

# Paradise South Phosphate Project

## Initial Advice Statement

4 June 2010

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### Legend International Holdings Incorporated

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Revision	Details	Date	Amended By
A	Original – Initial Draft	December 2009	G Gough
A2	Draft	3 December 2009	G Gough
B	Final Draft – Revised for changes to project	10 February 2010	P Allen
B	Final – Minor amendments	12 February 2010	P Allen
B1	Final – Minor amendments	March 2010	P Allen
C	Final – Inclusion of ecology summaries	25 May 2010	P Allen
C1	Final – Minor amendments	4 June 2010	P Allen

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Date: 4 June 2010 .....

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# Contents

	<b>Page number</b>
<b>Acronyms</b>	<b>iv</b>
<b>1. Introduction</b>	<b>1</b>
1.1 Purpose of this Initial Advice Statement	1
1.2 Overview of the project	1
1.3 The proponent	2
1.4 Project need	2
1.5 Environmental impact assessment process	5
1.6 Project location	5
1.7 Project tenure	5
1.8 Native Title	7
1.9 Community consultation	7
<b>2. Description of the Project</b>	<b>8</b>
2.1 Mining operation	8
2.2 Ore processing (Beneficiation)	8
2.3 Product transport	9
2.4 Slurry dewatering and rail load out facility	10
2.5 Infrastructure requirements	10
2.5.1 Water supply	10
2.5.2 Power supply	11
2.5.3 Access road	13
2.5.4 Additional mine infrastructure	13
2.5.5 Water management	13
2.6 Waste management	14
2.6.1 Mine waste	14
2.6.2 Non-mine waste	14
2.7 Workforce and accommodation	14
<b>3. Existing environment</b>	<b>15</b>
3.1 Land systems	15
3.1.1 Land use	15
3.1.2 Soils and land suitability	15
3.1.3 Topography	16
3.1.4 Geology of the Phosphate Deposit	16

3.2	Climate	20
3.3	Water resources	20
3.3.1	Surface water hydrology	20
3.3.2	Surface water quality	22
3.3.3	Groundwater	22
3.4	Biological characteristics	23
3.4.1	Existing flora	23
3.4.2	Existing fauna	27
3.4.3	EPBC Act assessment – terrestrial ecology	27
3.4.4	Aquatic ecology	27
3.4.5	EPBC Act assessment – aquatic ecology	28
3.5	Air quality	29
3.6	Noise and vibration	29
3.7	Socio-economic conditions	30
3.8	Cultural heritage values	30
<b>4.</b>	<b>Potential impacts and management requirements</b>	<b>31</b>
4.1	Land systems	31
4.2	Water management and hydrological impacts	31
4.2.1	Water resources	31
4.2.2	Water quality	32
4.3	Biological impacts	33
4.3.1	Terrestrial ecology	33
4.3.2	Aquatic ecology	35
4.4	Air quality	35
4.5	Noise and vibration impacts	35
4.6	Visual amenity impacts	36
4.7	Socio-economic impacts	36
4.8	Cultural heritage impacts	36
4.9	Waste management	36
4.10	Transport impacts	37
<b>5.</b>	<b>References</b>	<b>38</b>

## List of tables

Table 3.1	Stratigraphy of the Paradise South Phosphate Deposit	19
Table 3.2	Ecosystems (REs) in the MLA area and water supply dam inundation area based on DERM certified mapping	23
Table 3.3	Regional ecosystems (REs) in the MLA area and Water Supply Dam Inundation Area based on ground-truthing (Biodiversity Assessment and Management 2009)	24
Table 3.4	Ecosystems (REs) in the Slurry pipeline area based on DERM certified mapping	25
Table 3.5	Regional ecosystems (REs) in the powerline study area based on ground-truthing (Biodiversity Assessment and Management 2009)	26
Table 3.6	Commonwealth conservation status of significant species that may occur in the project area and downstream	28
Table 3.7	Nearest sensitive receptor locations	29

## List of figures

Figure 1.1	Regional location	3
Figure 1.2	Key components of the project	4
Figure 1.3	Mining lease application location and other tenures	6
Figure 3.1	Location of major phosphate deposits of the Georgina Basin, northwest Queensland (after Rogers and Keevers, 1976)	18
Figure 3.2	MLA area and stream locations	21

## List of photographs

Photo 2.1	Rock Phosphate (from Paradise South by hand tools, September 2009)	8
Photo 2.2	Birla Mt Gordon Substation (foreground) with Century Zinc transmission line tower (background)	12

## Acronyms

DERM	Queensland Department of Environment and Resource Management
DSO	Direct Shipment Ore
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
GRP	Gross Regional Product
Mt/a	million tonnes per annum
MLA	Mining Lease Application
PB	Parsons Brinckerhoff
P <sub>2</sub> O <sub>5</sub>	Phosphorus Pentoxide
RE	Regional Ecosystem
ROM	Run of Mine
The project	Paradise South Phosphate Project
TPA	Tonnes per annum

# 1. Introduction

## 1.1 Purpose of this Initial Advice Statement

This Initial Advice Statement (IAS) provides updated information regarding the proposed Paradise South Phosphate Project (the project). This IAS supersedes previous versions of the IAS submitted to DERM in December 2009 and in March 2010.

It is noted that, based on the IAS previously submitted to DERM in December 2009, the Chief Executive of the Department approved the application to voluntarily prepare an EIS on 7 December 2009.

This IAS seeks to provide updated information on the project only, and does not seek any amendment or change to the decision to voluntarily prepare an EIS.

## 1.2 Overview of the project

The project will comprise the development of phosphate resources for export markets and possibly domestic markets with an open-cut phosphate mine and related infrastructure. It is planned to produce up to 12.5 million tonnes per annum (Mtpa) run of mine (ROM) ore. The project deposit is located to the north-west of Mount Isa (Figure 1.1).

The project comprises:

- up to 12.5 Mtpa ROM open cut phosphate mine on Mining Lease Application (MLA) 90197
- up to 12.5 Mtpa ROM feed Beneficiation Plant on MLA 90197
- a 2 km long access road/haul road from the mine site to the Paradise North haul road
- a 45 km long water pipeline from the Thornton Borefield to the Beneficiation Plant
- an approximately 20 km long transmission line from the Mica Creek – Century Zinc transmission line, including a substation/transformer (if required)
- an approximately 142 km long slurry pipeline from the project beneficiation plant to Mount Isa and a 142 km long return water pipeline
- a slurry dewatering and rail load out facility in Mount Isa
- a 2,500 ML/a yield water supply dam
- accommodation facilities at existing mine camps or at a purpose built accommodation facility near the mine.

The key components of the project are shown in Figure 1.2. Further details of the components of the project are provided in Section 2.

It is noted that some components of this infrastructure outlined above will lie outside MLA 90197. For ease of reference, the areas within the boundaries of MLA 90197 are hereafter referred to as 'the MLA area'. The 'project area' is defined as the MLA area plus

the design footprint of the other off-mining lease components of the project (for example, the dam and impoundment design footprint).

Continuing commercial and other feasibility assessments of water, power supply or accommodation options may mean that one or more of these proposed options may be excluded as possible water, power supply or accommodation alternatives and therefore would not form part of the overall assessment undertaken for the EIS.

The concentrated phosphate ore will be transported to Mount Isa via a slurry pipeline. It is anticipated that, subject to further commercial considerations, the concentrated ore will be dewatered at Mount Isa then loaded directly onto trains at a Legend owned facility, for transport to the Port of Townsville. No upgrade to the existing Mount Isa to Townsville railway line or Port of Townsville storage and load out facilities is proposed. The concentrated phosphate ore may be transported via existing roads to Mount Isa if production tonnages are low.

### **1.3 The proponent**

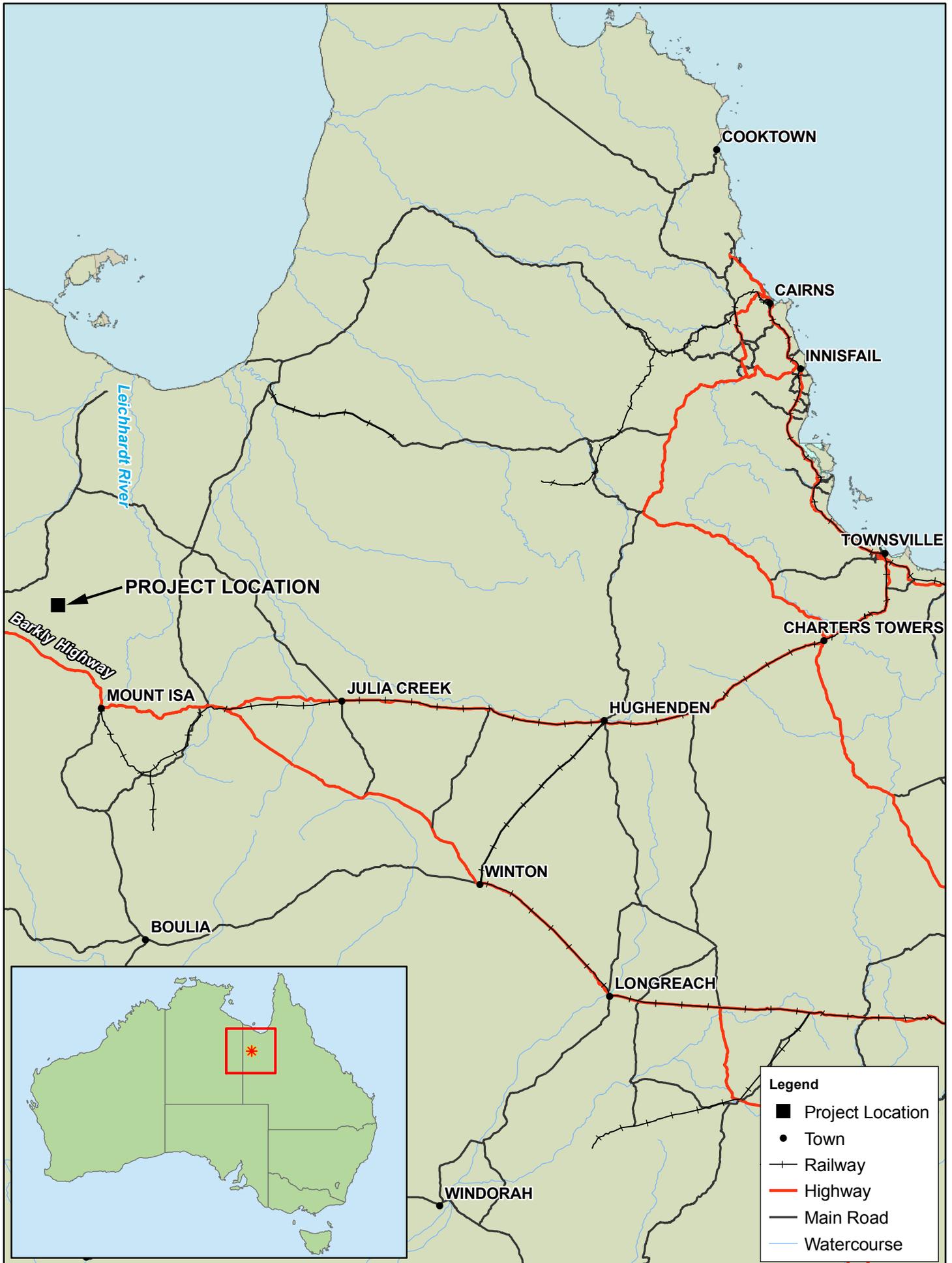
The proponent for the project is Legend International Holdings Incorporated (Legend).

