October 2009



Brockman Resources Limited
Marillana (E47/1408)
Vegetation and Flora Report

Version 5

Providing sustainable environmental strategies,
management and monitoring solutions
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Executive Summary

Brockman Resources Limited (Brockman) is proposing to conduct iron ore mining operations at its Marillana tenement, E47/1408. The tenement spans approximately 16 km along the base of the Hamersley Range, and covers an area of approximately 94 km^2. Brockman plans to mine the detrital iron ore deposits that are found along the base of the Range.

The tenement is located approximately 100 km north-west of Newman in the Pilbara region of Western Australia.

Following appropriate consultation with relevant stakeholders, Brockman commissioned *ecologia* Environment (*ecologia*) to undertake a two-phase survey of the vegetation and flora of its Marillana project area.

The primary objective of this survey was to provide sufficient information to the Environmental Protection Authority (EPA) to assess the impact of the project on the vegetation and flora of the area. The EPA's objectives with regards to management of native flora and vegetation are to:

- Avoid adverse impacts on biological diversity comprising the different plants and the ecosystems they form at the levels of genetic, species and ecosystem diversity.
- Maintain the abundance, species diversity, geographic distribution and productivity of vegetation communities.
- Protect declared rare flora consistent with the provisions of the *Wildlife Conservation Act 1950*.
- Protect other flora species of conservation significance.

The first phase of the survey was carried out in June 2008 and the second in September 2008. Systematic and opportunistic sampling methods were used. A total of 137 quadrats was assessed over both phases, 82 during phase 1 and 72 during phase 2; 17 of these 72 quadrats had been assessed during phase 1 also.

The Marillana survey area crosses six of the land systems that have been mapped in the Pilbara - the Fortescue, Turee, Fan, Boolgeeda, Divide and River land systems.

Vegetation

The vegetation of the survey area was mapped into eight main vegetation units, with some further classified into sub-units on the basis of landform and the structure and species composition of the dominant strata. The vegetation types mapped were associated with the following landforms: creek lines, drainage channels on the footslopes, clay pans, minor channel or drainage depressions, floodplains, longitudinal sand dunes, sandy plains and a minor footslope. The eight vegetation units follow:

1. *Eucalyptus victrix* and *Acacia citrinoviridis* low woodland (with two sub-units);

2. *Acacia tumida* and *Grevillea wickhamii* tall shrubland;

3. *Acacia aneura* low woodland, over *Acacia synchronicia* tall shrubland, over **Cenchrus* spp. tussock grassland;

4. *Acacia aneura* low open forest (with two sub-units);

5. *Acacia citrinoviridis, Corymbia hamersleyana, Acacia aneura* and *Acacia pruinocarpa* open woodland, over *Acacia* spp. tall shrubland, over **Cenchrus* spp. closed tussock grassland (with three sub-units);

6. *Acacia dictyophleba* tall shrubland, over *Triodia schinzii* open hummock grassland;

7. *Acacia* spp. medium to high open shrubland, over *Triodia basedowii* and *Triodia schinzii* hummock grassland; and

8. *Corymbia hamersleyana* isolated low trees, over *Eucalyptus gamophylla* mallee woodland, over *Acacia* spp. and *Grevillea wickhamii* tall shrubland, over *Triodia basedowii* hummock grassland (with five sub-units).

These vegetation units are similar to the vegetation recorded during other surveys conducted in this area of the Pilbara.

Database searches indicate that no threatened ecological communities occur within 50 km of the Marillana survey area. One State-listed priority ecological community (PEC) occurs within the survey area, the Priority 3 'Vegetation of sand dunes of the Hamersley Range and Fortescue Valley'. In addition, the Weeli Wolli Spring PEC occurs within 50 km of the survey area and the Fortescue Marsh PEC is approximately 15 km north of the survey area; both are Priority 1 PECs.

Flora

A total of 302 taxa resulted from the combined records for both phases of the survey. These taxa included 42 families and 116 genera. Of this combined total, 224 taxa from 38 families and 100 genera were recorded during the first phase of the survey and 244 taxa from 39 families and 104 genera during the second.

Diversity at the survey area was slightly higher than at other areas surveyed in the Pilbara.

Results of database searches carried out indicate that two declared rare flora taxa have been collected within 50 km of the survey area; *Lepidium catapycnon* and *Thryptomene wittweri.* Due to the habitat requirements of the species the likelihood of their occurrence in the survey area is low.

No declared rare flora species were recorded at the Marillana survey area.

Eighteen priority flora taxa have been recorded within 50 km of the survey area: *Calotis squamigera, Eremophila spongiocarpa, Myriocephalus nudus* (all Priority 1), *Acacia daweana*, *Eremophila forrestii* subsp. Pingandy (M.E. Trudgen 2662), *Olearia fluvialis*, *Spartothamnella puberula* (all Priority 2), and *Acacia bromilowiana, Calotis latiuscula, Hibiscus brachysiphonius, Indigofera gilesii* subsp. *gilesii* , *Polymeria* sp. Hamersley (ME Trudgen 11353), *Rhagodia* sp. Hamersley (M. Trudgen 17794), *Rhynchosia bungarensis, Rostellularia adscendens* var. *latifolia, Tephrosia* sp. Cathedral Gorge (F.H. Mollemans 2420), *Triumfetta leptacantha and Eremophila magnifica* subsp. *magnifica* (all Priority 3).

One Priority 3 flora species, *Goodenia nuda*, was recorded at two sites in the survey area.

No declared weeds were recorded in the area while 10 weed species were recorded over the two phases of the survey: **Aerva javanica*, **Argemone ochroleuca* subsp. *ochroleuca*, **Cenchrus ciliaris*, **Cenchrus setiger, *Chloris virgata, *Datura leichhardtii, *Malvastrum americanum*, **Portulaca oleracea, *Setaria verticillata* and **Vachellia farnesiana. *Argemone ochroleuca* subsp. *ochroleuca* and **Datura leichhardtii* are declared weeds in other parts of the State, but not in the East Pilbara.

Conformance of the Project to relevant EPA statements is addressed in Table S.1 of this summary while the conservation significance of the vegetation and flora of the survey area, and an assessment of potential impacts, are discussed in Sections 6 and 7.

Table S.1 – Conformance of the Marillana Survey to Relevant EPA Statements

Requirement	EPA Statement	Relevance to Project	Project Compliance
Impact on Biodiversity	Position Statement No. 3	Where impact on biodiversity cannot be avoided, the proponent must demonstrate that the impact will not result in unacceptable loss.	No declared rare flora species were recorded during the survey. One Priority 3 flora species, *Goodenia nuda,* was recorded once during phase 1, and once during phase 2. If impact to this species cannot be avoided, it is considered unlikely that it would result in the extinction of the species and consequent loss of biodiversity. *Goodenia nuda* is a relatively widespread priority species that can grow in a variety of habitats and is not restricted to the Marillana survey area. Impacts to biodiversity within proposed infrastructure areas have not been estimated in this report, however, they are included in the PER.
State, National and International Agreements, Legislation and Policy on Biodiversity	Position Statement No. 3	Information gathered for environmental impact assessment in Western Australia meets State, National and International Agreements, Legislation and Policy in regard to biodiversity conservation.	Impacts to species and communities listed under relevant legislature are addressed in Section 6. The relevance of the project to principles outlined in the *Environmental Protection Act 1986, Wildlife Conservation Act 1950* and *Environment Protection* and *Biodiversity Conservation Act 1999* is discussed in Sections 1.2, 1.3 and 6.
EPA Standards, Requirements and Protocols	Position Statement No. 3	The quality of information and scope of field surveys meets the standards, requirements and protocols as determined and published by the EPA.	The current survey conforms to a Level 2 survey, comprising a reconnaissance survey, a comprehensive two phase vegetation and flora survey and mapping of the vegetation of the area, as per Environmental Protection Authority Guidance Statement 51.
Biodiversity Conservation and Ecological Function Values	Position Statement No. 3	Sufficient information is provided to address biodiversity conservation and ecological function values.	Impacts to biodiversity and ecological function are discussed in Section 6. The value of the vegetation associations and conservation significant flora taxa occurring in the project area is also discussed in a bioregional context in Section 6.
State Biological Databases	Position Statement No. 3	Terrestrial biological surveys will be made publicly available and will contribute to the bank of data available for the region.	Voucher specimens of the priority flora species collected will be lodged at the WA Herbarium. Information collated from this survey will be included in public documents available for use by others.

