carnegie palaeodrainage on Lorna Glen Station	Priority 1	2	43 km W of lake study area, 24 km N of Wongawol Road
Millbillillie Bubble Well Calcrete	Millbillillie Bubble Well groundwater calcrete assemblage type on Carey palaeodrainage on Millbillillie Station	Priority 1	2	15 km W of Wiluna end of Wongawol Road
Uramurdah Calcrete	Uramurdah Lake calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station	Priority 1	2	Buffer intersects Wongawol Road
Wiluna BF Calcrete	Wiluna BF calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station	Priority 1	2	Intersects Wongawol Road

At total of 28 records of stygofauna were belonging to two species (one syncarid and one copepod) were identified in the desktop review (Table 5-8; Figure 5-8). Most of these were recorded in the subterranean calcrete PECs (Figure 5-8). Both species should be considered SREs as the records of the desktop review are the only ones for each species (Cho *et al.* 2006; Karanovic 2004).

Forty-one records of troglofauna in a variety of slater families were identified in the desktop review (Table 5-8; Figure 5-8) based on a recent study on subterranean slaters (Oniscoidea) collected in the calcretes near Wongawol Road, specifically Bubble Well, Lake Violet and Hinkler Well (Javidkar *et al.* 2016). All of these were recorded in the western part of the desktop review area and largely in calcrete of the road study area (Figure 5-8).

The analyses of surface geology of Carnegie Lake identified further calcrete bodies and Quaternary alluvial deposits that potentially harbour subterranean communities, both stygofauna and troglofauna. Calcretes include one near Wongawol Airstrip in the very west of the lake study area and two intersecting the south-eastern border of the lake study area (Figure 5-3). Deeper alluvial deposits potentially harbouring subterranean fauna include those near Wongawol Airstrip (draining into Lake Carnegie from the west), Kingston Pass (west of Windidda Calcrete), Miningarra Creek, and Skeleton Creek, Kalyaltcha Creek (all draining into the lake from the south), Windidda Creek (draining from the west into the southern part of the lake) and Brockman Creek (draining into the north of Lake Carnegie) (Figure 5-3).

In summary, considerable subterranean fauna values, including PECs but also apparently unsurveyed groundwater occurrences in alluvial and calcrete deposits, have been identified in the periphery of the study area. Any impacts on local hydrology may have the potential to impact on those.