Legend is a publicly listed company involved in the phosphate and fertiliser industry. Legend's current phosphate interests lie in the Georgina Basin, Queensland Australia. Projects include D-Tree North Direct Shipment Ore (DSO) Project, Paradise North DSO Project, Thornton, Lily Creek, Quita Creek, Sherrin Creek and Highland Plains which have combined deposits of more than 1 billion tonnes averaging 16% Phosphorous Pentoxide ( $P_2O_5$ ) based on historical estimates.

Legend has a phased implementation plan to become one of the world's leading suppliers of phosphate fertiliser.

### **1.4 Project need**

Legend is proposing to increase its approved production output of phosphate for export due to strong interest being expressed by offshore phosphate suppliers. Legend is well positioned in the phosphate market to take advantage of current and future market conditions, with expected increases in global demand for phosphate.



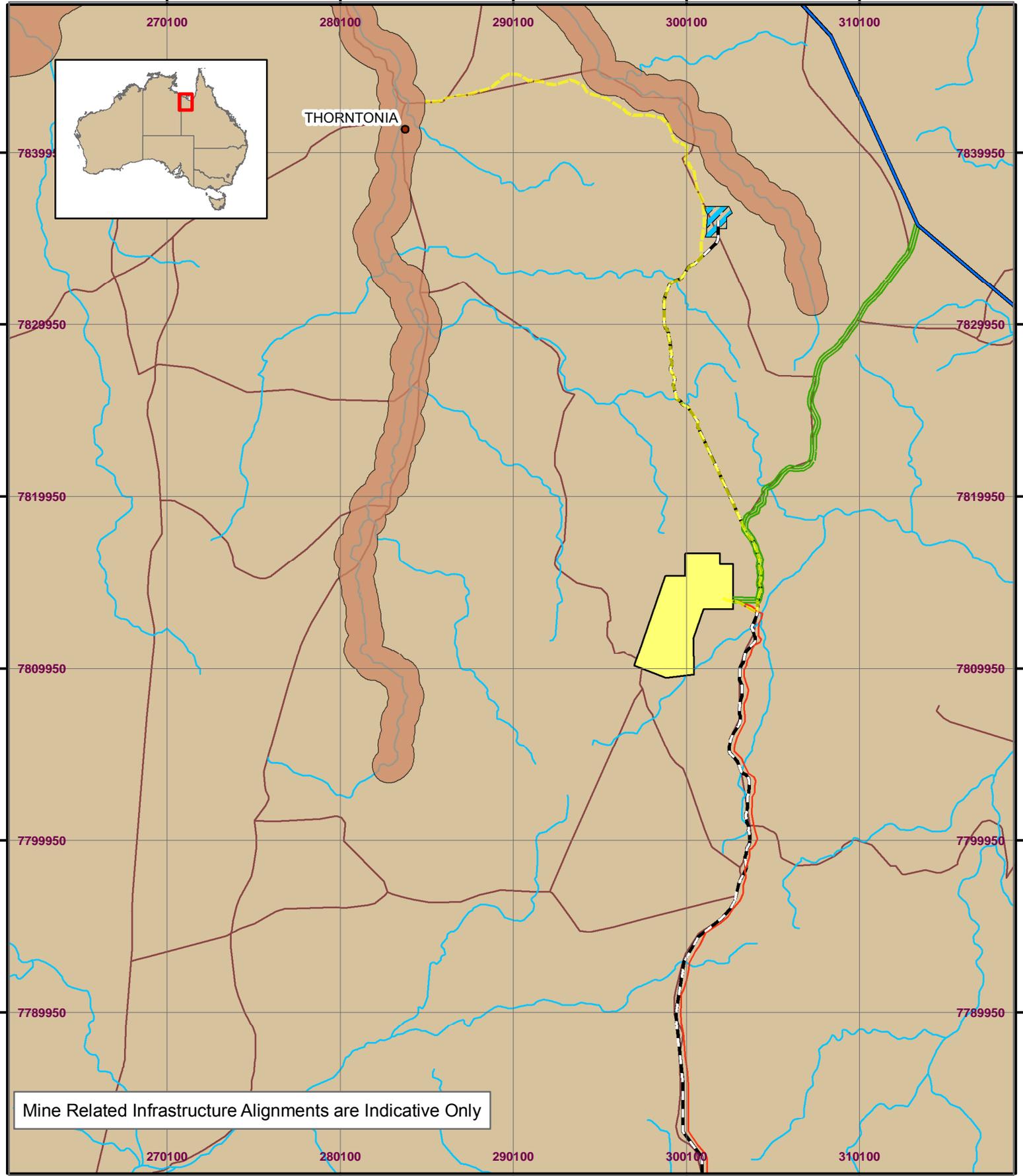
**Legend**

- Project Location
- Town
- +— Railway
- Highway
- Main Road
- Watercourse



Regional Location





Mine Related Infrastructure Alignments are Indicative Only

### Legend

- Thornton Groundwater Pipeline
- Century Zinc Transmission Line
- Proposed Power Transmission Line
- Slurry Pipeline & Return Water Pipeline
- Paradise North Haul Road
- Paradise South MLA Area
- High Preservation Area
- Paradise North MLA Area
- Unpaved roads



GDA94



## Paradise South Mine Lease Area & Mine Related Infrastructure

Date: 1/6/10      Author: S Cassin      Figure: 1.2

Filepath: K:\GIS\Company\Legend\Environment\Lady Annie\ArcGIS Project Files\Paradise South MLA Complete 270410.mxd

## 1.5 Environmental impact assessment process

It is proposed that the project EIS will be assessed under the *Environmental Protection Act 1994* (the Act).

In accordance with Section 70 of the Act, an Initial Advice Statement was prepared in consultation with the Department of Environment and Resource Management (DERM) to support an application for an *Approval to Prepare a Voluntary Environmental Impact Statement (EIS)* for the development of the Paradise South Phosphate Project on Mining Lease Application (MLA) 90197.

This IAS updates and revises information regarding the project, and it is not anticipated that this would affect the basis of the existing approval to prepare a Voluntary EIS.

Legend has assessed whether the project would significantly impact any Matters of National Environmental Significance (MNES) and whether the project would affect the environment on Commonwealth Land. The assessments included detailed aquatic and terrestrial field surveys. Legend has concluded that the project will not significantly impact any MNES or the environment on Commonwealth Land and that approval under the EPBC Act will not be required.

Accordingly, Legend does not propose to make an EPBC Act referral to the Minister for the Environment, Heritage, Water and the Arts for this project.

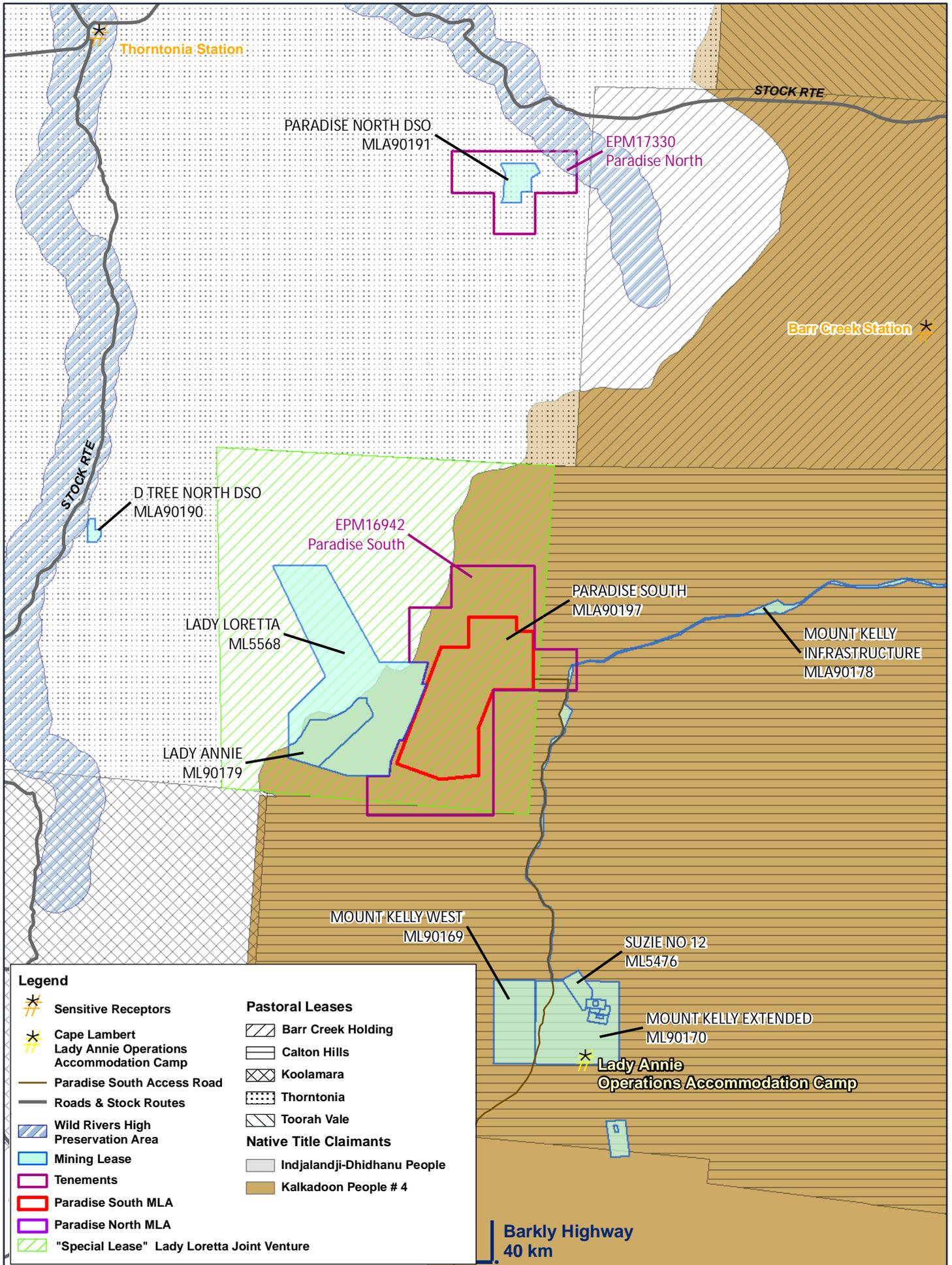
## 1.6 Project location

The project's mineral resource is located approximately 135 km north north-west of Mount Isa as shown in Figure 1.1. The region surrounding the project is broad-scale pastoral in nature and generally consists of large leasehold lots that support cattle grazing. There are also a number of other existing mines in the surrounding region, which includes Lady Loretta mine, Lady Annie mine, and the Mt Gordon mine. The project area is located entirely within the jurisdiction of the Mount Isa City Council and is predominantly within the Rural land use zone of the City of Mount Isa Planning Scheme.

## 1.7 Project tenure

Legend lodged a mining lease application (MLA 90197) with the Mining Registrar in November 2009 for a mining lease seeking an initial term of 30 years over the MLA Area. The project will proceed through a development process that currently targets first product ore in late 2011.

The MLA area and other land tenures are shown in Figure 1.3.



**Legend**

- |  |                               |
|--|-------------------------------|
| Sensitive Receptors                        | Pastoral Leases               |
| Cape Lambert                               | Barr Creek Holding            |
| Lady Annie Operations Accommodation Camp   | Calton Hills                  |
| Paradise South Access Road                 | Koolamara                     |
| Roads & Stock Routes                       | Thorntonia                    |
| Wild Rivers High Preservation Area         | Toorah Vale                   |
| Mining Lease                               | <b>Native Title Claimants</b> |
| Tenements                                  | Indjalandji-Dhidhanu People   |
| Paradise South MLA                         | Kalkadoon People # 4          |
| Paradise North MLA                         |                               |
| "Special Lease" Lady Loretta Joint Venture |                               |

## 1.8 Native Title

The project traverses lands subject to two registered Native Title claims. The MLA area and some of the supporting infrastructure lie within the claim described as Federal Court Claim Number QUD-579/05 – Kalkadoon People #4. One of the water supply options under investigation (the Thorntonia Borefield Pipeline) traverses the Indjalandji/Dhidhanu Peoples claim, Federal Court Claim Number QUD-243/09 – Indjilandji/Dithannoi People (NNTT No. QC09/3 Indjalandji/Dhidhanu).

