ENVIRONMENT — FORTESCUE METALS GROUP —
VEGETATION HEALTH MONITORING AND MANAGEMENT PLAN

2798. Hon Robin Chapple to the Minister for Environment:

I refer to the Fortescue Metals Group (FMG) Cloudbreak mine operations, Ministerial Statement 899, and to the Vegetation Health Monitoring and Management Plan (VHMMP) referred to in that statement, and I ask:

(a) can the Minister please table the VHMMP submitted by FMG prior to the commencement of its aquifer reinjection scheme at Cloudbreak;

(b) have vegetation health trigger levels been exceeded at any stage, as a result of the implementation of groundwater abstraction and disposal, since the commencement of the Cloudbreak operations:

  (i) if yes to (b), can the Minister please table details as to the dates, locations and circumstances in which those trigger levels were exceeded; and

(c) have vegetation health trigger levels been amended at any stage since the commencement of mining at Cloudbreak:

  (i) if yes to (c), on what dates;

  (ii) if yes to (c), what were the reasons for amendments to vegetation health trigger levels?

Hon Stephen Dawson replied:

(a) Yes. [See tabled paper no 3686.]

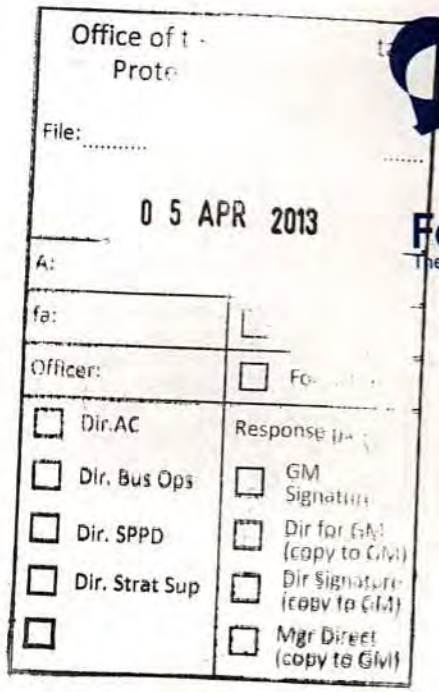
(b) No.

  (i) Not applicable.

(c) No.

  (i)–(ii) Not applicable.

Our Ref: CB-EN-0141
Your Ref:



Fortescue
The New Force in Iron Ore

Ian Munro
Manager Compliance
Office of the Environmental Protection Authority
The Atrium, Level 8
168 St Georges Terrace
PERTH WA 6000

27 March 2013

Dear Mr Munro

CLOUDBREAK LIFE OF MINE EXPANSION – MINISTERIAL STATEMENT 899 CONDITIONS 6-2 AND 6-3 VEGETATION HEALTH MONITORING AND MANAGEMENT PLAN

The Fortescue Metals Group Limited's (Fortescue) Cloudbreak Life of Mine Project was approved under Part IV of the *Environmental Protection Act* 1986 (EP Act) in June, 2012 under Ministerial Statement 899 (MS 899).

Conditions 6-2 and 6-3 of MS 899 state the following:

6-2 Within ten months from the date of issue of this Statement, the proponent shall prepare a Vegetation Health Monitoring and Management Plan for the Project Area, to the requirements of the CEO on advice of the Department of Environment and Conservation (DEC), to verify and ensure that the requirements of condition 6-1 shall be met.

6-3 The plan required by condition 6-2 shall include the following:

1. identification of keystone plant species and habitat characteristics and limits of acceptable change in health and condition of these to be used as the basis for monitoring;

2. locations for predicted indirect impact areas and reference monitoring sites (outside the predicted direct and indirect impact areas) for baseline and ongoing monitoring, with sites selected based on scientific rationale and to the satisfaction of the CEO on the advice of the DEC;

3. results of initial monitoring for flora and vegetation health and condition, species composition and habitat characteristics at both predicted indirect impact areas and reference monitoring sites, and groundwater levels and

Fortescue Metals Group Limited ABN 57 002 594 872 ACN 002 594 872
ADDRESS Level 2, 87 Adelaide Terrace, East Perth, Western Australia 6004
POSTAL ADDRESS PO Box 6915, East Perth, Western Australia 6892
TEL +61 8 6218 8888 FAX +61 8 6218 8880 EMAIL fmgl@fmgl.com.au

groundwater quality at agreed sites in proximity to the vegetation monitoring sites;

4. specifications for the monitoring program for flora and vegetation health and condition, species composition and habitat characteristics, including trigger levels for additional management actions to prevent further impacts and ensure compliance with condition 6-1; and

5. specific management and contingency actions beyond reporting or initiating assessment.

Please find enclosed the Vegetation Health Monitoring and Management Plan (CB-PL-EN-0019) which includes the Cloudbreak Life of Mine Expansion Project Vegetation Heath and Condition Baseline Report. These reports fulfil the requirements of Conditions 6-2 and 6-3 of MS 899.

Should you require further information, please contact Fiona Rowland on 9230 1534 or at frowland@fmgl.com.au.

Yours sincerely
FORTESCUE METALS GROUP

SHAUN GREIN
Manager, Environmental Studies

Plan

Vegetation Health Monitoring and Management Plan – Cloudbreak Life of Mine Expansion Project

Environment

March 2013
CB-PL-EN-0019. Rev 0

Fortescue
The New Force in Iron Ore

	Vegetation Health Monitoring and Management Plan – Cloudbreak Life of Mine Expansion Project		**CB-PL-EN-0019**
Revision Number	**REV 0**		**26/03/2013**
Status	**IFU - ISSUED FOR USE**		
Author	Jordan Reid (GHD)	JReid	25/03/2013
Checked	Anna Napier (GHD)	A.C. Napier	25/03/2013
Approved	Shaun Grein	Signature	26/03/2013
Confidentiality	**FORTESCUE STAFF & CONTRACTORS**	**Publish on Extranet**	☐ Yes ☒ No
Review Date	**N/A**		

This document was prepared on behalf of Fortescue Metals Group Limited by:

Approved by Fortescue:	Shaun Grein	Signature	26/03/2013

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1. INTRODUCTION

Fortescue Metals Group (Fortescue) is an integrated business comprised of mine, rail and port operations based in the Pilbara region of Western Australia, with its head office located in Perth.

Fortescue is developing the Cloudbreak Expansion Project, which involves expansion of its existing Cloudbreak iron ore mine, located approximately 120 kilometres (km) north of Newman (Figure 1). The project includes a range of new developments, upgrades and additional dewatering and water disposal activities. Dewatering is required to facilitate mining below the water table. The current rate of dewatering is proposed to be increased to approximately 100 gigalitres per annum (GL/a) with the surplus water (up to 85 GL/a) to be injected into groundwater aquifers.

To gain approval for the expansion project Fortescue submitted the Cloudbreak Life of Mine – Public Environmental Review (PER) to the Environmental Protection Authority (EPA). The proposal was assess under the Environmental Protection Act 1986 and in June 2012 approved by the Minister for Environment under Ministerial Statement (MS) 899

The EPA determined during its assessment of the proposal that Fortescue should manage groundwater to ensure significant vegetation communities are not adversely impacted.

The Project received State approval under the *Environmental Protection Act* 1986 (Ministerial Statement 899) (EPA 2012) on 5 June 2012 and is received Commonwealth approval under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Referral 2010/5696) on 29 November 2012.

1.1 Requirement for Management Plan

This Vegetation Health Monitoring and Management Plan (VHMMP, the Plan) is required by the Chief Executive Officer of the Office of the Environmental Protection Authority (OEPA) as a condition of approval for Conditions 6-2 and 6-3 of the Project outlined in Ministerial Statement 899 (MS 899).

The initial monitoring required by Condition 6-3(3) is subject to a separate report (GHD 2013).

1.2 Objectives and Scope

The objective of the VHMMP is to assess impacts to vegetation health and condition from changes in groundwater levels (from either drawdown or mounding) outside of the mine envelope required to satisfy Conditions 6-2 and 6-3 of MS 899.

Specifically, the VHMMP will:

- Identify keystone plant species and habitats and limits of acceptable change in their health and condition;
- Address the scientific rationale for monitoring site selection including locations;
- Provide results of initial monitoring for flora and vegetation health and condition, species composition and habitat characteristics at monitoring sites;
- Provide results of groundwater levels and groundwater quality at bore sites in proximity to monitoring sites;
- Outline the methodology required to undertake monitoring for vegetation health and condition, species composition and habitat characteristics;
- Identify vegetation trigger levels and appropriate management actions; and
- Specify management and contingency actions beyond reporting or initiating assessment.

The sections of the VHMMP which address Conditions 6-2 and 6-3 are summarised in Appendix A.

1.3 Definition of Keystone Plant Species

Keystone plant species are those species occurring in vegetation communities that play a critical role in maintaining the structure, function and diversity of that ecological community (Paine 1969). Keystone plant species identified in this VHMMP are considered to be significant and provide high ecosystem value to their respective communities. In this VHMMP, the following keystone plant species have been identified:

- Coolibah (*Eucalyptus victrix*) – Open woodland (riparian zone); and
- Mulga (*Acacia aneura sens. lat.*) – Low closed forest to low open woodland;
- Samphire communities (*Tecticornia* species) – Low shrubland.

1.4 Legislation and Regulatory Framework

Fortescue employees and contractors are obliged to comply with all relevant environmental Commonwealth and State legislation and guidelines. There is a range of legislation and guidelines that relates to this VHMMP in Western Australia (Table 1).

Table 1: Commonwealth and State Legislation and Guidelines Relating to the VHMMP

Legislation or Guideline	Application
Conservation and Land Management Act (WA)	Provides for the vesting or reservation of land for conservation purposes, and the ability to enter into agreements with private landholders and pastoral lessees. It establishes a number of statutory bodies including the Conservation Commission of Western Australia.
Environment Protection and Biodiversity Conservation Act 1999 (Cth)	Protection on environmental matters of national significance.
Environmental Protection Act 1986 (WA)	Prevention, control and abatement or pollution and conservation protection and enhancement of environment.
Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (WA)	Regulates the clearing of native vegetation.
Guidance for the Assessment of Environmental Factors: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia. Guidance Statement No. 51 (Environmental Protection Authority 2004);	Provides guidance and information on expected standards and protocols for terrestrial flora and vegetation surveys to environmental consultants and proponents.
Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3 (Environmental Protection Authority 2002).	Outlines the principles in relation to the provision of information in the assessment of biodiversity.
Rights in Water and Irrigation Act 1914 (WA)	Relates to rights in water resources, to make provision for the regulation, management, use and protection of water resources, to provide for irrigation schemes, and for related purposes.
Wildlife Conservation Act 1950 (WA)	Provides for the conservation and protection of wildlife (flora and fauna). Special provisions and schedules cover protection and management of gazetted rare flora and fauna.

The following Fortescue documents are also of relevance to this VHMMP:

- *Cloudbreak Groundwater Operating Strategy* (CB-PH-HY-0009).
- *Cloudbreak Groundwater Monitoring Procedure*
- *Flora and Vegetation Assessment Guidelines* (100-GU-EN-0005).
- *Significant Flora and Vegetation Monitoring Guidelines* (45-GU-EN-0001).
- *Vegetation Health Monitoring and Management Plan, Christmas Creek – Water Management Scheme* (CC-PL-EN-0004).

The *Vegetation Health Monitoring and Management Plan, Christmas Creek* was used a guide for monitoring methodology to allow for synergies in monitoring and consistency across the Chichester's.

2. ROLES AND RESPONSIBILITIES

All Fortescue employees and contractors are required to comply with the requirements of this Plan.

Accountability for fulfilling the requirements of this VHMMP is dependent on the stage of project development (construction, operations, decommissioning) and the project type (port, rail, mine).

Whether construction activities are undertaken by an external service provider, or internal Fortescue personnel, the Manager of HSES (Cloudbreak) will be accountable for ensuring the requirements of this VHMMP are met.

During operational stages, the Manager of HSES (Cloudbreak) will be accountable for ensuring the requirements of this VHMMP are met.

Where responsibilities are delegated, this must be clearly recorded and communicated.

In Section 8, specific Management Actions have been attributed to the appropriate personnel.

3. STAKEHOLDER CONSULTATION

The VHMMP methodology and monitoring site locations were discussed with personnel from the Department of Environment and Conservation (DEC) on Monday 28 May 2012. Personnel present included Johan Hurter (GHD), Jordan Reid (GHD), Murray Baker (DEC), Shaun Grein (Fortescue), Stephen van Leeuwen (DEC) and Todd Edwards (Fortescue).

This VHMMP will be submitted to the DEC for its feedback, and to the OEPA for its approval, in accordance with MS 899.

4. MONITORING AND EVALUATION FRAMEWORK

This plan uses the framework for assessing management effectiveness evaluation developed by the International Union for Conservation of Nature (IUCN). The Framework is based on a cyclic process with six elements that reflect three main themes of management, design/planning, adequacy/appropriateness and delivery.

Monitoring and evaluation for environmental management effectiveness uses the principles of active adaptive management. Active adaptive management is recognised as the most effective contemporary approach for the conservation of natural areas (Hockings *et al*. 2006) and is adopted by numerous environmental management agencies worldwide, including the Western Australian DEC. Adaptive management is highly applicable to environmental management since it assumes that it is impossible to have all knowledge regarding the management unit or ecosystem. However, it allows adjustment to management actions on the basis of learning new information regarding the management unit or ecosystem (Fortescue 2012b).

The Monitoring and Evaluation framework includes the following elements:

- Understand the current state of vegetation potentially effected by modified groundwater levels resulting from mine dewatering and reinjection activities (State).
- Determine the pressures or threats to the vegetation (Pressure).
- Evaluate and select adaptive management responses available to Fortescue to achieve a target vegetation state (i.e. avoiding unacceptable change to the vegetation) (Response).

These elements collectively comprise the Pressure-State-Response model used when applying an adaptive management approach for protecting environmental values in natural areas. This provides a framework for planning and implementing environmental management actions (Fortescue 2012b).

5. EXISTING ENVIRONMENT

Information regarding the existing environment and current state of vegetation is presented in Appendix B.

6. KEY ENVIRONMENTAL ACTIVITIES

Many of the activities[1] associated with Fortescue's exploration, construction, operation and decommissioning activities have the potential to impact on the environment (Fortescue 2012b).

The key activities associated with the Project which have the potential to impact on vegetation health and condition are:

- Groundwater drawdown caused by groundwater abstraction.
- Groundwater mounding caused by groundwater injection.
- Disruption of surface hydrology and vegetation clearing associated with installation of water infrastructure.

[1] Fortescue uses the term 'activities' to refer to 'Environmental Aspects' as defined by ISO14001.

7. POTENTIAL ENVIRONMENTAL IMPACTS

The potential impacts to vegetation health and condition arising from Project activities are presented in Table 2. The modelled impact areas on water levels for groundwater dewatering and reinjection are provided in Figure 2.

Table 2: Potential Environmental Impacts to Vegetation Health Arising from Project Activities

Aspect of Project	Potential Environmental impact
Vegetation clearing	Adverse impact (significant alteration beyond natural variation) to conservation significant vegetation – caused by clearing. Removal/death of keystone plant species.
Dewatering	Adverse impact (significant alteration beyond natural variation) to conservation significant vegetation – caused by groundwater drawdown. Death of keystone plant species.
Reinjection	Adverse impact (significant alteration beyond natural variation) to conservation significant vegetation – caused by groundwater mounding. Death of keystone plant species.
Disruption of surface hydrology	Adverse impact (significant alteration beyond natural variation) to conservation significant vegetation – caused by disruption of surface water flows. Death of keystone plant species.

8. ENVIRONMENTAL MANAGEMENT

Key environmental management objectives with respect to mitigating potential environmental impacts have been developed. These are:

- Prevent adverse impacts[2] to conservation significant vegetation, attributable to the Project, outside the mine envelope.
- Prevent mortality of keystone plant species or significant changes in habitat characteristics, attributable to the Project, outside the mine envelope.

For each objective, management actions have been developed to ensure the impacts from Fortescue's operations are managed and that appropriate monitoring, reporting and corrective action functions are implemented to support the successful implementation of the management actions.

The key elements of the environmental management process associated with each objective are described in Table 3.

Table 3: Description of Elements of Environmental Management Process to Achieve Identified Objectives

Element	Description
Objective	What is intended to be achieved.
Management Action	Tasks undertaken to enable the objective to be met.
Performance Indicators	Metrics for evaluating the outcomes achieved by the Management Action.
Groundwater Management Measures	Refer to *Cloudbreak Groundwater Operating Strategy.*
Reporting/Evidence	Demonstrates that the Management Action has been applied and the outcome evaluated.
Timing	Period during which the Management Action should be undertaken.
Responsibility	Accountability for ensuring Management Action is completed.

The key management action, performance indicators, evidence, timing and responsibilities for each objective are provided in Table 4.

[2] Adverse impacts are defined as statistically significant (either positive or negative) differences in monitoring criteria within impact sites in comparison to reference sites (allowing for natural variation between seasons and between years).

Table 4: Key Management Actions for Vegetation Health Monitoring and Management in the Project Area

Reference	Management Action	Objective	Performance Indicators	Reporting / Evidence	Timing	Responsibility
1.	Conduct a baseline vegetation assessment of keystone plant species in predicted dewatering and injection impact areas and reference areas.	1,2	• Baseline assessment conducted.	• Report • Baseline assessment	Design	Project Manager
2.	Implement the Vegetation Health Monitoring Program in Section 9 of this Plan to monitor any change in vegetation health and condition at dewatering impact areas and reinjection impact areas.	1,2	• No change greater than natural variation that is attributable to the Project measured by spatially distributed replicate monitoring sites. • No change greater than natural variation that is attributable to the Project measured by monitoring sites within impact areas in comparison to reference (no impact) areas. • Monitoring requirements are included in this document.	• Vegetation Health Monitoring Program • Monitoring reports • Annual Environmental Report	Design/ Construction / Operation	Project Manager/ Cloudbreak General Manager/ HSES Manager
3.	Where vegetation health monitoring detects vegetation stress potentially attributable to the Project, implement management measures outlined Section 11 of this Plan.	1,2	• No change greater than natural variation that is attributable to the Project measured by spatially distributed replicate monitoring sites. • No change greater than natural variation that is attributable to the Project measured by monitoring sites within impact areas in comparison to reference (no impact) areas. • Incident reports of vegetation stress potentially attributable to the Project.	• Vegetation Health Monitoring Program • Monitoring report • Annual Environmental Report	Construction / Operation	Project Manager/ Cloudbreak General Manager
4.	Where trigger levels have been exceeded as a result of the implementation of the Project, comply with Condition 6-6 of MS 899.	1,2	• Compliance with MS 899 6-6	• Monitoring report • Correspondence with the OEPA	Construction / Operation	Project Manager/ HSES Manager

9. MONITORING PROGRAM

This monitoring program has been prepared as part of the VHMMP to incorporate best practice methods to address the goals and objectives addressed in this Plan. This program will address the monitoring requirements outlined in Condition 6 of MS 899.