Requirement	EPA Statement	Relevance to Project	Project Compliance
Sampling design and intensity at two levels – regional and area specific	Guidance Statement No. 51	Sites were assessed at the area specific level.	Data was collected on an area specific level. A two-phase survey was carried out and 137 quadrats were assessed at the survey area (17 sites were surveyed in both phases). Regional data is available from other surveys undertaken in the area.
Landform – scale, rarity, heterogeneity	Guidance Statement No. 51	Sites should be established in the different landforms occurring across the study area.	Sites were selected from aerial photography before going to the field. Vegetation units occurring on the different landforms of the area were verified in the field, and sites were assessed based on their representation on those landforms. In most cases multiple sites were assessed on each landform.
Habitat – scale, rarity, heterogeneity	Guidance Statement No. 51	Sites should be established in the different habitats occurring across the study area.	Sites were selected from aerial photography before going to the field and ground-truthing of the vegetation types occurring in the different habitats took place during the survey. Sites were selected depending on a habitat's representation in the area. In most cases multiple sites were assessed in each habitat.
Potential for conservation significant flora to occur, based on habitat analysis	Guidance Statement No. 51	Sufficient information is to be provided to indicate the potential for significant flora to occur based on habitats in the area.	Lists of the conservation significant taxa recorded in the vicinity of the survey area are provided in Appendix A1. An analysis has been carried out on the likelihood of these taxa occurring in the survey area. Habitats where conservation significant taxa could potentially occur were targeted during the field surveys.
Information on adjacent areas – previous surveys and herbarium records	Guidance Statement No. 51	Adequate information was already available on the wider project area, as other surveys have been undertaken in the area.	Information was requested from relevant government databases and also was collated from reports on other surveys undertaken in the vicinity of Brockman's Marillana project area.

Requirement	EPA Statement	Relevance to Project	Project Compliance
Vegetation structure, diversity and seasonality	Guidance Statement No. 51	Sufficient information is to be provided in the report on vegetation structure, diversity and seasonality.	The report details the results of a vegetation mapping exercise carried out over the survey area. The data collected was analysed using multivariate statistical analysis. Following analysis the main vegetation associations occurring in the area were mapped and the structure of the vegetation associations was described. The two phases of the survey were carried out in different seasons, the first in winter and the second in spring. The diversity and seasonality in the flora of the survey area are represented in the species list.
Results including species/area curves, species and ecosystem diversity and heterogeneity	Guidance Statement No. 51	Adequate information is provided in the report to comply with this requirement.	A species accumulation curve is included in Section 5.1. Details on the flora of the survey area are included in this report and comparisons with the flora of other areas in the region are also included in Section 5.1. A vegetation map and detailed vegetation descriptions are provided for the survey area.

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1 INTRODUCTION

1.1 BACKGROUND

Brockman Resources Limited (Brockman) is proposing to conduct iron ore mining operations at Marillana (tenement E47/1408). The tenement covers approximately 16 km along the base of the Hamersley Range, and is approximately 94 km^2 in area. Brockman plans to mine the detrital iron ore deposits that are found along the base of the Hamersley Range.

The tenement is located approximately 100 km north-west of Newman in the Pilbara region of Western Australia (Figure 1.1).

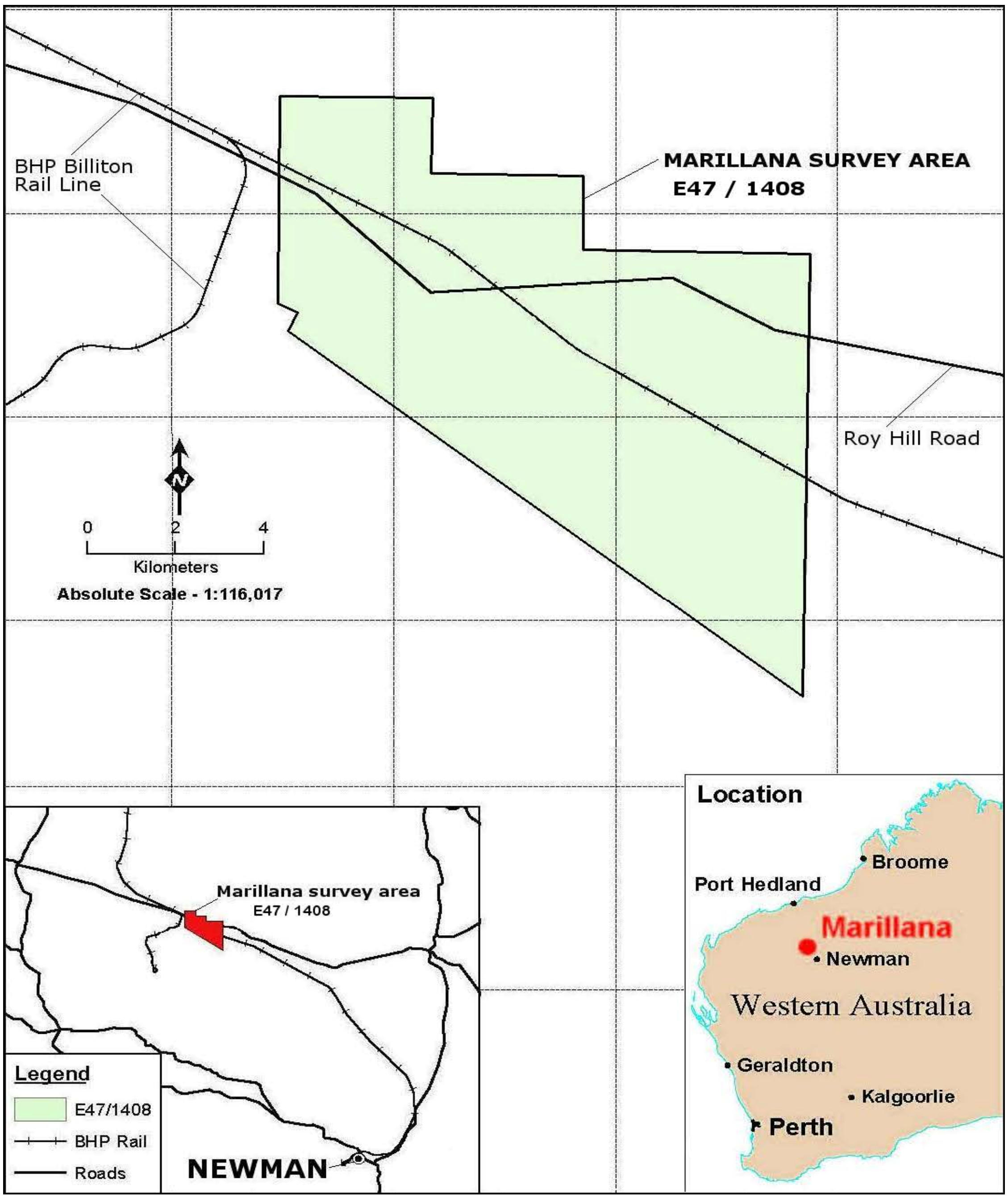

Figure 1.1 – Location of the Marillana Survey Area

1.2 LEGISLATIVE FRAMEWORK

Federal and State legislation applicable to the conservation of native flora and fauna includes, but is not limited to, the *Environmental Protection Act 1986* (*EP Act*), the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and the *Wildlife Conservation Act 1950* (*WC Act*).

Section 4a of the *EP Act* requires that developments take into account the following principles applicable to native flora and fauna:

The Precautionary Principle

Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

The Principle of Intergenerational Equity

The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

The Principle of the Conservation of Biological Diversity and Ecological Integrity

Conservation of biological diversity and ecological integrity should be a fundamental consideration.

