Subterranean Ecology
Scientific Environmental Services

Goldfields Highway
Wiluna - Meekatharra Upgrade
Groundwater Calcrete Assemblages
Desktop Assessment

Prepared for

Department of Main Roads Western Australia

21 May 2014

GOLDFIELDS HIGHWAY
WILUNA - MEEKATHARRA UPGRADE
GROUNDWATER CALCRETE ASSEMBLAGES
DESKTOP ASSESSMENT

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COVER: Blind diving beetle, endemic to groundwater calcrete in the Goldfields. Photo © Subterranean Ecology 2013.

LIMITATIONS: This survey was limited to the requirements specified by the client and the extent of information made available to the consultant at the time of undertaking the work. Information not made available to this study, or which subsequently becomes available may alter the conclusions made herein.

VERSION	PREPARED BY	REVIEWED BY	RECIPIENT	DATE
Ver. 1	S. Eberhard		Emma Fitzgerald DMRWA	21 May 2014

EXECUTIVE SUMMARY

This desktop assessment was commissioned by the Department of Main Roads Western Australia (DMRWA) to provide a desktop assessment of Calcrete Groundwater Assemblages (CGA's) that may be impacted by the upgrade of the Goldfields Highway from Wiluna to Meekatharra (185 kilometres).

The upgrade works will involve the widening (between 6 - 25 metres), raising (approximately 600mm) and sealing of the currently unsealed highway, and some minor realignments. The proposed works will require the draw of groundwater from a network of existing and new bores, and the extraction of road building materials (i.e. sand and gravel) to a maximum depth of 5 metres. Approximately 55 gravel pits will be developed in the local area, approximately 5 hectares each.

The scope of this report is to provide advice on the following questions:

1. Are the mapped extent of known CGA's accurate?
2. Are there potentially other CGA's in the study area?
3. What is the significance of these CGA's in the local, regional, state and national context?
4. Is the project likely to have an impact on these CGA's?
5. Would this impact be considered significant by the Environmental Protection Authority (EPA) under Environmental Protection Act 1986 (EP Act) or by Department of Sustainability, Environment, Water, Population and Community (DSEWPAC) under the Environmental Protection Biodiversity Conservation Act 1999 (EPBC Act) ?
6. The project will require the draw of groundwater from a network of existing and new bores. What distance should be applied to avoid impacts to the CGA's;
7. What management actions are recommended to avoid, reduce and manage potential impacts to CGA's ?

The main context and findings were:

Calcrete Groundwater Assemblages (CGA's) are the ecological community or assemblage of subterranean invertebrates (typically stygofauna) that inhabit groundwater in calcrete.

Seventy-four (74) CGA's in the northern Yilgarn are listed as Priority Ecological Communities (PEC's) (Priority 1) by the Department of Parks and Wildlife (DPaW). Thirty (30) of these listed PEC's occur within DMRWA's defined study area, of which three (Killara, Paroo, and Millbillillie Bubble Well) may be directly influenced by the highway upgrade.

Numerous additional calcrete deposits occur within the study area, and these very likely harbor CGA's that would qualify for listing as Priority 1 PEC's. Some of these calcretes may also be influenced by the highway upgrade and associated works (gravel pits and groundwater pumping).

1. Mapping Reliability

The mapped extent of known CGA's cannot be assumed to be accurate. While the 'accuracy' of mapped extent of known CGA's is likely to be reasonable in terms of general location of calcrete bodies, the mapping may be imprecise with respect to definition of boundaries. The likelihood that additional small and/or obscured CGA's lie undetected in the study area cannot be precluded.

2. Additional CGA's in the study area

A desktop review of available geology maps identified at least 19 additional calcrete deposits (or deposit clusters) which are not recognised as CGA's, or listed as PEC's. The locations of additional calcrete deposits are documented in this report.

3. Significance of CGA's

The CGA's in the study area are significant at all scales, from local to regional, state, national and global.

4. Potential Impacts

A suite of potential direct and indirect impacts to CGA's are considered in relation to the highway upgrade and associated works, however all of these can be avoided, managed and mitigated to ensure that the Project does not pose an unacceptable risk to conservation of CGA's.

5. Significance of Potential Impacts

There is a low likelihood that the highway upgrade and associated works will pose a significant threat to CGA's subject to the following conditions:

1. Groundwater pumping or drawdown will not impinge on any CGA's or other calcrete deposits.
2. Gravel pits will be located to avoid CGA's and other calcrete deposits.
3. Best practice operational procedures are applied to avoid and manage potential impacts to groundwater recharge and groundwater quality, that might result from road building activities on or near to CGA's including drainage, gravel pits and control of leakage / spills.

Environmental Management and Mitigation Recommendations

1. Groundwater pumping will be located so as to avoid all CGA's and calcrete deposits.
2. Groundwater pumping operations will be managed to ensure that a minimum 2000 m buffer of zero drawdown is maintained between any calcrete deposit and the maximum limit of drawdown propagation from a groundwater pumping station.
3. Modelling of the lateral extent of drawdown propagation will be undertaken as required to ensure 2000 m buffer (of zero drawdown) separation from any calcrete..
4. Gravel pits will be located at least 500m away from CGA's or any calcrete deposit.
5. The design of highway drainage should aim to maintain, so far as practicable, natural hydrological processes (run-off, infiltration, groundwater recharge) and water quality.

6. During highway works, best practice environmental management procedures pertaining to hydrocarbons and any other potentially harmful substances should be applied, including procedures for management of leakages and spills.
7. Where there is a likelihood that a CGA or other calcrete deposit may be affected by the highway works then it is recommended that field inspection by a suitably qualified person (geologist, hydrogeologist or groundwater ecologist) be undertaken to confirm that sites selected for groundwater pumping and gravel pits are located to avoid calcrete.

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1 INTRODUCTION

Project Description

This report was commissioned by the Department of Main Roads Western Australia (DMRWA) to provide a desktop assessment of Calcrete Groundwater Assemblages (CGA's) that may be impacted by the upgrade of the Goldfields Highway from Wiluna to Meekatharra (185 kilometres).

The upgrade works will involve the widening (between 6 - 25 metres), raising (approximately 600mm) and sealing of the currently unsealed highway. There are some minor realignments and one of these may be located on a CGA.

The proposed works will require the draw of groundwater from a network of existing and new bores, and the extraction of road building materials (i.e. sand and gravel) to a maximum depth of 5 metres. Approximately 55 road building materials pits will be developed in the local area, approximately 5 hectares each. The gravel pits and groundwater pumping will be located so as to avoid all CGA's.

Culverts and floodway's will be utilised where the road traverses ephemeral creek lines or areas subject to inundation. The proposed works are not expected to negatively impact upon surface water regimes and is expected to facilitate a more natural flow (i.e. rate and direction) of surface water than the current road design.