9.1 Monitoring Site Selection

9.1.1 Vegetation Health Monitoring

The monitoring program uses a Before-After-Control-Impact (BACI) design (Smith 2002) to determine the location of monitoring sites (referred to as vegetation monitoring units (VMUs)). A combination of reference and impact (direct and/or indirect) VMUs were established for each conservation significant vegetation community.

The rational used for VMU selection for this monitoring program included:

- Stratification between impact and references areas;
- Identification of partially phreatophytic communities in drawdown impact and reference areas;
- Identification of Mulga communities and Samphire communities in mounding impact and reference areas; and
- Selection of sampling locations close to existing groundwater bores.

In addition, VMU selection was guided by road access, future accessibility and took into account heritage constraints.

The locations of VMUs are shown in Table 5 and mapped Figure 2. Additional monitoring sites may be added should locations suitable for additional monitoring sites be identified and considered beneficial, following review of initial baseline monitoring events. A minimum number to provide robust design is presented in the Table 5.

9.1.2 Groundwater Bore Locations

Groundwater bores HSMB24_S, Kardardarrie and CBX10a_WT are located greater than 1 km in distance from respective VMUs. Therefore, any changes in vegetation health and condition at these VMUs cannot be confidently attributed to Project activities, and similarly any trigger exceedences at these bores cannot be considered to be directly impacting vegetation health and condition at VMUs.

The installation of groundwater monitoring bores (or a similar) at these VMUs will be reviewed following analysis of monitoring results, particularly if changes in vegetation health and condition are being consistently observed.

Table 5: Permanent Vegetation Monitoring Unit Details

Site ID	Vegetation	Keystone Species	Treatment	Potential Impact	Location (NW corner)	Nearest Bore and Distance From Site	Size (m^2)
ED1	Partially phreatophytic	*Eucalyptus victrix*	Direct Impact	Drawdown	734199mE; 7532629mN	HSMB03_S (453 m due SE)	2500
ER1.	Partially phreatophytic	*Eucalyptus victrix*	Reference	n/a	761220mE; 7528628mN	HSMB24_S (4.1 km due SE)	2500
ER2	Partially phreatophytic	*Eucalyptus victrix*	Reference	n/a	716370mE; 7532213mN	Kardardarrie (2.6 km due NW)	2500
MD1	Mulga	*Acacia aneura sens. lat.*	Direct Impact	Mounding	771080Em; 7523558mN	HSMB29_S (202 m due E)	2500
MI1	Mulga	*Acacia aneura sens. lat.*	Indirect impact	Mounding	774202mE; 7523648mN	HEMB05_S (405 m due SE)	2500
MI2	Mulga	*Acacia aneura sens. lat.*	Indirect impact	Mounding	769274mE; 7522360mN	SCX02_S (345 m due E)	2500
MR1	Mulga	*Acacia aneura sens. lat.*	Reference	n/a	771207mE; 7522286mN	SCX04_S (308 m due N)	2500
MR2	Mulga	*Acacia aneura sens. lat.*	Reference	n/a	714794mE; 7535429mN	Kardardarrie (1.4 km due S)	2500
SI1	Samphire	*Tecticornia* spp.	Impact	Mounding	742530mE; 7524652mN	CBX10a_WT (2 km due E)	200
SI2	Samphire	*Tecticornia* spp.	Impact	Mounding	734626mE; 7527483mN	CBX04_S (824 m due NW)	200
SR1	Samphire	*Tecticornia* spp.	Reference	n/a	740801mE; 7524805mN	CBFMM06_S (440 m due NE)	200
SR2	Samphire	*Tecticornia* spp.	Reference	n/a	727612mE; 7527963mN	CBFMM02_S (58 m due SW)	200

9.2 Frequency and Duration

Initial baseline monitoring was conducted prior to the commencement of Cloudbreak Expansion Project activities (i.e. dewatering and reinjection of water).

Baseline vegetation monitoring for the Project was conducted in June/July 2012. Biannual monitoring should be nominally conducted in May and November of each subsequent year.

The exact timing of monitoring may be subject to prevailing weather conditions, which may affect site accessibility and the utility of some monitoring methods. Any changes to the frequency of monitoring should be evaluated following the analysis of the repeat measures of data from previous monitoring events.

Groundwater monitoring for the Project will be undertaken as outlined in the *Cloudbreak Groundwater Operating Strategy*.

9.3 Baseline Groundwater Monitoring

Groundwater data including groundwater level and field electrical conductivity (ground water quality) are collected by Fortescue as outlined in the Cloudbreak Groundwater Operating Strategy and reported in Fortescue's quarterly aquifer review.

A total of 11 groundwater bores across the Project area, in proximity to VMUs, have been selected for monitoring groundwater levels and quality (Table 6). Fortescue considers this data is most appropriate to satisfy the second part of Condition 6-3(3) of MS 899.

Relevant groundwater bore details including screening intervals and accepted trigger values are provided in Table 6. The screening intervals of the bores are in the shallow aquifer, indicating that these bores are suitable to monitor fluctuations in the watertable. Given that the screening intervals in some of the bores are not located at the watertable, the precision of the depth to water measurements are not exact. This is resolved by the collection of baseline measurements, which are used to monitor changes in fluctuations.

The initial baseline hydrological data is presented in the *Cloudbreak Quarterly Groundwater Monitoring Review* CB-RP-HY-0033 (Fortescue 2012a).

Table 6: Groundwater Bore Details

Site ID	Nearest Bore	Monitoring Frequency	Zone	Screening Interval	Groundwater Level Trigger		Water Quality Trigger	Construction Details
					Class 1	Class 2	Class 1	
ED1	HSMB03_WT	Monthly	C	12-18 m	3 mbgl	2.2 mbgl	9,000 µS/cm	
ER1.	HSMB24_S	Monthly	C	22-24 m	3 mbgl	2.2 mbgl	9,000 µS/cm	
ER2	Kardardarrie	Biannual		Not known				Total depth 12 m
MD1	HSMB29_S	Monthly	C	18-30 m	3 mbgl	2.2 mbgl	9,000 µS/cm	
MI1	HEMB05_S	Monthly	C	27-32 m	3 mbgl	2.2 mbgl	9,000 µS/cm	
MI2	SCX02_S	Monthly	C	11-41 m	3 mbgl	2.2 mbgl	9,000 µS/cm	
MR1	SCX04_S	Monthly	C	14-38 m	3 mbgl	2.2 mbgl	9,000 µS/cm	
MR2	Kardardarrie	Biannual		Not known				Total depth 12 m
SI1	CBX10a_WT	Monthly	A	2-14 m	±0.65	±1	N/A	
SI2	CBX04_S	Monthly	A	6-18 m	±0.65	±1	N/A	
SR1	CBFMM06_S	Monthly	A	1-9 m	±0.65	±1	N/A	
SR2	CBFMM02_S	Monthly	A	0.5-9 m	±0.65	±1	N/A	

9.4 Baseline Vegetation Monitoring

The baseline vegetation monitoring included:

- Qualitative partially phreatophytic, Mulga and Samphire community habitat assessments in accordance with Fortescue's *Flora and Vegetation Assessment Guidelines* (2011a).
- Digital canopy photography cover measurements of partially phreatophytic trees (Eucalypts) in dewatering and reference areas and Mulga and Samphire plants in reinjection areas and reference areas;
- Qualitative partially phreatophytic tree health assessments following the method of Souter *et al.* (2010);
- Qualitative Mulga plant health assessments in accordance with Fortescue's *Significant Flora and Vegetation Guidelines* (Fortescue 2011b);
- Quantitative partially phreatophytic (Eucalypts) water status assessments using light and dark-adapted leaf water potential measurements in dewatering and reference areas;
- Quantitative Mulga water status assessments using light and dark-adapted leaf water potential measurements in reinjection and reference areas;
- Measurement of soil chemical and physical properties at 1 m depths in dewatering, reinjection and reference areas for partially phreatophytic (*Eucalyptus*), Mulga and Samphire vegetation;
- Samphire cover estimates of Samphire communities in belt transects within impact and control areas; and
- Samphire tip die-off measurements of plants following the method of Astron (2011) in quadrats in impact and reference areas.

For the first year of operations of the Project, biannual monitoring of keystone species health and condition and water status of partially phreatophytic trees and Mulga will be conducted. Biannual botanical survey of VMUs will be conducted. Appendix C contains the initial baseline vegetation monitoring report (GHD 2013).

A summary of monitoring conducted for this monitoring program is provided in Table 7.

Table 7: Summary of Monitoring to be Conducted for the VHMMP

Potential Impact	Monitoring Criteria	Data Analysis
Groundwater drawdown	Qualitative partially phreatophytic tree health assessments	Parametric/Non-parametric ANOVA (Zar 2009).
	Quantitative partially phreatophytic tree digital canopy photography	Univariate Control Chart – Level 1 management response required in exceedance of 1 Standard Deviation in percentage canopy cover. ANOVA – Level 1 management response required if significant differences (normalised data and $p<0.05$) detected.
	Quantitative partially phreatophytic tree water status health assessments	Multivariate Control Charts of multiple ecophysiological variables – Level 1 management response required in exceedance of 90% Confidence Interval in Control Chart trend (Anderson and Thompson 2004). ANOVA – Level 1 management response required if significant differences (normalised data, $p<0.05$) detected.
	Depth to water	Trigger levels and notifications as outlined in *Cloudbreak Groundwater Operating Strategy.*
Groundwater mounding	Qualitative Mulga health assessments	Parametric/Non-parametric ANOVA (Zar 2009).
	Quantitative Mulga digital canopy photography	Univariate Control Chart – Level 1 management response required in exceedance of 1 Standard Deviation in percentage canopy cover. ANOVA – Level 1 management response required if significant differences (normalised data and $p<0.05$) detected.
	Quantitative Mulga water status health assessments	Multivariate Control Charts of multiple ecophysiological variables – Level 1 management response required in exceedance of 90% Confidence Interval in Control Chart trend. ANOVA – Level 1 management response required if significant differences (normalised data, $p<0.05$) detected.
	Qualitative Samphire health assessments	Parametric/Non-parametric ANOVA (Zar 2009).
	Quantitative Samphire digital canopy photography	Univariate Control Chart – Level 1 management response required in exceedance of 1 Standard Deviation in percentage canopy cover. ANOVA – Level 1 management response required if significant differences (normalised data and $p<0.05$) detected.
	Quantitative Samphire community analysis	Univariate Control Chart – Level 1 management response required in exceedance of 1 Standard Deviation in tip die off and height. ANOVA – Level 1 management response required if significant differences (normalised data, $p<0.05$) detected.
	Depth to water	Trigger levels and notifications as outlined in *Cloudbreak Groundwater Operating Strategy.*

9.5 Monitoring Methodology

9.5.1 Groundwater

Groundwater monitoring will be undertaken at the groundwater monitoring bores presented in Table 6 and as outlined in the *Cloudbreak Groundwater Operating Strategy* and *Groundwater Monitoring Procedure*.

9.5.2 Vegetation

Vegetation monitoring will involve a combination of quantitative and qualitative vegetation measurements, ecophysiological measurements and health and condition assessments using qualitative criteria and digital canopy photography. An overview of the monitoring methodology for each conservation significant vegetation community defined by its keystone species is described below.

Partially Phreatophytic Vegetation Communities

Management Targets and Monitoring Hypotheses

Table 8 outlines the management targets and monitoring hypotheses for partially phreatophytic vegetation communities.

Table 8: Management Targets and Monitoring Hypotheses for Partially Phreatophytic Vegetation Communities

Management Targets	Details
Vegetation management target	No adverse impact, beyond natural variability, to existing partially phreatophytic trees or to recruitment due to dewatering.
Groundwater management trigger	Management of groundwater decline to ensure actual groundwater levels do not fall to below 16 m beneath the ground surface and/or and/or EC levels 50 % higher from baseline levels in dewatering areas in accordance with the *Cloudbreak Groundwater Operating Strategy* CB-PH-HY-0006.
Vegetation monitoring management triggers	Stem water potentials of partially phreatophytic trees significantly greater in dewatering areas (impact areas) in comparison to reference ($p<0.05$).
	Percentage canopy cover of partially phreatophytic trees significantly less than reference ($p<0.05$) in dewatering areas (impact areas).
	Deaths of partially phreatophytic tree significantly greater in dewatering areas (impact areas) in comparison to reference ($p<0.05$).
Management hypothesis	The water status, health and recruitment of partially phreatophytic trees in areas of dewatering and lowering of the water table will not alter significantly in comparison to partially phreatophytic trees in areas not affected by lowering of groundwater though dewatering.

Methodology

Each VMU will include a permanent quadrat of 2,500 square meters (m2) in area and permanent sample trees. Within each VMU ten mature partially phreatophytic trees (E. victrix) will be randomly selected as sample trees and will be permanently marked with a fence dropper and labelled with a metal tag. Each sample tree will be subjected to a range of qualitative and quantitative measures including a visual health assessment, plant characterisation including height, diameter at breast height over bark (DBHOB; at 130 centimetres (cm) above ground level), leaf and stem water potentials and projected foliar cover (PFC). A permanent photo point to measure PFC will be marked for each sample tree with a fence dropper.

Optional monitoring components, habitat characterisation and landscape function analysis (LFA) assessments of each VMU may be undertaken. These components were undertaken for each VMU in the initial monitoring.

Sites will be selected to provide a good spatial representation of the potential impact area, where significant stands of partially phreatophytic vegetation exist, and in areas easily accessible for future monitoring.

Plant Characterization

The height (in meters), diameter at breast height over bark (DBHOB; at 130 cm above ground level) and age class will be determined for each sample plant. This method will enable the size of each sample plant to be compared temporally and provide quantitative measures to complement visual assessment methods.

Visual Assessment

All sample plants (ten per site) will be visually assessed following the method of Souter et al. (2010) to monitor the health of partially phreatophytic eucalypts. The assessment method is based on a conceptual model of the symptoms of decline due to water stress and indicators of recovery as conditions improve. The method incorporates the following aspects of tree health:

- Crown extent;
- Crown density;
- Epicormic growth;
- New tip growth;
- Reproduction;
- Leaf die off;
- Presence of Mistletoe; and
- Bark condition.

Crown extent and density scores are based on a scale from 0 to 7 which correspond to both descriptive and percentage divisions. A rating of 0 corresponds to a tree with no leaves and a rating of 7 corresponding to a tree where the canopy is completely foliated and the foliage is at maximum density. A score of 4 represents a tree with medium canopy foliation and medium foliage density.

Epicormic growth, new tip growth, reproduction, leaf die off and mistletoe presence are all scored based on a four category scale (0 to 3). A rating of 0 corresponds to effect absent and a rating of 3 corresponds to effect abundant (Souter *et al*. 2010). All variables are scored on the visibility of the effect throughout the assessable crown.

The final variable scored is bark condition which is assessed on the main stem(s) and lower branches on a scale from 0 to 4. A rating of 0 corresponds to a tree with intact bark, ratings of 1, 2 or 3 correspond to the extent of bark cracks (i.e. minor, moderate and extensive) and a rating of 4 corresponds to no bark (i.e. long-term dead tree) (Souter *et al*. 2010).

Leaf and Stem Water Potentials

Leaf water potential (LWP) and stem water potential (SWP) measurements will be taken using a pressure chamber instrument (Model 1505D, PMS Instrument Company, Oregon, USA). Two shoots (two to five leaves) from the mid-canopy of five of the ten permanent sample plants will be placed in tin foil wrapped envelopes and dark-adapted for one hour to become equilibrated with the water potential in the tree trunk. A total of four shoots (two for LWP, and two for SWP) will be excised from each sample plant and their water potentials measured using a pressure chamber instrument.

LWP and SWP measurements are a scientifically robust technique that can provide an in situ indication of a plant's water status (Turner 1988). SWP is an effective way of measuring whole plant water potential and can be correlated with the water potential measurements obtained from stem psychrometers, while LWP is an indication of effective transpiration rate and photosynthetic activity. These two measurements can be taken at the same time of day.

A third way of measuring a plant's water status using a pressure chamber instrument is to measure leaf water potential before dawn. Predawn leaf water potential (PDLWP) measurements are taken from 3:30 AM to an hour before dawn and are used as a measure of soil water potential when it is theorised that the plant is at equilibrium with the water potential in the soil. However, it is unlikely that large trees such as Mulga will be in equilibrium with the soil water potential in the Pilbara. These plants exhibit extremely large negative potentials and it is likely that they move water through the soil at night by means of hydraulic lift (Larcher 2003). Additionally, equipment such as an Infrared Gas Analyser (IRGA) would also be needed to prove that transpiration is not taking place at night, which would otherwise make such data superfluous. This method was excluded for this study due to the above reasoning. Future monitoring events will be adaptive and incorporate additional water potential methods if considered necessary.

Projected Foliar Cover

Projected foliar cover (PFC) will be determined for sample trees. PFC is related to canopy density which is often related to plant stress, as the shedding of leaf canopy is one of the first physiological responses to water stress (Souter et al. 2009).