Legend is in discussion with both the Kalkadoon People and Indjalandji-Dhidhanu People with regards to registering the project under the *Commonwealth Native Title Act 1993* in relation to the Mining Lease application and infrastructure for the project.

## 1.9 Community consultation

It is proposed that community consultation will be conducted with the local community and other relevant stakeholders as part of the EIS process for the proposed project development. The public consultation process will identify broad issues of concern to local community and interest groups at all stages including project planning, construction, commissioning, operations and final decommissioning.

The community and stakeholder consultation proposed to be undertaken during the EIS process will also aim to build on the community consultation undertaken during the D-Tree North DSO Project and the Paradise North DSO Project.

A separate document entitled “Paradise South Project – Affected and Interested Persons” has been prepared by Legend and submitted to DERM identifying potential project stakeholders.

## 2. Description of the Project

### 2.1 Mining operation

The Paradise South Phosphate Project involves conventional open-cut mining techniques without the need for blasting due to the friability of the ore. From historical data, the rock phosphate ore body ranges from near surface depths to the east of the MLA to approximately 60 m to the base of the deposit in the western part of the MLA.

The run of mine ore (refer Photo 2.1) will be extracted from the open-cut pits using a truck and shovel operation. The extracted ore will then be transported to the ROM pad located adjacent the beneficiation plant using mine dump trucks.

Topsoil and overburden materials will be separately stockpiled for progressive rehabilitation in the future.



**Photo 2.1 Rock Phosphate (from Paradise South by hand tools, September 2009)**

### 2.2 Ore processing (Beneficiation)

In October 2009 Legend, together with Amdel, developed a pilot beneficiation plant at McLaren Vale near Adelaide. The pilot plant operated for six weeks with the objective of verifying the design process flow sheet of the beneficiation plant. The results of the pilot plant testing are currently being analysed. A general description of the beneficiation process is provided below.

The ore will be transferred from the ROM pad using front-end loaders and fed into the screening circuit of the beneficiation plant. The process would take up to 12.5 Mtpa of ROM ore.

A crushing circuit may not be required due to the natural fine particle size of the ore. The screened material will be fed to a milling circuit followed by a particle separation circuit. The oversize particle product will be sent back to the milling circuit. The finer particle product would be fed to froth flotation tanks to concentrate the phosphate material. Reagents would be added to the flotation circuit to improve concentrate recovery.

Water is recovered from the tailings of the flotation circuit before the solids are fed to the tailings facilities. The tailings are predominantly silica-calcium oxide sand. Legend is considering both purpose built tailings facilities as well as the option of direct backfill of mined areas (prior to reinstatement of overburden and topsoil to progressively rehabilitate the mine workings).

## 2.3 Product transport

Legend engaged Pipeline Systems International (PSI) to undertake a conceptual study for assessment of a slurry pipeline to transport the beneficiated phosphate ore from the mine site to existing rail facilities. Mount Isa is proposed as the location for the slurry dewatering and rail load out facility.

The product transport system comprises a dewatering facility at the rail terminal and return water pipelines to the beneficiation plant following the route of the slurry pipeline. The dewatered phosphate ore concentrate would be loaded into rail wagons and transported by rail to the Port of Townsville for storage and loading to ship. Storage and loading at the Port of Townsville will utilise existing licensed port infrastructure provided by a third party.

The concentrated phosphate ore may be transported via existing roads to Mount Isa if production tonnages are low and a slurry pipeline is not commercially viable. The road transport route would follow the McNamara Road south from the Paradise South Beneficiation Plant to the Barkly Highway, then east along the Barkly Highway to Mount Isa, before heading south on the Diamantina Developmental Road to the proposed rail load out facility.

Type 2 road trains (triple road trains with tri-axle trailers and bogey axle dollies) would transfer twenty-foot equivalent unit covered containers from the Paradise South beneficiation plant to the rail load out facility in Mount Isa for direct loading onto flat bed rail wagons.

Eight road trains will operate daily completing four round trips and transferring approximately 2,850 tonnes of beneficiated phosphate rock to the Mount Isa rail load out facility and onward by rail to Townsville. Storage and loading at the Port of Townsville will be via existing licensed port infrastructure provided by a third party.

## 2.4 Slurry dewatering and rail load out facility

A slurry dewatering and rail load out facility is proposed at a site approximately 7 km south of Mount Isa. The dewatering facility will comprise a thickener, clarifier and filter plant to dewater the slurry, recycled water storage tanks, return water pump station, dryers (blowers), dry product storage and office buildings.

The rail load out facility will comprise a rail siding and closed conveyor for wagon loading. The total footprint of the facility will be approximately 10 ha.

In the event that road transportation is adopted a slurry dewatering plant will not be required and the site would only provide a rail load out facility.

## 2.5 Infrastructure requirements

### 2.5.1 Water supply

Three water supply options are under consideration for the Paradise South mine and beneficiation plant.

#### 2.5.1.1 Thorntonia Borefield option

Legend has commenced commercial negotiations in regard to the lease of the existing Thorntonia Borefield water permit. A licence for the allocation of water by permit from the Department of Natural Resources and Water dated 23 July 2007 (number 403766) for the taking of up to 950 ML per year from the Thorntonia Limestone aquifer for industrial use.

The Thorntonia Borefield water will need to be pumped approximately 45 kilometres to the beneficiation plant via an above ground pipeline.

#### 2.5.1.2 New Dam option

The option of constructing a dam to supply water to the project is currently being assessed. Based on these findings and other commercial assessments, a decision will be made as to whether to proceed further with this option.

#### 2.5.1.3 Lake Julius option

Legend engaged SunWater to undertake a pre-feasibility study to assess the option of directing unallocated water from Lake Julius to the proposed mine and beneficiation plant. Lake Julius is located approximately 85 kilometres east southeast of the proposed mine and beneficiation plant. The findings of this study will be compared against the other options presented above.

#### 2.5.1.4 Slurry dewatering and rail load out facility water supply

Less than 500 kilolitres per year will be required at the dewatering and rail load out facility for not potable use in office buildings and workshops (ablution facilities, wash water, dust suppression and garden maintenance). Legend proposes that water from the slurry

dewatering plant will be used to provide the non-potable water supply. Potable water will be supplied to the site as bottled water for use in water coolers.

## **2.5.2 Power supply**

### **2.5.2.1 Generation**

Legend has commenced commercial negotiations with local power generators in regards to the supply of power for the proposed beneficiation plant. The total connected load for the beneficiation plant will be approximately 48.5 MW with an expected maximum demand of 38 MW based on an annual consumption of 258,950 MWh with a load factor of 80% for a 24 hr-7 day a week operation.

Two power distribution options are under consideration for the beneficiation plant.

### **2.5.2.2 Power distribution option 1**

Legend has made a connection enquiry and application to Ergon Energy for distribution of an additional 38 MW to the Birla Mt Gordon substation (refer Photo 2.2) via the Century Zinc 220 kV 100 MW transmission line. Legend has been advised that these lines have sufficient capacity to deliver the required power to the Birla Mt Gordon substation from Mount Isa.

The initial connection proposed for the beneficiation plant, subject to negotiations with Lady Annie Operations, will be an 11 kV connection onto the Birla Mt Gordon 11 kV main switchboard via the spare 11 kV circuit breaker at the existing substation. Legend will need to construct a step-up transformer (11/66 kV) positioned adjacent to the existing Lady Annie Operations transformer. The substation was initially designed to allow for this expansion and will be incorporated within the approved footprint.

Legend proposes to use Lady Annie Operations existing 66 kV 25 MW transmission line between Mt Gordon and Mt Kelly (Lady Annie Operations) or duplicate the existing power lines. Legend will need to construct a 2 km transmission line from the existing line to the proposed beneficiation plant. It is proposed to build the line adjacent to the proposed access road from the Paradise North access road to the beneficiation plant to minimise land disturbance.



**Photo 2.2 Birla Mt Gordon Substation (foreground) with Century Zinc transmission line tower (background)**

### **2.5.2.3 Power distribution option 2**

Option 2 would involve direct connection to Ergon Energy's Century Zinc 220 kV 100 MW power transmission line. This will require the building of approximately 20 km of transmission line from the takeoff point. Legend currently has a connection enquiry and application to Ergon Energy regarding this option.

### **2.5.2.4 Slurry dewatering and rail load out facility power supply**

The power requirements for the slurry dewatering and rail load station are less than 100kW and can be serviced from the existing power generation and transmission network.

### 2.5.3 Access road

The section of the haul road north of Lady Annie Operations to the proposed Paradise North DSO mine will have been constructed as part of the Paradise North DSO project.

Legend proposes to construct an additional (approximate) two kilometre long of access road from the main Paradise North haulage road to the beneficiation plant.

### 2.5.4 Additional mine infrastructure

Mine infrastructure additional to that described above would consist of:

- communications infrastructure
- light vehicle access roads and heavy vehicle haul roads (within the MLA area)
- a water management system
- waste water treatment facilities
- fuel and oil storage facilities
- high voltage transmission lines/poles and reticulation facilities
- maintenance workshop, offices and associated amenities
- tailings facilities.

Further detail on the infrastructure facilities will be described in the EIS once the project's feasibility studies have been completed.

### 2.5.5 Water management

A Water Management System (WMS) will need to be established to manage water across the sites. The Mine WMS will comprise a network of water management infrastructure that will allow for flexibility in transport of water around site. The water management goal for the project will be to minimise the potential downstream impacts of the project. The key commitment to meet this strategy will be to design the WMS to control mine water discharge from site within the constraints of the WMS design.

'Mine water' will include surface runoff and groundwater inflow, captured in the open-cut pits. Mine water will be diverted for storage into environmental dams for appropriate reuse as required.

The Mine WMS will address the following water sources and define corresponding control strategies:

- runoff from undisturbed upstream catchments will be passed through the proposed mining areas in defined drainage corridors or captured and stored within the MLA area for use in project operations
- overland flow and runoff from catchments disturbed by mining activities will be directed through sediment basins where necessary, to reduce sediment load and allowed to flow off-site or captured and stored within the MLA area for use in project operations

- runoff from mining pits and ROM stockpiles, and industrial areas such as workshops, will be directed to environmental dam(s) for storage to be used as a source of water for dust suppression as required, with no planned discharge from environmental dams
- process water from the beneficiation plant will be managed in dedicated tailings storage facilities.

Stormwater runoff from the slurry dewatering and rail load out facility will be directed to sediment and environmental control facilities on the site.

Assessment of groundwater and surface water hydrology, riparian vegetation and aquatic ecology will be undertaken as part of the development of the WMS within the MLA and the slurry dewatering and rail load out site areas.

## 2.6 Waste management

### 2.6.1 Mine waste

Tailings management will be required since the ROM ore will require beneficiation on-site. The method of tailings disposal will be ascertained in conjunction with the water resource study as part of the EIS assessment process.

### 2.6.2 Non-mine waste

General and regulated wastes will be generated during the construction and operations stages of the project. On-site sewage storage facilities, which would be pumped out routinely, will be required during the construction phase. It is anticipated that an on-site sewage treatment plant and waste disposal system will be constructed to provide sewerage facilities for the operational workforce at the beneficiation plant.