Scope

The scope of this desktop assessment is to provide advice on the following questions, as specified in the brief from DMRWA (via email from J. Johnston) and reproduced below:

1. Are the mapped extent of known CGA's accurate?
2. Are there potentially other CGA's in the study area?
3. What is the significance of these CGA's in the local, regional, state and national context?
4. Is the project likely to have an impact on these CGA's?
5. Would this impact be considered significant by the Environmental Protection Authority (EPA) under Environmental Protection Act 1986 (EP Act) or by Department of Sustainability, Environment, Water, Population and Community (DSEWPAC) under the Environmental Protection Biodiversity Conservation Act 1999 (EPBC Act) ?
6. The project will require the draw of groundwater from a network of existing and new bores. What distance should be applied to avoid impacts to the CGA's;
7. What management actions are recommended to avoid, reduce and manage potential impacts to CGA's ?

2 METHODS

Legislation and Policy Guidelines

This assessment was prepared with consideration to the following State and Federal legislation and relevant assessment guidelines:

- *Environmental Protection Act 1986* (*EP Act 1986*) (WA).
- Environmental Protection Authority (2013) Environmental Assessment Guideline for consideration of subterranean fauna in environmental impact assessment in Western Australia. EAG No. 12. Environmental Protection Authority, Western Australia, June 2013.
- *Environment Protection and Biodiversity Conservation Act 1999.*
- Department of the Environment, Water, Heritage and the Arts (DEWHA) (2009) Matters of National Environmental Significance: Significant Impact Guidelines 1.1.
- Threatened Species Scientific Committee (TSSC) (2012) National Threatened Ecological Community Strategic Workshop, 8 – 9 March 2012, Canberra.

Information Sources

The following site-specific information sources were used in this assessment:

- Geological Survey of Western Australia (GSWA) maps – 1:250,000 and 1:100,000 series.
- GSWA Hydrogeology map Western Australia – 1:2,500,000 (Commander 1989).
- Western Australian Museum specimen database search northern Yilgarn region.
- Published scientific literature.

3 DEFINITIONS

Terms

Most of the following definitions are from Department of Parks and Wildlife web page on threatened ecological communities <www.dpaw.wa.gov.au/>

An **assemblage** is a defined group of biological entities.

Ecological Community - A naturally occurring biological assemblage that occurs in a particular type of habitat.

Threatening processes are defined as follows:
"Any process or activity that threatens to destroy or significantly modify the ecological community and/or affect the continuing evolutionary processes within any ecological community."

Definitions of Modification and Destruction of an ecological community:

Modification: "changes to some or all of ecological processes (including abiotic processes such as hydrology), species composition and community structure as a direct or indirect result of human activities. The level of damage involved could be ameliorated naturally or by human intervention."

Destruction: "modification such that reestablishment of ecological processes, species composition and community structure within the range of variability exhibited by the original community is unlikely within the foreseeable future even with positive human intervention."

A **threatened ecological community (TEC)** is one which is found to fit into one of the following categories; "presumed totally destroyed", "critically endangered", "endangered" or "vulnerable".

The Minister for Environment may list an ecological community as being threatened if it is presumed to be, or is at risk of becoming, totally destroyed.

"Possible threatened ecological communities that do not meet survey criteria are added to DPaW's **Priority Ecological Community (PEC)** Lists under Priorities 1, 2 and 3.

Calcrete Groundwater Assemblage (CGA) – Unique assemblage of subterranean invertebrates (stygofauna) inhabiting groundwater in calcrete.

Stygofauna are aquatic subterranean fauna that inhabit groundwater in both the saturated and unsaturated zones.

Troglofauna are air-breathing terrestrial subterranean fauna that inhabit the unsaturated zone of aquifers above the watertable and below the soil layer.

Threatened Ecological Communities (TECs)

The department of Parks and Wildlife (ex DEC) has been identifying and informally listing **threatened ecological communities (TECs)** since 1994.

As of March 2013, 367 ecological communities had been entered into the TEC database.

- The WA Minister for Environment has endorsed 69 of these:
  - 21 critically endangered
  - 17 endangered
  - 28 vulnerable
  - 3 presumed totally destroyed.
- 23 of these TECs are also listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*.

Note: None of the above listed TEC's are Calcrete Groundwater Assemblages and therefore do not require further consideration in relation to this Project scope.

- The remaining 297 ecological communities are allocated to one of five priority categories (**priority ecological communities**).

Ecological communities with insufficient information available to be considered a TEC, or which are rare but not currently threatened, are placed on the Priority list and referred to as **priority ecological communities (PEC's)**.

Priority Ecological Communities (PECs)

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community List under priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as threatened ecological communities. Ecological communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

Note: All Calcrete Groundwater Assemblages are treated as Priority 1 PECs.

Priority 1 PEC's

Priority 1 PEC's are poorly-known ecological communities. Priority 1 PEC's are defined as:

"Ecological communities that are known from very few occurrences with a very restricted distribution (generally ≤5 occurrences or a total area of ≤ 100ha). Occurrences are believed to be under threat either due to limited extent, or being on lands under immediate threat (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) or for which current threats exist. May include

communities with occurrences on protected lands. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range."

4 POLICY & STATUTORY CONTEXT

In Western Australia, the Environmental Protection Authority (EPA) has legislative responsibility to protect the environment and to prevent, control and abate pollution and environmental harm. The EPA fulfils these duties in part by conducting environmental impact assessment (EIA) of major projects and providing independent advice to Government on whether the environmental risks and impacts can be managed. The EPA has developed a series of Guidance Statements for the EIA of major projects including guidance statements specifically for subterranean fauna (EPA 2003, 2007, 2012).

In the last two decades subterranean fauna has become prominent as a key environmental factor in around 40 major project assessments in Western Australia (EPA 2012). Most of these EIA's have related to mining projects in the mineral-rich regions of the Pilbara and Yilgarn. In accordance with the *Wildlife Conservation Act 1950* and the *Environmental Protection Act 1986*, the EPA 'will ensure that proposals do not potentially threaten the viability of any subterranean species' and 'ensure adequate protection of important habitats for these species' (EPA 2003).

Environmental Protection Act 1986

"The Environmental Protection Act 1986 (the Act) provides for the referral and environmental impact assessment (EIA) of proposals and schemes likely, if implemented, to have a significant effect on the environment. The EPA uses environmental factors and associated objectives as the basis for assessing whether a proposal or scheme's impact on the environment is acceptable. They therefore underpin the EIA process."

Environmental Assessment Guidelines

"Environmental Assessment Guidelines (EAGs) – formerly Guidance Statements – are issued by the EPA to provide advice to proponents and the public generally on the procedures and minimum environmental requirements that the EPA expects to be met during the environmental impact assessment process.

EAGs are not statutory documents. However, a proponent wishing to deviate from the minimum level of performance set out in an EAG would be expected to put a well-researched and clear justification to the EPA arguing the need for the deviation. An argument to deviate from the requirements in an EAG should demonstrate that all practicable endeavours have been made to meet the intent of the Guideline."

EAG No. 8 Environmental factors and objectives

"This guideline sets out the EPA's environmental factors and associated objectives for the purposes of EIA. An environmental factor is described as the part of the environment that may be impacted by an aspect of the proposal. The related environmental objective for each factor is the desired goal that, if met, will indicate that the proposal is not expected to have a significant impact on the environment."