For assessing the PFC within the canopy of individual trees, a permanent photo point will be marked for each of the ten sample trees at each site with a fence dropper. A 12.0 megapixel digital camera will be locked onto a tripod (height of 1.5 m) and used to photograph the entire tree. A surface level (or bubble level) will be used to ensure the camera is kept level. By placing the tripod at the same permanent location and through the use of the surface level the PFC images can be replicated on a temporal scale to give an indication of changes into canopy density. Images will be analysed to estimate a PFC in accordance with MacFarlane et al. (2007a; 2007b). Data obtained from these images can only be used to interpret changes in foliar cover on a temporal scale. Therefore, this data will not be presented after the first monitoring event (not baseline).

Habitat Characterization (Optional component)

The habitat of each VMU will be characterized following the method outlined in Fortescue's Flora and Vegetation Assessment Guidelines (100-GU-EN-0005). Additions to the guidelines were recommended by DEC and included the following:

- Locations and numbers of ant nests were recorded; and
- Locations and numbers of cow patts were recorded.

Habitat characterization will enable the flora composition and cover of each VMU to be compared temporally as well as between reference and impact areas.

Landscape Function Analysis (Optional component)

A Landscape Function Analysis (LFA) assessment will be undertaken at each VMU following the method of Tongway and Hindley (2004b). The LFA method (Tongway and Hindley 1995, 2004a) is used to describe landscape type, characterize landscape organization and assess soil surface condition. This method derives a number of indices for site stability, infiltration and nutrient cycling, from the above three principles to assess how well an ecosystem functions from a biophysical perspective. Sites are characterised according to their topographic location (e.g. crest, mid slope, flat or stream channel), soils, slope, vegetation type, land use and state of the soil surface. A LFA assessment will provide reference landscape or ecosystem function condition appropriate to each VMU.

Mulga Vegetation Communities

Management Targets and Monitoring Hypotheses

Table 9 outlines the management targets and monitoring hypotheses for Mulga vegetation communities.

Table 9: Management Targets and Monitoring Hypotheses for Mulga Vegetation Communities

Management Targets	Detail
Vegetation management target	No adverse impact to vegetation community or Mulga and associated *Acacia* species trees due to groundwater mounding.
Groundwater management trigger	Groundwater to remain 3 m below ground level and/or EC levels 9000 µS/cm, unless baseline levels higher, then 50 % increase from baseline levels in accordance with the *Cloudbreak Groundwater Operating Strategy* CB-PH-HY-0006.
Vegetation monitoring management triggers	Stem water potentials of Mulga significantly greater in mounding impact areas in comparison to reference ($p<0.05$).
	Percentage canopy cover of Mulga trees significantly less than reference in reinjection zones (impact areas) ($p<0.05$).
	Deaths of Mulga trees significantly greater in mounding impact areas in comparison to reference ($p<0.05$).
Management hypothesis	The water status, health and recruitment of Mulga plants within areas of reinjection and rising of the water table will not alter significantly in comparison to Mulga plants in areas not affected by rising groundwater through reinjection.

Methodology

Vegetation monitoring will follow the methodology described for partially phreatophytic vegetation communities with the following additions and/or changes:

- Visual assessment of vegetation health to be undertaken following the method outlined in Fortescue's *Significant Flora and Vegetation Monitoring Guidelines* (45-GU-EN-0001) – Section 7.1.2.
- LWP and SWP measurements will be taken on all ten sample plants at each VMU.

Samphire Vegetation Communities

Management Targets and Monitoring Hypotheses

Table 10 outlines the management targets and monitoring hypotheses for Samphire vegetation communities.

Table 10: Management Targets and Monitoring Hypotheses for Samphire Vegetation Communities

Management Targets	Detail
Vegetation management target	No adverse impact to Samphire vegetation community due to groundwater mounding.
Groundwater management trigger	Groundwater level to not exceed an absolute value change of 0.8 m in 12 months in accordance with the *Cloudbreak Groundwater Operating Strategy* CB-PH-HY-0006.
Vegetation monitoring management triggers	Percentage cover of Samphire significantly less than reference in reinjection zones (impact areas) ($p<0.05$).
	Tip die off or tip growth of Samphire plants is not significantly greater than in reinjection areas (impact areas) in comparison to reference areas ($p<0.05$).
	Deaths of keystone Samphire significantly greater than in mounding impact areas in comparison to reference ($p<0.05$).
Management hypothesis	The health and recruitment of Samphire vegetation within areas of reinjection and rising of the water table will not alter significantly in comparison to Samphire vegetation in areas not affected by rising groundwater through reinjection.

Methodology

Monitoring sites will include permanent quadrats of 200 m^2 in area (S. van Leeuwen, DEC, pers. comm.) and permanent sample plants. Within each site ten plants (*Tecticornia* spp.) will be randomly selected as sample plants and will be permanently marked with a fence dropper and labelled with a metal tag. Each sample plant will be assessed qualitatively for health and condition (following the method of Astron 2011) and quantitatively for PFC. A permanent photo point to measure PFC will be recorded for each sample plant.

In addition the habitat of each VMU will be characterized following the method outlined in Fortescue's *Flora and Vegetation Assessment Guidelines* (100-GU-EN-0005), and a LFA assessment will be undertaken following the method of Tongway and Hindley 2004.

9.6 Data Analysis

Two methods will be applied to determine if differences or trends in monitoring data are occurring. These are:

- Application of single variable (univariate) or multiple variable (multivariate) Control Charts, to identify trends in data that may indicate changes taking place within impact sites in comparison to reference sites (Anderson and Thompson 2004, Morrison 2008). Control Charts contain a centre line value (represents the mean value), an upper control limit and a lower control limit. Parameters are expected to fall within control limits in the absence of significant impacts.
- Tests of significant differences between impact sites and reference sites in single variables (Analysis of Variance – ANOVA) or multiple variables (Permutation Multiple Analysis of Variance; PERMANOVA) (Anderson 2001, Zar 2009).

Parametric statistics are commonly used to detect changes in impact and reference areas using the Before-After-Controlled-Impact monitoring. The application of Control Charts is becoming a

common tool for the interpretation of trends in environmental monitoring data. Control Charts are relatively easy to interpret and update as additional data is made available (Morrison 2008).

9.7 Adaptive Management

Analysis of the effectiveness of vegetation management, as identified in the monitoring program, will be compiled within the VHMMP annual report for 2013. The OEPA and DEC will be consulted if any changes to the monitoring methodologies are proposed.

Results, discussion and new information obtained from the monitoring program will be included in the annual report. Opportunities for adaptive management that may arise from these analyses will be explored.

10. AUDIT

Internal auditing of activities associated with the VHMMP will be carried out in accordance with Fortescue's internal audit schedule and Condition 4 of MS 899.

Audit criteria may include, but is not limited to:

- Management actions within this document;
- Implementation of the monitoring program; and
- Applicable conditions and commitments within Ministerial Statements.

Where non-conformance issues or opportunities for improvement are identified these will be documented and tracked via the Business Management System (BMS).

11. CORRECTIVE ACTIONS

The management trigger-response framework adopted in the VHMMP includes two levels. At the outset of the program a Level 1 response will be triggered if Control Charts indicate change greater than 1 Standard Deviation in a univariate measure(s), or beyond the 90% Confidence Interval for multivariate Control Charts (Anderson and Thompson 2004). Level 2 Management Response Triggers will be implemented when significant adverse differences attributable to the project are determined or predicted to occur without management intervention.

Level 1 Vegetation Management Response Trigger

This is considered the first level of vegetation monitoring response. Monitoring will identify if changes occur in a range of metrics related to vegetation condition. The magnitude of change in dewatering and reinjection zones, in comparison with reference areas, provides the basis for detecting potential adverse impacts. A Level 1 Management Response Trigger represents the amount of change in a measured parameter, or group of parameters, in excess of a defined statistical threshold necessary to enact a management response.

On the identification of a Level 1 management trigger, the management response will be:

- Re-examination of groundwater levels and groundwater quality to validate that groundwater is within groundwater management trigger levels;
- Increase in vegetation monitoring frequency;

Note that the detection of change in a repeated measurement dataset does not enable cause and effect to be determined. As such the exceedence of a Level 1 trigger value does not imply that an adverse impact has occurred, but rather indicates that additional analysis is required to determine this.

Level 2 Vegetation Management Response Trigger

This is considered the second level of vegetation monitoring response. On the identification of a Level 2 management trigger, the management response will be:

- Increase in vegetation monitoring frequency (as per Trigger Level 1);
- Adaptive water management response (modified dewatering and reinjection regime) following management guidance within the *Cloudbreak Groundwater Operating Strategy* CB-PH-HY-0006; and
- In accordance with Condition 6-6 of MS 899:
    - Report the trigger exceedence findings to the CEO within 7 days of the exceedence being identified.
    - Provide evidence to the satisfaction of the CEO which allows determination of the cause of the exceedence within 21 days of the exceedence being identified;

- If determined by the CEO to be a result of activities undertaken in implementation of the proposal, then submit a plan of actions to be taken to address the exceedence to the satisfaction of the CEO within 21 days of the determination being made by the CEO.
- Implement the plan of actions to address the exceedence upon approval of the CEO and continue until such time as the CEO determines that this may cease.

With regards to adaptive water management, Fortescue has developed a system for assigning and managing an appropriate distribution of monitoring points (bores), associated trigger levels (Class 1 and Class 2) and management responses for groundwater embodied in the *Cloudbreak Groundwater Operating Strategy* (CB-PH-HY-0006).

The full description of the groundwater monitoring triggers is provided in the *Cloudbreak Groundwater Operating Strategy* (CB-PH-HY-0006). These management responses are to occur with the exceedence of a Class 2 Groundwater trigger. This involves implementation of modifications to operational activities including:

- Reducing volumes of water piped to the affected area by redirecting water to other injection areas;
- Redirection of disposal water to transfer and/or infiltration ponds; and
- Redirection of disposal water to void mine pits.

12. REPORTING

Following each monitoring survey, details of monitoring undertaken, results and any problems encountered are to be included in the Environment Monthly Report. A report will be prepared annually, which will provide a detailed summary of monitoring, analysis of results and contingency actions undertaken. The annual report will assist in evaluating the effectiveness of the management and monitoring program and will provide information on the current status of the vegetation in relation to the Project.

13. REVIEW

It is important that Management Plans are frequently reviewed and revised as Fortescue's operations change and opportunities for improved management practices are identified.

The VHMMP will be reviewed following analysis of monitoring results obtained during the first 11 months of monitoring commencing in June/July 2012. Depending on the outcome of this review, the VHMMP may be expanded, continued unchanged or reduced in scope. If necessary, new management targets will be set using an adaptive management approach (Stem et al. 2005).

Upon review, the document will be revised where appropriate and the revision status will be updated in accordance with Fortescue's document control procedures.

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Figures

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Figure 1

Regional Project Location

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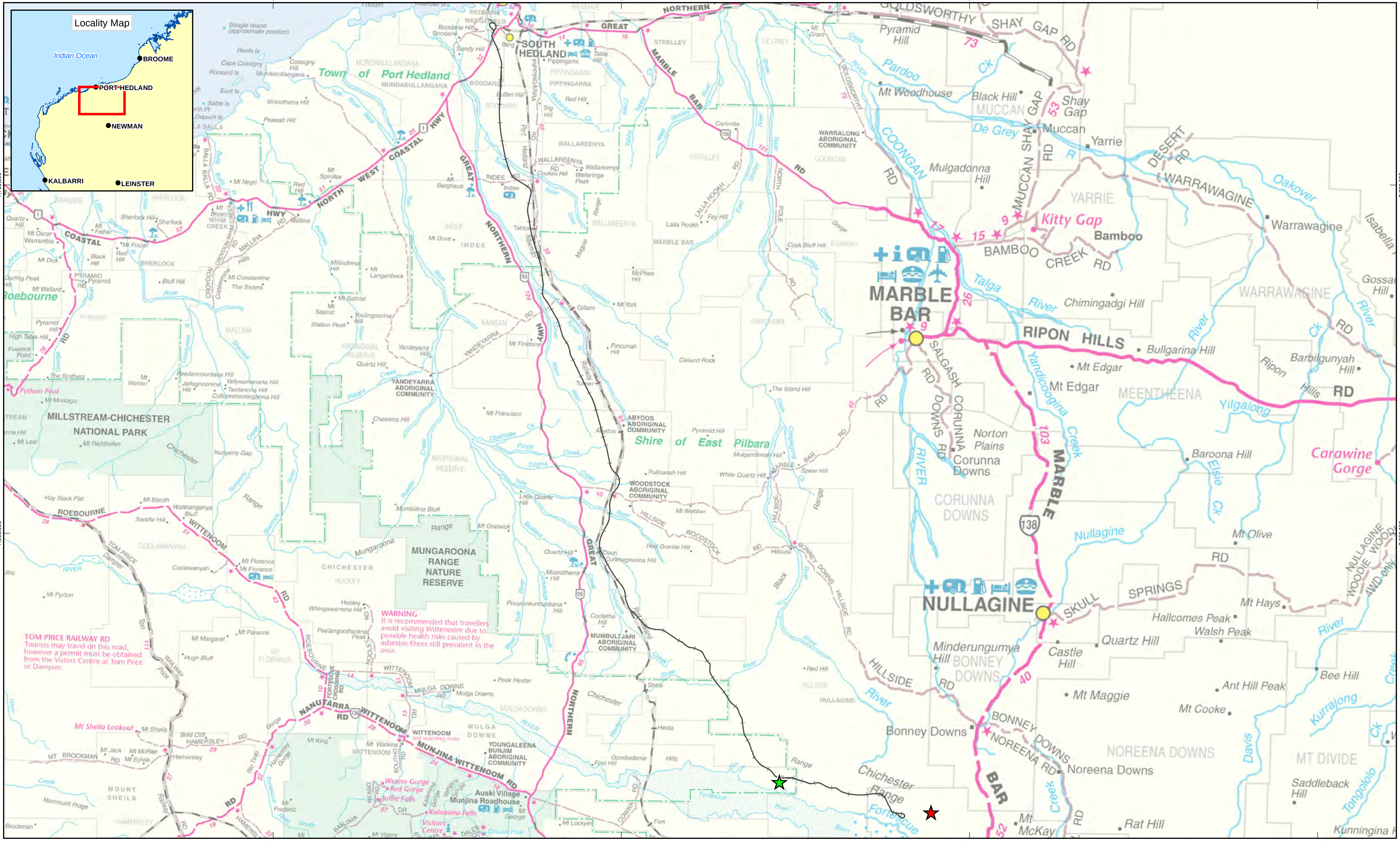

1:1,000,000 (at A3)

0 10 20 30 40 50

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone50

N

LEGEND

FMG Minesite

Christmas Creek

Cloudbreak

FMG Rail

Fortescue Metals Group Ltd
Cloudbreak Vegetation
Heath Monitoring

Job Number 61-28112
Revision 0
Date 12 Mar 2013

Locality

Figure 1

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Data source: FMG: FMG Rail - 2012, FMG Minesite - 2012; Landgate: Travellers Atlas 2004 - 20120806. Created by: cagilbert, jrutherford

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Figure 2

Predicted Impact Areas and Monitoring Locations

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715,000 732,500 750,000 767,500

7,540,000

7,522,500

MR2
Kardardarrie
ER2
ED1
HSMB03_WT
SR2
CBFMM02_S
CBX04_S
SI2
SR1
SI1
CBFMM06_S
CBX10a_WT
ER1
HSA08
MD1
HSMB29_S
MI1
HEMB05_S
MI2
MR1
SCX04_S
SCX02_S

1:175,000 (at A3)

0 1.75 3.5 5.25 7 8.75

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone50

N

LEGEND

Vegetation Monitoring Units (VMU)

- Eucalyptus
- Mulga
- Samphire

FMG Bore

Project Area

Contours greater than 1m

- Mounding
- Drawdown

Fortescue Metals Group Ltd
Cloudbreak Vegetation
Heath Monitoring

Job Number	61-28112
Revision	0
Date	12 Mar 2013

Monitoring Locations and Impact Areas

Figure 2

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Data source: FMG: FMG Bore - 20120606, Chichester Mosaic 2011, Project Area - 2020510, Contours - 2012; GHD: Vegetation Monitoring Units - 20120621; Landgate: Mount Marsh 2008 Mosaic - 20120625, Warrie 2008 Mosaic - 20120625. Created by: cagilbert, jrutherford

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Appendices

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Appendix A.

Cross reference to State and Federal Statutory Requirements

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Appendix A: Cross reference to State Statutory Requirements

Ministerial Statement and Condition	Requirement or Issue	Location in this Plan
MS 899: 6-3(1)	Identification of keystone plant species and habitat characteristic and limits of acceptable change in health and/or condition of these to be used as the basis for monitoring.	Appendix B
MS 899: 6-3(2)	Locations for predicted indirect impact and reference monitoring sites (outside the predicted direct and indirect impact areas) for baseline and ongoing monitoring, with sites selected based on scientific rationale and to the satisfaction of the Department of Environment and Conservation.	Figure 2 Section 9
MS 899: 6-3(3)	Results of baseline monitoring for vegetation health and condition, species composition and habitat characteristics at both predicted indirect impact and reference monitoring sites, and groundwater levels and groundwater quality at agreed sites in proximity to the vegetation monitoring sites.	Appendices C & E
MS 899: 6-3(4)	Specifications for the monitoring program for vegetation health and condition, species composition and habitat characteristics, including trigger levels for additional management actions to prevent further impacts and ensure compliance with condition 6-1.	Section 9
MS 899: 6-3(5)	Specific management and contingency actions beyond reporting or initiating assessment	Sections 8 &11
MS 899: 6-5	The monitoring is to be carried out according to a method and schedule as specified in the VHMMP, and is to be carried out until such a time as the CEO determines on advice from the DEC that monitoring may cease.	Section 9 Appendix D & E
MS 899: 6-6(1) MS 899: 6-6(2) MS 899: 6-6(3) MS 899: 6-6(4)	In the event that monitoring required by condition 6-5 indicates an exceedance of trigger levels as described in the VHMMP: 1. The proponent shall report such findings to the CEO of the OEPA within 7 days of the exceedance being identified; 2. The proponent shall provide evidence which allows determination of the cause of the exceedance within 21 days of the exceedance being identified; 3. If determined by the CEO of the OEPA to be a result of activities undertaken implementing the proposal, the proponent shall submit actions to be taken to address the exceedance within 21 days of the determination being made to the CEO of the OEPA; and 4. The proponent shall implement the plan of actions to address the exceedance upon approval of the CEO of the OEPA and shall continue until such a time the CEO of the OEPA determines the remedial actions may cease.	Sections 8 & 11

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Appendix B.