A pump out system, septic tank or connection to Mount Isa's sewerage system will be installed at the slurry dewatering and rail load out facility.

A waste identification and management strategy will be developed during the EIS stage of the project.

## 2.7 Workforce and accommodation

Accommodation facilities will be required for mine personnel covering both the construction and operational phases of the project.

Legend is currently in consultation with Lady Annie Operations regarding the sharing of its camp facilities. Alternatively Legend would develop a purpose-built camp possibly on the MLA area.

Accommodation for the small number of slurry dewatering and rail load out facility personnel (less than 25 people) will be sourced within Mount Isa. It is noted that Legend currently owns accommodation facilities in Mount Isa for 10 people.

## 3. Existing environment

### 3.1 Land systems

#### 3.1.1 Land use

The predominant land use in the wider region is low intensity cattle grazing on native and improved pasture, including areas of thinned vegetation.

The MLA area is remote from towns, settlements and homesteads. The nearest permanent residents (i.e. sensitive receptors) are located at Thornton homestead and Barr Creek Station which are located approximately 32.4 km north-west and 25 km north-east respectively of the MLA 90197. In addition, the Lady Annie Operations Accommodation Camp is located approximately 16.5 km south of MLA 90197 as shown in Figure 1.2.

The slurry dewatering and rail load out facility site is zoned 'Industrial' in the Mount Isa town planning scheme, however, it is currently used for low intensity cattle grazing. The site is approximately 7 km from Mount Isa City Council offices and approximately 1.5 km south of the Mica Creek Power Station. The nearest permanent resident is a single dwelling 1.1 km from the site. The next closest permanent residents are the ten dwellings within the Mica Creek Power Station compound and dwellings adjacent the power station on Mica Creek Road.

#### 3.1.2 Soils and land suitability

Regional mapping of the region is shown in the Atlas of Australian Soils (Bureau of Rural Resources, 1991) and in the Survey of the Barkly Region, Northern Territory and Queensland (Christian et al. 1954). From this existing information, and PB's recent soil logging in the area and a review of available aerial photographs, the soils of the project site are anticipated to comprise "limestone, calcareous desert soils, brown alluvial soils and heavy grey pedocals" (Christian et al. 1954). Soils are anticipated to be shallow, gravelly surfaced, bleached red duplex soils (Bureau of Rural Resources 1991).

Gravels found in soil horizons are likely to be siltstone or sandstone fragments transported through alluvial or colluvial transportation on alluvial flats and gentle slopes. Soils at the project site are also likely to be underlain by dolomite, sandstone, siltstone, shale, slate and conglomerate from the Beetle Creek and Paradise Creek Formations at shallow depth.

Land use in this area is described in Christian et al. (1954) as mining and low rate cattle grazing which is consistent with current uses. The report suggests mining as the most beneficial use for the area due to low potential for improvements to be implemented to increase agricultural use.

Soil testing and land suitability assessment will be conducted for the Paradise South MLA area as part of the EIS.

The dewatering and rail load out site is part of the alluvial plain of Mica Creek and Leichhardt River potentially comprising abandoned former river terraces, forming plateaus elevated above the current floodplain. The terraces could be part of the former floodplain of the Leichhardt River. The plateaus formed by these terraces appear to be dissected by mainly east trending gullies. Tests pits at the site indicate gravelly sandy clays and sandy clayey gravels ( $\pm$  cobbles) interpreted to be of inferred older alluvial terrace origin with depths greater than 3.0 m in this area.

### 3.1.3 Topography

The mine lease area consists of undulating to flat lands with some isolated rounded rock outcrops. Elevations range from approximately 250 m to 320 m (AHD). Slopes are generally very gently to moderately sloping with long, approximately 250 m to 350 m slope lengths. The area is considered erosional in nature although sediment is stored for extended period of time in the area before being moved further downstream.

The elevation of the slurry dewatering and rail load out facility site is from 360 m to 370 m (AHD), sloping easterly at a two percent grade. The site is located over 10 m above the bed of the Leichhardt River.

### 3.1.4 Geology of the Phosphate Deposit

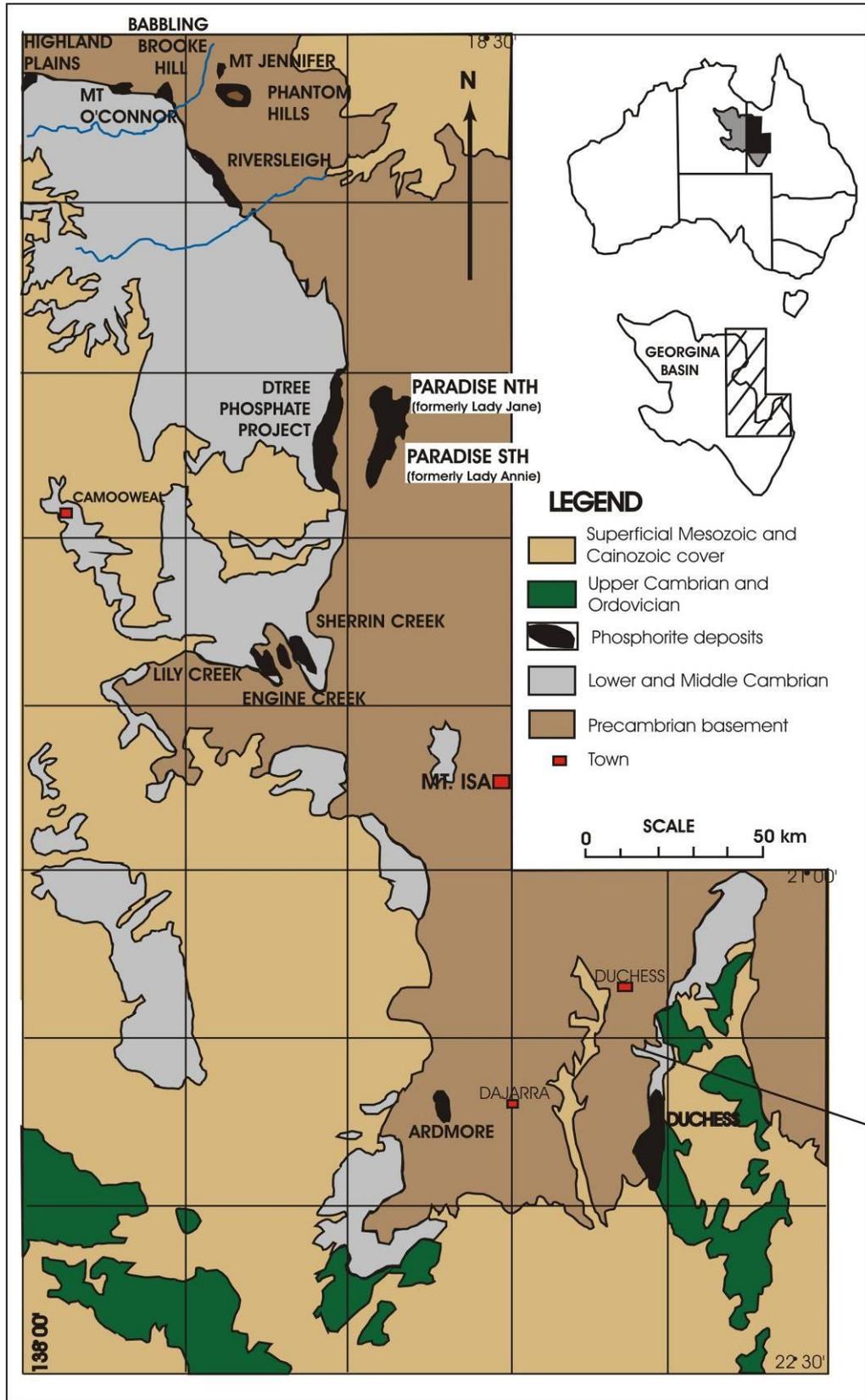
The Paradise South phosphorite deposit, discovered in the late 1960's and formerly known as the Lady Annie phosphate deposit, is located in an outlier of the Georgina Basin, separated from the D-Tree deposit to the west by outcropping Precambrian sediments (refer Figure 3.1). The Paradise South phosphate deposit is confined to an area of low relief, approximately 25 km long and 5 km wide, trending north-south between ridges and hills of Precambrian shales, quartzites, siltstones and dolomite. The sedimentary phosphate rock was deposited in an embayment of the inland sea that covered the Georgina Basin during the early Middle Cambrian.

The stratigraphy of the embayment hosting the Paradise South phosphorite is comprised of sediments of Cambrian and Mesozoic age, with some thin overlying tertiary and recent deposits. The phosphatic unit proposed to be mined is the Beetle Creek Formation. The most prominent units of the MLA area are as follows:

- tertiary laterite and silcrete up to 5 m thick
- mesozoic quartz sandstones, micaceous mudstone and coarse conglomerate beds. These sediments are mostly confined to the western boundary of the project area, adjacent to the Western Fault and can be up to 40 m thick
- the Inca Formation of Middle Cambrian age consists of well-laminated fissil shale with some interbeds of siltstone and minor chert. This unit has a recorded maximum thickness of 24 m in the project area
- the Beetle Creek Formation of Lower Middle Cambrian age consists of beds of phosphorite, siltstone, shale and chert. Phosphorite lithologies include friable pelletal phosphorite and soft clayey phosphatic mudstone. This unit attains a maximum thickness of 46.5 m in the project area

- the Thornton Limestone underlies the Beetle Creek Formation on the eastern margin of the Paradise South project area. In contrast to the Beetle Creek Formation this unit is characterised by dolomitic limestone containing abundant chert nodules. The thickness of this unit is highly variable and reaches a maximum of 16 m
- the Mt Hendry Formation forms the basal unit of the Cambrian stratigraphy and is typically a 2 m thick conglomerate with lesser sandstone.

The stratigraphy of the MLA area is detailed further in Table 3.1.



**Figure 3.1** Location of major phosphorite deposits of the Georgina Basin, northwest Queensland (after Rogers and Keevers, 1976)