Native flora in Western Australia is protected at a federal level under the *EPBC Act* and at a state level under the *WC Act.*

The *EPBC Act* was developed to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance. It aims to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources, and to promote the conservation of biodiversity. The *EPBC Act* includes provisions to protect native species and, in particular, to prevent the extinction and promote the recovery of threatened species. In addition to the principles outlined in Section 4a of the *EP Act*, Section 3a of the *EPBC Act* includes a principle of ecologically sustainable development dictating that decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.

The *WC Act* was developed to provide for the conservation and protection of wildlife in Western Australia. Under Section 14 of this Act, all flora within Western Australia is protected; however, the Minister may, via a notice published in the *Government Gazette*, declare a list of flora taxa identified as likely to become extinct, or as rare, or otherwise in need of special protection. The current listing was gazetted on the 5th August 2008.

Biological surveys undertaken as part of the Environmental Impact Assessment (EIA) process in Western Australia are required to address the Environmental Protection Authority's (EPA) Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA, 2002), Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004a) and Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004b).

Following appropriate consultation with relevant stakeholders, Brockman commissioned *ecologia* Environment (*ecologia*) to undertake a two-phase survey of the vegetation and flora of its Marillana project area, as part of the EIA process for the project.

1.3 SURVEY OBJECTIVES

The EPA's objectives with regards to management of native flora and vegetation are to:

- Avoid adverse impacts on biological diversity comprising the different plants and the ecosystems they form at the levels of genetic, species and ecosystem diversity.
- Maintain the abundance, species diversity, geographic distribution and productivity of vegetation communities.
- Protect declared rare flora consistent with the provisions of the *WC Act*.
- Protect other flora species of conservation significance.

Hence, the primary objective of this study was to provide sufficient information to the EPA to assess the impact of the project on the vegetation and flora of the area, thereby ensuring that these objectives are upheld.

More specifically, the objectives were to undertake a survey that satisfies the requirements documented in EPA Guidance Statement 51 and Position Statement No. 3, thus providing:

- A review of background information (including literature and database searches).
- An inventory of vegetation units and flora species occurring in the study area, incorporating recent published and unpublished records.
- An inventory of species of biological and conservation significance recorded or likely to occur within the project area and surrounds.
- A map and detailed description of vegetation units occurring in the study area.
- A description of the characteristics of the vegetation units.
- An appraisal of the current knowledge base for the area, including a review of previous surveys conducted in the area, which are relevant to the current study.
- A review of regional and biogeographical significance, including the conservation status of species recorded in the project area.

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2 EXISTING ENVIRONMENT

2.1 CLIMATE

Marillana is situated in the Pilbara region of Western Australia and experiences an arid-tropical climate with two distinct seasons; a hot summer from October to April and a mild winter from May to September. Annual evaporation exceeds rainfall by as much as 500 mm per year. Seasonally low but unreliable rainfall, together with high temperatures and high diurnal temperature variations are also characteristic of the region.

In the past the region has received zero rainfall during the year, which is typical of a desert climate. Within the Pilbara, the temperature range is large and maxima are high. Summer temperatures may reach as high as 49°C, with a mean maximum of 30°C, while the winter mean maximum is 23°C (ranging from 14–35°C). Light frosts occasionally occur during July and August. The climate experienced throughout the year is usually very dry since high temperatures and humidity seldom occur simultaneously (Beard, 1975).

Rainfall in the Pilbara is highly unpredictable and recordings are highest at stations around the Hamersley Range which reach altitudes of up to 900 m. The majority of the Pilbara has a bimodal rainfall distribution, resulting in two rainfall maxima per year. From January to March rains result from tropical storms producing sporadic thunderstorms. Tropical cyclones moving south from northern Australian waters also bring sporadic heavy rains. From May to June extensive cold fronts move easterly across the state and occasionally reach the Pilbara. These fronts produce only light winter rains that are ineffective for the growth of plants other than herbs and grasses. Larger perennial species require the intense and prolonged storms of summer. Surface water can be found in some pools and springs in the Pilbara all year round, although watercourses only flow briefly due to the short wet season (Beard, 1975).

The closest Bureau of Meteorology (BOM) weather station to the project area is at Sand Hill (22.78° S, 119.62° E) (BOM 2008); however, data collection ceased at this station in 1984. Newman Aero weather station (23.42° S, 119.80° E) is the next closest to the Marillana tenement (75 km to the south) and its data have been used to provide an indication of climatic conditions at the project area (Figure 2.1).

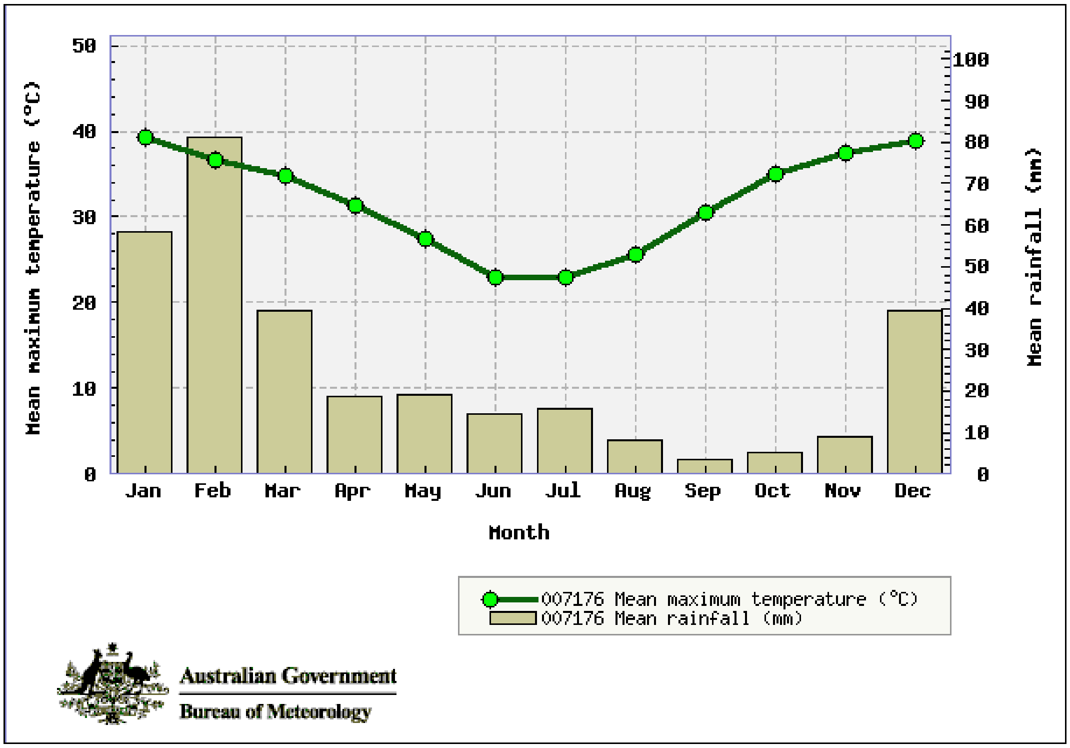

Figure 2.1 – Newman Aero Climatic Data.

The average annual rainfall at Newman Aero is 317.6 mm, occurring over 40.1 rain days (Table 2.1). It loosely follows the typical Pilbara bimodal distribution pattern, with a peak between December and March (Figure 2.1). Most of the rainfall is received in the summer period, with over 68% of it falling between December and March.

Mean annual maximum and minimum temperatures for Newman Aero are 31.9°C and 15.9°C respectively. Mean monthly maxima range from 39.3°C during January to 22.9°C in June, while mean monthly minima range from 24.8°C in January to 6.3°C in June (Table 2.1).

Table 2.1 – Newman Aero Climatic Data.