Existing Environment

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1. EXISTING ENVIRONMENT

1.1 Climate

The Pilbara region of Western Australia is subject to an arid-tropical climate with two distinct seasons; a hot wet summer (October to April) and a mild dry winter (May to September) (BOM 2012).

The majority of the Pilbara region has a bimodal rainfall distribution, resulting in two rainfall maxima per year. From January to March, rain results from storms penetrating from the north, producing sporadic and intense thunderstorms. Tropical cyclones and depressions moving southwards from northern Australian waters also cause heavy rainfall events. From May to June cold fronts move easterly across Western Australia and may occasionally reach the Pilbara Region. These fronts produce light winter rains that are generally ineffective for extensive plant growth. Surface water can be found in some pools and springs in the Pilbara Region all year round, although watercourses only flow briefly due to the short wet season.

Bureau of Meteorology (BOM) weather recording stations in the vicinity of the Project Area included Marillana (Station No. 5009). The mean maximum temperature at Marillana is 31.8 ºC with summer temperatures often exceeding 40 ºC. The long-term mean annual rainfall at Marillana is 317.3 mm with most of the rain falling between January and March (BOM 2012).

1.2 Geology and Soils

The Project Area is within the southern section of the Pilbara Craton, which is dominated by the Hamersley Basin. In its northern part, the Hamersley Basin comprises Archaean basalt, shale, sandstone, conglomerate, tuff and carbonate. These rocks are collectively known as the Fortescue Group, and together with a narrow strip of banded iron formation, make up the Chichester Ranges (Tille 2006). In the south, the Hamersley Basin comprises Archaean-Palaeoproterozoic metamorphosed banded iron formations, shales, dolerite, carbonate, chert and rhyolite. These rocks are collectively known as the Hamersley Group, and make up part of the Ophthalmia Fold Belt (Tille 2006).

The Jeerinah formation is the youngest formation within the Fortescue Group, and marks the base of the main ore body. The Jeerinah is sub-divided into a number of members, with Roy Hill Shale the uppermost. Mineralisation at Cloudbreak is confined to the Nammuldi member of the Mara Mamba Formation (MMF), the lowest formation of the Hamersley Group. The MMF outcrops in areas towards the Chichester Ranges, but is generally overlain by tertiary detritals and alluvium in current and proposed mining areas, which deepen closer to the Fortescue Marsh.

The most recent and detailed mapping of Western Australia's rangelands and arid interiors was documented by Tille (2006), who characterised the soils into a hierarchy of soil-landscape mapping units. According to this mapping the Project Area occurs within the Fortescue Province, which is based on the Fortescue botanical district of Beard (1990). Tille (2006) divides

the Fortescue Province into ten soil-landscape zones with the Project Area occurring within the Chichester Ranges Zone and the Fortescue Valley Zone.

The Chichester Ranges Zone contains hills and dissected plateaux (with some stony plains) on basalt and sedimentary rocks of the Hamersley Basin and stony soils with some red shallow loams and hard cracking clays (Tille 2006). The Fortescue Valley Zone contains alluvial plains, hardpan wash plains and sand plains (with stony plains, floodplains and some salt lakes) on alluvial deposits over sedimentary rocks of the Hamersley Basin. Soils include red deep sands, red loamy earths and red/brown non-cracking clays with some red shallow loams and hard cracking clays (Tille 2006).

1.3 Land Systems

The Pilbara region has been surveyed by the Western Australian Department of Agriculture and Food (DAFWA), for the purposes of land classification, mapping and resource evaluation. The Project Area is located within six land systems, which are distinguished on the basis of topography, geology, soils and vegetation (van Vreeswyk *et al.* 2004). Details of the land systems occurring within the Project Area are presented in Table 1.

Table 1: Details of land Systems found in the Project Area

Land System	Location in Project Area	Description	Geology	Geomorphology
Jamindie	Extensive (central and eastern)	Occupies 2,074 km^2 and consists of stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey.	Partly cemented Quaternary colluvium, alluvium and laterite; minor sedimentary rocks of Proterozoic age.	Depositional surfaces; non-saline plains with hardpan at shallow depth and groved vegetation, stony upper plains and low rises on hardpan or rock, very widely spaced tributary drainage tracts and channels; minor stony gilgai plains, sandy banks and low ridges and hills.
Newman	North	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.	Lower Proterozoic jaspilite, chert, siltstone, shale, dolomite and minor acid volcanics.	Erosional surfaces; plateaux and mountains - extensive high plateaux, mountains and strike ridges with vertical escarpments and steep scree slopes and more gently inclined lower slopes; moderately spaced dendritic and rectangular tributary drainage patterns of narrow valleys and gorges with narrow drainage floors and channels
Christmas	West	Occupies 232 km^2 and consists of stony alluvial plains supporting snakewood and mulga shrublands with sparse tussock grasses.	Quaternary alluvium and colluvium.	Depositional surfaces; level to gently inclined stony plains subject to sheet flow with numerous small, diffuse drainage foci and groves, stony clay plains with gilgai microrelief; sparse or rare drainage tracts with tributary, distributary and reticulated channels.
Turee	South-east	Occupies 581 km^2 and consists of stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands.	Quaternary alluvium and colluvium.	Depositional surfaces, level plains with a mosaic of stony gilgaied and non-gilgaied surfaces, groved hardpan plains and stony saline alluvial plains subject to sheet flow; sparse through drainage tracts with non-tributary and distributary channels.
Cowra	South	Occupies 203 km2 and consists of plains fringing the Marsh land system and supporting snakewood and mulga shrublands with some halophytic undershrubs.	Quaternary colluvium and alluvium.	Depositional surfaces; almost level plains of non-saline and weakly saline alluvium with gravelly surfaces, subject to overland sheet flow; drainage foci as small groves of dense vegetation and through drainage tracts with minor non-tributary and distributing channels.
Marsh	South	Occupies 977 km2 and consists of lakebeds and flood plains subject to regular inundation, supporting samphire shrublands, salt water couch grasslands and halophytic shrublands.	Quaternary alluvium and lacustrine deposits.	Depositional surfaces; lake beds and saline peripheral flood plains forming a termination basin for the upper reaches of the Fortescue River.

Source: Van Vreeswyk *et al.* 2004

1.4 Surface Hydrology

The Project Area is located on the southern part of the Chichester Plateau, north of the Fortescue Marsh (Fortescue 2005). Within the Project Area there are numerous small drainage lines that discharge southwards towards the Marsh. These drainage lines are generally characterised by flat slopes. The largest drainage line within the Project Area is Gorman Creek, with a catchment area of approximately 30 km^2 (Fortescue 2005).

In the Project Area there are large areas of sheet-flow along the lower slopes of the Chichester Ranges. Catchments to these sheet-flow areas are difficult to delineate, as they comprise a combination of the directly up gradient overland flow areas plus overspill from nearby main creek flow zones (Fortescue 2005). Mulga vegetation dominates these broad sheet-flow areas and form banding across the landscape.

1.5 Ground Water

The Project area is underlain by the fractured rock aquifers of the Roy Hill Shales, and above this the Marra Mamba Formation, which is a semi-continuous aquifer. The Marra Mamba Formation aquifer is unconfined to partially confined in the north and partially confined to confined in the south (Fortescue 2011). In the Fortescue Marsh area the Marra Mamba Formation is overlain by the Wittenoom Formation (predominately Wittenoom Dolomite), and by Tertiary Detritals in the upslope areas (Fortescue 2011).

Groundwater levels at Cloudbreak vary from the mine site (where the watertable is approximately 409 to 415 mAHD) to the Fortescue Marsh margin (approximately 405 mAHD) (Fortescue 2010). Groundwater in the Cloudbreak region ranges from brackish (<6000 mg/L Total Dissolved Solids [TDS]) in recharge areas to hypersaline in areas closer to the Fortescue Marsh and in fractured rock zones below the Marra Mamba Formation (>100 000 mg/L TDS) (Fortescue 2010).

1.6 Biological Environment

1.6.1 Regional Biogeography

The Project Area is situated within the Eremaean Botanical Province (Beard 1990) in the Pilbara Interim Biogeographic Regionalisation of Australia (IBRA) region, sub-region Fortescue.

The Fortescue sub-region is characterised by alluvial plains and river frontages supporting salt marshes, *Acacia aneura* (Mulga) and grass communities, and *Eucalyptus camaldulensis* (River Gum) woodlands fringing drainage lines (Kendrick 2001).

The Fortescue March occurs within the Fortescue sub-region and is situated south of the Project Area. The Marsh is an extensive, episodically inundated samphire marsh that is approximately 100 km long x 10 km wide. The Fortescue Marsh is listed on the Directory of

Important Wetlands in Australia and also as an 'Indicative Place' on the Register of the National Estate (Australian Heritage) (Environment Australia 2012)

1.6.2 Broad Vegetation Types

Broadscale vegetation mapping across the Pilbara region has been undertaken by Beard (1975) at a scale of 1:1,000,000. Beard (1975) mapping indicates three vegetation associates present within the Project Area:

- Sparse low woodland; mulga, discontinuous in scattered groups (association 29).
- Mosaic: Low woodland; mulga in valleys / Hummock grasslands, open low tree-steppe; snappy gum over *Triodia wiseana* (association 562).
- Succulent steppe; samphire (association 676).

1.6.3 Vegetation Types and Communities

A total of 21 vegetation types have been described and mapped in the Cloudbreak mine area (ENV 2011). These vegetation types consist of four communities near the creek and drainage lines, four communities on the extensive flats and broad plains, four communities on the ranges, hills and hillslopes, and nine communities on the fringes of the Fortescue Marsh (or Samphire flats) (ENV 2011). None of the vegetation communities are considered Threatened Ecological Communities (TECs). Four vegetation communities associated with the Fortescue Marsh form part of the Fortescue Marsh (Marsh Land System) Priority 1 Priority Ecological Community (PEC).

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2. CURRENT STATE OF VEGETATION WITHIN THE PROJECT AREA

2.1 Vegetation Condition

The vegetation condition within the Project Area ranged from Excellent to Good (ENV 2011). Condition was largely depended on fire frequency and grazing impacts from both native and introduced fauna, and these pressures were most evident on the flats and broad plains.

Grazing from cattle was the most obvious disturbance across the Project Area, particularly on Mulga Downs pastoral station. Impacts were the greatest near watering bores with reductions in palatable plant biomass and extensive disturbance of surface soil.

2.2 Keystone Species and Habitat Characteristics within the Project Area

2.2.1 Partially Phreatophytic Vegetation

Partially phreatophytic vegetation communities within the Project Area were restricted to major drainage lines and were represented by one vegetation type as mapped by ENV (2011). These communities occurred as open woodlands, dominated by *Eucalyptus victrix* (Coolibah) and *E. camaldulensis* (River Red Gum) Mattiske (2005a). *Eucalyptus victrix* and *E. camaldulensis* are considered to be partially phreatophytic species, which are species that can utilise groundwater sources opportunistically at time when water availability is limited (Froend 2009, ENV 2011). Although recorded as occurring within the Project Area *E. camaldulensis* could not be located.

Eucalyptus victrix is a small to medium sized tree with smooth, white powdery bark and are usually confined to floodplains and creeksides (Brooker & Kleinig 2001). The species is considered partially phreatophytic, the extent is dependent on local groundwater conditions, and may utilise available groundwater, but is not completely reliant on it for survival and reproduction (Ecoscape 2009). Coolibah is characterised by a dimorphic root system, having both tap and lateral spreading roots (Grigg *et. al.* 2008).

Gradual water table decline may not affect *E. victrix*, but the long-term effects depend on the adaptive ability of individual plants (Muir 1995). A study by Loomes (2010) indicates *E. victrix* can tolerate on average water depths from just under three metres to approximately 4.2 m below the surface, while more hardy individuals can survive with the water table 8.5 m below the surface and almost two metres of inundation. Studies reviewed by Batini (2008) indicate *E. victrix* can tolerate a drawdown of between three and four metres.

The habitat characteristics for partially phreatophytic vegetation targeted for monitoring include canopy health and recruitment.

2.2.2 Mulga Vegetation Communities

Mulga vegetation communities within the Project Area generally occurred on flats and broad plains and ranged from low open woodlands to low open forest. These communities were

represented by three vegetation types as mapped by ENV (2011) and were dominated by members of the Mulga group, mainly *Acacia aptaneura* but included other *Acacia* species such as *A. pruinocarpa*, *A. tetragonophylla* and *A. xiphophylla*. These Mulga Woodlands are considered locally significant as they represent some of the most northern occurrences of Mulga in Western Australia (Mattiske 2005a).

Mulga communities occupy over 150 000 000 hectares or about 20% of land surface of the Australian continent (Sattler 1986). Mulga group species are generally rounded or obconic, multi-stem shrubs or relatively small, obconic trees (commonly 3–10 m tall) (Maslin & Reid 2012). The species' occur where soil moisture is the most limiting factor, but in areas where there is some probability of moisture recharge in any season (Anderson and Hodgkinson 1997). Mulga is characterised by spreading root systems, and roots have been reported to extend to a depth of at least 135 cm, however, the majority of the roots are thought to be located in the top 30 cm of soil (Pressland 1975, 1976). Mulga vegetation is largely dependent on surface water flow (sheetflow) to replenish of soil water (Williams 2002) and studies indicate that the vegetation does not access soil water below approximately 5 m even in drought conditions (University of Western Australia 2010). The capacity of mulga communities to withstand a decrease in sheet water flow or prolonged waterlogging and elevated saline levels is largely unknown (University of Western Australia 2010).

The habitat characteristics for Mulga vegetation targeted for monitoring include plant cover, canopy health and recruitment, plant water status and ant community structure.

2.2.3 Samphire Vegetation Communities

Samphire vegetation communities within the Project Area occurred on the fringes of the Fortescue Marsh and were represented by two vegetation types as mapped by Mattiske (2005a). These communities were low halophytic shrublands dominated by *Tecticornia* spp. Samphire species zonation occurred from the fringes to the centre of the Fortescue Marsh and is reflective of the varied edaphic and water quality conditions, and varied tolerance levels of the species to salt concentration, ground water levels and drainage.

Samphires are succulent sub-shrubs or shrubs that are largely endemic to Australia (Datson 2002). They are mostly perennial plants that are commonly associated with saline environments. Samphires are characterised by shallow, lateral root systems and often develop adventitious roots to tolerate periodic inundation (Datson 2002). Whilst there is limited knowledge on the waterlogging tolerance in the genus *Tecticornia* (English and Colmer 2011), there are a number of studies that focus on a small selection of species (e.g. English 2004, Colmer *et al.* 2009).

The habitat characteristics for Mulga vegetation targeted for monitoring include plant cover and health.

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Appendix C.

Baseline Vegetation Data Report

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Fortescue Metals Group

Cloudbreak Life of Mine Expansion Project

Vegetation Heath and Condition Baseline Report

March 2013

Abbreviations

ANOSIM	A one-way analysis of similarities
ANOVA	Analysis of variances
BACI	Before-After-Control-Impact
BOM	Bureau of Meteorology
CEO	Chief Executive Officer of the Office of the Environmental Protection Authority
EPA	Environmental Protection Authority
Fortescue	Fortescue Metals Group Limited
GHD	GHD Pty Ltd
IBRA	Interim Biogeographic Regionalisation of Australia
IUCN	International Union for Conservation of Nature
LFA	Landscape function analysis
LWP	Leaf water potential
mAHD	Meters with respect to Australian Height Datum
MS	Ministerial Statement
OEPA	Office of Environmental Protection Authority
PEC	Priority Ecological Community
SWP	Stem water potential
TEC	Threatened Ecological Community
VHMMP	Vegetation health monitoring management plan
VMU	Vegetation monitoring unit
Ψ	Water potential

Executive Summary

Fortescue Metals Group Limited (Fortescue) is developing the Cloudbreak Expansion Project, which involves expansion of its existing Cloudbreak iron ore mine, located in the Pilbara region of Western Australia. Fortescue submitted a proposal (Cloudbreak Life of Mine) to the Environmental Protection Authority (EPA). The proposal was assessed under the Environmental Protection Act 1986 and in June 2012 approved by the Minister for Environment under Ministerial Statement (MS) 899.

The EPA determined during its assessment of the proposal that Fortescue should manage indirect impacts (groundwater) to ensure significant vegetation communities are not adversely impacted (Condition 6 of MS 899). To satisfy the requirement of Condition 6 Fortescue was required to develop a site specific Vegetation Health Monitoring and Management Plan (VHMMP) for the Cloudbreak mine, and undertake vegetation health baseline monitoring, for the Project Area.

This document is a baseline report comprising the results of initial monitoring for vegetation health and condition and groundwater levels and quality at monitoring sites required by Condition 6-3(3) of MS 899.

Vegetation health and condition baseline data collection was undertaken on 11- 18 June 2012 and 30 June-6 July 2012 at Cloudbreak mine site prior to any impact activities (dewatering or reinjection of water from the expansion project). Keystone species were identified and included *Eucalyptus victrix* (partially phreatophytic vegetation), which may potentially be impacted as a result of groundwater drawdown from dewatering activities, *Acacia aneura sens. lat*. (Mulga vegetation), which may potentially be impacted as a result of groundwater mounding from reinjection activities and *Tecticornia indica* (Samphire vegetation) which may potentially be impacted from any changes in groundwater levels as a result of project activities.

A total of 12 vegetation monitoring units (VMUs) were established across the Cloudbreak Project Area based on a vigorously applied VMU selection rationale. This included three partially phreatophytic VMUs (two reference and one direct impact), five Mulga VMUs (two reference, two indirect impact and one direct impact) and four Samphire VMUs (two reference and two impact).