**Table 3.1 Stratigraphy of the Paradise South Phosphate Deposit**

Age		Stratigraphic Unit	Description	Strat. Code
Cenozoic (0-65Ma)	Quaternary	Alluvium (Qa)	Sand, silt, clay, minor gravel	Czg
		Colluvium, residual soil	Poorly sorted sand, silt, clay and gravel	
	Tertiary	Laterite (ferricrete)	Ferruginous, nodular ferricrete. Most extensively developed on Mesozoic rocks, where up to 5m of indurated pebbly laterite form the tops of mesas.	Tpf/M
		Silcrete	Pale grey to white, composed of rounded silicified pebbles cemented with silica. Has developed on the more siliceous Precambrian rocks and as local minor developments on the Beetle Creek Fm and Mesozoic sediments.	Tzd
	Wondoola Beds	Red and grey clay, silt, sand, residual soil and colluvium, minor gravel and calcrete.	TQr	
Mesozoic (65-251 Ma)		Sandstone, Mudstone, Conglomerate	Quartz sandstone with some coarse conglomerate beds. The sandstones are generally medium to coarse grained with some clay and iron oxide matrix. The mudstone are commonly white to pink with ill-defined bedding and show typical mudstone fracture; they contain abundant muscovite. Unconformably overlies the Cambrian sediments and has eroded large channels into the Cambrian stratigraphy in places.	M
Cambrian (490-545Ma)		Inca Formation	Thinly interbedded siliceous white fissile shale, with lesser siltstone, and thinly bedded chert. The chert characteristically shows thin and laterally persistent laminations, a feature not apparent in the Beetle Creek Fm. Bituminous where not weathered, can be ferruginous. Characteristic fossil assemblage of agnostid trilobites and tetrad sponge spicules. This unit is not phosphatic. The Inca Formation conformably overlies the Beetle Creek Fm and is unconformably overlain by Mesozoic sediments. Where characteristic Inca Fm cherts are lacking, the upper contact may be difficult to determine in the field.	Cmi
		Beetle Creek Formation	Interbedded chert-siltstone-phosphorite. Lateral and vertical facies changes are defined by variable amounts of chert and phosphorite interbedded with phosphatic and barren siltstone lenses from about 5cm to 1m thick. Phosphatic lithologies are hard to differentiate from non-phosphatic lithologies in hand-specimen without chemical tests. The chert of this unit is characteristically grey to brown and forms nodular, thin ribbon-like beds. Nodules of silicified coquina-type chert (fossil clast-rich) are also present. Phosphorite occurs predominantly as mudstone and silty mudstone phosphorite (microphosphorite), peloidal grainstone phosphorite and replacement phosphorite. Replacement phosphorite is an indurated phosphate rock (harder than other phos ore types) comprised of microcrystalline collophane with minor quartz silt, chert and clay. Replacement rock is generally higher grade than the other phosphate ore types and is therefore a DSO target.	Cme
		Thorntonia Limestone	Slightly phosphatic, hard, brown, yellow-brown or mottled dolomite with chert nodules and lenses, dolomitic limestone and limestone. In parts it contains intraclasts, pellets, pisoliths, fossil fragments, and glauconite and can yield a bituminous odour when grey, less weathered material is broken. Through most of the area it rests unconformably on Precambrian, or conformably on the Mount Hendry Fm. This unit underlies and interfingers with the chert-siltstone-limestone-phosphorite unit. A pronounced karst surface has been recognised at the top of this unit in some areas, ie. Hilary Ck and Paradise Ck.	Cmt
		Mount Hendry Formation	<i>Basal sandstone-conglomerate</i> . Localised distribution adjacent to Precambrian bedrock. Lithologically variable ranging from polymictic, angular conglomerate to white, fine-grained dolomitic sandstone. Commonly consists of a gritty sandstone at the base with a sandy or clayey matrix. Interbeds of quartz sandstone comprise angular clasts of quartzite and some clay clasts. Contains interbeds of ferruginous clay up to 0.6m thick as well as horizons of pyrolusite and/or hematite. Scour channels are filled with blocks of quartzite up to 30cm in diameter set in a fine-grained quartz sand matrix, or earthy ferruginous or manganiferous material.	Cmh
Precambrian (>545 Ma)		Lady Loretta Fm	Dolomitic siltstone, pyritic carbonaceous shale	Pml
		Esperanza Fm	Stromatolitic chert and dolomite.	Pmz
		Paradise Creek Formation	Dolomitic siltstone, shale, sandstone, minor chert. Typically pink-purple in colour.	Pmx
		Mt Oxide Chert	Grey algal laminated chert. Regionally a very thin unit.	Pmc
		Gunpowder Creek Formation	Dominantly red-brown flaggy micaceous shale and siltstone, dolomitic siltstone, sandstone	Pmw

Descriptions after Rogers and Keevers (1976)

## 3.2 Climate

The nearest Bureau of Meteorology (BOM) weather station site to the Paradise South mine and beneficiation plant is situated at Camooweal, located approximately 85 km west south west of the MLA area. This site has been active since 1891.

The nearest BOM weather station site to the proposed dewatering and rail load out facility is Mount Isa Mine located approximately 7 km north of the site. This station has been operating since 1932.

The project area lies in the Queensland North West Minerals Province and experiences predominantly warm weather. The monthly averages show December to be the hottest month and July to be the coldest.

On average, the highest rainfall occurs in January. The average annual rainfall is 396 mm and 420 mm at Camooweal and Mount Isa Mine respectively, mostly occurring in summer.

## 3.3 Water resources

### 3.3.1 Surface water hydrology

The MLA area is located in the Leichhardt River catchment. The hydrology on the MLA area is dominated by a number of ephemeral drainage lines and creeks flowing generally to the southeast into Battle Creek before flowing eastwards into the Gunpowder Creek at Gunpowder and ultimately north into the Leichhardt River and the Gulf of Carpentaria (Figure 3.2). Battle Creek traverses the southern section of the MLA and is the only notable watercourse. There are no major creeks or rivers located within the MLA area. The watercourses are ephemeral - generally only flowing for brief periods during and following rainfall.

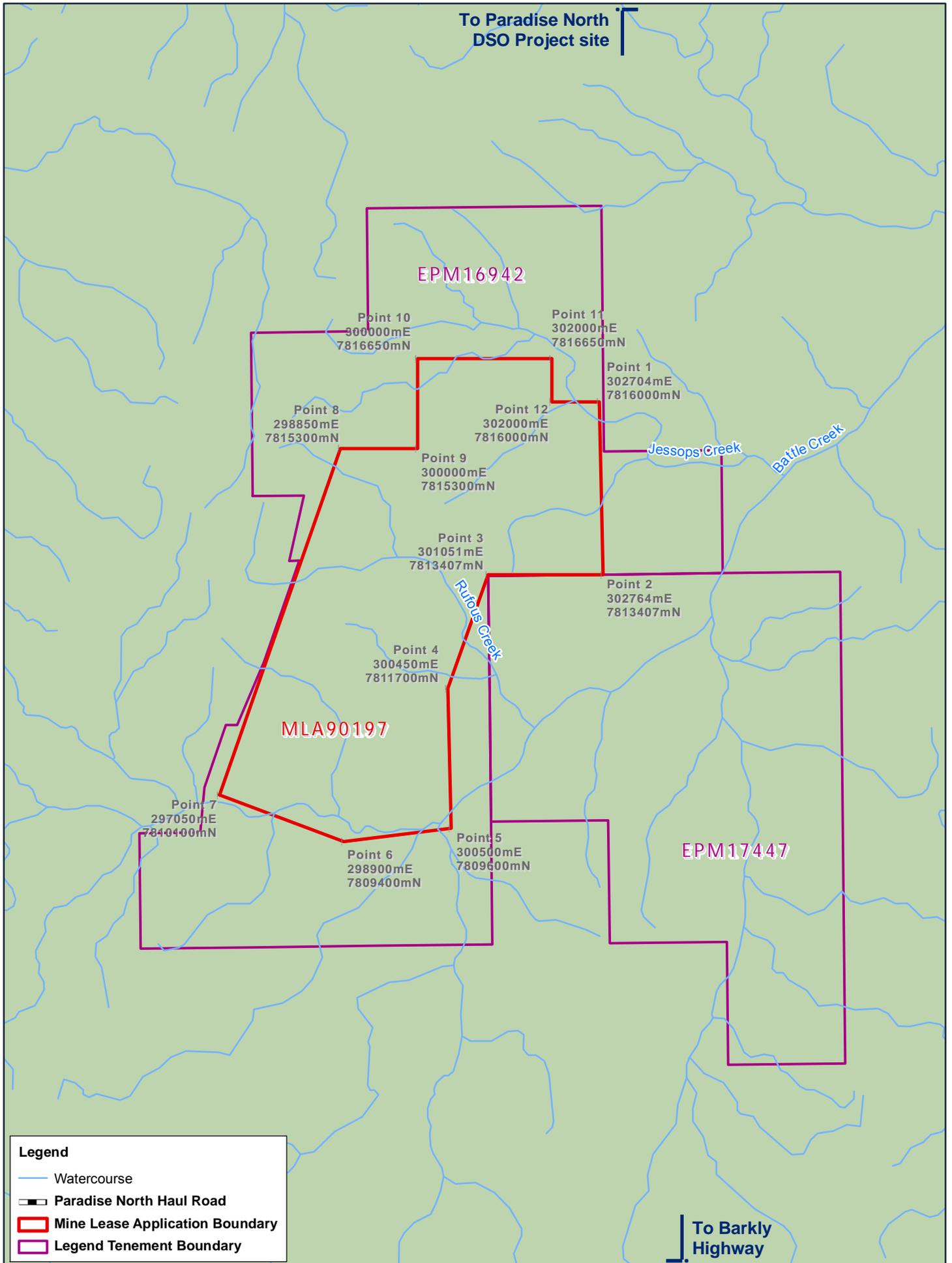
The 2 km access road is also located within the Leichhardt River catchment. It is noted that, while not a component of the project, the southern portion of the Paradise North Access road, south of the Lady Annie Operations camp and processing plant, lies within the Georgina/Diamantina basin.

The Thornton borefield pipeline water supply option traverses the Leichhardt and Gregory Rivers catchments.

The dam water supply option is within the Leichhardt River catchment.

The power supply transmission line options are both within the Leichhardt River catchment.

The final alignment of the slurry pipeline and return water pipeline is not yet defined, however these elements will lie within the Leichhardt River basin and possibly some short sections within the Georgina/Diamantina River basin. The slurry dewatering and rail load out facility is located near the confluence of the Leichhardt River and Mica Creek within the Leichhardt River catchment.



**Legend**

- Watercourse
- Paradise North Haul Road
- Mine Lease Application Boundary
- Legend Tenement Boundary



MLA and Stream Locations

### **3.3.2 Surface water quality**

Based on assessments undertaken to date, water and sediment quality in the MLA and surrounding areas was found to be similar to that of other ephemeral streams in the catchment. In situ dissolved oxygen concentrations have been found to be generally low and well below the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (ANZECC and ARMCANZ 2000) guidelines. In-situ turbidity concentrations were high and well above the ANZECC and ARMCANZ (2000) guidelines. In situ conductivity and pH levels were also found to be generally within the ANZECC and ARMCANZ (2000) guidelines. Contaminants in the water column will be sampled as required during the EIS process.

Slightly elevated levels of some metals and metalloids have been recorded from stream sediments (arsenic, cadmium, copper and zinc), and are likely to be related to the highly mineralised nature of the region. Levels of copper were also found to exceed the ANZECC and ARMCANZ (2000) sediment quality guidelines at one site. Petroleum hydrocarbons were also detected in some of the sediments. No pesticides have been detected in any testing conducted to date.

The slurry dewatering and rail load out facility is located near the confluence of the Leichhardt River and Mica Creek. Surface water quality data is available upstream of the confluence on the Leichhardt River and the Mica Creek respectively.

### **3.3.3 Groundwater**

Groundwater in the vicinity of the MLA area is predominantly used for mining, cattle watering and domestic purposes.

A number of existing groundwater bores occur within the project area, in an area known as Lady Annie East (LAE) Borefield, however, it was determined that the groundwater potential of the LAE Borefield and other existing bores is insufficient to meet the water demand for the project.

One water supply option includes abstraction of groundwater from a licensed borefield within the Thornton Limestone aquifer, located near Thornton Station, and located approximately 32.5 km to the north-west of the project area. The aquifer is generally confined and contains good quality groundwater, with slightly alkaline pH and low salinity.

Anecdotal evidence indicates that there are developed but unproductive groundwater bores to the east of the proposed slurry dewatering and rail load out facility. Legend understands these bores may have been previously developed by mining companies.

## 3.4 Biological characteristics

### 3.4.1 Existing flora

Most of the vegetation contained within the MLA area and water supply dam inundation area is remnant and is typical of the broader region. Ten (10) Regional Ecosystems (REs) have been identified from the DERM certified mapping (Version 6.0) for the MLA area (refer Table 3.2). However, following ground-truthing, nine (9) REs have been verified as occurring within the MLA area (refer Table 3.3).

A total of 201 flora species occur within the MLA area. Of these species 192 (95.5%) are native and nine are exotic. Alternatively, 156 flora species were observed within the water supply dam inundation area. Of these species, 136 (87.2%) are native and 20 (12.8%) are exotic. No flora species of conservation significance (listed as *Rare* under the provisions of the NC Act) or weed species listed under the *Land Protection (Pest and Stock Route Management) Act 2002* (LP Act) was recorded in the MLA or water supply dam inundation area.