EAG No. 9 Application of a significance framework in the EIA process

"The EPA applies a Significance Framework to make decisions through the environmental impact assessment process, based on the concept of significance established under the Environmental Protection Act 1986. The likely significance of impacts in relation to meeting the EPA's environmental objectives for each key environmental factor will be the focus of the EIA process."

"Key environmental factors are those factors where the EPA's objectives may be met, but where there is a (current) lack of confidence, signifying the need for more information or conditions related to implementation (including, if necessary, offsets).

If there is early confidence that none of the factors are key environmental factors, the proposal will not be assessed by the EPA. As soon as there is confidence that a factor is not a key environmental factor, that factor will receive no further consideration by the EPA."

EAG No. 11 Recommending environmental conditions

The EPA may consider that conditions are required for particular factors so they are adequately mitigated to meet the environmental objective (that is, to bring the proposal below the significance threshold), and will recommend conditions accordingly.

EAG No. 12 Subterranean fauna

EAG No. 12, finalised and released 30 June 2013, sets out the EPA's preferred approach for the consideration of subterranean fauna in environmental impact assessment. It aims to ensure that the standard of survey and type of information provided to the EPA have a sound scientific basis to enable it to understand impacts. This EAG supersedes Guidance Statement No. 54 (EPA 2003) however Draft Guidance Statement 54a (EPA 2007a) is still used to provide information on sampling techniques.

Environmental Protection & Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as matters of national environmental significance. Under the EPBC

Act an action will require approval from the minister if the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance.

Note: None of the CGA's listed as PEC's by DPaW are listed threatened ecological communities (or species) under the EPBC Act. This does not mean that these CGA's would not qualify for listing as a TEC under the EPBC Act if a proposed 'action' posed a 'significant impact'.

The Significant Impact Guidelines 1.1 (DEWHA 2009) for matters of National Significance (EPBC Act 1999), state the following:

What are matters of national environmental significance?

"The matters of national environmental significance are:

- *listed threatened species and ecological communities*
- *migratory species protected under international agreements*
- *Ramsar wetlands of international importance*
- *the Commonwealth marine environment*
- *World Heritage properties*
- *National Heritage places*
- *Great Barrier Reef Marine Park, and*
- *nuclear actions.*

A person who proposes to take an action that will have, or is likely to have, a significant impact on a matter of national environmental significance must refer that action to the minister for a decision on whether assessment and approval is required under the EPBC Act."

What is an action?

'Action' is defined broadly in the EPBC Act and includes: a project, a development, an undertaking, an activity or a series of activities, or an alteration of any of these things.

Actions include, but are not limited to: construction, expansion, alteration or demolition of buildings, structures, infrastructure or facilities; industrial processes; mineral and petroleum resource exploration and extraction; storage or transport of hazardous materials; waste disposal; earthworks; impoundment, extraction and diversion of water; agricultural activities; aquaculture; research activities; vegetation clearance; culling of animals; and dealings with land.

Actions encompass site preparation and construction, operation and maintenance, and closure and completion stages of a project, as well as alterations or modifications to existing infrastructure.

An action may have both beneficial and adverse impacts on the environment, however only adverse impacts on matters of national environmental significance are relevant when determining whether approval is required under the EPBC Act."

What is a significant impact?

"A 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts."

Potential Impacts Subterranean Fauna

The EPA's (2013) EAG No. 12 states that impacts on (subterranean) fauna may be direct or indirect. Direct impacts include the removal, disturbance or compaction of habitat or water quality changes. Indirect impacts include changes to hydrology, siltation, alteration to nutrient balance (EPA 2013). The likely degree of the impact can be determined from a series of characteristics including the proportion and extent of habitat removal, duration of impact, effects on water quality and hydrology, and degree of ecological isolation if contiguous habitat is interrupted. Depending on the proportion of the geological feature containing the troglofauna habitat proposed to be extracted, the degree of impact would be moderate to high (EPA 2013).

Examples of impact types include (from EAG No. 12; EPA 2013,):

- *Excavation of rock*
- *Groundwater extraction/dewatering (single bore/bore-field)*
- *Groundwater reinjection*
- *Changed surface topography due to compaction or creation of hard surfaces resulting in altered groundwater flow paths and increased runoff and reduced infiltration and aquifer recharge*
- *Potential leaks resulting in alterations to ground water quality including waste water, introduction of toxins or radiation*
- *Salinization due to pit voids or intrusion*
- *Vegetation clearing - leading to sedimentation and changed nutrient inputs.*

Impact Assessment Subterranean Fauna

The EPA's (2013) EAG No. 12 for subterranean fauna does not provide criteria for ranking the degree of impact as either 'low', 'moderate', 'high' (ie. significant) , but it does recommend that justification of measures used to define the scale for each characteristic should be outlined, and should be based on the unique impacts of a proposal.

The EPA's EAG No. 12 further states:

> *"For example the degree of impact to stygofauna is likely to be low where the project impact is only above ground. Examples of groundwater abstraction on stygofauna could range from a single bore impacting on a relatively large aquifer to a series of bores impacting on a similar sized aquifer. In the former, if the duration was short and the spatial extent was low, the degree of impact would be low. In the latter, if the duration was long, the spatial extent was moderate or high and the level of water drawdown was several metres, the degree of impact would be high. Excavation or mining of rock would impact permanently on troglofauna. Depending on the proportion of the geological feature containing the troglofauna habitat proposed to be excavated, the overall degree of impact would be moderate to high."*

5 GROUNDWATER CALCRETES

In the semi-arid northern Yilgarn craton there occur numerous (> 100) isolated groundwater calcretes developed along palaeoriver systems (Morgan 1993, Mann and Horwitz 1996) (Figure 1). Development of these calcretes was initiated during dry climatic conditions in the Oligocene and has continued during subsequent arid phases of the Late Miocene and Pliocene onwards (Morgan 1993). The calcrete aquifers have a well-developed karstic porosity and therefore provide an ideal habitat for stygofauna.

The mapped distribution of groundwater calcretes in the northern Yilgarn is shown in Figure 1. Around 200 major calcretes are shown on the 1:2,500,000 GSWA hydrogeological map (Commander 1989). Many more smaller calcretes are shown on the finer-scale 1:250,000 and 1:100,000 GSWA maps.