Monitoring parameters incorporated a range of quantitative and qualitative measurements including: habitat characterisation, visual plant health assessments, stem and leaf water potential measures, landscape function analysis assessments and soil sampling, as detailed in VHMMP (Fortescue 2013a).

The main findings of the vegetation health and condition baseline data collection included:

- Habitat characteristics of all VMUs within each vegetation type were consistent across the Project Area, with the vegetation in similar condition and sites comprising a good spatial and age structure representation of the target keystone species.
- No significant differences in any monitoring parameters were observed for VMUs within vegetation types with the exception of water potential measures in partially phreatophytic VMUs and plant health scores in Mulga VMUs. These results would indicate that all VMUs within vegetation types are of similar condition in their baseline state and are suitable for monitoring vegetation health and condition changes relating to changes in groundwater levels.
- The spatial distribution of VMUs across the Project Area is considered adequate to monitor changes in vegetation health and condition from project activities relating to dewatering and reinjection.

- Landscape function analysis assessments were undertaken at each VMU and were variable within and between vegetation types. However, limited inferences can be made regarding landscape function analysis results in the absence of temporal data.
- Baseline measure of soils at each VMU showed all soil parameters to be within acceptable ranges compared to other studies in similar environments (e.g. Baker and Eldershaw 1993, Hazelton and Murphy 2007, GHD 2010, Kew 2011).

Additionally, baseline groundwater data collected by Fortescue (2012c) showed all bores associated with VMUs to exhibit very little change in groundwater levels and water quality during the June-July 2012 period, with the exception of one bore, which recorded a water quality Class 1 trigger exceedance.

This baseline vegetation health and condition assessment has been undertaken at the Cloudbreak mine site and conforms to the monitoring program and procedures outlined in Fortescue (2013a), which addresses Condition 6.2 and 6.3 of MS 899 and is consistent with Fortescue (2012b) allowing for synergies in monitoring across the Chichester's.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.5 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background

Fortescue Metals Group Limited (Fortescue) is developing the Cloudbreak Expansion Project ('the Project'), which involves expansion of its existing Cloudbreak iron ore mine, located in the Pilbara region of Western Australia. This project includes a range of new developments and upgrades as well as additional dewatering and water disposal activities. Fortescue submitted a proposal (Cloudbreak Life of Mine) to the Environmental Protection Authority (EPA). The proposal was assessed under the Environmental Protection Act 1986 and in June 2012 approved by the Minister for Environment under Ministerial Statement (MS) 899.

The EPA determined during its assessment of the proposal that Fortescue should manage indirect impacts (groundwater) to ensure significant vegetation communities are not adversely impacted. Condition 6 (Conservation Significant Vegetation – Indirect Impacts) of MS 899 relates to this point.

Condition 6 states:

6-1 The proponent shall manage the proposal in a manner that ensures there is no adverse impact to conservation significant vegetation as a result of implementing this proposal, greater than:

- 315 ha to Mulga vegetation;
- 763 ha to Samphire vegetation; and
- 3 ha to Coolibah/River Red Gum creekline vegetation

outside the Mine Envelope.

6-2 Within ten months from the date of issue of this Statement the proponent shall prepare a Vegetation Health Monitoring and Management Plan for the Project Area, to the requirements of the CEO on advice of the Department of Environment and Conservation to verify and ensure that the requirements of condition 6-1 shall be met.

6-3 The plan required by condition 6-2 shall include the following:

1. identification of keystone plant species and habitat characteristics and limits of acceptable change in health and condition of these to be used as the basis for monitoring;
2. locations for predicted indirect impact areas and reference monitoring sites (outside the predicted direct and indirect impact areas) for baseline and ongoing monitoring, with sites selected based on scientific rationale and to the satisfaction of the CEO on the advice of the Department of Environment and Conservation;
3. results of initial monitoring for flora and vegetation health and condition, species composition and habitat characteristics at both predicted indirect impact areas and reference monitoring sites and groundwater levels and groundwater quality at agreed sites in proximity to the vegetation monitoring sites;
4. specifications for the monitoring program for flora and vegetation health and condition, species composition and habitat characteristics, including trigger levels for additional management actions to prevent further impacts and ensure compliance with condition 6-1; and

5. specific management and contingency actions beyond reporting or initiating assessment.

6-4 The proponent shall implement the Vegetation Health Monitoring and Management Plan required by condition 6-2.

6-5 The monitoring is to be carried out according to a method and schedule as specified in the plan required by condition 6-2 to the satisfaction of the CEO, and is to be carried out until such time as the CEO determines on advice from the Department of Environment and Conservation that monitoring may cease.

6-6 In the event that monitoring required by condition 6-5 indicates an exceedence of trigger levels, as described in the plan required by condition 6-2:

1. the proponent shall report such findings to the CEO within 7 days of the exceedence being identified;
2. the proponent shall provide evidence to the satisfaction of the CEO which allows determination of the cause of the exceedence within 21 days of the exceedence being identified;
3. if determined by the CEO to be a result of activities undertaken in implementing the proposal, the proponent shall submit a plan of actions to be taken to address the exceedence to the satisfaction of the CEO within 21 days of the determination being made by the CEO; and
4. the proponent shall implement the plan of actions to address the exceedence upon approval of the CEO and shall continue until such time as the CEO determines that this may cease.

6-7 The proponent shall make the Vegetation Health Monitoring and Management Plan required by condition 6-2 publicly available in a manner approved by the CEO.

GHD (Pty Ltd) was commissioned by Fortescue to develop a site specific Vegetation Health Monitoring and Management Plan (VHMMP) for the Cloudbreak mine, and undertake vegetation health baseline monitoring, for the Project Area, in order to satisfy the requirement of Condition 6 of MS 899 (Fortescue 2012a).

A VHMMP has been completed (CB-PL-EN-0019) (Fortescue 2013a) and will be submitted to the Western Australian Department of Environment and Conservation (DEC) and Chief Executive Officer of the Office of the Environmental Protection Authority (CEO) for approval required by Condition 6-2 and 6-3 of MS 899. The VHMMP comprises the detailed methodology undertaken to complete the baseline monitoring (see Fortescue 2013b).

This document is a baseline report comprising the results of initial monitoring for vegetation health and condition and groundwater levels and quality at monitoring sites required by Condition 6-3(3) of MS 899.

1.2 Objectives and scope

The objective is to assess impacts to vegetation health and condition from changes in groundwater levels (from either drawdown or mounding) outside of the mine envelope required to satisfy Conditions 6 MS 899.

GHD has developed a monitoring program which incorporates best practice methods to address the monitoring requirements outlined in Condition 6 of MS 899. This program is based upon the program developed for Fortescue's adjacent Christmas Creek mine (Astron 2011) to allow for synergies in monitoring and consistency across the Chichester's.

The broad monitoring hypothesis is that measurements of ecological parameters within keystone plant species at impact sites (or potential impact sites), do not, over time, alter significantly beyond the natural variation of reference sites.

1.3 Project area

The Cloudbreak mine site is situated within the Eremaean Botanical Province (Beard 1990) in the Pilbara Interim Biogeographic Regionalisation of Australia (IBRA) region, sub-region Fortescue (DSEWPaC 2012). The site is located approximately 120 kilometres (km) north of Newman within the Mulga Downs and Hillside pastoral leases (Figure 1, Appendix A).

1.4 Keystone species and habitats

Keystone plant species identified in the VHMMP are those species occurring in vegetation communities that are considered to be of ecological importance. For the VHMMP, the following keystone plant species were identified in consultation with DEC:

- *Eucalyptus victrix* (Coolibah) (partially phreatophytic) – Open woodland (riparian zone);
- *Acacia aneura sens. lat*. (Mulga) – Low closed forest to low open woodland; and
- *Tecticornia* species (Samphire) – Low Halophytic Shrubland.

1.5 Limitations and Assumptions

This report: has been prepared by GHD for Fortescue Metals Group and may only be used and relied on by Fortescue Metals Group for the purpose agreed between GHD and the Fortescue Metals Group as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Fortescue Metals Group arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Where GHD has relied upon external data, namely publicly available databases, the accuracy of this data lies with the provider, not with GHD.

2. Methodology

2.1 Monitoring program design

The monitoring program uses a Before-After-Control-Impact (BACI) design (Smith 2002) to determine the location of monitoring sites (referred to as vegetation monitoring units (VMUs)). A combination of reference and impact (direct and/or indirect) VMUs were established for each conservation significant vegetation community. Reference VMUs were located outside the mine envelope and outside any impact areas (i.e. predicted drawdown or mounding impact areas). Impact VMUs were located within impact areas and the mine envelope (direct impact VMUs) or located within impact areas but outside of the mine envelope (indirect impact VMUs).

The rational used for VMU selection for this monitoring program included:

- Stratification between impact and references areas;
- Identification of partially phreatophytic communities in potential drawdown impact and reference areas;
- Identification of Mulga communities and Samphire communities in potential mounding impact and reference areas;
- Selection of sampling locations as close as possible to existing groundwater bores;
- Road access and future accessibility; and
- Avoidance of heritage areas.

The locations of VMUs and the closest appropriate groundwater bores are mapped Figure 2 (Appendix A).

Initial baseline data collection was conducted at the commencement of the Project, prior to impact activities associated with the Project (i.e. dewatering and reinjection of water). Data collection at the Cloudbreak mine site was undertaken on 11-18 June 2012 and 30 June-6 July 2012.

2.2 VMU locations and details

2.2.1 Partially phreatophytic vegetation

Three partially phreatophytic VMUs were established, one direct impact VMU and two reference VMUs (Table 1, Figure 2).

Despite extensive searches throughout the Project Area, there were minimal and scattered occurrences of partially phreatophytic vegetation within the mine envelope or outside the mine envelope but within the predicted drawdown impact area. Furthermore, it is envisaged that the direct impact VMU will ultimately be lost to mining as the Cloudbreak mine expands. However, the VMU is still considered valuable and will provide data over several years.

Each partially phreatophytic VMU included a permanent quadrat of 2500 square meters (m^2) in area and ten sample trees. The sample trees were randomly selected represented one species (*Eucalyptus victrix*) and encompassed a range of ages (juvenile to mature). Quadrat corners were permanently marked with a fence dropper and all sample trees labelled with a numbered metal tag.

2.2.2 Mulga vegetation

Five Mulga VMUs were established, one direct impact VMU, two indirect impact VMUs and two reference VMUs (Table 1, Figure 2). The Mulga VMUs are predominately located at the eastern end of the mine envelope with one reference VMU located to the west of the mine envelope on Mulga Downs station.

Each Mulga VMU included a permanent quadrat of 2500 m^2 in area and ten sample trees. Sample trees were randomly selected, represented two species (*Acacia aptaneura* and *Acacia paraneura*) and encompassed a range of ages (juvenile to mature). Quadrat corners were permanently marked with a fence dropper and all sample trees labelled with a metal tag.

2.2.3 Samphire vegetation

Four Samphire VMUs were established, two impact VMUs and two reference VMUs (Table 1, Figure 2).

Despite extensive searches along the southern boundary of the Project Area, no Samphire vegetation was located within the predicted mounding impact areas or the predicted drawdown impact area. Furthermore, there were limited occurrences of Samphire vegetation within the mining envelope. Both impact VMUs occur within the mining envelope, but not within the predicted mounding impact area; these VMUs represent some of the most northern occurrences of Samphire vegetation within the Project Area.

Only potential mounding impacts to Samphire vegetation were considered in this monitoring program design based on discussions with DEC on 28 May 2012.

Each Samphire VMU included a permanent quadrat of 200 m^2 in area to accord with DEC recommendations (S. van Leeuwen, DEC, pers. comm.) and ten sample plants. The quadrat area of 200 m^2 conforms to DEC monitoring standards for Samphire vegetation, and allows data to be compared with other monitoring sites. The sample plants were randomly selected and represented one species (*Tecticornia indica*). Quadrat corners and all sample plants were permanently marked with a fence dropper and labelled with a metal tag.

Table 1 Vegetation Monitoring Unit Details

VMU ID	Vegetation	Keystone Species	Treatment	Potential Impact	Location (NW corner)	Nearest Bore	Size (m^2)	No. Sample Plants
ED1	Partially phreatophytic	*Eucalyptus victrix*	Direct impact	Drawdown	734199 mE 7532629 mN	HSMB03_WT (453 m due SE)	2,500	10
ER1	Partially phreatophytic	*Eucalyptus victrix*	Reference	n/a	761220 mE 7528628 mN	HSMB24_S (4.1 km due SE)	2,500	10
ER2	Partially phreatophytic	*Eucalyptus victrix*	Reference	n/a	716370 mE 7532213 mN	Kardardarrie (2.6 km due NW)	2,500	10
MD1	Mulga	*Acacia aneura sens. lat.*	Direct impact	Mounding	771080 mE 7523558 mN	HSMB29_S (202 m due E)	2,500	10
MI1	Mulga	*Acacia aneura sens. lat.*	Indirect impact	Mounding	774202 mE 7523648 mN	HEMB05_S (405 m due SE)	2,500	10
MI2	Mulga	*Acacia aneura sens. lat.*	Indirect impact	Mounding	769274 mE 7522360 mN	SCX02_S (345 m due E)	2,500	10
MR1	Mulga	*Acacia aneura sens. lat.*	Reference	n/a	771207 mE 7522286 mN	SCX04_S (308 m due N)	2,500	10
MR2	Mulga	*Acacia aneura sens. lat.*	Reference	n/a	714794 mE 7535429 mN	Kardardarrie (1.4 km due S)	2,500	10
SI1	Samphire	*Tecticornia* spp.	Impact	Mounding	742530 mE 7524652 mN	CBX10a_WT (2 km due E)	200	10
SI2	Samphire	*Tecticornia* spp.	Impact	Mounding	734626 mE 7527483 mN	CBX04_S (824 m due NW)	200	10
SR1	Samphire	*Tecticornia* spp.	Reference	n/a	740801 mE 7524805 mN	CBFMM06_S (440 m due NE)	200	10
SR2	Samphire	*Tecticornia* spp.	Reference	n/a	727612 mE 7527963 mN	CBFMM02_S (58 m due SW)	200	10

2.3 Monitoring parameters

Monitoring included a combination of quantitative, qualitative vegetation measurements, physiological measurements, and health and condition assessments using qualitative criteria and digital canopy photography. Baseline data was collected for the below described parameters, and methodologies approved by DEC.

Detailed procedures for each measurement are outlined in (Fortescue 2013b).

2.3.1 Habitat characterisation

VMU habitat characterisation followed the method outlined in *Flora and Vegetation Assessment Guidelines* (100-GU-EN-0005) (Fortescue 2011b). Additions to the guidelines were recommended by DEC and included the following:

- Locations and numbers of ant nests were recorded; and
- Locations and numbers of cow pats were recorded.

2.3.2 Plant characterisation

Plant characterisation measurements were undertaken *in–situ* (field) on *Eucalyptus victrix* and *Acacia aptaneura* sample plants only. The height in meters (m) and diameter in centimetres (cm) at breast height over bark (DBHOB; at 130 cm above ground level) were measured for sample plants. Additionally, the age class was determined for *Acacia aptaneura* sample plants using the method outlined in *Significant Flora and Vegetation Monitoring Guidelines* (Fortescue 2011c).

2.3.3 Plant health assessment

All sample plants were visually assessed for health and condition.

Eucalyptus victrix sample plants were assessed visually following the method of Souter *et al.* (2010). This assessment method is based on a conceptual model of the symptoms of decline due to water stress and indicators of recovery as conditions improve.

Acacia aptaneura sample plants were assessed visually following the method set out by Fortescue's *Significant Flora and Vegetation Monitoring Guidelines* (Fortescue 2011c). This assessment method has been adapted from Souter *et al.* (2010).

Tecticornia indica sample plants were assessed visually following the method of Astron (2011). This assessment method is based on the percentage of tip browning on individual plants.

All methods comprise a range of variables that are based on numerical scales which correspond to both descriptive and percentage divisions. The overall health and condition of a sample plant was calculated by summing all the assigned scores to provide a single numerical value for each plant.

2.3.4 Leaf and stem water potential

Leaf water potential (LWP) and stem water potential (SWP) measurements were undertaken using a pressure chamber instrument (Model 1505D, PMS Instrument Company, Oregon, USA) on *Eucalyptus victrix* and *Acacia aptaneura* sample plants only.

Two shoots (two to five leaves) from the mid-canopy of sample plants were placed in tin foil wrapped envelopes and dark-adapted for at least one hour to become equilibrated with the water potential in the tree trunk. A total of four shoots (two for LWP, and two for SWP) were excised from each sample plant and their water potentials measured using a pressure chamber instrument.

LWP and SWP measurements were made on all *Acacia aneura sens. lat.* sample plants and a random subset of five *Eucalyptus victrix* sample plants at each VMU (due to difficulties in reaching foliage and accompanying safety issues).

2.4 Landscape function analysis

A landscape function analysis (LFA) assessment was undertaken at each VMU following the methodology of Tongway and Hindley (2004a). This assessment provided reference landscape or ecosystem function condition appropriate to each VMU.

The LFA method (Tongway and Hindley 1995, 2004b) is used to describe landscape type, characterise landscape organization and assess soil surface condition. This method derives a number of indices for site stability, infiltration and nutrient cycling, from the above three principles to assess how well an ecosystem functions from a biophysical perspective. Sites are characterised according to their topographic location (e.g. crest, mid slope, flat or stream channel), soils, slope, vegetation type, land use and state of the soil surface.

2.4.1 Site selection

Site locations were established based on VMU locations, with a single transect surveyed for each VMU. The location and extent of each transect was selected based on an assessment of landscape characterisation including:

- Direction, appropriate to characterise the downslope overland flow direction (maximum slope). Due to the flat nature of most VMUs, beds of deposited material were used as an indicator of flow direction and the transect orientated perpendicular to these deposits; and
- Classification of patch and inter-patch and the number of replicates appropriate to develop a baseline (minimum 5 replicates for each patch and inter-patch zones).