**Table 3.2 Ecosystems (REs) in the MLA area and water supply dam inundation area based on DERM certified mapping**

RE code	RE Short Description (Version 6b REDD)	VM status	Biodiversity status	EPBC status
1.11.2	Snappy Gum <i>Eucalyptus leucophloia</i> low open-woodland	Not of concern	Not of concern at present	Not listed
1.3.6	Ghost Gum <i>Corymbia aparrerinja</i> and Bloodwood <i>C. terminalis</i> open woodland on sandy terraces	Not of concern	Of concern	Not listed
1.3.7	Red Gum <i>Eucalyptus camaldulensis</i> woodland on channels and levees	Not of concern	Endangered	Not listed
1.5.3	Snappy Gum <i>Eucalyptus leucophloia</i> low open woodland on red earths on plateaus	Not of concern	Not of concern at present	Not listed
1.5.4	Cloncurry Box <i>Eucalyptus leucophylla</i> low open woodland on red earths in valleys	Not of concern	Of concern	Not listed
1.5.5	Silver-leaved Box <i>Eucalyptus pruinosa</i> low open woodland on red earth plains	Not of concern	Of concern	Not listed
1.5.6	Gidgee <i>Acacia cambagei</i> and Whitewood <i>Atalaya hemiglauca</i> low open woodland on red earth plains	Not of concern	Not of concern at present	Not listed
1.7.1	Snappy Gum <i>Eucalyptus leucophloia</i> low open woodland on skeletal soils on lateritic scarps and plateaus	Not of concern	Not of concern at present	Not listed
1.9.1	Mitchell Grass <i>Astrebla</i> spp. grassland on shallow clays on limestone	Not of concern	Not of concern at present	Not listed
1.9.5	Cloncurry Box <i>Eucalyptus leucophylla</i> low open woodland-woodland on low hills on limestone's and calcareous shale's	Not of concern	Not of concern at present	Not listed

**Table 3.3 Regional ecosystems (REs) in the MLA area and Water Supply Dam Inundation Area based on ground-truthing (Biodiversity Assessment and Management 2009)**

RE code	Approx. area (ha)	RE Short description (Version 6b REDD)	VM status	Biodiversity status	EPBC status
1.11.2	1128.6	Snappy Gum <i>Eucalyptus leucophloia</i> low open-woodland	Least concern	No concern at present	Not listed
1.11.4	54.5	Silver-leaved Box <i>Eucalyptus pruinosa</i> low open woodland on shallow soils in valleys below folded sediments	Of concern	Of concern	Not listed
1.3.7	66.5	Red Gum <i>Eucalyptus camaldulensis</i> woodland on channels and levees	Least concern	Endangered N	ot listed
1.5.2	55.8	Mixed eucalypt woodland on sandy plains	Of concern	Of concern	Not listed
1.5.4	385.3	Cloncurry Box <i>Eucalyptus leucophloia</i> low open woodland on red earths in valleys	Least concern	Of concern	Not listed
1.5.8	150.7	Gidgee <i>Acacia cambagei</i> and Whitewood <i>Atalaya hemiglauca</i> low open woodland on red earth plains	Least concern	No concern at present	Not listed
1.7.1	496.9	Snappy Gum <i>Eucalyptus leucophloia</i> low open woodland on skeletal soils on lateritic scarps and plateaus	Least concern	No concern at present	Not listed
1.9.7	3.5	Sugar Box <i>Eucalyptus pruinosa</i> low open woodland on pre-Cambrian shales	Least concern	No concern at present	Not listed
1.11.3	91.7	Inland Bloodwood <i>Corymbia terminalis</i> low open woodland on basic metamorphic sediments	Least concern	No concern at present	Not listed

The proposed two kilometre access road follows a similar linear pathway as the slurry pipeline from the beneficiation plant to the Paradise North Haul road (assessed under a separate project). The surveys conducted for the first two kilometres of the slurry pipeline therefore cover the proposed access road. Twenty eight (28) RE's have been identified from the DERM Certified Mapping (Version 6.0b) along the proposed slurry pipeline route. Ten (10) RE's have been identified from the DERM Certified Mapping along the powerline. The vegetation communities contained within the proposed slurry pipeline and powerline alignments are remnant vegetation and are characteristic of the area. A total area of approximately 3,178 ha was surveyed. Of this, ground-truthing has indicated that approximately 84 ha (2.7%) is analogous to RE 1.3.7. This RE has a biodiversity status of Endangered. This RE was restricted to drainage lines.

No flora species listed under the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) were identified within the MLA area, slurry pipeline, Thornton Borefield Pipeline, powerline and water supply dam survey areas. In addition, no weed species listed under the *Land Protection (Pest and Stock Route Management) Act 2002* (LP Act) were identified in these areas.

**Table 3.4 Ecosystems (REs) in the Slurry pipeline area based on DERM certified mapping**

RE code	RE Short Description (Version 6b REDD)	VM status	Biodiversity status	EPBC status
1.11.2	Snappy Gum <i>Eucalyptus leucophloia</i> low open-woodland	Not of concern	No concern at present	Not listed
1.11.3	<i>Corymbia terminalis</i> low open woodland on basic metamorphics	Not of concern	No concern at Present	Not listed
1.11.4	Silver-leaved box <i>Eucalyptus pruinosa</i> low open woodland on shallow soils in valleys below folded sediments	Not of concern	Of concern	Not listed
1.3.1	Mitchell grass <i>Astrebla</i> spp. Grassland on alluvial plains	Not of concern	No concern at present	Not listed
1.3.4	Gidgee <i>Acacia cambagei</i> low open woodland to woodland on earths in clays	Not of concern	Of concern	Not listed
1.3.5	Mixed eucalypt open woodland on sandy alluvial terraces	Not of concern	Of concern	Not listed
1.3.6	Ghost Gum <i>Corymbia aparrerinja</i> and Bloodwood <i>C. terminalis</i> open woodland on sandy terraces	Not of concern	Of concern	Not listed
1.3.7	Red Gum <i>Eucalyptus camaldulensis</i> woodland on channels and levees	Not of concern	Endangered N	ot listed
1.3.8	Red Gum <i>Eucalyptus camaldulensis</i> woodland on channels and levees	Not of concern	Endangered N	ot listed
1.5.3	Snappy Gum <i>Eucalyptus leucophloia</i> low open woodland on red earths on plateaus	Not of concern	No concern at present	Not listed
1.5.4	Cloncurry Box <i>Eucalyptus leucophylla</i> low open woodland on red earths in valleys	Not of concern	Of concern	Not listed
1.5.5	Silver-leaved Box <i>Eucalyptus pruinosa</i> low open woodland on red earth plains	Not of concern	Of concern	Not listed
1.5.6	Whitewood <i>Atalaya hemiglauca</i> vine tree <i>Ventilago viminalis</i> , beefwood <i>Grevillea striata</i> low open woodland on red earth plains	Not of concern	Of concern	Not listed
1.5.9	Vine tree <i>Ventilago viminalis</i> low open woodland on loams and sand sheets	Not of concern	Of concern	Not listed
1.7.1	Snappy Gum <i>Eucalyptus leucophloia</i> low open woodland on skeletal soils on lateritic scarps and plateaus	Not of concern	No concern at present	Not listed
1.7.2	Silver-leafed box ( <i>Eucalptus pruinosa</i> ) low open woodland on calcareous red/brown earths	Not of concern	Of concern	Not listed
1.9.1	Mitchell Grass <i>Astrebla</i> spp. grassland on shallow clays on limestone	Not of concern	No concern at present	Not listed
1.9.2	Mixed shrubby woodland on low rocky hills on tertiary limestone	Of concern	Of concern	Not listed
1.9.4	Mixed shrubby woodland on rocky limestone hills	Of concern	Of concern	Not listed
1.9.5	Cloncurry Box <i>Eucalyptus leucophylla</i> low open woodland-woodland on low hills on limestone's and calcareous shale's	Not of concern	No concern at present	Not listed

RE code	RE Short Description (Version 6b REDD)	VM status	Biodiversity status	EPBC status
1.9.6	Cloncurry Box <i>Eucalyptus leucophylla</i> with Western Bloodwood <i>Corymbia terminalis</i> low woodland- open woodland on low hills on limestone hills	Not of concern	No concern at present	Not listed
1.10.4	Snappy gum <i>Eucalyptus leucophloia</i> and/or Acacia spp. low open woodland on stony sandstone plateaus	Not of concern	No concern at present	Not listed
1.12.1	<i>Eucalyptus leucophloia</i> low open woodland on granites	Not of concern	No concern at present	Not listed
4.3.3	<i>Eucalyptus coolabah</i> , <i>E. Camaldulensis</i> +/- <i>Lysiphyllum gilvum</i> open woodland on drainage lines/plains	Not of concern	Of concern	Not listed
4.3.4	<i>Eucalyptus coolabah</i> open woodland on drainage lines/plains	Not of concern	No concern at present	Not listed
4.3.8	<i>Acacia cambagei</i> low woodland on braided channels of alluvial plains	Not of concern	No concern at present	Not listed
4.3.17	<i>Astrelba pectinata</i> +/- <i>Astrelba</i> spp.. +/- <i>Aristida latifolia</i> grassland on alluvium	Not of concern	No concern at present	Not listed
4.3.18	<i>Eulalia aurea</i> , <i>Astrelba squarrosa</i> +/- <i>Astrelba</i> spp. Grassland on alluvial plains	Not of concern	No concern at present	Not listed

**Table 3.5 Regional ecosystems (REs) in the powerline study area based on ground-truthing (Biodiversity Assessment and Management 2009)**

RE code	RE Short description (Version 6b REDD)	VM status	Biodiversity status	EPBC status
1.11.2	Snappy Gum <i>Eucalyptus leucophloia</i> low open-woodland	Not of concern	No concern at present	Not listed
1.3.6	Ghost Gum <i>Corymbia aparrerinja</i> and Bloodwood <i>C. Terminalis</i> open woodland on sandy terraces	Not of concern	Of concern	Not listed
1.3.7	Red Gum <i>Eucalyptus camaldulensis</i> woodland on channels and levees	Not of concern	Endangered	Not listed
1.5.1	Darwin Woolly Butt <i>Eucalyptus miniata</i> woodland on red earth plateaus	Of concern	Of concern	Not listed
1.5.4	Cloncurry Box <i>Eucalyptus leucophylla</i> low open woodland on red earths in valleys	Not of concern	Of concern	Not listed
1.5.5	Silver-leaved Box <i>Eucalyptus pruinosa</i> low open woodland on red earth plains	Not of concern	Of concern	Not listed
1.7.1	Snappy Gum <i>Eucalyptus leucophloia</i> low open woodland on skeletal soils on lateritic scarps and plateaus	Not of concern	No concern at present	Not listed
1.7.2	Silver leaved Box <i>Eucalyptus pruinosa</i> low open woodland on red earth plains	Not of concern	No concern at present	Not listed
1.9.1	Mitchell Grass <i>Astrelba</i> spp. grassland on shallow clays on limestone	Not of concern	No concern at present	Not listed
1.9.5	Cloncurry Box <i>Eucalyptus leucophylla</i> low open woodland-woodland on low hills on limestones and calcareous shales	Not of concern	No concern at present	Not listed

The slurry dewatering and rail load out site has been mapped by DERM as remnant Regional Ecosystems (REs), all classified as Least Concern. No threatened ecological communities listed under the EPBC Act occur within the site and as such no development constraints with respect to threatened ecological communities have been identified.