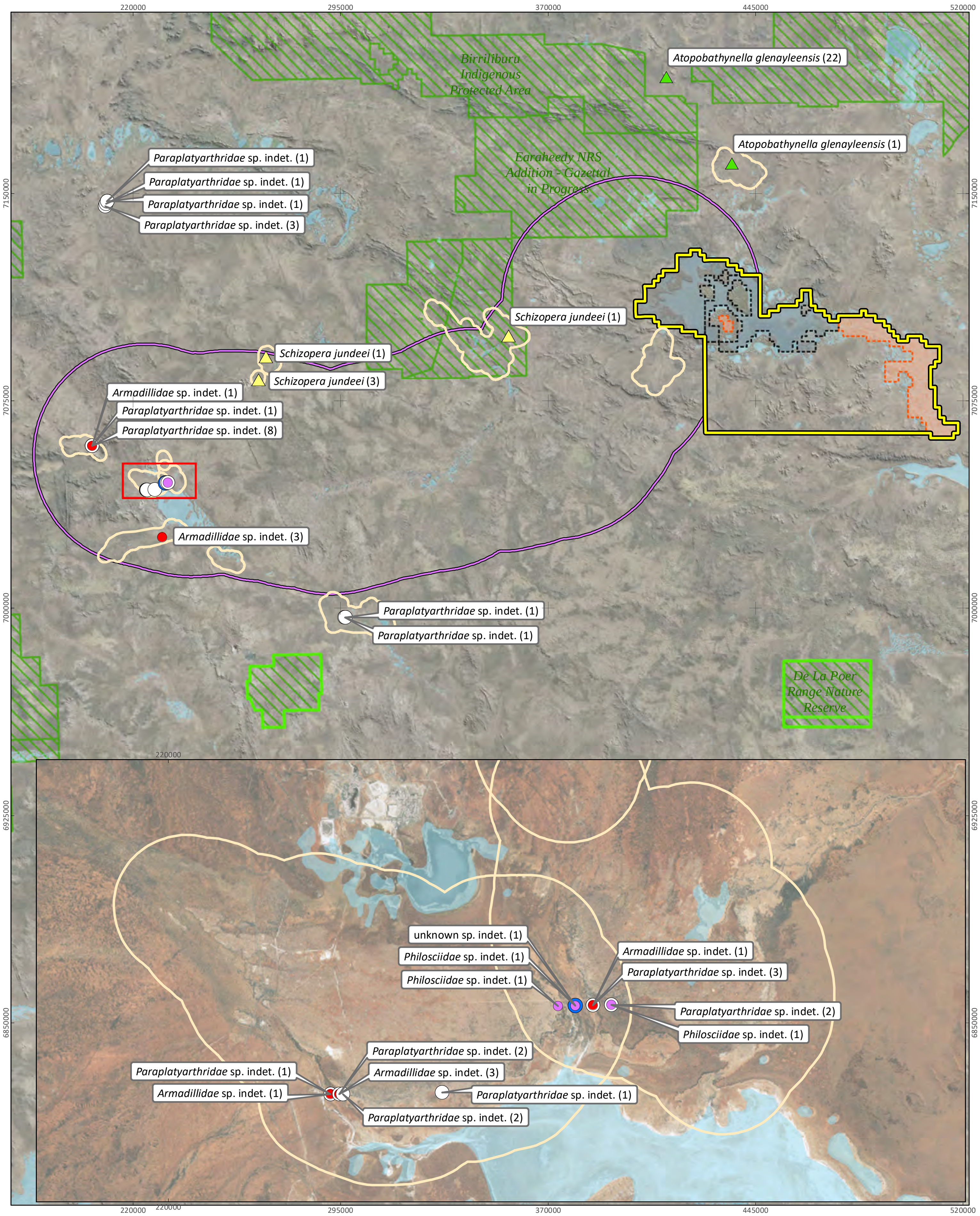
Table 5-8 Subterranean fauna identified by the desktop review

WAM reg.	Family	Species	Location	Latitude (GDA94)	Longitude (GDA94)
Stygofauna (all WAM database search)					
C34417	Parabathynellidae	*Atopobathynella glenayleensis*	Carnegie Downs Stn, nr engine bore	-25.6666	122.367
C34405	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34406	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34407	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34408	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34409	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34410	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34411	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34412	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34413	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34414	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34415	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34416	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34404	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34403	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34395	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34396	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34397	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34398	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34399	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133

WAM reg.	Family	Species	Location	Latitude (GDA94)	Longitude (GDA94)
C34400	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34401	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C34402	Parabathynellidae	*Atopobathynella glenayleensis*	Glenayle Station, Gidgee Bore	-25.3833	122.133
C28498	Diosaccidae	*Schizopera jundeei*	Lorna Glen Station, No. 10 Well	-26.2266	121.555
C28497	Diosaccidae	*Schizopera jundeei*	Jundee Station, JE 149 South Bore	-26.2833	120.677
C28496	Diosaccidae	*Schizopera jundeei*	Jundee Station, "Sacred" Well	-26.3566	120.648
C28495	Diosaccidae	*Schizopera jundeei*	Jundee Station, "Sacred" Well	-26.3566	120.648
C28494	Diosaccidae	*Schizopera jundeei*	Jundee Station, "Sacred" Well	-26.3566	120.648
Troglofauna (from Javidkar *et al.* 2016)					
BES17210	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.5607	120.0409
BES14602	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES15065	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES15092	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES15095	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES15065	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES15095	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES16617	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES16653	Armadillidae	Armadillidae sp. indet.	Bubble Well	-26.56067	120.04092
BES16342	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Bubble Well	-26.56067	120.04092
BES16619	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Cunyu	-25.78064	120.10745
BES15081	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Cunyu	-25.78064	120.10745
BES15090	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Cunyu	-25.78064	120.10745