The upslope end of each transect was marked with a fence dropper which generally but not always aligned with the top end of the VMU. The fence dropper location was recorded by GPS and the transect direction captured in degrees by compass. Transect length was dependent on the scale of patch and inter-patch zones and varied from 6 m (Samphire vegetation) to 105 m (Mulga vegetation).

The location and associated details of each LFA are provided in Table 2.

Table 2 Landscape Function Analysis Transect Details

VMU ID	LFA ID	Start Position (Easting)	Start Position (Northing)	Compass bearing (°)	Length (m)
ED1	ED1_LFAJuly2012	734160 mE	7532689 mN	90	28
ER1	ER1_LFAJuly2012	761231 mE	7528607 mN	150	25
ER2	ER2_LFAJuly2012	716385 mE	7532253 mN	210	60
MD1	MD1_LFAJuly2012	771043 mE	7523566 mN	135	76.6
MI1	MI1_LFAJuly2012	774272 mE	7523572 mN	270	52.2
MI2	MI2_LFAJuly2012	769371 mE	7522351 mN	240	101.2
MR1	MR1_LFAJuly2012	771221 mE	7522268 mN	214	105
MR2	MR2_LFAJuly2012	714815 mE	7535440 mN	300	74
SI1	SI1_LFAJuly2012	742526 mE	7524648 mN	240	6
SI2	SI2_LFAJuly2012	734644 mE	7527519 mN	150	9.2
SR1	SR1_LFAJuly2012	740803 mE	7524802 mN	220	25.15
SR2	SR2_LFAJuly2012	727638 mE	7527994 mN	212	9.3

2.4.2 Patch and Inter-patch Characterisation

Patch and inter-patch zones were classified as follows:

- Patches are long lived features which act as depositional zones, collecting, filtering, obstructing or diverting water. These zones act as resource accumulators.
- Inter-patches are active zones characterised by mobilisation and transport of water, litter and soil material, generally in a downslope direction unless wind is a dominant factor.

Patch and inter-patch zones for the vegetation communities monitored vary in scale and nature due to the ecological differences between these communities. Specific characteristics for patch and inter-patch zones for each of the vegetation communities are described in Appendix C.

2.5 Soil sampling

Soil sampling was undertaken to provide baseline data of the soil physical and chemical properties at each VMU. Soil was sampled from two locations within each VMU, one adjacent to the NW corner and the second adjacent the SE corner. Soil samples were obtained using an 82 mm diameter hand auger, with augering extending to a maximum depth of 1 m. Approximately 500 grams (g) of soil was collected per sample, with all samples sealed in labelled plastic sample bags. Samples were stored in plastic tubs at air temperature before being dispatched to laboratory for analysis.

All soil samples were sent to Cumming Smith British Petroleum (CSBP) for analysis. Each sample was analysed for pH, electrical conductivity, dispersion, percentage moisture, particle size, and the following nutrients and metals: nitrate nitrogen, ammonium nitrogen, phosphorus, potassium, sulphur, organic carbon, aluminium calcium chloride, boron, exchangeable cat ions aluminium, calcium, magnesium, potassium and sodium, DTPA trace elements copper, iron, manganese and zinc and heavy metals cadmium, chromium, cobalt, lead, molybdenum and selenium using standard analytical techniques (available from CSBP on request).

2.6 Groundwater Data

Groundwater data including groundwater level (measured in meters with respect to the Australian Height Datum (mAHD)) and water quality (measured as electrical conductivity (EC) in microSiemens per centimetre (µS/cm)) were collected by Fortescue as outlined in Fortescue (2012d) and reported in Fortescue's quarterly aquifer review (2012c).

2.7 Data analysis

Detailed data analysis procedures for each monitoring parameter are outlined in (Fortescue 2013b). Data analysis included:

- Initial testing of raw data for normal distribution using Shapiro-Wilk test, and homogeneity of variance with Levene's test;
- Use of multivariate statistical tests including resemblance, multi-dimensional scaling (MDS), cluster (CLUSTER) and one-way analysis of similarities (ANOSIM) for VMU habitat characteristics; and
- Use of parametric univariate statistical tests including one-way analysis of similarities (ANOVA) and two sampled t-test (Student's t-test) for plant health scores and water potential measures.

A minimum of two samples per treatment is required for MDS, therefore MDS was undertaken for Mulga and Samphire vegetation only (both vegetation types have at least two impact and

two reference VMUs). CLUSTER was undertaken for partially phreatophytic data, as this vegetation type had only one impact and two reference VMUs.

ANOSIM requires a minimum of three factors, therefore ANOSIM was only undertaken for Mulga vegetation where three factors included direct impact, indirect impact and reference. Partially phreatophytic and Samphire vegetation only had two factors each.

LFA data was analysed following methods developed by Tongway and Hindley (2004a).

2.8 Limitations

Limitations associated with this project are outline below.

2.8.1 VMU Locations

There were a restricted number of potential VMU locations within the Project Area that met the site selection criteria. The most limiting criteria was the presence of appropriately screened water bores and in some instances the presence of focus or keystone vegetation. The Project Area was extensively searched for appropriate VMU locations before quadrats were established.

Partially phreatophytic vegetation communities were minimal and scattered throughout the Project Area additionally occurrences usually contained a low numbers of trees (< 10 trees in a quadrat –sized area). No indirect impact partially phreatophytic VMUs were established due to no sites meeting the site selection criteria throughout the Project Area.

Mulga VMUs were mostly established in the eastern part of the Project Area. This was the only area that met the site selection criteria for indirect impact sites.

Samphire VMUs were also limited by the site selection criteria. Only three appropriate water bores were located outside of the mining envelope and the potential mounding impact areas. Two of these were selected for Samphire Reference VMUs. No Samphire vegetation occurred within the mounding impact areas, therefore, no Samphire direct or indirect impact VMUs could be established. However, Samphire vegetation occurred within 1 km of the potential mound impact areas, therefore two Samphire impact VMUs were established. These sites were located within the mining envelope, but outside of the potential mounding impact areas.

3. Existing Environment

3.1 Climate

The Pilbara region of Western Australia is subject to an arid-tropical climate with two distinct seasons; a hot wet summer (October to April) and a mild dry winter (May to September) (BOM 2012).

The majority of the Pilbara region has a bimodal rainfall distribution, resulting in two rainfall maxima per year. From January to March, rain results from storms penetrating from the north, producing sporadic and intense thunderstorms. Tropical cyclones and depressions moving southwards from northern Australian waters also cause heavy rainfall events. From May to June cold fronts move easterly across Western Australia and may occasionally reach the Pilbara Region. These fronts produce light winter rains that are generally ineffective for extensive plant growth. Surface water can be found in some pools and springs in the Pilbara Region all year round, although watercourses only flow briefly due to the short wet season.

The closest Bureau of Meteorology (BOM) weather recording station to the Project Area is Marillana (Station No. 5009). Additionally, Fortescue records weather data at Cloudbreak mine site. Recorded rainfall data for Marillana and Cloudbreak mine site for the period January 2011 to June 2012 is presented below.

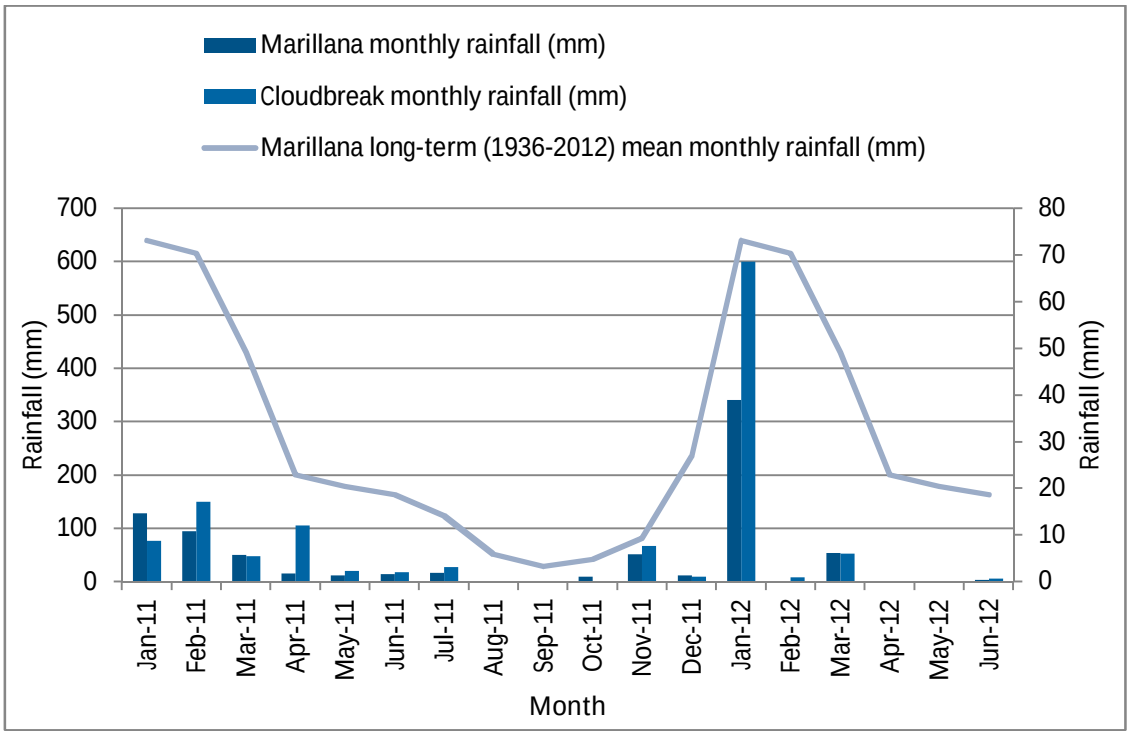

Figure 3 Monthly rainfall (mm) sourced from Cloudbreak weather station (Fortescue 2012), and monthly rainfall (mm) and long-term mean monthly rainfall (mm) sourced from Marillana weather station (BOM 2012).

3.2 Geology and Soils

The Project Area is within the southern section of the Pilbara Craton, which is dominated by the Hamersley Basin. In its northern part, the Hamersley Basin comprises Archaean basalt, shale, sandstone, conglomerate, tuff and carbonate. These rocks are collectively known as the Fortescue Group, and together with a narrow strip of banded iron formation, make up the Chichester Ranges (Tille 2006). In the south, the Hamersley Basin comprises Archaean-Palaeoproterozoic metamorphosed banded iron formations, shales, dolerite, carbonate, chert and rhyolite. These rocks are collectively known as the Hamersley Group, and make up part of the Ophthalmia Fold Belt (Tille 2006).

The Jeerinah formation is the youngest formation within the Fortescue Group, and marks the base of the main ore body. The Jeerinah is sub-divided into a number of members, with Roy Hill Shale the uppermost. Mineralisation at Cloudbreak is confined to the Nammuldi member of the Mara Mamba Formation (MMF), the lowest formation of the Hamersley Group. The MMF outcrops in areas towards the Chichester Ranges, but is generally overlain by tertiary detritals and alluvium in current and proposed mining areas, which deepen closer to the Fortescue Marsh.

The most recent and detailed mapping of Western Australia's rangelands and arid interiors was documented by Tille (2006), who characterised the soils into a hierarchy of soil-landscape mapping units. According to this mapping the Project Area occurs within the Fortescue Province, which is based on the Fortescue botanical district of Beard (1990). Tille (2006) divides the Fortescue Province into ten soil-landscape zones with the Project Area occurring within the Chichester Ranges Zone and the Fortescue Valley Zone.

The Chichester Ranges Zone contains hills and dissected plateaux (with some stony plains) on basalt and sedimentary rocks of the Hamersley Basin and stony soils with some red shallow loams and hard cracking clays (Tille 2006). The Fortescue Valley Zone contains alluvial plains, hardpan wash plains and sand plains (with stony plains, floodplains and some salt lakes) on alluvial deposits over sedimentary rocks of the Hamersley Basin. Soils include red deep sands, red loamy earths and red/brown non-cracking clays with some red shallow loams and hard cracking clays (Tille 2006).

3.3 Land Systems

The Pilbara region has been surveyed by the Western Australian Department of Agriculture and Food (DAFWA), for the purposes of land classification, mapping and resource evaluation. The Project Area is located within six land systems, which are distinguished on the basis of topography, geology, soils and vegetation (van Vreeswyk *et al.* 2004). Details of the land systems occurring within the Project Area are presented in Table 3.

Table 3 Details of Land Systems found in the Project Area

Land system	Location in Project Area	Description	Geology	Geomorphology
Jamindie	Extensive (central and eastern)	Occupies 2,074 km^2 and consists of stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey	Partly cemented Quaternary colluvium, alluvium and laterite; minor sedimentary rocks of Proterozoic age	Depositional surfaces; non-saline plains with hardpan at shallow depth and groved vegetation, stony upper plains and low rises on hardpan or rock, very widely spaced tributary drainage tracts and channels; minor stony gilgai plains, sandy banks and low ridges and hills.
Newman	North	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands	Lower Proterozoic jaspilite, chert, siltstone, shale, dolomite and minor acid volcanics.	Erosional surfaces; plateaux and mountains - extensive high plateaux, mountains and strike ridges with vertical escarpments and steep scree slopes and more gently inclined lower slopes; moderately spaced dendritic and rectangular tributary drainage patterns of narrow valleys and gorges with narrow drainage floors and channels
Christmas	West	Occupies 232 km^2 and consists of stony alluvial plains supporting snakewood and mulga shrublands with sparse tussock grasses	Quaternary alluvium and colluvium	Depositional surfaces; level to gently inclined stony plains subject to sheet flow with numerous small, diffuse drainage foci and groves, stony clay plains with gilgai microrelief; sparse or rare drainage tracts with tributary, distributary and reticulated channels.
Turee	South-east	Occupies 581 km^2 and consists of stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands	Quaternary alluvium and colluvium	Depositional surfaces, level plains with a mosaic of stony gilgaied and non-gilgaied surfaces, groved hardpan plains and stony saline alluvial plains subject to sheet flow; sparse through drainage tracts with non-tributary and distributary channels
Cowra	South	Occupies 203 km^2 and consists of plains fringing the Marsh land system and supporting snakewood and mulga shrublands with some halophytic undershrubs	Quaternary colluvium and alluvium	Depositional surfaces; almost level plains of non-saline and weakly saline alluvium with gravelly surfaces, subject to overland sheet flow; drainage foci as small groves of dense vegetation and through drainage tracts with minor non-tributary and distributing channels
Marsh	South	Occupies 977 km^2 and consists of lakebeds and flood plains subject to regular inundation, supporting samphire shrublands, salt water couch grasslands and halophytic shrublands	Quaternary alluvium and lacustrine deposits	Depositional surfaces; lake beds and saline peripheral flood plains forming a termination basin for the upper reaches of the Fortescue River

Source: Van Vreeswyk *et al.* 2004

3.4 Surface Hydrology

The Project Area is located on the southern part of the Chichester Plateau, north of the Fortescue Marsh (Fortescue 2005). Within the Project Area there are numerous small drainage lines that discharge southwards towards the Marsh. These drainage lines are generally characterised by flat slopes. The largest drainage line within the Project Area is Gorman Creek, with a catchment area of approximately 30 square km^2 (Fortescue 2005).

In the Project Area there are large areas of sheet-flow along the lower slopes of the Chichester Ranges. Catchments to these sheet-flow areas are difficult to delineate, as they comprise a combination of the directly up gradient overland flow areas plus overspill from nearby main creek flow zones (Fortescue 2005). Mulga vegetation dominates these broad sheet-flow areas and form banding across the landscape.

3.5 Ground Water

The Project area is underlain by the fractured rock aquifers of the Roy Hill Shales, and above this the Marra Mamba Formation, which is a semi-continuous aquifer. The Marra Mamba Formation aquifer is unconfined to partially confined, in the north and partially confined to confined, in the south (Fortescue 2011a). In the Fortescue Marsh area the Marra Mamba Formation is overlain by the Wittenoom Formation (predominately Wittenoom Dolomite), and by Tertiary Detritals in the upslope areas (Fortescue 2011a).

Groundwater levels at Cloudbreak vary from the mine site (where the water table is approximately 409 to 415 mAHD) to the Fortescue Marsh margin (approximately 405 mAHD) (Fortescue 2010). Groundwater in the Cloudbreak region ranges from brackish (<6000 milligrams per litre (mg/L) Total Dissolved Solids (TDS)) in recharge areas to hyper saline in areas closer to the Fortescue Marsh and in fractured rock zones below the Marra Mamba Formation (>100 000 mg/L TDS) (Fortescue 2010).

3.6 Biological Environment

3.6.1 Regional Biogeography

The Project Area is situated within the Eremaean Botanical Province (Beard 1990) in the Pilbara Interim Biogeographic Regionalisation of Australia (IBRA) region, sub-region Fortescue (DSEWPaC 2012).

The Fortescue sub-region is characterised by alluvial plains and river frontages supporting salt marshes, *Acacia aneura* (Mulga) and grass communities, and *Eucalyptus camaldulensis* (River Gum) woodlands fringing drainage lines (Kendrick 2001).

The Fortescue March occurs within the Fortescue sub-region and is situated south of the Project Area. The Marsh is an extensive, episodically inundated samphire marsh that is approximately 100 km long x 10 km wide. The Fortescue Marsh is listed on the Directory of Important Wetlands in Australia and also as an 'Indicative Place' on the Register of the National Estate (Australian Heritage) (Environment Australia 2012)

3.6.2 Broad Vegetation Types

Broadscale vegetation mapping across the Pilbara region has been undertaken by Beard (1975) at a scale of 1:1,000,000. Beard (1975) mapping indicates three vegetation associates present within the Project Area:

- Sparse low woodland; mulga, discontinuous in scattered groups (association 29).

- Mosaic: Low woodland; mulga in valleys / Hummock grasslands, open low tree-steppe; snappy gum over *Triodia wiseana* (association 562).
- Succulent steppe; samphire (association 676).