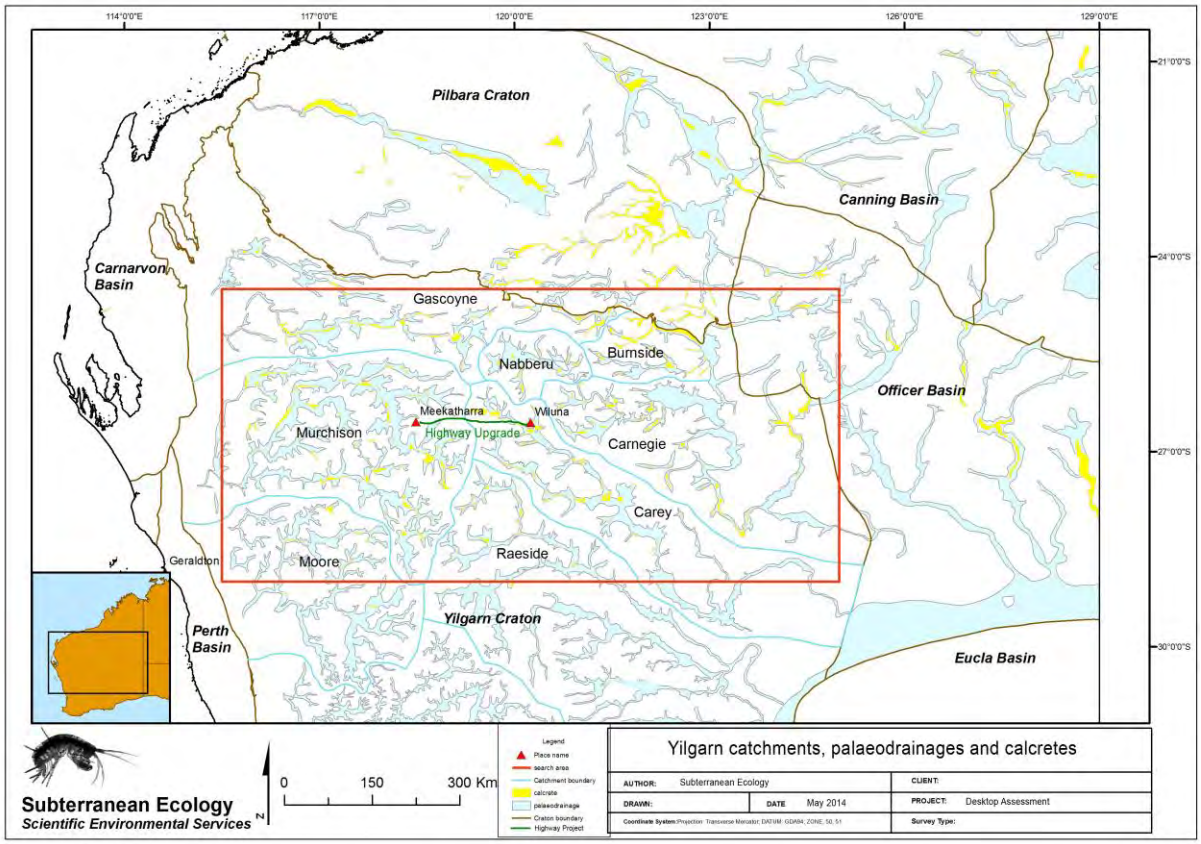

Figure 1 Yilgarn and Pilbara cratons showing palaeodrainages and calcrete deposits, Yilgarn palaeoriver catchments, stygofauna data search area boundary (red) and Wiluna – Meekatharra Highway (green). Hydrogeology adapted from Commander (1989).

6 CALCRETE GROUNDWATER ASSEMBLAGES (CGA's)

The term Calcrete Groundwater Assemblage (CGA) refers to the ecological community or assemblage of subterranean invertebrates (typically stygofauna) that inhabit groundwater in calcrete.

Groundwater of (semi-) arid Western Australia is becoming known as a globally significant hotspot for subterranean biodiversity (Humphreys 2008, Eberhard *et al.* 2009, Guzik *et al.* 2011). Most of this rich diversity has only been discovered in the last 15 years in two main geographic regions, the Pilbara craton and the northern Yilgarn craton (Figure 1).

In the northern Yilgarn each calcrete aquifer functions as a hydrogeological 'island' (Cooper et al. 2002, 2008); and many species of stygofauna are locally endemic to a single calcrete, or a few geographically proximal calcretes (Leys and Watts 2008). Each calcrete 'island' or proximal cluster of islands typically harbors a unique assemblage of species considered to represent a 'type' of Calcrete Groundwater Assemblage (CGA).

The CGA's in the Yilgarn calcretes harbor many species of stygofauna including dytiscid diving beetles (Cooper et al. 2002; Leys et al. 2003) and numerous crustaceans, including amphipods (Cooper et al. 2007; Bradford et al. 2010), isopods (Cooper et al. 2008), ostracods (Karanovic and Marmonier 2002; Karanovic 2004, 2006), parabathynellids (Guzik et al. 2008), and copepods (De Laurentiis et al. 2001; Karanovic and Cooper 2011, 2012).

More recently, troglofauna have also been found in the Yilgarn calcretes. They have been less-studied than stygofauna, but similarly comprise unique assemblages of troglobitic arthropods including palpigrades (Barranco and Harvey 2008), pseudoscorpions (Edward and Harvey 2008) and spiders (Platnick 2008) for example. Their concordant occurrence within groundwater calcretes suggests that troglofauna should also be considered as comprising an element within a CGA.

CGA's in the northern Yilgarn

Review of the published scientific literature and collation with results from the WA Museum database search revealed subterranean fauna records from 68 groundwater calcretes in the northern Yilgarn (Figure 2).

Note: Many additional calcretes have not been sampled for stygofauna, however it can be assumed with a high degree of confidence that any calcrete body that intersects permanent groundwater is likely to harbor a CGA, and, that the stygofauna / troglofauna assemblage is likely to include short range endemic species of conservation significance.