### 3.4.2 Existing fauna

Fauna assessment conducted within the MLA area and water supply dam inundation area found 79 terrestrial vertebrate fauna species, including one frog, five reptiles, 66 bird and seven mammal species. One introduced species, the Cane Toad *Rhinella marina* (Class 1 under the LP Act), was identified.

Three conservation significant species listed as Rare, (i.e. Black chinned Honeyeater *Melithreptus gularis*, Carpentarian Grasswren *Amytornis dorotheae*, Pictorella Mannikin *Heteromunia pectoralis*) and one conservation significant species listed as Vulnerable (i.e. Purple-necked Rock-wallaby *Petrogale purpureicollis*), under the provisions of the *Nature Conservation Act 1992* (NC Act), were detected.

No fauna species listed as threatened under the provisions of the NC Act and/or the EPBC Act were observed within the haul road, slurry pipeline and powerline survey areas. No pest species listed under the provisions of the LP Act were observed. Areas identified as providing significant habitat for fauna species coincided with areas analogous to RE 1.3.7 (i.e. drainage lines dominated by River Red Gum *Eucalyptus camaldulensis*).

An ecological field reconnaissance of the slurry dewatering and rail load out facility site identified no significant development constraints with respect to threatened or migratory species listed under the EPBC Act.

### 3.4.3 EPBC Act assessment – terrestrial ecology

The terrestrial ecology surveys and assessments concluded that there are no EPBC Act-listed flora or fauna species or Threatened Ecological Communities present in the project area. Terrestrial ecology studies also concluded that the project will not significantly impact EPBC Act-listed migratory species. Therefore the project will not require approval under the provisions of the EPBC Act relating to the protection of terrestrial ecology.

### 3.4.4 Aquatic ecology

Surveys of the aquatic habitat, flora and fauna of waterways within and surrounding the MLA area were completed in June 2009 and March 2010, using the *Queensland AusRivAS* Sampling and Processing Protocols. Aquatic flora and fauna within the MLA area, Leichhardt River in Mount Isa and comparative sites in the region was similar to that of other ephemeral streams in the catchment. Aquatic habitat in the MLA area was in moderate condition, due to moderate bank erosion, low habitat variability, and a range of substrate types. Within the MLA area, watercourses consisted of ephemeral channels, dams and trenches. During the June 2009 aquatic ecology survey, all of the channels within the MLA area were dry; however, the dams, trenches and comparative sites contained water. A post-wet season survey was undertaken in March 2010. The dominant substrate type in the MLA area was sand and gravel.

The channels of the Mica Creek and Leichhardt River adjacent to the slurry dewatering and rail load out site in Mount Isa mainly comprise gravelly sand with cobble size rock fragments.

The aquatic flora community was comprised of few species and coverage at each site was very low (typically less than 3% at each site). A total of ten macrophyte species were recorded in the MLA area. These species were all emergent, and no floating or submerged forms were present. The macroinvertebrate communities present in the MLA area and surrounding survey points were indicative of moderate habitat and water quality.

Fish diversity was moderate: ten species were captured in June 2009. Eastern rainbowfish (*Melanotaenia splendida*) and spangled perch (*Leiopotherapon unicolor*) were the most common fish (recorded at most sites) in the MLA area and surrounds. No introduced species were recorded.

No rare or threatened species of aquatic flora or fauna have been recorded from the waterways of the project area during dry and post-wet season surveys undertaken.

### 3.4.5 EPBC Act assessment – aquatic ecology

No threatened species listed under the EPBC Act were recorded in the project area, though several aquatic species listed under the EPBC Act are known in the region (refer Table 3.4). Of the listed species, it is possible that the Gulf snapping turtle (*Elseya lavarackorum*, listed as endangered) and freshwater crocodile (*Crocodylus johnstoni*, a listed ‘marine’ species) may be seasonally present in the Leichhardt River.

As a listed marine species, freshwater crocodiles are only protected under the EPBC Act where they are found in Commonwealth Marine Waters, which are remote from the project area.

**Table 3.6 Commonwealth conservation status of significant species that may occur in the project area and downstream**

Family	Species	Common name	EPBC Act *
Chelidae	<i>Elseya lavarackorum</i>	Gulf snapping turtle	E
Pristidae	<i>Pristis microdon</i>	freshwater sawfish	V
Crocodylidae	<i>Crocodylus johnstoni</i>	freshwater crocodile	O
Crocodylidae	<i>Crocodylus porosus</i>	estuarine crocodile	M

Source: (DEWHA 2008)

\* The status of species under the Environmental Protection & Biodiversity Conservation Act 1999:  
E: Endangered, M – Migratory, O – Marine, V – Vulnerable.

Based on the aquatic ecology assessment of the project, which include field surveys, it is concluded that the project would not result in a significant impact to any EPBC Act-listed aquatic species, aquatic-migratory species or marine species. As such, the project would not require approval under those sections of the EPBC Act relating to the protection of aquatic ecology and marine species.

### 3.5 Air quality

There is limited air quality data currently available for the local area surrounding the MLA area. Based on the findings of the Paradise North DSO project air quality impact assessment (PB 2009) the existing air quality is considered characteristic of a rural environment.

Sources and activities that may currently be contributing to the regional air quality include:

- emissions from vehicles on the surrounding road network
- particulate and combustion emissions from bushfires and control burns
- adjacent mining activities in the area
- the Barkly Highway.

Table 3.7 summarises the nearest sensitive receptors to the MLA area (1 to 3) and the slurry dewatering and rail load out facility (4 to 6).

**Table 3.7 Nearest sensitive receptor locations**

Sensitive receptor ID	Sensitive receptor description	Approximate distance from project site (Km)
1	North-east (Barr Creek Station)	25.0
2	North-west (Thorntonia Homestead)	32.4
3	South (Lady Annie Operations Accommodation Camp)	16.5
4	Single dwelling to southeast of dewatering site	1.1
5	Ten dwellings within Mica Creek Power Station compound	1.1
6	Dwellings on Mica Creek Road	1.5

### 3.6 Noise and vibration

There is limited noise data currently available for the area surrounding the MLA. Background noise levels in the existing environment would be typical of most remote rural areas.

The regional noise sources that impact on ambient noise levels include low-level agricultural activities and traffic. There are no population-based sources of noise within the immediate vicinity of the MLA area or slurry dewatering and rail load out facility areas, with the nearest industrial noise sources being the Lady Annie mine and processing plant and the non-operational Lady Loretta mine for the MLA area and the Mica Creek Power Station and railway for the slurry dewatering site. The nearest noise sensitive receptors are listed in Table 3.5.

Background vibration for the MLA area is expected from blasting undertaken at the nearby Lady Annie operation. Similarly, background vibration for the rail load out and slurry dewatering facility is expected from the underground mining operations in Mount Isa, the railway in Mount Isa and the Mica Creek Power Station.

### 3.7 Socio-economic conditions

The MLA area is situated in a rural environment surrounded by large leasehold land primarily used for pastoral activities. The nearest townships are Mount Isa located approximately 120 km to the south east, and Camooweal located approximately 80 km west south west of the mine lease area. The proposed slurry dewatering and rail load out facility is located approximately 7 kilometres from Mount Isa.

The project will directly create approximately 1,060 jobs in its planning and construction phase. It is estimated that these jobs will in turn generate another 1,180 jobs through industrial and consumption effects. The planning and construction phase will impact the North and North West regional economies by creating an estimated \$374.75 million in value added, equating to a 2.56% increase in GRP. Gross Regional Product: (GRP) is the total value of final goods and services produced in the region over the period of one year; this includes exports but subtracts imports.

The operational phase of project would directly create 296 jobs which are estimated to generate another 293 jobs through industrial and consumption effects. The impact on the region's economies is estimated at \$145.49 million annually or an increase in GRP of 1.07%. (McDonald, 2009).

### 3.8 Cultural heritage values

At the time of preparing this IAS, indigenous cultural heritage clearance for exploration drilling within the Paradise South MLA had been undertaken with indigenous cultural heritage assessment of the proposed MLA area and access road currently underway. Cultural heritage assessment of the water supply options is subject to the outcome of further commercial assessment and will be undertaken where required for the EIS.

The dewatering facility is located on freehold land. An Indigenous site is located on a chert hill approximately 500 metres south of the boundaries of the slurry dewatering and rail load out facility. This area has been delineated as Lot 5, SP222005 in Mount Isa.

Non indigenous cultural heritage assessment will be undertaken where required.

Within the greater project area, it is therefore possible that there may exist indigenous or non indigenous sites and/or objects which are of cultural heritage significance.

## 4. Potential impacts and management requirements

### 4.1 Land systems

The proposed mining of phosphate rock using truck and shovel operations will result in a number of out-of-pit spoil dumps. The spoil would be reshaped, topsoiled using previously stockpiled material and progressively revegetated. Factors which can impact the long term stability of these spoil dumps, reducing their ability to meet or maintain the proposed land use capability, include climatic factors, geotechnical factors, chemical factors, and geomorphologic factors such as erosion rates.

These factors will be investigated to assist in determining the associated rehabilitation design parameters and the most appropriate post mine land use. Much of this information will be determined during the EIS process while the remainder will be obtained from studies undertaken during the rehabilitation program. Proposed monitoring of rehabilitated areas will also be outlined in the EIS.

As the mine develops, progressive rehabilitation of dump and other mining areas would occur in order to minimise the total land area disturbed by mining at any time. It is expected that an on-site landfill facility will be managed for the disposal of general waste and possibly tyres.

Land use suitability impacts will be limited to areas directly affected by mining activities. The degree to which the land use capability is impacted by the proposed operation will be documented in the EIS. This will include plans for project rehabilitation and decommissioning including that of the beneficiation plant, associated infrastructure and slurry dewatering and rail load out facility in Mount Isa. A study is currently being undertaken for Legend by the Centre for Mined Land Rehabilitation to investigate potential rehabilitation options for mined areas.

### 4.2 Water management and hydrological impacts

#### 4.2.1 Water resources

##### 4.2.1.1 Surface water hydrology

Due to the preliminary nature of studies for the project, a WMS has not yet been developed. Drains will be established adjacent to disturbed areas such as roads to intercept sediment laden run-off into sediment dams to minimise the movement of sediment into the adjacent waterways. Mine water from active mining areas, stockpiles and the beneficiation plant will be contained in environmental management dams and reused to manage the risk of off-site discharge, with no planned releases from the site. Similarly sediment and environmental management dams will be employed at the proposed slurry dewatering and rail load out facility in Mount Isa.

The magnitude of groundwater inflows to mine pits, and the extent of the resultant lowering of the groundwater table and the consequent potential impact on surrounding groundwater users are unknown at this stage. These issues will be addressed during the EIS process.

The potential impacts and mitigation strategies associated with the WMS, including flood impact assessment, surface water quality assessment, and a water balance, will be undertaken as part of the EIS assessment process.

As discussed in Section 3.3, a number of drainage lines and creeks traverse the MLA area. An assessment of the potential flooding issues and investigation into the management and diversion of clean water flows around the MLA area or capture and storage for use in mine operations will be carried out as part of the EIS assessment process. A flood risk assessment will also be undertaken for the slurry dewatering and rail load out facility.

The water supply option to establish a new dam within the Leichhardt River catchment may cause hydrological impacts to the flow regime of the downstream watercourses. These potential impacts will be assessed as part of the dam feasibility and included in the EIS.

#### **4.2.1.2 Groundwater**

The potential impacts of the groundwater inflows to mine pits and the possible construction of a water supply dam are currently being assessed by Legend and will be further investigated during the EIS process.

It is noted that the drawdown on the Thornton aquifer and surrounding groundwater users and land owner consultation was undertaken as part of the approval process for the Thornton borefield licence (Permit No. 403766).