3.6.3 Vegetation Types and Communities

A total of 21 vegetation types have been described and mapped in the Cloudbreak mine area (ENV 2011). These vegetation types consist of four communities near the creek and drainage lines, four communities on the extensive flats and broad plains, four communities on the ranges, hills and hillslopes, and nine communities on the fringes of the Fortescue Marsh (or Samphire flats) (ENV 2011). None of the vegetation communities are considered Threatened Ecological Communities (TECs). Four vegetation communities associated with the Fortescue Marsh form part of the Fortescue Marsh (Marsh Land System) Priority 1 Priority Ecological Community (PEC).

Partially Phreatophytic Vegetation

Partially phreatophytic vegetation communities within the Project Area were restricted to major drainage lines and were represented by one vegetation type as mapped by ENV (2011). These communities occurred as open woodlands, dominated by *Eucalyptus victrix* (Coolibah) and *E. camaldulensis* (River Red Gum) Mattiske (2005). *Eucalyptus victrix* and *E. camaldulensis* are considered to be partially phreatophytic species, which are species that can utilise groundwater sources opportunistically at time when water availability is limited (Froend 2009, ENV 2011). Although recorded as occurring within the Project Area *E. camaldulensis* could not be located.

Mulga Vegetation

Mulga vegetation communities within the Project Area generally occurred on flats and broad plains and ranged from low open woodlands to low open forest. These communities were represented by three vegetation types as mapped by ENV (2011) and were dominated by members of the Mulga group, mainly *Acacia aptaneura* but included other *Acacia* species such as *A. pruinocarpa*, *A. tetragonophylla* and *A. xiphophylla*. These Mulga Woodlands are considered locally significant as they represent some of the most northern occurrences of Mulga in Western Australia (Mattiske 2005).

Samphire vegetation

Samphire vegetation communities within the Project Area occurred on the fringes of the Fortescue Marsh and were represented by two vegetation types as mapped by Mattiske (2005). These communities were low halophytic shrublands dominated by *Tecticornia* spp. Samphire species zonation occurred from the fringes to the centre of the Fortescue Marsh and is reflective of the varied edaphic and water quality conditions, and varied tolerance levels of the species to salt concentration, ground water levels and drainage.

4. Results

4.1 Partially Phreatophytic Vegetation

4.1.1 Habitat Characteristics

Habitat characteristics for partially phreatophytic VMUs are summarised in below. The vegetation of each partially phreatophytic VMU was described based on species composition, structure and dominance. The vegetation condition of each VMU was similar with ED1 (direct impact) and ER2 (reference) showing more signs of disturbance compared with ER1 (reference). ER1 contained a significantly lower number of plant taxa compared with ED1 and ER2. All VMUs had introduced (weed) taxa present, **Cenchrus ciliaris* being the most common taxon recorded, and occurring at high densities at both Reference VMUs. Cow pats were only recorded at ER2, most likely due the close proximity to a pastoral bore (Kardardarrie Bore).

Full VMU descriptions including photographs and flora taxa lists are provided in Appendix C.

Ant Nests

No ant nests were recorded at any partially phreatophytic VMU.

Table 4 Partially Phreatophytic VMU Habitat Characteristics

VMU ID	Vegetation Description
ED1 (direct impact)	*Eucalyptus victrix* mid woodland over *Eucalyptus victrix, Atalaya hemiglauca, Acacia coriacea* low woodland over *Grevillea wickhamii, Acacia tumida* var. *pilbarensis*, *Atalaya hemiglauca* low open shrubland over *Tephrosia rosea, Acacia tumida* var. *pilbarensis*, *Acacia pyrifolia* mid open shrubland over *Grevillea wickhamii, Acacia tumida* var. *pilbarensis*, *Pterocaulon sphacelatum* low open shrubland over *Amphipogon sericeus, Triodia longiceps, Triodia epactia* mid sparse hummock grassland and **Cenchrus ciliaris, Themeda triandra* mid sparse tussock grassland and *Pluchea dentex, Hybanthus aurantiacus, Stemodia viscosa* low isolated herbs.
ER1 (reference)	*Eucalyptus victrix* mid open forest over *Acacia trachycarpa, Acacia pyrifolia* tall open shrubland over *Indigofera monophylla, Pterocaulon sphacelatum* low open shrubland over *Triodia longiceps* low sparse hummock grassland and **Cenchrus ciliaris* low closed tussock grassland and *Cyperus vaginatus* tall sedgeland and *Pluchea dentex, Rhynchosia minima* low open herbland.
ER2 (reference)	*Eucalyptus victrix* mid open forest over *Acacia xiphophylla, Acacia distans* low woodland over *Acacia tetragonophylla, Acacia synchronicia, Acacia xiphophylla* tall open shrubland over *Acacia synchronicia, Rhagodia eremaea* mid sparse shrubland over *Rhagodia eremaea, Salsola tragus* low sparse shrubland over **Cenchrus ciliaris* low sparse tussock grassland and *Evolvulus alsinoides, Amaranthus cuspidifolius* low sparse herbland over *Bulbostylis barbata* low isolated sedges.

Table 5 Partially Phreatophytic VMU Habitat Characteristics

VMU Characteristic	ED1	ER1	ER2
Vegetation condition (Keighery 1994)	Very Good	Excellent	Very Good
Total flora taxa (count)	49	25	55
Native taxa (count)	47	24	49
Introduced taxa (count)	2	1	6
Conservation significant taxa (count)	1	0	0
Cow pats (count)	0	0	18
Ant nests (count)	0	0	0

Flora species composition and cover for each partially phreatophytic VMU was compared. The comparison was based on a presence/absence data matrix created for all VMUs. The dendrogram produced showed ED1 (direct impact) and ER1 (reference) to be the most similar VMUs, however, the degree of similarity was not strong (Figure 4).

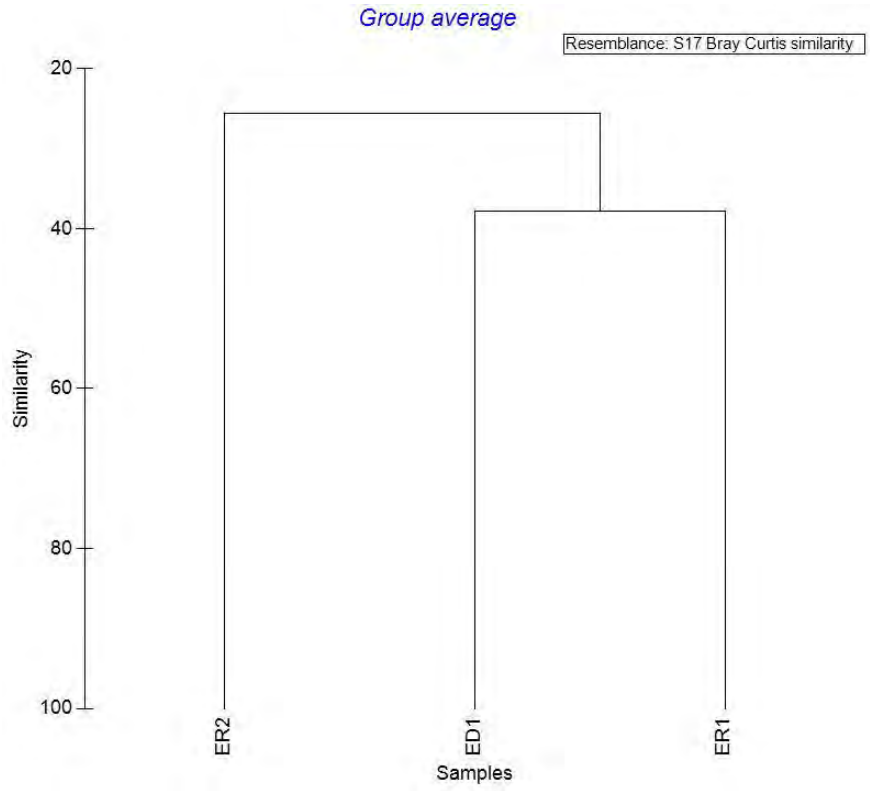

Figure 4 Hierarchical cluster presented as a dendrogram of flora species composition and cover plotted by partially phreatophytic VMU.

4.1.2 Plant Health Assessment

Mean plant health scores for partially phreatophytic sample plants were based on a cumulative total of eight different variables and ranged from 10 to 14 across all VMUs. Only one sample plant, from ED1, showed minimal evidence of new growth and no sample plants showed any reproductive capability (i.e. presence of buds, flowers or fruits). A summary of cumulative plant health assessment scores for each VMU is provided in Table 6, scores for all variables of individual sample plants are provided in Appendix B.

Table 6 Partially Phreatophytic VMU Plant Health Scores Summary

Variable	ED1	ER1	ER2
Mean score	12.1	12	11.3
Standard deviation	0.41	0.26	0.30
Minimum score	10	11	10
Maximum score	14	14	13
Range	4	3	3

An Analysis of Variances (ANOVA) was undertaken to compare the cumulative plant health scores of each VMU. No significant differences were found between any VMU, indicating that there are no differences in the health of all sample plants between VMUs. Pairwise analysis (t-tests) were undertaken to show comparisons between each VMU. A summary of the pairwise analysis is provided in Table 7

Table 7 Pairwise Analysis for Partially Phreatophytic Vegetation Health Scores for each VMU.

Partially phreatophytic vegetation health scores (p) values			
	ED1	ER1	ER2
ED1	-	0.838	0.131
ER1	-	-	0.094
ER2	-	-	-

p values were calculated by t-tests using 95% confidence intervals. Significant differences (if present) are denoted in bold.

4.1.3 Leaf and Stem Water Potentials

Water potentials (Ψ) from LWP and SWP sampling on partially phreatophytic sample plants were compared across all VMUs. A summary of Ψ measures for each VMU is provided in Table 8 and graphically represented in Figure 5, scores for all Ψ measures of individual sample plants are provided in Appendix B.

Water potential measures varied between SWP and LWP measures at each VMU, with the average increase of Ψ between LWP and SWP sampling 134.80 hPa, 144.70 hPa and 195.43 hPa for ED1, ER1 and ER2 was respectively. Water potential measures also differed between VMUs with ER1 values noticeably lower than values from ED1 and ER2.

Table 8 Partially Phreatophytic VMU Water Potential Measures Summary

VMU ID	ED1		ER1		ER2	
	LWP	SWP	LWP	SWP	LWP	SWP
Mean	719.70	584.90	510.80	366.10	720.571	525.14
Standard deviation	94.56	81.92	81.28	71.16	136.81	79.08
Minimum	642.50	457.00	441.50	264.00	495.50	449.50
Maximum	881.50	658.50	649.00	449.50	885.00	667.50
Range	239.00	201.50	207.50	185.50	389.50	218.00

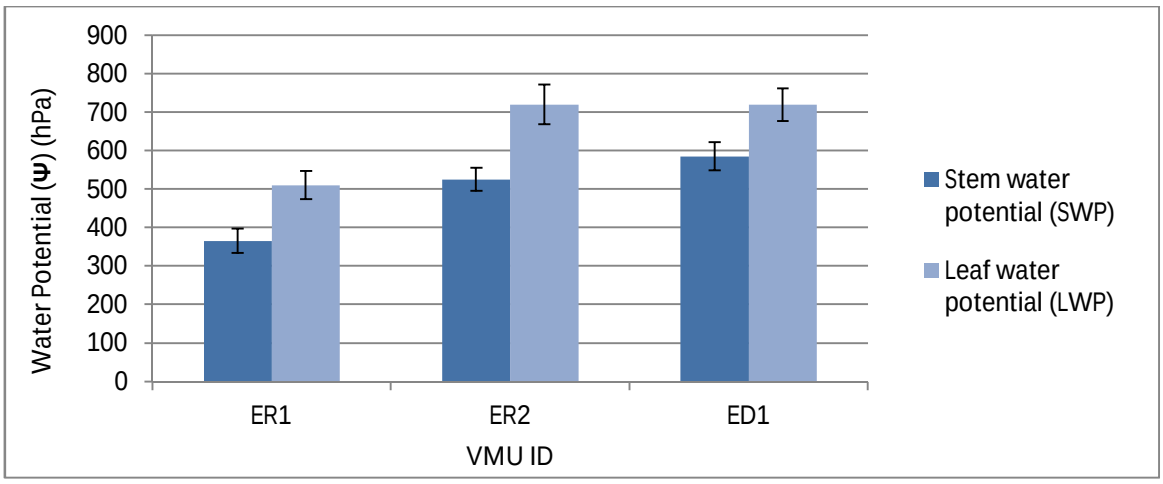

Figure 5 Mean water potential (Ψ) from SWP and LWP sampling for partially phreatophytic VMUs. Error bars represent calculated standard error for each VMU.

An Analysis of Variances (ANOVA) was undertaken to compare the LWP and SWP measures between each VMU. Significant differences were found for both LWP and SWP, indicating differences in the water potential measures between VMUs. Additional pairwise analysis (t-tests) were undertaken to determine between which VMUs the variation occurred. Significant differences were found between ER1 and ED1, and ER1 and ER2 for both LWP and SWP measures. A summary of the pairwise analysis is provided in Table 9.

Table 9 Pairwise Analysis for Partially Phreatophytic Vegetation LWP and SWP Measures for each VMU.

LWP (p) values				SWP (p) values			
	ED1	ER1	ER2		ED1	ER1	ER2
ED1	-	**0.006**	0.990	ED1	-	**0.001**	0.232
ER1	-	-	**0.012**	ER1	-	-	**0.005**
ER2	-	-		ER2	-	-	

p values were calculated by t-tests using 95% confidence intervals. Significant differences are denoted in bold.

4.2 Mulga Vegetation

4.2.1 Habitat Characteristics

Habitat characteristics for Mulga VMUs are summarised in Table 10 and Table 11. The vegetation of each Mulga VMU was described based on species composition, structure and dominance. The vegetation condition of each VMU was similar with MI2, MR1 and MR2 all rated as Very Good in condition, MD1 was rated as Excellent to Very Good and MI1 rated as Very Good to Good due to increased grazing disturbance. All VMUs contained similar numbers of plant taxa, and had introduced (weed) taxa present, **Portulaca oleracea* was the most common taxon and occurred at all VMUs, but in low densities. Cow pats were recorded at all VMUs with the highest numbers from both MI1 and MI2.

Full VMU descriptions including photographs and flora taxa lists are provided in Appendix B.

Ant Nests

Mulga ant (*Polyrhachis macropa*) nests were only recorded at MD1, MI1 and MI2. A second species of ant was also recorded at MI1; this species appeared to actively forage from a series of discreet nests sunk into a wide and often very long ant trail.

Table 10 Mulga VMU Habitat Characteristics

VMU ID	Vegetation Description
MD1 (direct impact)	*Acacia aptaneura, Acacia aneura* var*. intermedia* low open forest over *Acacia aptaneura* tall shrubland over *Sida* sp. dark green fruits (S. van Leeuwen 2260), *Eremophila forrestii* mid open shrubland over *Enchylaena tomentosa* low open shrubland over *Aristida contorta, Enneapogon polyphyllus* low tussock grassland and *Polycarpaea corymbosa* low herbland*.*
MI1 (indirect impact)	*Acacia paraneura, Acacia synchronicia* low open forest over *Acacia paraneura* tall sparse shrubland over *Senna artemisioides* subsp*. oligophylla* mid sparse shrubland over *Senna artemisioides* subsp*. oligophylla, Acacia synchronicia* low sparse shrubland over *Aristida contorta, Aristida inaequiglumis* low tussock grassland*.*
MI2 (indirect impact)	*Acacia aptaneura* low closed forest over *Acacia aptaneura* tall open shrubland over *Acacia aptaneura* mid shrubland over *Pterocaulon sphacelatum, Eremophila forrestii* low open shrubland over *Sclerolaena cuneata, Eremophila lanceolata* over **Cenchrus ciliaris, Enneapogon polyphyllus, Aristida contorta* open tussock grassland.
MR1 (reference)	*Acacia aptaneura* low closed forest over *Psydrax latifolia* tall sparse shrubland over *Senna artemisioides* subsp*. helmsii* mid sparse shrubland over *Sida* sp. dark green fruits (S. van Leeuwen 2260) low sparse shrubland over *Aristida contorta, Enneapogon polyphyllus* low tussock grassland and *Streptoglossa bubakii l*ow sparse herbland.
MR2 (reference)	*Acacia aptaneura* low closed forest over *Acacia aptaneura, Acacia tetragonophylla* tall shrubland over *Acacia synchronicia, Psydrax latifolia* mid sparse shrubland over *Sclerolaena cuneata, Abutilon otocarpum, Eremophila forrestii* low open shrubland over *Aristida contorta, Enneapogon polyphyllus, Sporobolus australasicus* low sparse tussock grassland.

Table 11 Mulga VMU Habitat Characteristics

VMU Characteristic	MD1	MI1	MI2	MR1	MR2
Vegetation condition (Keighery 1994)	Excellent-Very Good	Very Good-Good	Very Good	Very Good	Very Good
Total flora taxa (count)	59	48	57	45	51
Native taxa (count)	57	45	54	43	47
Introduced taxa (count)	2	3	3	2	4
Conservation significant taxa (count)	0	0	0	0	1
Cow pats (count)	5	17	14	6	8
Ant nests (count)	2	5	3	0	0

Flora species composition and cover of each Mulga VMU was compared. The comparison was based on a presence/absence data matrix created for all VMUs. A multi-dimensional scaling (MDS) ordination was produced to show the similarities (and dissimilarities) between all Mulga VMUs (Figure 6).The two dimensional ordination showed MD1 (direct impact) and MI2 (indirect impact) to be the most similar VMUs, with some similarity to MR1 (reference) and MR2 (reference). MI1 (indirect impact) was distinctly different from all other VMUs, even given its close proximity (< 5.1 km) from MD1, MI2 and MR1.

The MDS ordination had a stress level of 0, indicating an adequate summary of the data and representation of relationships between data points (PRIMER-E Inc. manual, 2008).