WAM reg.	Family	Species	Location	Latitude (GDA94)	Longitude (GDA94)
BES17217	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Cunyu	-25.7726	120.1108
BES16627	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Cunyu	-25.76419	120.11429
BES17212	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Cunyu	-25.7642	120.1143
BES14619	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Lake Violet	-26.70905	120.23217
BES16458	Armadillidae	Armadillidae sp. indet.	Lake Violet	-26.70905	120.23217
BES15097	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Lake Violet	-26.70903	120.23463
BES16625	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Lake Violet	-26.70903	120.23463
BES16656	Armadillidae	Armadillidae sp. indet.	Lake Violet	-26.70903	120.23463
BES16461	Armadillidae	Armadillidae sp. indet.	Lake Violet	-26.70903	120.23463
BES16386	Armadillidae	Armadillidae sp. indet.	Lake Violet	-26.70903	120.23463
BES16659	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Lake Violet	-26.70907	120.23568
BES15080	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Lake Violet	-26.70907	120.23568
BES16476	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Lake Violet	-26.70923	120.26404
BES15104	Armadillidae	Armadillidae sp. indet.	Hinkler Well	-26.86436	120.28737
BES16639	Armadillidae	Armadillidae sp. indet.	Hinkler Well	-26.86436	120.28737
BES16641	Armadillidae	Armadillidae sp. indet.	Hinkler Well	-26.86436	120.28737
BES15085	Philosciidae	Philosciidae sp. indet.	Lake Violet	-26.68761	120.29771
BES16633	unknown	unknown sp. indet.	Uramurdah	-26.6876	120.30271
BES15089	Philosciidae	Philosciidae sp. indet.	Uramurdah	-26.6876	120.30271
BES16614	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Uramurdah	-26.68757	120.30777
BES16631	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Uramurdah	-26.68757	120.30777
BES16655	Armadillidae	Armadillidae sp. indet.	Uramurdah	-26.68757	120.30777

WAM reg.	Family	Species	Location	Latitude (GDA94)	Longitude (GDA94)
BES15087	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Uramurdah	-26.68757	120.30777
BES15067	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Uramurdah	-26.68762	120.313
BES15088	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Uramurdah	-26.68762	120.313
BES15088	Philosciidae	Philosciidae sp. indet.	Uramurdah	-26.68762	120.313
BES16622	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Barwidgee	-27.13758	120.94638
BES15062	Paraplatyarthridae	Paraplatyarthridae sp. indet.	Barwidgee	-27.13748	120.94945



Western Australia
PERTH

Kalium Lakes Ltd
Carnegie Potash Project JV

Project No 1152
Date 24-May-17
Drawn by KW
Map author KC

0 10 20 40 60
Kilometres

1:1,750,000 (at A4) GDA 1994 MGA Zone 51

Lake study area
Road study area
Tenements within study area
Live tenement
Pending tenement
DPaW TEC/PEC search results (All P1)
Nature Reserve
Protected areas (CAPAD)

Troglofauna*
Armadillidae sp. indet.
Paraplatyarthridae sp. indet.
Philosciidae sp. indet.
unknown sp. indet.
Stygofauna*
Atopobathynella glenayleensis
Schizopera jundeei
* labelled with species name, and number of records at each unique location

Figure 5-8
Desktop records of subterranean fauna and subterranean priority ecological communities

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5.6 ENVIRONMENTAL FACTOR – HYDROLOGICAL PROCESSES

Lake Carnegie is a large shallow saline internal drainage basin positioned at 440 m ASL. It is listed under the national Directory of Important Wetlands (DIW) under two criteria (Department of the Environment and Energy 1995):

1. it is a good example of a wetland type occurring within a biogeographic region in Australia
2. it is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.

Lake Carnegie is classified as an environmentally sensitive area (ESA), as declared by the Minister for Environment under section 51B of the *Environmental Protection Act 1986* (EP Act), due to its listing as a DIW (Figure 5-9).

Surface inflow to Lake Carnegie occurs from numerous creeks including Kulele, Charles Wells, Wongawell and Banjo creeks to the western end, Miningarra and Fourteen Mile creeks from the south, Sholl, Anne and Brockman creeks from the north and Windidda Creek to the eastern end (Department of the Environment and Energy 1995). Inundation is episodic. Old water depth readings (25 September 1980) are to about 1 m deep. Water salinity is probably fresh initially, becoming saline as the lake-bed salt-crust dissolves. At the end of its hydrocycle, it is likely to be hypersaline and poikilohaline.