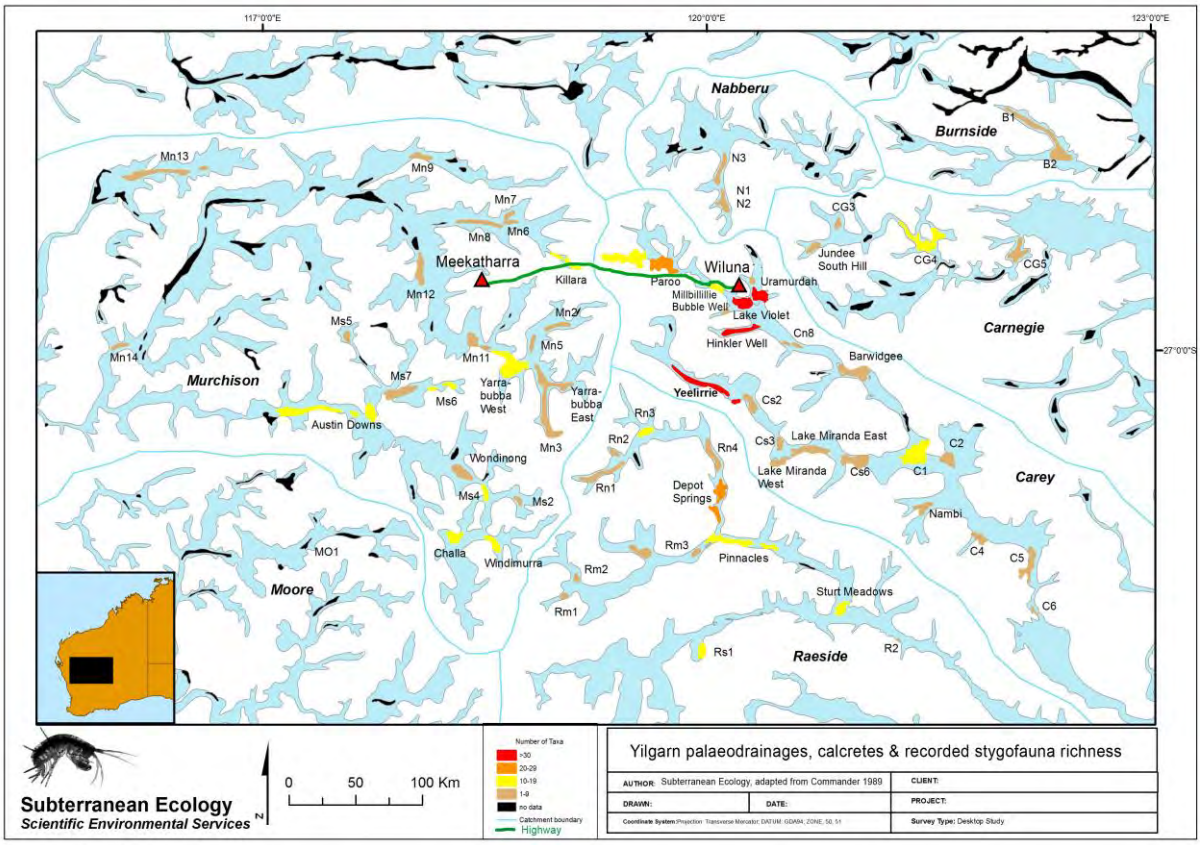

Figure 2 Northern Yilgarn stygofauna records search area showing palaeodrainages and calcrete deposits, palaeoriver catchments, and Wiluna – Meekatharra Highway (green). Hydrogeology adapted from Commander (1989).

CGA's listed as PEC's

Seventy-four (74) CGA's in the northern Yilgarn are listed as PEC's (Priority 1) by DPaW (version 19, September 2013). Each of these PEC's are identified by a unique name (eg. Millbillillie Bubble Well Calcrete) and all carry the same generic description - "unique assemblage of invertebrates." Similarly, for all these PEC's the identified threat is "mining". This of course does not preclude other potential threats from non-mining activities including this Project.

Thirty (30) listed CGA PEC's occur within DMRWA's defined study area which extends for approximately 50 km of the Wiluna-Meekatharra Highway (Table 1). Three of these listed PEC's are relevant to this project. These are the Killara, Paroo, and Millbillillie Bubble Well CGA's.

Note: Numerous additional calcretes occur within the study area, and these very likely also harbor CGA's that would qualify for listing as Priority 1 PEC's. These have not been listed as PEC's by DPaW because they have not been sampled for stygofauna. These additional calcretes and potential CGA's are identified later in this report.

Table 1. Listed CGA PEC's on DPaW database located within approximately 50 km of the Wiluna-Meekatharra Highway (data provided by DMRWA). Three calcretes of particular relevance to this project are highlighted in bold.

Name	Priority	Buffer (m)	Approx. Area (Ha)
Killara Calcrete	Priority 1	2000	5,219
Paroo Calcrete	Priority 1	2000	14,547
Millbillillie Bubble Well Calcrete	Priority 1	2000	2,107
Doolgunna Calcrete	Priority 1	2000	1,922
Hillview Calcrete	Priority 1	2000	2,451
Murchison Calcrete	Priority 1	2000	4,249
Hinkler Well Calcrete	Priority 1	2000	7,322
Kaluwiri Calcrete	Priority 1	2000	4,710
Lake Way South Calcrete	Priority 1	2000	1,706
Milgun Central Calcrete	Priority 1	2000	2,303
Milgun South Calcrete	Priority 1	2000	219
Mount Padbury Calcrete	Priority 1	2000	4,016
Old Cunyu Calcrete	Priority 1	2000	6,424
Polelle Calcrete	Priority 1	2000	6,007
Three Rivers Calcrete	Priority 1	2000	269
Three Rivers Plutonic Calcrete	Priority 1	2000	26,958
Yeelirrie Calcrete	Priority 1	2000	17,691
Belele Calcrete	Priority 1	2000	10,769
Albion Downs Calcrete	Priority 1	2000	4,085
Cunyu Calcrete	Priority 1	2000	8,625
Killara North Calcrete	Priority 1	2000	2,110
Karalundi Calcrete	Priority 1	2000	1,090
Wiluna BF Calcrete	Priority 1	2000	232
Uramurdah Calcrete	Priority 1	2000	2,105
Lake Violet Calcrete	Priority 1	2000	3,211
Yarrabubba West Calcrete	Priority 1	2000	1,554
Nowthanna Calcrete	Priority 1	2000	5,307
Colga Calcrete	Priority 1	2000	7,948
Yarrabubba East Calcrete	Priority 1	2000	12,401
Mingah Springs Calcrete	Priority 1	2000	37

7 ASSESSMENT

Mapping Reliability

Is the mapped extent of known CGA's accurate?

The mapped extent of known CGA's cannot be assumed to be accurate. Moreover, reliability in mapping will vary between and within geological map sheets. While the 'accuracy' of mapped extent of known CGA's is likely to be reasonable in terms of general location of calcrete bodies, the mapping may be imprecise with respect to definition of boundaries. For example, there are significant discrepancies between the 1:250,000 and 1:100,000 scale geological maps in the mapped extent for many calcrete bodies, including the three CGA's of relevance to this project. This is not unusual and is to be expected with regard to the practicalities in geological survey.

For the major calcrete bodies depicted on the geological maps and those listed as PEC's, the mapped geological boundaries may be considered representative but cannot necessarily account for subsurface extensions or discontinuities, or completely buried calcrete deposits that exhibit no surface expression at all. It is possible, indeed likely, that small calcrete bodies, or larger calcrete bodies with little or no surface expression, remain undetected and undocumented. For purposes of this assessment, the locations and areas of occupation of calcrete bodies may be treated as broadly indicative, but a precautionary approach is recommended with respect to boundary definition. It is noted that DPaW's list of CGA PEC's (Table 1) provides an estimate of each calcrete area (ha) but also applies a 2000m buffer around each.

The likelihood that additional small and/or obscured CGA's lie undetected in the study area cannot be precluded. Indeed, this is likely. This uncertainty can be managed by taking a precautionary approach and planning for this contingency in operational procedures (see mitigation options later).

Additional unlisted CGA's

Are there potentially other CGA's in the study area?

In the study area there are at least 19 additional calcrete deposits (or deposit clusters) shown on the geology maps which are not recognised as CGA's or listed as PEC's. It can be assumed with a high degree of confidence that any calcrete body that intersects permanent groundwater is likely to harbor a CGA and therefore qualify as a PEC Priority 1.