Latitude: 23.42 °S				Longitude: 119.80 °E			Commenced: 1971		Last record: April 2009			Elevation: 524 m	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily max. temp (°C)													
	39.3	36.6	34.7	31.4	27.4	22.9	23.0	25.6	30.5	34.9	37.5	38.8	31.9
Mean daily min. temp (°C)													
	24.8	23.7	21.4	17.0	11.7	6.3	5.7	7.3	11.9	17.1	20.6	23.5	15.9
Mean monthly rainfall (mm)													
	58.5	81.2	39.5	18.7	19.0	14.3	15.7	8.2	3.6	5.0	8.9	39.5	317.6
Highest monthly rainfall (mm)													
	239.8	305.6	214.2	89.6	110.3	77.8	139.8	79.6	35.6	34.8	50.2	236.0	
Mean no. of rain days													
	6.1	7.1	4.6	3.2	2.7	2.9	2.6	1.4	0.9	1.3	2.2	5.1	40.1

Source: Bureau of Meteorology, April 2009.

Total rainfall in the three months preceding the Marillana phase 1 survey (in June 2008) was 36.2 mm, which is 50.9 mm less than the long-term mean for the same three months of the year (87.1 mm) (Table 2.2).

The total rainfall in the three months preceding the phase 2 survey (in September 2008) was 40.8 mm, which is 7.3 mm less than the long-term mean for the same three months of the year (48.1 mm) (Table 2.2).

Table 2.2 – Newman Aero Monthly Rainfalls for 2008 / 2009 Compared with the Long-term Mean.

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2008	15.6	125	35	1.2	0	34.6	0	6.2	0.8	1	17.8	41.6
2009	39											
Mean	51.4	80.1	38.6	25.3	23.2	25.0	12.6	10.5	4.1	3.9	9.8	27.0

2.2 LANDFORMS

The survey area lies in the Fortescue Valley and follows the northern-eastern escarpment of the Hamersley Range. The mining operations will focus on the iron rich detrital deposits at the base of the Range that are a result of erosion from this escarpment.

The Hamersley Plateau is comprised mainly of the Hamersley and Ophthalmia Ranges, characterised by long strike ridges rising 300 m or more above the valley floors. Flats of Cainozoic sediments are found on the Fortescue Valley floors, which were deposited on the less resistant units of the lower Hamersley Group (Thorne and Tyler, 1997).

2.3 GEOLOGY

The Pilbara region comprises a portion of the ancient continental Western Shield, which dominates the geology of Western Australia. The Western Shield comprises of pre-Cambrian Proterozoic and Archaean rocks. The Pilbara Craton dates back to the Archaean, and includes some of the oldest rocks in the world. It is overlain by Proterozoic rocks deposited in the Hamersley and Bangemall Basins. The Hamersley Basin, which overlies most of the southern part of the Pilbara Craton, can be divided into three stratigraphic groups; the Fortescue, Hamersley and Turee Creek Groups (Beard, 1975).

The Marillana survey area occurs in the Fortescue Group (Fortescue Valley), bordering the Hamersley Group. The Fortescue Valley geology is generally described as Quaternary alluvium, colluvium and sand plains overlying the Tertiary Oakover formation (limestone and calcareous gravels) and chert breccia can be exposed locally (Beard, 1975).

The Hamersley Group is important as it contains both the Brockman and Marra Mamba Iron Formations, which together are the most economically important formations and provide most of the known major iron ore deposits in the Pilbara region (O'Brien and Associates, 1992).

Thorne and Tyler (1997) mapped the geological units of Western Australia (1:250,000). Locally the Marillana survey area is characterised by:

- Alluvium and colluvium deposits forming red-brown clayey and sandy soils on the lower slopes and sheet-wash areas (flat clay pans);
- Eolian sand deposits in sheets and longitudinal dunes (sandy plains and sand dunes);
- Alluvium, unconsolidated silt, sand and gravel in drainage channels and adjacent floodplains (creek lines and floodplains);
- Hematite-goethite deposits on banded iron-formations and adjacent scree deposits (rocky hill slopes); and,

- Banded Iron formation and pelite (as part of the Brockman Iron Formation on the rocky hill slopes).

2.4 SOILS

The Fortescue Valley is characterised by alluvial plains, hard pan wash plains and sandplains (with stony plains, floodplains and some salt lakes) on alluvial deposits over sedimentary rocks of the Hamersley Basin. The soils associated with these habitat types include; red deep sands, red loamy earths and red-brown non-cracking clays with some red shallow loams and hard cracking clays. These soils support mulga shrublands and spinifex grasslands (with some tussock grasslands and halophytic shrublands).

The areas of Marillana that extend into the hills and dissected plateaus of the Hamersley Range have stony soils with red shallow loams, some red-brown non-cracking clays and red-loamy earths. These soils support spinifex grasslands with Snappy Gum (*Eucalyptus leucophloia*) and Kanji (*Acacia inaequilatera*) (Beard, 1975).

2.5 LAND SYSTEM CLASSIFICATION

The Marillana survey area spans six land systems (Figure 2.2) as mapped by Van Vreeswyk *et al.* (2004). Table 2.3 shows the total area of each land system in the survey area and in Western Australia and presents the percentage total impact to each land system if all of the survey area was to be impacted by the proposed mining activities.

Table 2.3 – Land Systems of the Marillana Survey Area.

Land system	Habitat	Total area in the Pilbara (km^2)	Approx. area at Marillana E47/1408 (km^2)	Proportion of the total area in the Marillana survey area (%)
Fortescue	Alluvial plains and floodplains supporting patchy grassy woodlands, shrublands and tussock grasslands	504	42	**8.31**
Turee	Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands of mulga and snakewood	581	6.8	1.16
Fan	Wash plains and gilgai plains supporting groved mulga shrublands and minor tussock grasslands	1,482	10.5	0.70
Boolgeeda	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands	7,748	20.6	0.26
Divide	Sandplains and occasional dunes supporting shrubby hard spinifex grasslands	5,293	12.2	0.23
River	Active floodplains and major rivers supporting grassy *Eucalyptus* spp. woodlands, tussock grasslands and soft spinifex grasslands	4,088	3.4	0.08

Information in columns 2 and 3 sourced from Van Vreeswyk *et al*. (2004).

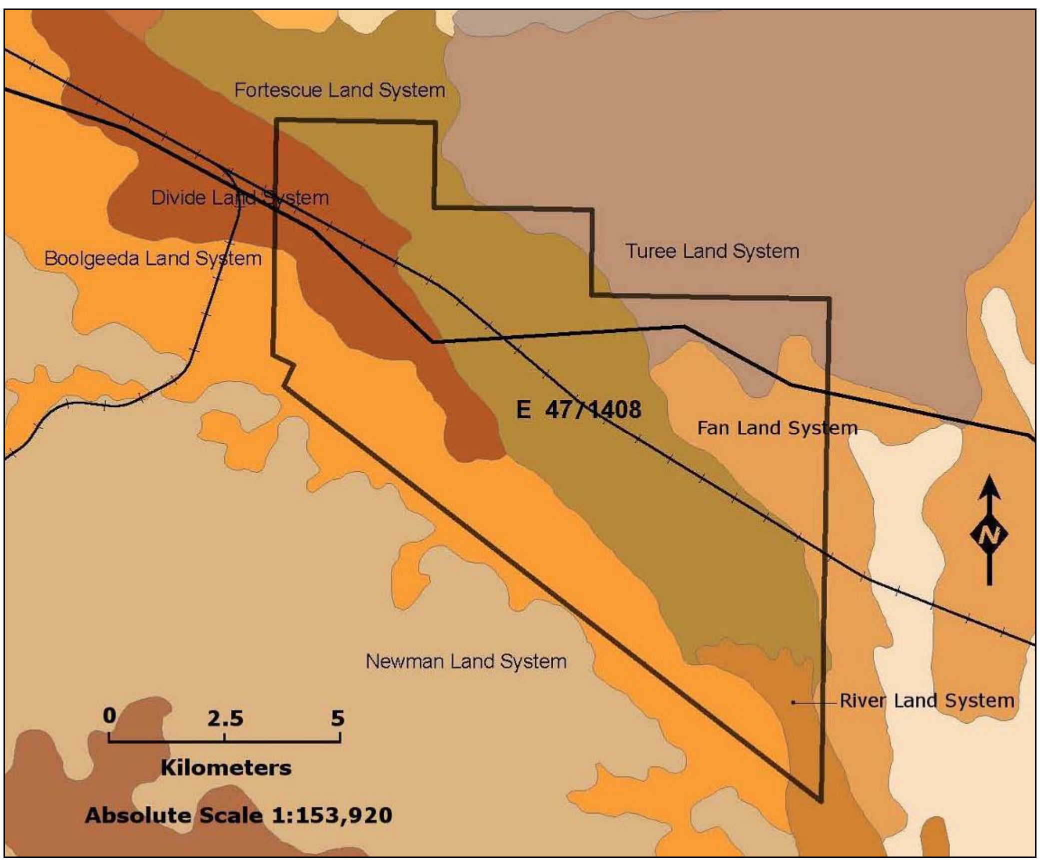

Figure 2.2 – Land Systems of the Marillana Survey Area.