A brief review of the lake against the environmentally significant water dependent ecosystems identified by the EPA (EPA 2016e) identified the following:

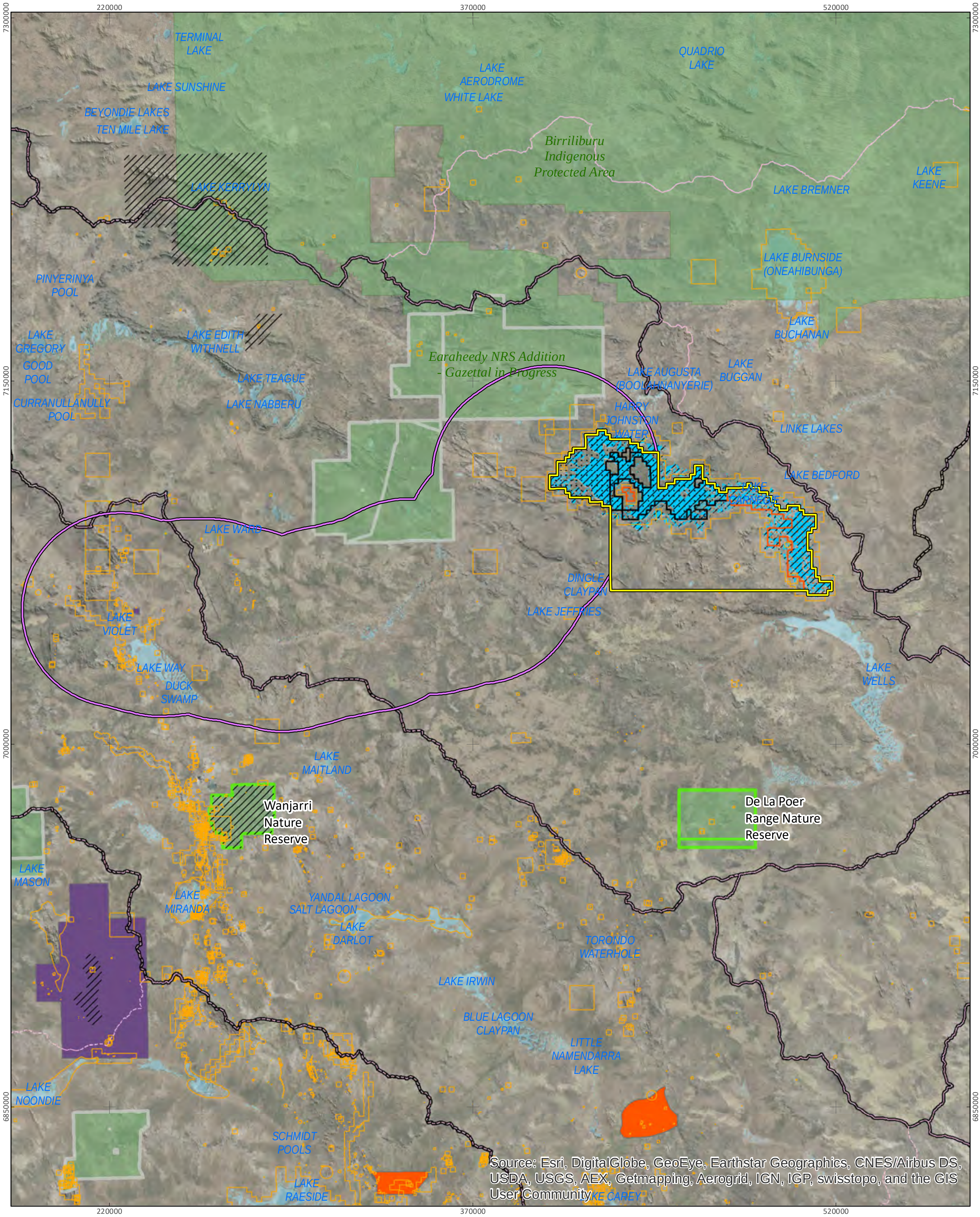
- wetlands which are Ramsar listed – Lake Carnegie is not a RAMSAR wetland
- Conservation Category – Lake Carnegie is not a conservation category wetland
- Directory of Important Wetlands in Australia – the Lake Carnegie system is listed in the National Directory of Important Wetlands
- wild and scenic rivers - the study area does not intersect any wild and scenic rivers
- wetland types which may be poorly represented – Lake Carnegie is significant because it represents a good example of a large intermittent saline lake unusual in the bioregion
- natural springs and pools, particularly in arid areas – none identified but requires further investigation
- ecosystems which support conservation significant flora/vegetation and fauna species or communities, including migratory waterbirds, bats, and subterranean fauna – Lake Carnegie is listed as a major episodic breeding area for Black Swan *Cygnus atratus* and also a major habitat for other waterfowl (Department of the Environment and Energy 1995)
- ecosystems which support significant amenity, recreation and cultural values – the whole of the Lake study area falls within the buffer of an Aboriginal Heritage Place and there are several other sites in the vicinity (Figure 5-9).