These additional calcrete deposits are not listed as PEC's because they have not been sampled for subterranean fauna. They have not been sampled owing to the very large number of calcrete deposits throughout the Yilgarn, and the limited number of subterranean fauna surveys carried out to date. Many calcretes, or portions of calcretes, are not accessible for sampling if there are no water bores or

pastoral wells present. Any calcrete deposits that intersect permanent groundwater are likely to harbor CGA's.

The listed PEC's and additional calcrete deposits shown on the geology maps are listed in Table 2 and also highlighted on the geology maps appended to this report. Many deposits are geographically clustered and clearly genetically related, and these clusters have been grouped together to avoid an inordinately lengthy list. The identified additional deposits have been assigned a provisional name based on their geographic location or a named nearby feature. It is possible, indeed likely, that small calcrete bodies, or larger calcrete bodies with little or no surface expression, remain undetected and undocumented on the geological maps.

For ease of interpretation, all mapped calcretes, including those shown on the 100k series maps but not shown on the 250k series, have been indicated on the two 250k series maps which cover the project area (Glengarry and Wiluna 1:250k sheets). The 100k series maps should also be referred to for more detailed locations and boundaries as required. There are five 100k maps covering the project area which are provided attached to this report but note that two additional 100k maps (Gabanintha and Yanganoo) relevant to this project area were not available on the DMP site (http://www.dmp.wa.gov.au/) so they may be out of print or unpublished.

Table 2 Additional calcretes and potential CGA's identified on 250k and 100k geological series maps (refer maps appended). Sites are listed approximately from west to east. Listed PECs are in bold.

Name	Description	250k geo sheet	100k geo sheets	Notes
Karalundi Calcrete	Karalundi calcrete groundwater assemblage type on Murchison palaeodrainage on Karalundi Station	Glengarry	Glengarry	
Cork Tree Bore	Two calcretes south of Karalundi Calcretes	Glengarry	Glengarry	
Holt Well (Bolt Well)	Calcretes east of Karalundi Calcretes	Glengarry	Glengarry	
Munarra	Small calcrete E of Munarra Homestead and SW of Deep Well	Glengarry	Glengarry	Not indicated on 100k
Glengarry Creek	Glengarry Creek 8 km S of Bolts (Holts) Well & 4 km NW Mistletoe Well	Glengarry	Glengarry	Not mapped on 250k
Talval	South of Talval Outcamp, NE of Limestone Well, south of Meekatharra	Glengarry	Gabanintha NA	
Limestone Well	SW of Talval Outcamp, south of Meekatharra	Glengarry	Gabanintha NA	
Hillview Calcrete	Hillview calcrete groundwater assemblage type on Murchison palaeodrainage on Hillview Station	Glengarry	Gabanintha NA	
Murchison Calcrete	Murchison Downs calcrete groundwater assemblage type on Murchison palaeodrainage on Murchison Downs Station	Glengarry	Gabanintha - Yaganoo NA	
Top Well	NE of Murchison Calcretes	Glengarry	Yaganoo NA	
Killara North Calcrete	Killara North calcrete groundwater assemblage types on Murchison palaeodrainage on Killara Station	Glengarry	Glengarry - Moologool	
Killara Calcrete	Killara calcrete groundwater assemblage types on Murchison palaeodrainage on Killara Station	Glengarry	Moologool	
Morrie Northwest	Small calcrete approx. 1.5 km NW of Morrie Bore	Glengarry	Moologool	
Morrie Bore	Small calcrete at Morrie Bore	Glengarry	Moologool	Not mapped on 250k
Morrie North	Small calcrete (?) approx. 2 km N of Morrie Bore Morrie Bore	Glengarry	Moologool	Mapped as siltstone on 100k
Large Gum Creek	Small calcrete on tributary of Large Gum Creek, N of Diamond Well Homestead	Glengarry	Mount Bartle	
Dura Bore	Small calcrete NE of Paroo Homestead	Glengarry	Mount Bartle	
Paroo West	Series of > 20 scattered calcrete deposits forming a western extension of main Paroo Calcrete, includes Limestone & White Wells, Rabbit, Meeks, Saltbush and Bobs Bores.	Glengarry	Moologool - Mount Bartle	
Paroo Calcrete	Paroo calcrete groundwater assemblage type on Carey palaeodrainage on Paroo Station	Glengarry	Mount Bartle	
Paroo Southwest	Two calcrete deposits southwest of main Paroo Calcrete	Glengarry	Mount Bartle	Not mapped on 250k

Paroo Southeast	Six calcrete deposits comprising southeast extension of main Paroo Calcrete	Glengarry	Mount Bartle	Not mapped on 250k
Mount Bartle	Four calcrete deposits between Mount Bartle and Mount Russell	Glengarry	Mount Bartle-Merewether	Not mapped on 250k
Yandil	Mutliple calcrete clusters north and east of Yandil Homestead	Glengarry	Mount Bartle	Not mapped on 250k
Gum Creek	Small calcrete north of Millbillillie Bubble Well Calcrete	Glengarry - Wiluna	Mount Bartle - Wiluna	Not shown Glengarry 250k
Bellah Bore	Small calcrete west of Mt Merewether	Glengarry	Merewether	
Millbillillie Bubble Well Calcrete	Millbillillie Bubble Well groundwater calcrete assemblage type on Carey palaeodrainage on Millbillillie Station	Glengarry - Wiluna	Merewether - Wiluna	
Uramurdah Calcrete	Uramurdah Lake calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station	Wiluna	Wiluna	
Lake Violet Calcrete	Lake Violet south and Lake Violet calcrete groundwater assemblage types on Carey palaeodrainage on Millbillillie Station	Wiluna	Wiluna	
Hinkler Well Calcrete	Hinkler Well calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station	Wiluna	Wiluna	

Significance of CGA's

What is the significance of these CGA's in the local, regional, state and national context?

The CGA's in the study area are significant at all scales, from local to regional, state, national and global.

Each CGA has local significance because it contains a unique assemblage of invertebrates, including species that are locally endemic to each calcrete.

Collectively, the CGA's have regional significance because each calcrete 'island' with its unique invertebrate assemblage comprise an element making up an 'archipelago' which collectively represent a significant component of Western Australia's subterranean biodiversity.

At national levels, the richness and significance of the Yilgarn CGA's has only been recognized over the last decade or so, but has led to them being recognised as a globally significant biodiversity hotspot for stygofauna (Culver and Pipan 2009).

The high conservation significance of the CGA's is exemplified by the blind diving beetles of the family Dytiscidae. More than 100 species of dytiscid diving beetles have been described from calcrete aquifers throughout the Yilgarn, representing the highest stygal diversity of this group in the world. The calcrete island distribution pattern is replicated in other stygofauna groups (e.g. syncarids, amphipods, isopods), with the majority of species being SRE, restricted to single (or proximal) calcrete aquifers (Bradford *et al*. 2010; Cooper *et al*. 2002, 2007, 2008; Guzik *et al*. 2008, 2009; Humphreys 2001, 2006, 2008, Humphreys *et al*. 2009; Watts and Humphreys 1999, 2000, 2001, 2003, 2004, 2006, Leys *et al*. 2003).