2.6 PILBARA IBRA BIOGEOGRAPHIC REGION

The survey area lies in the Pilbara biogeographic region of the Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway and Cresswell, 1995). This is a system of some 85 biogeographic regions covering the whole of Australia, and is the result of collaboration between all state conservation agencies with co-ordination by the Australian Nature Conservation Agency (ANCA). Bioregions are defined on the basis of climate, geology, landforms, vegetation and fauna.

With an area of 179,287 km^2, the Pilbara bioregion is in the largest area class. Other bioregions vary from 2,372 to 423,751 km^2, most being between 14,000 and 200,000 km^2. The size of the Pilbara bioregion is fairly typical of bioregions situated in remote arid and semi-arid areas.

Dominant limiting factors and constraints for the Pilbara bioregion listed by Thackway and Cresswell (1995) include extinction of critical weight range (CWR) mammals, wildfire, feral animals (in particular the cat and fox), weeds, and grazing or pastoral activities. The reservation status of the bioregion is 1-5%, which is relatively low (some bioregions have a greater than 10% reservation status).

The Pilbara bioregion is divided into four sub-regions; the Hamersley, Fortescue Plains, Chichester and Roebourne sub-regions. Most of the Marillana survey area is located within the Fortescue sub-region, with a small section occurring in the Hamersley sub-region (Figure 2.3).

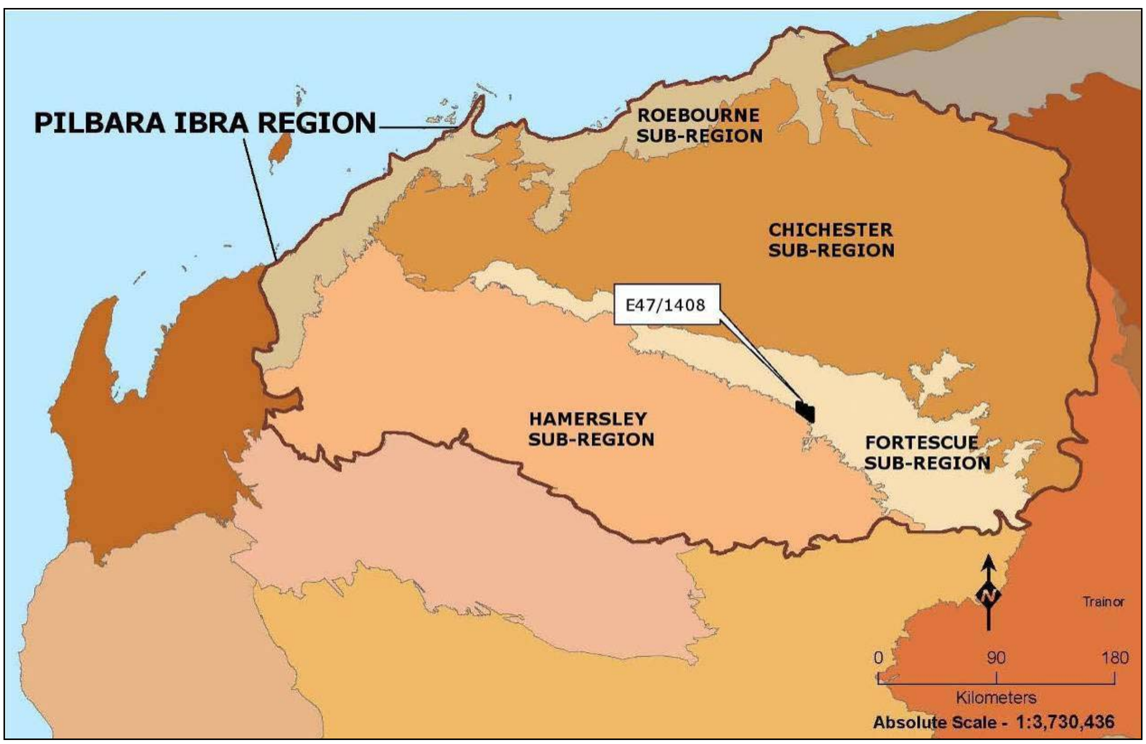

Figure 2.3 – Pilbara IBRA Sub-regions.

2.7 LAND USE HISTORY

The mineral exploration history of the Pilbara began in 1888 when gold was found in the Pilbara Creek. Although this did not prove productive, more consistent deposits were subsequently discovered at Marble Bar. Tin was discovered in 1899 and since then manganese and asbestos have been mined. Massive iron-ore deposits were discovered, with exploitation expanding in the 1960s when the Commonwealth embargo on exporting iron-ore was relaxed (Beard, 1975). Subsequently, a number of mining towns were constructed. Newman was developed in the early 1970s to provide accommodation for workers at the Mount Whaleback iron-ore mine. Ports, such as Port Hedland and Dampier, and standard gauge railways from Mt. Tom Price and Paraburdoo to Dampier, Pannawonica to Cape Lambert and Mt. Goldsworthy and Mt. Newman to Port Hedland, were also constructed. The development of the iron ore industry has resulted in activity within the Pilbara changing from cattle and sheep stations and small coastal ports, to a large mining economic base with a commensurate increase in the population.

Tourism is a smaller but rapidly developing industry within the region. The nearest conservation reserve to the Marillana survey area is Karijini National Park, located approximately 70 km to the west.

2.8 PREVIOUS BIOLOGICAL SURVEYS

The Pilbara is a region of considerable environmental significance, lying on the southern limits of the Northern Botanical Province (Burbidge, 1959; Beard, 1979). The region includes species from the north-west, a region of high species endemism, and the arid interior, as well as numerous species which are either endemic to the Pilbara or have restricted geographic distributions (Beard, 1975). Beard (1975) provides a detailed account of previous exploration in the area. Early flora survey work was carried out by Royce (1948) and Burbidge (1959), while broad scale vegetation mapping was first carried out by Burbidge (1945) and later refined by Beard (1975, 1979). The increased development of mineral resources in the region during the last 20 to 30 years has resulted in site-specific detailed flora and fauna surveys being conducted. The surveys conducted in the local and wider area and of relevance to the Marillana survey area are discussed below.

A number of flora and vegetation assessments have been undertaken in the areas surrounding the Marillana survey area. To the west surveys of the flora of the Yandi mining lease have been conducted (*ecologia* 1995a, 2004a; Maunsell, 2003). A soil and vegetation survey (*ecologia*, 1998a), rare and priority flora surveys along the Yandi airstrip access road (*ecologia*, 2002), Newman to Yandi powerline (*ecologia*, 2003) and a survey at Koodaideri (*ecologia*, 2008a) have been carried out in addition to flora and vegetation surveys of the Yandicoogina Junction area (EM Mattiske and Assoc., 1995), Marillana (*ecologia*, 2007) and the Upper Marillana exploration lease (*ecologia*, 2005).

Southwest of the Marillana survey area, surveys of the Weeli Wolli Creek area have been conducted by Trudgen (1984) and *ecologia* (1998b) and biological surveys of Hope Downs and Area C by *ecologia* (1997, 2000a, 2004) and Biota (2004a). Additionally, numerous surveys at West Angelas have been conducted. These include a number of vegetation and flora surveys of the mine site and along the rail line (Weston and Trudgen, 1997; ME Trudgen and Assoc., 1998; Trudgen and Casson, 1999; *ecologia*, 2000b, 2000c, 2000d, 2001a, 2001b). While Biota (2004b) conducted a flora and vegetation survey for the entire FMG rail corridor from Port Hedland to the Mindy Mindy mine site.