#### **4.2.2 Water quality**

The project has the potential to impact the quality of surface waters and in-stream sediment through:

- vegetation clearing and earth works during construction of the mine and related infrastructure (including haul roads and the slurry dewatering and rail load out facility in Mount Isa) resulting in sediment-laden stormwater runoff (and associated salts, nutrients and contaminants) entering downstream waterways
- runoff from ore stockpiles and pits transporting nutrients and contaminants during mining operations to downstream waterways
- domestic wastewater spills entering natural waterways, resulting in nutrient enrichment,
- industrial waste (which may contain fuels, oils, lubricants and other contaminants) from infrastructure areas entering natural waterways
- spills from vehicles and machinery, entering the waterways.

These potential impacts will be managed and mitigated through:

- development of a WMS that minimises discharge of mine water to the receiving environment, and ensures the quality of any water that is discharged meets licence conditions
- implementation of erosion and sediment control

- implementation of fuel-handling and storage procedures in accordance with Australian Standard AS 1940 (2004) – The storage and handling of flammable and combustible liquids
- rehabilitation of both temporary and permanent creek crossing sites, and the project area after completion of mining.

## 4.3 Biological impacts

### 4.3.1 Terrestrial ecology

#### 4.3.1.1 Flora

Direct impacts to terrestrial flora communities will be limited to vegetation within the MLA area, the access road and power supply corridors, the water supply and slurry pipelines, and, the dam construction footprint and inundation area.

Flora communities in the MLA area have been surveyed and mapped. With the exception of RE 1.5.2, all vegetation communities that will be removed from the MLA area are well represented within adjacent areas and in the broader landscape, with no significant biodiversity impacts expected. It should be noted that one RE (RE 1.3.7) has a biodiversity status of Endangered. This community is generally distributed along the drainage lines located within the southern portion of the MLA area and within the central portions of the proposed water supply dam inundation area. Impacts to this community within the MLA area and dam inundation area will be reduced where possible.

Exotic flora species are relatively uncommon within the MLA and water supply dam inundation area, and no species listed under the provisions of the LP Act was observed. However, weed diversity was greater within the proposed inundation area.

There is potential for exotic species to invade during road and dam construction and throughout mining activities. It is therefore proposed that a weed management plan is developed in the EIS for implementation as part of the project to ensure that weed species listed under the LP Act are eradicated when observed.

Direct impacts to terrestrial flora communities will be limited to vegetation within the path of the linear infrastructure.

Flora communities in the off mining lease components of the project (the power line, slurry pipeline and access road) were also surveyed and mapped. With the exception of three RE's (RE 1.5.1, RE 1.9.2 and RE 1.9.4) all vegetation communities that will be disturbed as part of the proposed activities are well represented within adjacent areas and in the broader landscape, with no significant biodiversity impacts expected. However, RE 1.3.7 has a biodiversity status of Endangered; therefore disturbance to this area will be minimised or avoided wherever possible.

Exotic flora species are relatively uncommon within the infrastructure areas. However, given the linear nature of the proposed infrastructure and disturbance footprint, there is potential for exotic species to invade during the construction and operational works stage. This will be addressed in more detail in the EIS.

Additional impact assessment will be provided in the EIS to address the potential impacts of the mine associated infrastructure of the project including the slurry dewatering and rail load out facility in Mount Isa.

#### 4.3.1.2 Fauna

The potential for impacts to terrestrial fauna communities have been assessed in the MLA area, infrastructure corridors and dewatering facility and include:

- activities that affect stream morphology and water quality through siltation as a result of mine activities and construction and maintenance of the beneficiation plant, slurry dewatering and rail load out facility and associated infrastructure. This may impact a number of water dependent species including the conservation significant Pictorella Mannikin *Heteromunia pectoralis* (known from the MLA area and expected to occur)
- activities that alter rocky outcrop formations that may provide shelter habitat for conservation significant fauna including Purple-necked Rock-wallaby and Troughton's Sheathail Bat *Taphozous troughtoni* (expected to be present within the MLA although not recorded)
- mining operations, plant development and access road alteration/expansion will necessitate the removal of vegetation. Tree hollows are abundant throughout the site, including the low vegetation on the site. This will result in the displacement of fauna utilising these hollows as shelter/nesting sites, as well as displacing fauna utilising shelter sites on the ground
- an increase in traffic volumes would result in increased fauna road kill, especially should traffic continue at night.

Management programs to be considered will include:

- water sources available for vertebrate species in the project area and surrounds that may be impacted by the project should be accurately mapped and design of the project should ensure for sufficient retention of this important resource
- an erosion and sediment control strategy should be developed and implemented to mitigate any potential impacts on waterways within and adjacent to the project area. Future monitoring of watering points for vertebrate activity in the project area will indicate the success of these measures
- existing rock formations that provide shelter for conservation significant species should be avoided where possible
- fauna spotters should be utilised prior to vegetation removal activities to locate, remove and relocate fauna residing in tree hollows that will be removed by such activities
- minimise vehicle speeds reduce the incidence of road kill. Opportunity for a night time reduction in vehicle speed on the access road should be investigated
- a dust suppression strategy should be developed and implemented for the mine site and access road to reduce the potential for dust related impacts to native fauna and flora communities.

Additional assessment of the potential impacts of the mine associated infrastructure will be presented in the EIS including the slurry dewatering and rail load out facility in Mount Isa.

#### **4.3.2 Aquatic ecology**

Construction, mining and plant activities have the potential to impact aquatic ecology through activities including the operation of mining equipment and vehicles, and other plant and equipment, vegetation clearing and earth moving, management of water resources, construction of creek crossings and the loss of catchment area.

Typically, these impacts can be effectively managed and mitigated through:

- development of a WMS that minimises discharge of mine water and plant site runoff to the receiving environment
- implementation of erosion and sediment control measures
- implementation of fuel-handling and storage in accordance with Australian Standard AS 1940 (2004) – The storage and handling of flammable and combustible liquids
- constructing creek crossings in accordance with QPIF Fish Habitat Guideline, Fish Passage in Streams, Fisheries guidelines for design of stream crossings
- rehabilitation of both temporary and permanent creek crossing sites, and of the project area after completion of mining
- translocating aquatic fauna from an isolated workspace in accordance with the QPIF Fish Salvage Guidelines.

More detailed assessment of the potential impacts of the project, and specifically the mine related infrastructure (pipelines (including dewatering facility) and water supply dam) will be prepared for the EIS.

### **4.4 Air quality**

Detailed air quality studies will be completed as part of the EIS process. This will ensure that sensitive receptors are not adversely affected by particulate matter and other potential pollutants generated by the project.

### **4.5 Noise and vibration impacts**

The project is expected to operate on and 24 hour per day, 7 day per week basis. However, given the location of sensitive receptors to the mine and beneficiation plant facilities and that blasting will not be required, it is expected that noise impacts would be negligible.

Since no blasting will be undertaken for the project, it is expected that vibration impacts will also be negligible, and limited to low levels of localised vibration associated with the transport of heavy materials to the site during the construction stage, and, during the transport of beneficiated ore if undertaken by road trains.

Noise and vibration effects of the construction of the various mine related infrastructure elements will generally be of a short duration, and in most cases, well away from sensitive receptors. The potential impacts of these components will be assessed in more detail in the EIS.

Noise and vibration from the slurry dewatering and rail load out facility will be assessed as part of the EIS process.

## **4.6 Visual amenity impacts**

The EIS will investigate impacts to visual amenity associated with the project. Given the location of the project, visual impacts produced by the mine's operations are expected to be low. Impacts will be minimised by progressive rehabilitation of areas affected by mining activities.

Visual amenity will be considered during the design of the slurry dewatering and rail load out facility in Mount Isa.

## **4.7 Socio-economic impacts**

A number of accommodation alternatives will be considered, as discussed in Chapter 2. These proposed locations take into account responsible safe pre and post-work travel distances.

Some of the construction workforce is anticipated to be sourced from Mount Isa and the surrounding regional area, with the remainder being sourced elsewhere. Local and other appropriately experienced mine workers will be employed by the project.

The feedback from the community consultation program, as discussed in Chapter 1, will be used to inform the assessment of the potential socioeconomic impacts of the project. Consultation will continue during the EIS process to ensure that community issues are identified and addressed.

## **4.8 Cultural heritage impacts**

Following the completion of the both the indigenous and non indigenous cultural heritage assessments, action plans will be developed with the relevant parties to mitigate potential impacts identified.

## **4.9 Waste management**

Likely wastes to be generated during the construction stage include general wastes, green waste, concrete materials, metals, waste hydrocarbons, timber, tyres, sealant/resin and paint materials, sewage effluent, vehicle washdown, and exhaust emissions. Wastes that are anticipated to be produced during the operations phase include green waste, batteries, general waste (e.g. paper, cans cardboard), scrap metal, tyres, water treatment plant waste, and tailings and crushed rock waste.

The management of crushed rock waste and tailings is discussed in Chapter 2.2 – Ore processing (beneficiation).

Fuels, oils, detergents and other chemicals will be stored on site during the construction and operational phases of the project. Hazardous materials such as batteries and hydrocarbon materials will be stored in accordance with the relevant Australian Standards to ensure that any spillages are contained. General and industrial waste management strategies will be developed in the EIS.

## **4.10 Transport impacts**

Concentrated phosphate ore will be transported by slurry pipeline to a slurry dewatering and rail load out area located in Mount Isa.

A transport impact assessment will be undertaken to address any potential increases in traffic generated during the construction and operations phases of the project. Legend will consult with the Department of Transport and Main Roads in regards to determining the necessary mitigation measures required for the project.

## 5. References

ANZECC & ARMCANZ 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand.

Bureau of Rural Resources, 1991, *Digital Atlas of Australian Soils*, Australian Government. Access via the Queensland Department of Mines and Energy interactive resource and tenure maps ([http://www.dme.qld.gov.au/mines/tenure\\_maps.cfm](http://www.dme.qld.gov.au/mines/tenure_maps.cfm), accessed on 13 November 2009)

Christian, C.S., Noakes, L.C., Perry, R.A., Slatyer, R.O., Stewart, G.A., and Traves, D.M. 1954, *Survey of the Barkly Region, Northern Territory and Queensland 1947-48*, Land Research Series No. 3, CSIRO, Melbourne.

DEWHA, 2008, EPBC Protected Matters Search Tool, <http://www.environment.gov.au/erin/ert/epbc/index.html>, updated 23 October 2008, accessed August 2009.

EPA 2007, Queensland Water Quality Guidelines 2006, Environmental Protection Agency, Brisbane.

(McDonald, L. 2009, REMPLAN modelling of the economic benefits of Legend International's DSO Rock Phosphate, Beneficiated Rock Phosphate and MAP/DAP manufacturing projects on the Northern & North West Statistical Divisions, Townsville Enterprise Ltd, August 2009).

PB, 2009, Paradise North DSO Project – Environmental Management Plan, October 2009

Rogers, J.K. and Keevers, R.E. 1976. Lady Annie-Lady Jane Phosphate Deposits, Georgina Basin, Queensland. In: *Economic Geology of Australia and Papua New Guinea, Vol. 4. Industrial Minerals and Rocks* (Ed C.L. Knight), pp. 251-265. Australasia Institute of Mining and Metallurgy, Monograph 8.

Shergold, J.H. and Druce, E.C. 1980. Upper Proterozoic and Lower Palaeozoic rocks of the Georgina Basin. In: *The Geology and Geophysics of North-Eastern Australia* (Eds R.A. Henderson and P.J. Stephenson), pp. 149 – 174. Geological Society of Australia, Queensland Division, Brisbane.