More recently, troglofauna have been discovered in the Yilgarn calcretes, including, for example, a species of spider (Platnick 2008), a pseudoscorpion (Edward and Harvey 2008), and the first Australian native species of palpigrade (Barranco and Harvey 2008). All of these species are currently known from single calcretes and are likely to include short range endemic (SRE) species.

Potential Impacts

Is the project likely to have an impact on CGA's?

Based on the EPA's (2013) EAG for consideration of subterranean fauna in environmental impact assessment in Western Australia, the potential direct and indirect impacts relevant to CGA's and considered in regard to this Project are listed below with project-specific qualifications [underlined in square brackets]:

- Excavation of rock / gravel [only if on calcrete].
- Groundwater extraction/dewatering [single bore/bore-field if affecting calcrete aquifer].
- Changed surface topography due to compaction or creation of hard [impermeable road] surfaces resulting in increased runoff and reduced infiltration and aquifer recharge [or modified infiltration / recharge regime].
- Potential leaks [or sediment-laden runoff] resulting in alterations to ground water quality including waste water, introduction of toxins or radiation [eg. hydrocarbon spills, sediments]
- Salinization due to pit voids or intrusion [if gravel pits extend below watertable in or near calcrete]
- Vegetation clearing [road drainage and runoff] - leading to sedimentation and changed nutrient inputs [only when on or near calcrete].

While there exist a diverse suite of potential impacts, all of these can be avoided, managed and mitigated to ensure that the Project does not pose an unacceptable risk to conservation of CGA's. Management and mitigation measures are outlined in a later section.

Significance of Potential Impacts

Would any potential impacts be considered significant by the EPA under EP Act 1986 or by DSEWPAC under the EPBC Act 1999?

The EPA's (2013) EAG No. 12 for subterranean fauna does not provide criteria for ranking the degree of impact as either 'low', 'moderate', 'high' (ie. significant) , but it does recommend that justification of measures used to define the scale for each characteristic should be outlined, and should be based on the unique impacts of a proposal.

To address the question - 'Would the impact of this Project be considered significant by the EPA under EP Act 1986 or by DSEWPAC under the EPBC Act 1999? – the EPBC Act listing criteria for assessing TECs (Threatened Species Scientific Committee 2012) were tested against the situation evidence for this Project (Table 3).

Table 3 suggests that there is no existing evidence and a low likelihood that the proposed Project actions will pose a threat to CGA's subject to the following key assumptions / mitigation measures:

4. Groundwater pumping or drawdown will not impinge on any CGA's.
5. Best practice operational procedures are applied to avoid and manage potential impacts to groundwater recharge and groundwater quality, that might result from road building activities on or near to CGA's including drainage, gravel pits and control of leakage / spills.

Table 3 Evaluation of Project against EPBC Act listing criteria for assessing Threatened Ecological Communities (TSSC 2012). Note key assumptions at bottom (continued overleaf).

Criterion		EPBC Act Category			Goldfields Highway Upgrade Project		
		Critically Endangered	Endangered	Vulnerable	Situation / Evidence	Assumptions /Comments	* Meets Criteria for TEC listing?
1	Its decline in geographic distribution is:	very severe > 95%	severe > 90%	substantial > 70%	No evidence and low likelihood that proposed actions will cause a decline in geographic distribution if assumptions are true*	*Assumes groundwater pumping or drawdown impacts will not affect any CGA's.	No
2	Its geographic distribution is: and the nature of its distribution makes it likely that the action of a threatening process could cause it to be lost in:	very restricted the immediate future	restricted the near future	limited the medium-term future	Geographic distribution of CGA's is very restricted but No evidence and low likelihood that proposed actions will pose a threat if assumptions are true*	*Assumes groundwater pumping or drawdown impacts will not affect any CGA's.	No
3	For a population of a native species that is likely to play a major role in the community, there is a: to the extent that restoration of the community is not likely to be possible in:	very severe decline the immediate future	severe decline the near future	substantial decline the medium-term future	No declines documented and low likelihood that proposed actions will pose a threat if assumptions are true*	*Assumes groundwater pumping or drawdown impacts will not affect any CGA's.	No
4	The reduction in its integrity across most of its geographic distribution is: as indicated by degradation of the community or its habitat, or disruption of important community processes, that is:	very severe very severe	severe severe	substantial substantial	No degradation of community, habitat or processes documented, and low likelihood that proposed actions will pose a threat if assumptions are true*	*Assumes groundwater pumping or drawdown impacts will not affect any CGA's. *Assumes best practice operational procedures are applied to avoid and manage potential impacts to groundwater quality that might result from road building activities on or near to CGA's, including drainage, gravel pits and control of leakage / spills.	No

5	Its rate of continuing detrimental change is: as indicated by: (a) rate of continuing decline in its geographic distribution, or a population of a native species that is believed to play a major role in the community, that is: or (b) intensification, across most of its geographic distribution, in degradation, or disruption of important community processes, that is:	very severe very severe very severe	severe severe severe	substantial serious serious	No detrimental changes documented, and low likelihood that proposed actions will pose a threat if assumptions are true*	*Assumes groundwater pumping or drawdown impacts will not affect any CGA's. *Assumes best practice operational procedures are applied to avoid and manage potential impacts to groundwater quality that might result from road building activities on or near to CGA's, including drainage, gravel pits and control of leakage / spills.	No
6	A quantitative analysis shows that its probability of extinction, or extreme degradation over all of its geographic distribution, is:	at least 50% in the immediate future	at least 20% in the near future	at least 10% in the medium-term future	Quantitative analysis not attempted.	Insufficient data for reliable quantitative analysis.	N/A

Notes:
Species in the extinct and conservation dependant categories of species listed under the EPBC Act, and listed ecological communities in the vulnerable category of ecological communities listed under the EPBC Act, are not matters of national environmental significance for the purposes of Part 3 of the EPBC Act (requirements for environmental approvals).

Species and ecological communities listed under the EPBC Act may differ from those listed under State and Territory legislation. This is due to the different status of some species and ecological communities in the different States and Territories, and nationally.

*** Key Assumptions:**
*Assumes groundwater pumping or drawdown impacts will not affect any CGA's.
* Best practice operational procedures are applied to avoid and manage potential impacts to groundwater quality that might result from road building activities on or near to CGA's, including drainage, gravel pits and control of leakage / spills.

8 ENVIRONMENTAL MANAGEMENT & MITIGATION

8.1 Environmental Management Objectives

The environmental factors and objectives adopted by the EPA (EAG No. 8) which are relevant to this Project and scope are listed in Table 4.

While the scope of this report is primarily focused on subterranean fauna the importance of **hydrological processes** and **water quality** to maintain the habitat and environmental conditions for subterranean fauna is emphasised.

Recommendation:

It is recommended that the EPA's Management Objectives for relevant environmental factors (Table 4) be adopted for CGA's and this Project.

Table 4 Environmental factors and management objectives for subterranean fauna, hydrological processes and water quality. From EPA (EAG No. 8).