2.8.1 Vegetation Described by Beard

The Marillana survey area falls within Beard's (1975) Fortescue Botanical region of the Pilbara. Beard mapped the vegetation communities of the area (Figure 2.4) and they are described as:

- *Acacia aneura* (mulga) in groved patterns;
- *Eucalyptus gamophylla* sparse shrubs, over *Triodia basedowii* (spinifex) hummock grassland; and
- *Eucalyptus brevifolia* (Snappy Gum) sparse low trees, over *Triodia wiseana* open hummock grassland.

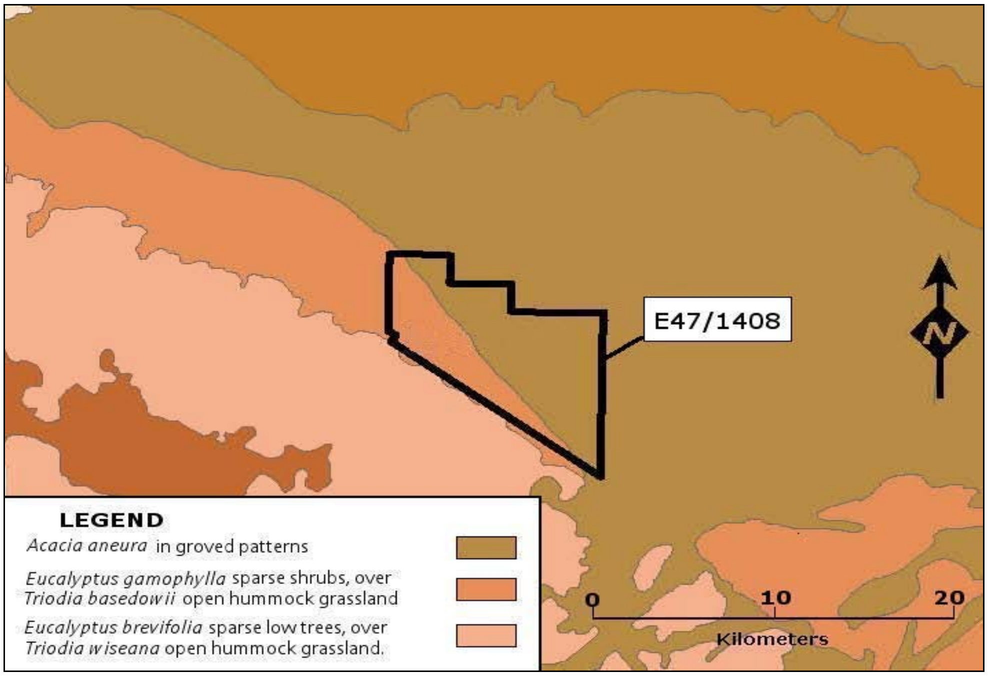

Figure 2.4 – Vegetation Described by Beard at the Marillana Survey Area.

2.8.2 Vegetation Described by IBRA

The Marillana survey area lies in the IBRA Pilbara biogeographic region. Approximately 95% of the area lies in the Fortescue Plains sub-region and the remainder in the Hamersley sub-region.

The vegetation of the Fortescue Plains sub-region is described by Kendrick (2001a) as:

- Salt marshes fringing salt lakes;
- *Acacia aneura* (mulga) and tussock grasses on alluvial plains;
- Short grass communities on alluvial plains; and
- *Eucalyptus camaldulensis* (River Gum) woodlands fringing drainage lines.

The vegetation of the Hamersley sub-region is described by Kendrick (2001b) as:

- *Acacia aneura* (mulga) low woodlands, over tussock grasses on valley floors; and
- *Eucalyptus leucophloia* (Snappy Gum) over *Triodia brizoides* on skeletal soils of the ranges.

2.8.3 Vegetation Previously Recorded Adjacent to the Survey Area

The closest area to Marillana previously surveyed by *ecologia* is a mining tenement located directly adjacent to the Marillana survey area. A single phase flora and vegetation survey for this area was conducted by *ecologia* in 2005 (*ecologia*, 2007). Sixteen vegetation units were recorded in this area and these are described in Table 2.4.

Table 2.4 – Vegetation Units Recorded at Marillana (*ecologia*, 2007).

Habitat	Vegetation Description
Hill crest – high relief	*Eucalyptus leucophloia* low open woodland *(+/- E. gamophylla, E. kingsmillii* low mallee), over *Acacia spondylophylla, Grevillea wickhamii, Goodenia stobbsiana (+/- A. hilliana)* low shrubland, over *Triodia basedowii (+/- T. wiseana)* hummock grassland.
Hill crest – low relief	*Eucalyptus leucophloia* scattered low trees (+/- *E. gamophylla. kingsmillii* low mallee), over *Grevillea wickhamii*, *Hakea chordophylla* scattered tall shrubs, over *Acacia hilliana* low shrubland, over *Triodia basedowii* hummock grassland.
	Eucalyptus leucophloia scattered low trees, over *E. gamophylla* low mallee, over *Acacia spondylophylla, A. hilliana* low shrubland over *Triodia basedowii* hummock grassland.
	Eucalyptus leucophloia scattered low trees, over *E. gamophylla* low mallee, over *Acacia spondylophylla* low shrubland over *Triodia basedowii* hummock grassland.
	Eucalyptus leucophloia scattered low trees, over *Grevillea wickhamii* high open shrubland, over *Acacia spondylophylla* low shrubland, over *Triodia basedowii* hummock grassland.
Hill slope	*Eucalyptus leucophloia* scattered low trees, over low open shrubland, over *Triodia basedowii* hummock grassland.
Upper hill slope	Low scattered shrubs, over *Triodia basedowii* hummock grassland.
Lower hill slope	*Eucalyptus leucophloia* scattered low trees, over low open shrubland, over *Triodia basedowii* hummock grassland.
Footslope	*Corymbia hamersleyana* scattered low trees, over *Eucalyptus gamophylla* open low mallee (restricted to base of ridge), over *Acacia inaequilatera, Grevillea wickhamii* high open shrubland, over *Triodia wiseana* (+/- *T. basedowii*) hummock grassland and **Cenchrus ciliaris* tussock grassland.
Breakaway slope above gorge	*Triodia basedowii* hummock grassland.
Upper floodplain	*Corymbia hamersleyana* low open woodland, over *Grevillea wickhamii, Senna glutinosa* subsp. *glutinosa, S. artemisioides* subsp. *oligophylla* open shrubland, over *Aristida contorta* tussock grassland. This includes localised patches of mulga (*Acacia aneura* var. *intermedia*) tall shrubland.
Floodplain	*Corymbia hamersleyana* low open woodland, over *Grevillea wickhamii* high open shrubland over *Acacia* spp. shrubland, *over *Cenchrus ciliaris* and other mixed species tussock grassland.
Gorge	*Eucalyptus leucophloia, Corymbia ferriticola, Ficus brachypoda* low woodland over *Grevillea wickhamii, Petalostylis labicheoides* high shrubland over *Acacia monticola* low shrubland over *Themeda triandra, *Cenchrus ciliaris* tussock grassland, with +/- *Cyperus cunninghamii* sedges.
Gully	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. shrubland over *Themeda triandra* open tussock grassland.
Minor drainage channel	*Grevillea wickhamii / Acacia tumida* closed scrub over **Cenchrus ciliaris* closed grassland (+/- *Corymbia hamersleyana* scattered low trees).
Major drainage channel	*Eucalyptus victrix* woodland over *Acacia* spp. shrubland over **Cenchrus ciliaris* tussock grassland.

2.9 GROUNDWATER DEPENDENT ECOSYSTEMS

Groundwater dependent ecosystems (GDEs) are defined as “ecosystems that must have access to groundwater to maintain their ecological structure and function” (Murray *et al*., 2006) or “ecosystems that are dependent on groundwater for their existence and health” (National Water Commission, 2006).