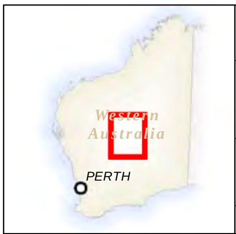
The Bureau of Meteorology's National Atlas of Groundwater Dependent Ecosystems (GDEs) maps the whole of Lake Carnegie as a GDE with high potential for groundwater interaction (BoM 2017). This includes the GDE class 'ecosystems that may rely on the surface expression of groundwater' for the lake and the GDE class 'ecosystems that may rely on the surface expression of groundwater' for riparian vegetation around the lake.

The GDE Atlas provides information to support the recognition and identification of GDEs in natural resource management, including environmental impact assessment (BoM 2017). The dataset expresses the potential for groundwater interaction for rivers, springs, and wetland ecosystems across Australia. It shows the ecosystems that may rely on groundwater that has been discharged to the surface, for example, as baseflow or spring flow. Ecosystem polygons are represented as having high, moderate or low potential for groundwater interaction. The accuracy of the GDE mapping depends on the accuracy of input data; several hundred input datasets were used so the accuracy varies across Australia and the mapping has not been verified in the field.

In relation to extractive values:

- no Public Drinking Water Source Areas (PDWSAs) are located in the study area (see Figure 5-9 for closest PDWSAs to study area)
- the study area does not overly any Department of Water groundwater subareas or intersect any fresh and high order surface water systems.





Kalium Lakes Ltd
Carnegie Potash Project JV

Project No	1152
Date	24-May-17
Drawn by	KW
Map author	KC

0 12.5 25 50 75
Kilometres

1:2,000,000 (at A4) GDA 1994 MGA Zone 51

Lake study area
Road study area
Tenements within study area
Live tenement
Pending tenement
A Directory of Important Wetlands
Aboriginal heritage places
ESAs
Protected areas (CAPAD)
Subcatchments
Catchments
Other lakes
DPAW Managed Lands and Waters
Nature Reserve
Unallocated Crown Land - Dept Interest
Public Drinking Water Source Areas (PDWSAs)
Not Assigned
Priority 1

Figure 5-9

Surface water and groundwater values

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5.7 ENVIRONMENTAL FACTOR – INLAND WATERS ENVIRONMENTAL QUALITY

There is limited information available in relation to the hydrological values, including water quality, of Lake Carnegie (but see section 5.1.2). The lake represents an ephemeral system that only contains water after considerable rainfall. Opportunites for in-depth investigations are therefore rare.

There is no information on the aquatic biota of the lake (i.e. no aquatic macroinvertebrates were returned by the WAM database searches), but with a likely temporal change in salinity during the hydrocycle (see section 5.6), concomitant temporal changes in the aquatic communities are likely. With an initial fresh phase, productivity of the lake is expected to be high, supported by its importance for waterbirds to breed. Due to the size of the lake and apparent diversity in its geomorphology (i.e. with a number of island and variable sumplands), Lake Carnegie is also likely to show spatial variability in its aquatic biota.

Knowledge of groundwater values are similarly fragmentary and most investigations are comparatively old (e.g. Sanders & Harley 1971). However, it appears clear that the groundwater systems around salt lakes in arid Western Australian are characterised by high spatial and temporal variability. The calcrete groundwater estuaries display marked and complex physico-chemical gradients along, across and through the groundwater flow path (Humphreys *et al.* 2009). Consequently, Lake Carnegie is listed as groundwater dependent ecosystem with high potential for groundwater interaction (BoM 2017).

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