Environmental factor	Management Objective
Subterranean Fauna	To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.
Hydrological Processes	To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.
Inland Waters Environmental Quality	To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.

8.2 Site selection for groundwater pumping and gravel pits

Because of uncertainties in geological mapping and imprecisely defined boundaries for many CGA's, and the likelihood of encountering different boundaries to those shown on geology maps, and the additional possibility of discovering new calcrete deposits, these scenarios should be considered and planned for in operational procedures.

Where there is a likelihood that a CGA or other calcrete deposit may be affected by the Project then it is recommended that field inspection by a suitably qualified person (geologist / hydrogeologist / groundwater ecologist) be undertaken to confirm that sites selected (via desktop) for groundwater pumping and gravel pits are located to avoid calcrete.

It is recommended that DMRWA document the location and relevant boundaries of any calcrete deposits within 2000 m of Project operations and to report these (with locations mapped) to DPaW.

8.3 Buffers

For most of the listed Priority 1 PEC's, including those relevant to this project, the 2000m buffer zone prescribed by DPaW is a default precautionary distance and probably adequate for reducing the risk of unintentionally impinging upon a known CGA. This buffer distance might potentially be reduced if the boundaries of the CGA are accurately known and depending upon the nature and magnitude of potential impacts occurring within the buffer zone.

For example a gravel pit that does not intersect calcrete or the watertable is unlikely to pose a significant threat to CGA's, and in this case a 500m buffer should be adequate. It is noted that for other types of listed PEC in the study area, namely banded ironstone formation vegetation complexes (Wiluna West, Montague Range) and the invertebrate assemblages of Mibbley Pool, a 500m buffer is prescribed by DPaW. On the other hand, if pumping of groundwater might result in watertable drawdown extending for more 2000 m then a wider buffer zone would be required for any CGA's in the proximity.

Conceptual buffers are indicated in Figure 3.

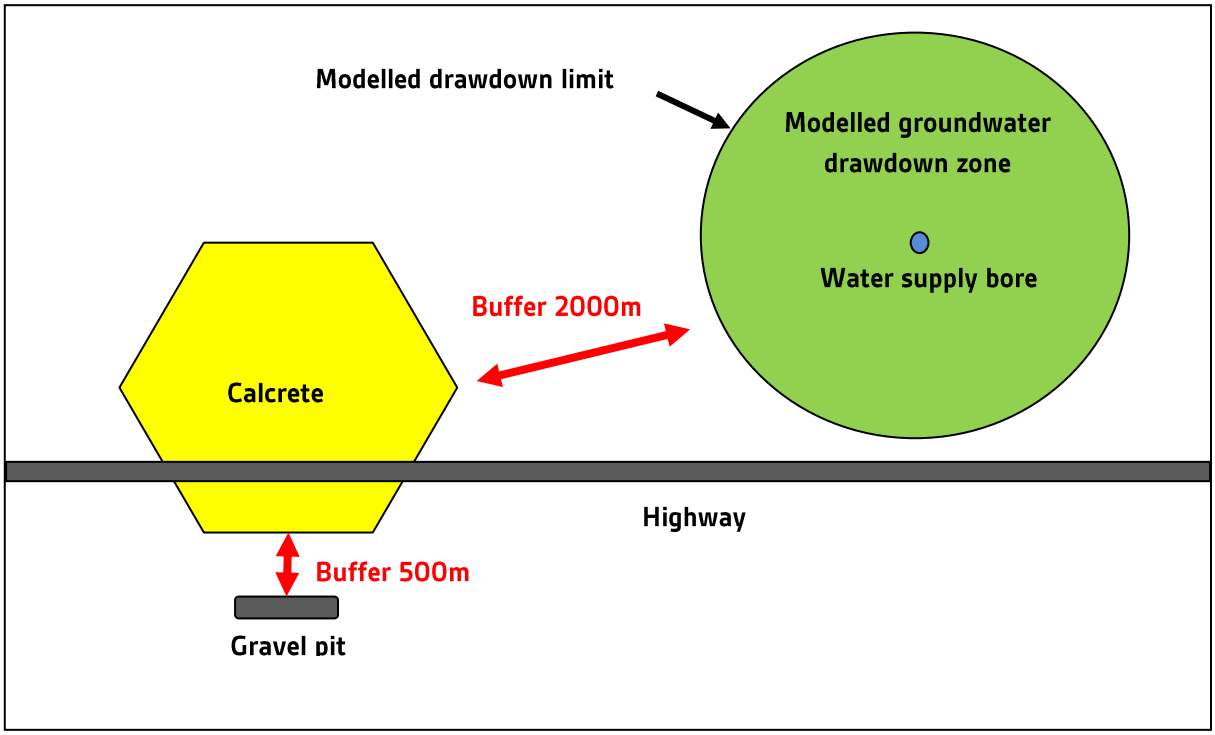

Figure 3 Conceptual buffers for groundwater pumping and gravel pits.

8.4 Groundwater Pumping

What distance should be applied to avoid groundwater drawdown impacts to the CGA's from the network of existing and new bores?

Because the calcrete aquifers and CGA's are typically shallow and have a narrow depth range (often extending only a few metres or tens of metres below watertable) they are vulnerable to desaturation from pumping of groundwater. While CGA's may be tolerant of partial temporary desaturation (assuming rapid watertable recovery), a precautionary approach is recommended owing to the uncertainty of this impact.

Hence, if there is any risk that groundwater drawdown may impinge on a known CGA or other calcrete deposit, then modelling of the lateral extent of groundwater drawdown propagation based on the pumping rate and local aquifer properties may be required to determine an acceptable precautionary distance of separation.

Recommendations:

1. Groundwater pumping will be located so as to avoid all CGA's and calcrete deposits.
2. Groundwater pumping operations will be managed to ensure that a minimum 2000 m buffer of zero drawdown is maintained between any calcrete deposit and the maximum limit of drawdown propagation from a groundwater pump (Figure 3).
3. Modelling of the lateral extent of drawdown propagation will be undertaken as required to ensure 2000 m buffer (of zero drawdown) separation from any calcrete.

8.5 Gravel pits:

Gravel pits that do not intersect calcrete or the watertable are unlikely to pose a significant threat to CGA's, and in this situation a 500m buffer should be adequate.

Where there is a likelihood that a CGA or other calcrete deposit may be affected by gravel pits then it is recommended that field inspection by a suitably qualified person (geologist / hydrogeologist / groundwater ecologist) be undertaken to confirm that sites selected for gravel pits are located to avoid calcrete.

Recommendations:

4. Gravel pits will be located so as to avoid all known (and potential) CGA's.
5. Gravel pits will be located at least 500m away from any calcrete deposit (Figure 3).

8.6 Highway Works:

Recommendations:

6. The design of highway drainage should aim to maintain, so far as practicable, natural hydrological processes (run-off, infiltration, groundwater recharge) and water quality.
7. During highway works, best practice environmental management procedures pertaining to hydrocarbons and any other potentially harmful substances should be applied, including procedures for management of leakages and spills.

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