The extent to which ecosystems are dependent on groundwater is classified into five categories: ecosystems entirely dependent on groundwater; ecosystems highly dependent on groundwater; ecosystems with proportional dependence on groundwater; ecosystems which may only use groundwater opportunistically or to a very limited extent; and ecosystems with no apparent dependence on groundwater (Hatton and Evans, 1998). The dependency of ecosystems on groundwater is based on groundwater flow or flux, level, pressure, and quality. The ecosystem response to alterations in these groundwater parameters is variable (Sinclair Knight Merz Pty Ltd, 2001).

Less than 1% of the land area of Australia is represented by ecosystems that are entirely dependent on groundwater, and the percentage is the same for ecosystems highly dependent on groundwater. Less than 5% of the land area is associated with ecosystems that are proportionally dependent on groundwater (Hatton and Evans, 1998). These ecosystems represent a small but unique and important part of the Australian environment (Hatton and Evans, 1998; Sinclair Knight Merz Pty Ltd, 2001).

Australian GDEs that are entirely dependent on groundwater include the Pilbara spring ecosystems and arid zone groundwater calcrete ecosystems. The importance of these two GDEs (based on vulnerability, value and risk) is rated as high (Sinclair Knight Merz Pty Ltd, 2001).

Currently, six distinct types of GDEs are recognized in Australia: terrestrial vegetation, river base flow systems; aquifer and cave ecosystems; wetlands; terrestrial fauna; and estuarine and near-shore marine ecosystems (Sinclair Knight Merz Pty Ltd, 2001).

The National Water Commission (2006) reported on the Pilbara Groundwater Management Unit. Two GDE types, terrestrial vegetation and wetlands, were identified within this unit in 1995, and the environmental water requirements and environmental water provisions for these GDEs have been determined.

Determination of the environmental water requirements of GDEs is associated with the following factors: the nature of ecosystem dependency on groundwater; the water requirements of the ecosystem; the groundwater regime that will meet the requirements of the ecosystem; and impacts of change in groundwater regime on ecological processes (Sinclair Knight Merz Pty Ltd, 2001). Sustainable borefield developments require an understanding of the use of ecosystem groundwater requirements and adaptability (Eamus and Froend, 2006).

Phreatophytes (deep-rooted plants that can access the water table) utilise groundwater the most during the driest season of the year, when alternative sources of water become exhausted and transpiration is highest. The risk to GDEs from borefield operations is affected by the timing and modification of abstraction, and the magnitude and rate of drawdown. Therefore, the risk to GDEs may be lowered considerably by avoiding periods of peak environmental demand and allowing adaptation of dependent biota to a lower water table. Information concerning the process of adaptation to changes in groundwater availability is limited (Eamus and Froend, 2006).

The maintenance of GDEs is directly related to the maintenance of specific ecosystem processes such as: flowering, seed set and germination; growth and persistence; seedling establishment and recruitment to reproductive age; mortality; and nutrient cycling (Eamus *et al*., 2006). A GDE may experience a decline in the functioning of the ecosystem following the extraction of groundwater, as opposed to a total collapse of the ecosystem (Murray *et al*., 2006).

In March 2009 the National Water Commission (2009) initiated a project that seeks to identify major GDEs across Australia with the aim of producing a national, comprehensive geographic database inventory (an atlas) of GDEs.

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3 METHODOLOGY

3.1 DATABASE SEARCHES

Before the Marillana vegetation and flora survey was undertaken, searches of the Department of Environment and Conservation (DEC) electronic databases were requested for the survey area. Coordinates of the boundaries of the tenement were provided to the DEC and a 50 km buffer was added to produce a more comprehensive list of any conservation significant flora species that could potentially occur in the area. Searches were undertaken of:

- The DEC's Threatened (Declared Rare) Flora Database.
- The WA Herbarium Database for priority species opportunistically collected in the area of interest.
- The DEC's Declared Rare and Priority Flora List.
- The DEC's Threatened Ecological Communities and Protected Ecological Communities Database.

The Department of Environment and Water Resources' Protected Matters database was also searched and the combined results of these database searches are provided in Appendix A1.

3.2 FLORA AND VEGETATION SURVEY METHODS

The EPA *Guidance for the Assessment of Environmental Factors No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (Environmental Protection Authority 2004a), and EPA *Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA, 2002) were taken into consideration when survey methods were developed.

Detailed methods employed during the flora survey are provided in Sections 3.2.1 to 3.2.4 below.

3.2.1 Survey Timing

The survey was carried out in two phases. The first phase was conducted in winter from the 4th – 12th of June 2008 totalling 16 person survey days. The survey was conducted after a low rainfall season (in the three months prior to the survey, rainfall was 50.9 mm less than the long term mean). However, rain in February 2008 was 125 mm, which is 44.9 mm higher than the long-term mean for that month (80.1 mm).

The second phase was conducted in spring from the 10th – 15th of September 2008 totalling 15 person survey days. In the three months prior to the survey, rainfall was 7.3 mm less than the long-term mean for that month (48.1 mm).

3.2.2 Survey Sites

The field surveys involved systematic flora sampling using quadrats. Sites were either 50 m x 50 m quadrats in large areas of similar vegetation or of an equivalent area (2 500 m^2) along drainage lines or in irregularly shaped patches of vegetation. This quadrat size / area is standard for surveys conducted in the Pilbara bioregion.

Quadrats were chosen from aerial photography before going to site. They were selected on the basis of topography, habitat and vegetation. Ground truthing of quadrat locations was carried out in the field and locations were amended as necessary. The number of quadrats surveyed was determined by the size and the heterogeneity of the area.

One hundred and thirty-seven quadrats were assessed at the survey area; 82 during phase 1 (phase 1 quadrats = A) and 72 during phase 2 (phase 2 quadrats = B). Seventeen of the sites assessed during phase 2 had also been assessed in phase 1 (resurveyed sites = R). These quadrats are mapped in Figure 3.1 and listed in Appendix A2. The following information was collected at each quadrat:

- The height range and percentage cover (or abundance) for each species recorded in the quadrat.
- GPS coordinates for the centre of each quadrat (WGS84, UTM).
- A digital photograph and photo direction.
- Habitat, including information on drainage lines, slope intensity, soil texture, soil colour, surface layer and rock presence, type and abundance.
- Leaf and wood litter levels and distribution.
- Vegetation condition, based on Bush Forever (2000).
- Fire history of the area.

Specimens of each species recorded in the field were collected multiple times for later identification and verification by a plant taxonomist. Nomenclature and taxonomy follow the conventions currently adopted by the Western Australian Herbarium (FloraBase, 2009). Data collected at individual quadrats are included electronically as Appendix A3.

3.2.3 Opportunistic Collections

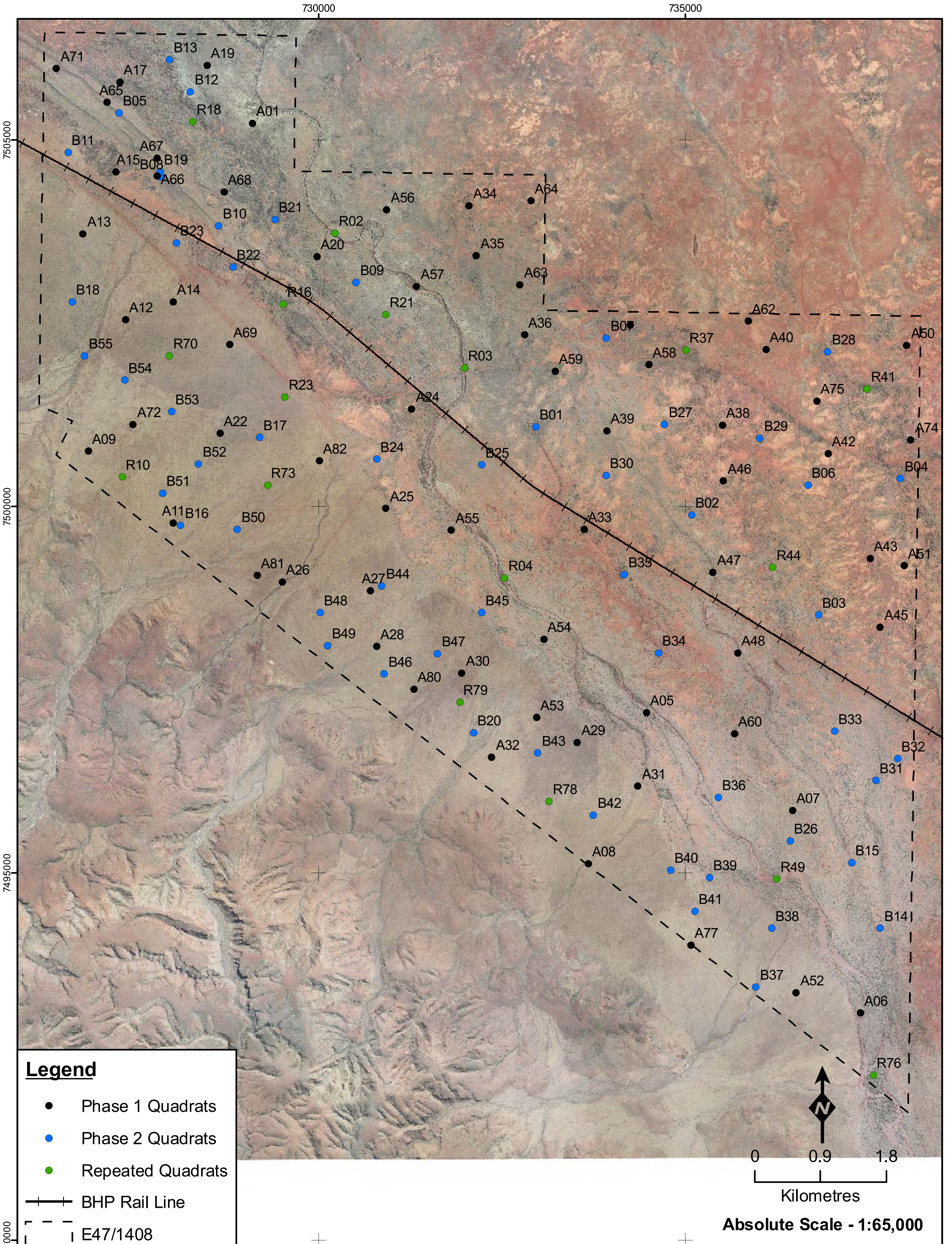
While traversing between quadrats the botanists made opportunistic collections of any flora taxa not already collected at the quadrats. This ensured that a more comprehensive species list was produced for the survey area.

3.2.4 Vegetation Mapping

Vegetation mapping is the delineation of plant communities into groups or associations. The distinctive characteristics that these groups or associations share include features such as species dominance, stratum structure and species composition (Heddle *et al.,* 1980). Data collected within quadrats was analysed using the multivariate statistical programme PATN^{TM}, using species presence/absence records with Pearson complete linkage analysis to produce a dendrogram to statistically show the similarities between sites. This method provides an objective means of defining boundaries between vegetation types when mapping. However, it is constrained by the limited number of quadrats that can be surveyed in the field. Therefore quadrat information is supplemented by notes made on vegetation community boundaries while in the field and these notes are used to confirm vegetation boundaries.

Phase 1 data was used for the statistical analysis, as the quadrats were more evenly distributed across the Marillana survey area. Aerial photographs (1:15,000) were used to map the vegetation associations of the survey area, and information gathered during phase 2 was used to confirm the distribution and bundaries of the mapped units.

The vegetation assemblages have been described using the National Vegetation Information System (NVIS) methodology as described in Appendix A4.



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Flora Quadrats Surveyed in the Project Area

Figure: 3.1	**Drawn: SG**
Project ID: 1140	**Date: 22/10/09**

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: S046

A4

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3.2.5 Survey Limitations and Constraints

According to the EPA Guidance Statement for Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004), flora and vegetation surveys may be constrained by the following:

- Scope (i.e. the influence in terms of reference, such as what life forms etc. were sampled);
- Proportion of flora collected and identified (based on sampling, timing and intensity);
- Sources of information (i.e. pre-existing background versus new material);
- The proportion of the task achieved and further work which might be needed;
- Timing/weather/season/cycle;
- Disturbances (e.g. fire, flood, accidental human intervention, etc.);
- Intensity (i.e. in retrospect, was the intensity adequate?);
- Completeness (e.g. was the relevant area fully surveyed?);
- Resources (e.g. degree of expertise available in plant identification to taxon level);
- Access problems;
- Availability of contextual information; and
- Experience levels.

These constraints are addressed in Table 3.1 below.

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Table 3.1 – Vegetation and Flora Survey Constraints.

Constraint	Comment
Sources of information and availability of contextual information (*i.e.* pre-existing background versus new material)	Areas of the Pilbara region have been relatively well surveyed by *ecologia* and others. The results of these surveys provide comparative data for analysis. See section 2.8 for details of other surveys undertaken in the vicinity of the current survey area.
The scope (*i.e*. what life forms were sampled)	The vascular flora of the survey area was sampled during both phases of the assessment. The survey scope was prepared in consultation with the relevant government agencies (via Brockman), and was designed to comply with EPA requirements.
Proportion of flora collected and identified (based on sampling, timing and intensity)	Approximately 1451 voucher specimens were collected during the two phases of this survey and the following identifications were made from these specimens. Taxa identified to species, subspecies and variety (including forms and affinities): 302. Identified to family only: 1 taxon. Identified to genus only: 15 taxa. From the 820 voucher specimens collected during the first phase of the survey in June 2008 a species list of 224 taxa resulted. The second phase survey was carried out in September 2008 and 244 taxa were recorded from the 631 voucher specimens collected. Forty-five annual or weakly perennial species were recorded during phase 1 of the survey and 54 during phase 2. A species accumulation curve analysis indicates 85.6% of the flora of the area was recorded.
Completeness and further work which might be needed (*e.g.* was the relevant area fully surveyed)	Aerial photography was used to determine different areas to be sampled during the survey. This ensured that all areas displaying potentially different or unique vegetation were visited during the survey. In addition, the botanists undertaking the survey ground-truthed the vegetation associations occurring in the sites chosen from the aerial photography, and added or removed sites depending on the vegetation encountered while traversing the survey area. The first phase of the survey was carried out in June after the summer rains and the second phase in September following the winter rains. Because of this and the large number of quadrats surveyed in the area, no further work should be needed to define the vegetation of the area. Further work might be needed to identify and mark populations of priority flora once infrastructure locations are known.
Mapping reliability	Good aerial imagery was used to select sites and to map the vegetation of the area. Sampling intensity was relatively high, as 137 quadrats were surveyed over the 94 km^2 tenement.
Timing/weather/season/cycle	Rainfall recorded at Newman in the three months preceding the first phase of the survey (June 2008) was 36.2 mm which is 50.9 mm less than the long-term mean of 87.1 mm for the same three months. Rainfall in the three months preceding the second phase of the survey was 40.8 mm, which is comparable with the long term mean of 48.1 mm for those three months. Despite the below average rainfall prior to phase 1, the year's first significant rains (125 mm in February 2008, and 44.9 mm above the long term mean) occurred approximately 12 weeks before the first phase survey.

Constraint	Comment
Disturbances (e.g. fire, flood, accidental human intervention)	A portion of the survey area had been affected by fire approximately 1-3 years before phase 1 of the survey. This was a small area and it is believed that the vegetation units occurring in these areas were assessed in other un-burnt areas.
Intensity (in retrospect, was the intensity adequate?)	The intensity of these surveys was adequate and will add to existing knowledge on the vegetation and flora in the vicinity of the survey area. Thirty-one person days were spent on the survey. Two vegetation units occurring in the survey area were sampled only once. All other vegetation units were surveyed more than once. One hundred and thirty-seven quadrats were assessed over the two phases of the survey.
Resources	Resources were adequate for the botanical survey as 31 person days were spent in the field.
Access problems	All sections of the survey area were accessible by foot.
Experience levels (e.g. degree of expertise in plant identification to taxon level)	The field botanists each had more than two years experience in conducting botanical surveys of this type. Plant specimens were collected from each quadrat assessed. The plant taxonomist had more than eight years of experience of the flora of the Pilbara.