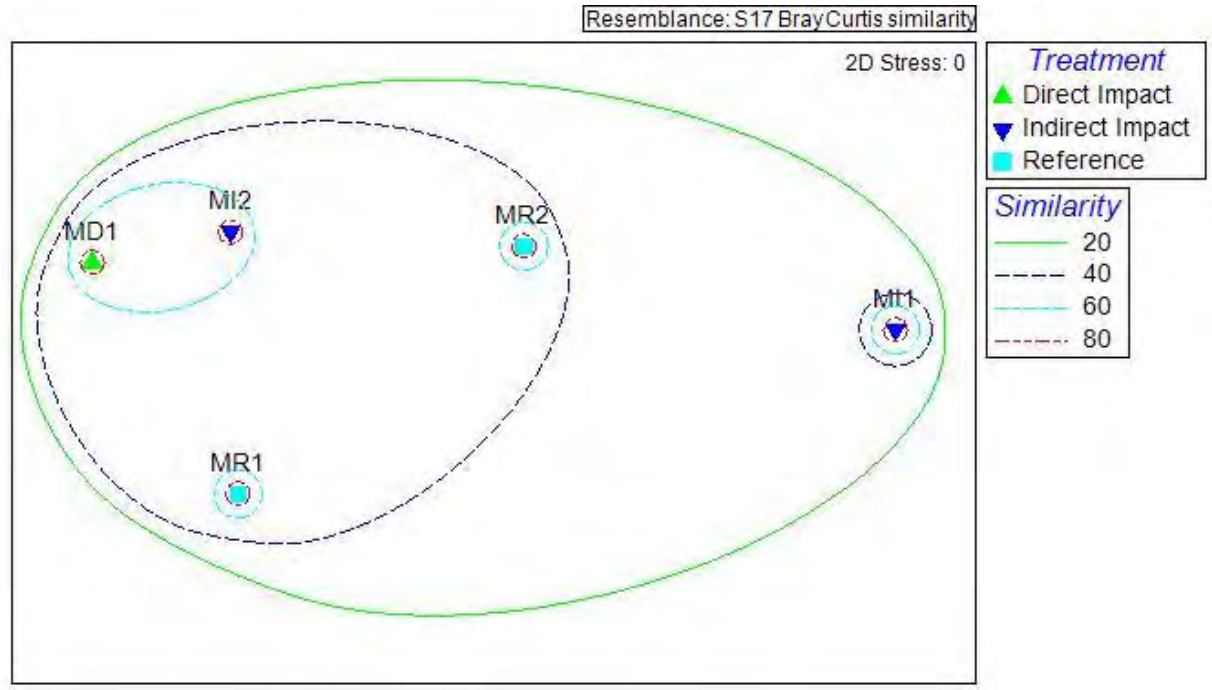

Figure 6 MDS ordination plot representing flora species composition and cover plotted by Mulga VMU. Contours of similarity (%) were derived from classification analysis.

Additionally, a one-way analysis of similarities (ANOSIM) was undertaken for Mulga vegetation to test for differences between VMUs based on flora species composition. No significant difference were detected between the direct and indirect impact VMUs (Global R=0, p=0.333, permutations=3), nor between direct impact and reference VMUs (Global R=0, p=0.333, permutations=3). However, a significant difference was detected between indirect impact VMUs and reference VMUs (Global R=-0.25, p=0, permutations=3).

4.2.2 Plant Health Assessment

Mean plant health scores for Mulga sample plants were based on a cumulative total of three different variables and ranged from four to seven across all VMUs. A summary of cumulative plant health assessment scores for each VMU is provided in Table 12, scores for all variables of individual sample plants are provided in Appendix B.

Table 12 Mulga VMU Plant Health Scores Summary

Variable	MD1	MI1	MI2	MR1	MR2
Mean score	6.5	6.6	6.3	5.5	5.2
Standard deviation	0.53	0.52	0.95	0.85	0.79
Minimum score	6	6	5	4	4
Maximum score	7	7	7	7	6
Range	1	1	2	3	2

An Analysis of Variances (ANOVA) was undertaken to compare the cumulative plant health scores of each VMU. Significant differences were found between VMUs, indicating that there are differences in plant health between sample plants. Pairwise analysis (t-tests) were undertaken to determine between which VMUs the variation occurred. These analyses showed that reference Mulga VMUs had significant differences in plant health compared to impact Mulga VMUs with the exception of MR1 & MI2. A summary of the pairwise analysis is provided in Table 13.

Table 13 Pairwise Analysis for Mulga Vegetation Health Scores for each VMU.

Mulga vegetation health scores (p) values					
	MD1	MI1	MI2	MR1	MR2
MD1	-	0.673	0.567	**0.005**	**0.0004**
MI1	-	-	0.391	**0.003**	**0.0002**
MI2	-	-	-	0.624	**0.011**
MR1	-	-	-	-	0.424
MR2	-	-	-	-	-

p values were calculated by t-tests using 95% confidence intervals. Significant differences (if present) are denoted in bold.

4.2.3 Leaf and Stem Water Potentials

Water potentials (Ψ) from LWP and SWP sampling on Mulga sample plants were compared across all VMUs. A summary of Ψ measures for each VMU is provided in Table 14 and graphically represented in Figure 7, scores for all Ψ measures of individual sample plants are provided in Appendix B.

Water potential measures varied marginally between SWP and LWP measures at each VMU, with the average of Ψ between LWP and SWP sampling 29.95 hPa, 40.85 hPa, 39.20 hPa, -4.45 hPa and -8.20 hPa hPa for MD1, MI1, MI2, MR1 and MR2 respectively. Water potential measures also differed only marginally between VMUs with MI1 values noticeably higher than values from all other VMUs.

Table 14 Mulga VMU Water Potential Measures Summary

VMU ID	MD1		MI1		MI2		MR1		MR2	
	LWP	SWP	LWP	SWP	LWP	SWP	LWP	SWP	LWP	SWP
Mean	1019.4	989.5	1146.8	1105.9	1011.6	972.4	990.8	995.3	956.75	964.6
St. Dev.	172.9	141.8	229.9	224.4	296.7	296.6	280.5	325.7	271.6	286
Min.	822	849.5	814	851	625.5	545	530	408.5	654.5	595.5
Max.	1311	1300.5	1518.5	1495.5	1420	1381.5	1343	1415	1373.5	1341.5
Range	489	451	704.5	644.5	794.5	836.5	813	1006.5	719	746

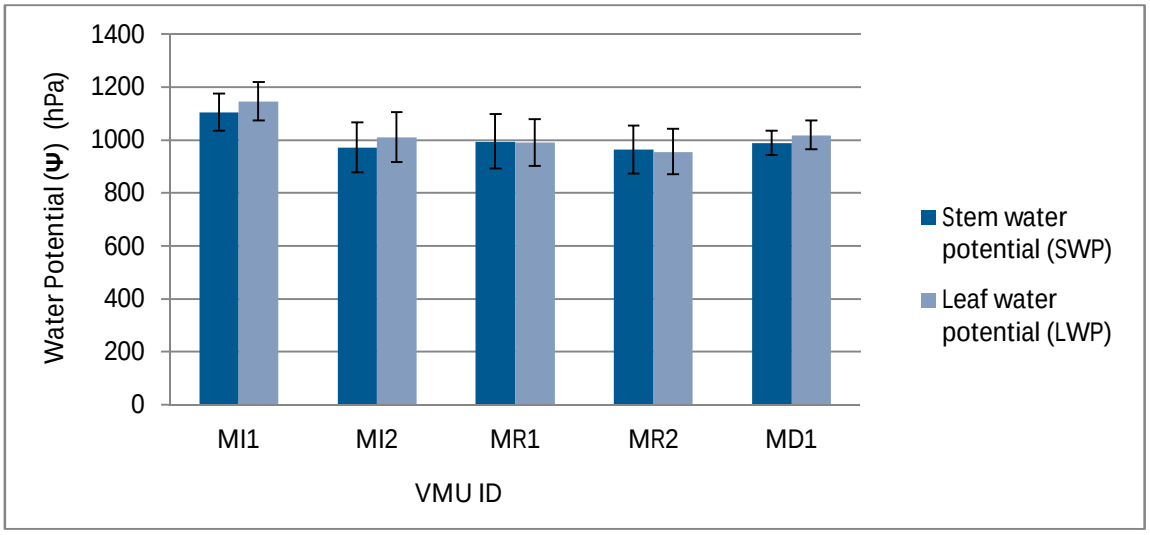

Figure 7 Mean water potential (Ψ) from SWP and LWP sampling for Mulga VMUs. Error bars represent calculated standard error for each VMU.

An Analysis of Variances (ANOVA) was undertaken to compare the LWP and SWP measures between each VMU. Significant differences were found for both LWP and SWP, indicating differences in the water potential measures between VMUs. Additional pairwise analysis (t-tests) were undertaken to determine between which VMUs the variation occurred. Significant differences were found between ER1 and ED1, and ER1 and ER2 for both LWP and SWP measures. A summary of the pairwise analysis is provided in Table 15 and Table 16.

Table 15 Pairwise Analysis for Mulga Vegetation LWP Measures for each VMU.

LWP (p) values					
	MD1	MI1	MI2	MR1	MR2
MD1	-	0.178	0.943	0.787	0.546
MI1	-	-	0.269	0.191	0.109
MI2	-	-	-	0.874	0.672
MR1	-	-	-	-	0.786
MR2	-	-	-	-	-

p values were calculated by t tests using 95 % confidence intervals. Significant differences (if present) are denoted in bold.

Table 16 Pairwise Analysis for Mulga Vegetation SWP Measures for each VMU.

SWP (p) values					
	MD1	MI1	MI2	MR1	MR2
MD1	-	0.182	0.871	0.959	0.810
MI1	-	-	0.270	0.388	0.236
MI2	-	-	-	0.871	0.955
MR1	-	-	-	-	0.828
MR2	-	-	-	-	-

p values were calculated by t tests using 95 % confidence intervals. Significant differences (if present) are denoted in bold.

4.3 Samphire Vegetation

4.3.1 Habitat Characteristics

Habitat characteristics for Samphire VMUs are summarised in Table 17 and Table 18. The vegetation of each Samphire VMU was described based on species composition, structure and dominance. The vegetation condition of each VMU was similar with all VMUs rated as Excellent, except SI1 (impact) which was rated as Good. SI2 (impact) contained a greater number of plant taxa compared to other Samphire VMUs, and SR2 (reference) had the lowest number of plant taxa recorded. SI1 had three introduced (weed) taxa present, and SR1 had one introduced taxa present; all weeds occurred in low densities. No cow pats were recorded within any VMU.

Full VMU descriptions including photographs and flora taxa lists are provided in Appendix B.

Ant Nests

No ant nests were recorded at any Samphire VMU.

Table 17 Samphire VMU Habitat Characteristics

VMU ID	Vegetation Description
SI1 (impact)	*Tecticornia indica, Eremophila spongiocarpa* low closed shrubland over *Eragrostis falcata, Sporobolus australasicus* low sparse tussock grassland.
SI2 (impact)	*Tecticornia indica, Eremophila spongiocarpa, Eremophila youngii* mid closed shrubland over *Eremophila youngii, Tecticornia indica, Eremophila spongiocarpa* low open shrubland over *Eragrostis falcata* low isolated tussock grasses and *Nicotiana heterantha* low sparse herbland.
SR1 (reference)	*Tecticornia auriculata* mid isolated shrubs over *Tecticornia indica* low closed shrubland over *Eragrostis falcata* low tussock grassland and *Nicotiana heterantha, Cullen cinereum* low closed herbland.
SR2 (reference)	*Tecticornia indica, Muellerolimon salicorniaceum, Tecticornia glomerata* low closed shrubland over *Eragrostis falcata* low tussock grassland and *Nicotiana heterantha* low open herbland.

Table 18 Samphire VMU Habitat Characteristics

VMU Characteristic	SI1	SI2	SR1	SR2
Vegetation condition (Keighery 1994)	Good	Excellent	Excellent	Excellent
Total flora taxa (count)	14	17	14	11
Native taxa (count)	14	14	13	11
Introduced taxa (count)	0	3	1	0
Conservation significant taxa (count)	2	2	2	2
Cow pats (count)	0	0	0	0
Ant nests (count)	0	0	0	0

Flora species composition and cover of each Samphire VMU was compared. The comparison was based on a presence/absence data matrix created for all VMUs. A multi-dimensional scaling (MDS) ordination was produced to show the similarities (and dissimilarities) between all Samphire VMUs (Figure 8). The two dimensional ordination showed SI1 and SI2 were different from each other as well as other Samphire VMUs.

The MDS ordination had a stress level of 0, indicating an adequate summary of the data and representation of relationships between data points (PRIMER-E Inc. manual, 2008).

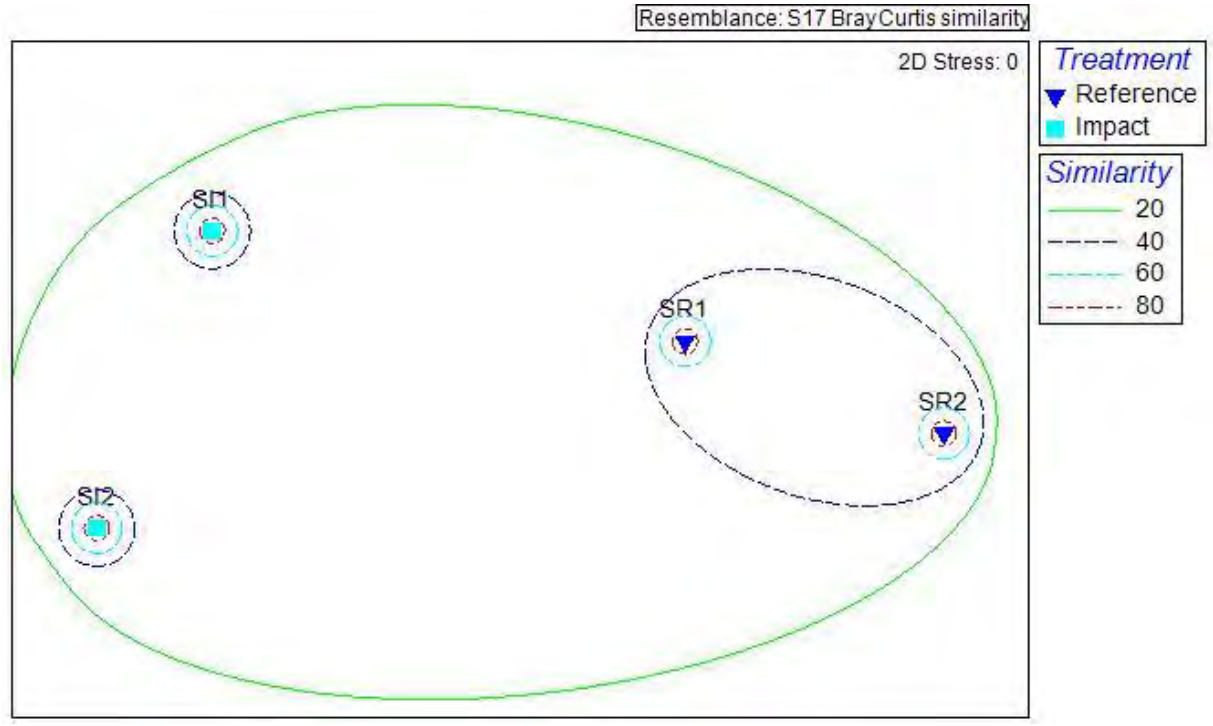

Figure 8 MDS ordination plot representing flora species composition and cover plotted by Samphire VMU. Contours of similarity (%) were derived from classification analysis

4.3.2 Plant Health Assessment

Mean plant health scores for Samphire sample plants were based on a single variable score. The mean plant health score for all Samphire VMUs was three, which indicated healthy plants with minimal (0-25 %) tip die off which was three for all Samphire VMUs. A summary of cumulative plant health assessment scores for each VMU is provided in Table 19, scores for all variables of individual sample plants are provided in Appendix B.

Table 19 Samphire VMU Plant Health Scores Summary

Variable	SI1	SI2	SR1	SR2
Mean score	3	3	3	3
Standard deviation	0	0	0	0
Minimum score	3	3	3	3
Maximum score	3	3	3	3
Range	0	0	0	0

No further analysis was undertaken of Samphire plant health scores due to the identical score for all sample plants for all VMUs.

4.4 Landscape Function Analysis (LFA)

LFA results are discussed within the context of each vegetation community in the absence of temporal data. A summary table for all VMUs is presented below. LFA data sheets for each VMU are presented in Appendix C.

4.4.1 Patch and Inter-patch Characteristics

Patch and inter-patch zones were generally influenced by the vegetation community and structure present. Partially phreatophytic VMUs were generally characterised by a low number of patches per 10 m, with the exception of ER1 which recorded a higher number of patches per 10 m compared to other partially phreatophytic VMUs. Mulga VMUs were characterised by very low numbers of patches per 10 m, this was consistent for all Mulga VMUs. Samphire VMUs were generally characterised by medium numbers of patches per 10 m, with the exception of SR1, which was considerably lower than all other Samphire VMUs.

Average inter-patch lengths ranged from 0.79 to 3.00 m for partially phreatophytic VMUs. Mulga VMUs showed the most variation in average inter-patch lengths ranging from 1.70 m in MI1 to 15.60 m in MI2. Samphire VMUs average inter-patch lengths ranged from 0.33 to 1.16 m.

A landscape organisation index (LOI) was calculated for all VMUs and ranged from 0.26 in MR2 to 0.81 in SR1. LOI can vary from 0.0 (reflective of a totally bare site) to 1.0 (reflective of a site totally covered by vegetation).

4.4.2 Indices Characteristics

Indices of stability, infiltration and nutrient cycling are characteristically governed by landscape complexity. At all VMUs bare soil zones (representative of inter-patches) had consistently low values for all indices: stability, infiltration and nutrient cycling compared to other zones (representative of patches), except at MR2 where plant hummocks had a lower stability value.

Table 20 Summary of Landscape Function Analysis Assessments

Site	Landscape %	No. of Patches/10m	Total Patch Area (sq. m.)	Patch Area Index total patch area/max. area of patches (transect length * 10)	Landscape Organisation Index (length of patches/length of transect)	Average Interpatch Length (m)	Range Interpatch length (m)	Soil Surface Assessment					
								Individual Zones			Individual zones contribution to the whole landscape		
								Stability	Infiltration	Nutrients	Stability	Infiltration	Nutrients
ED1		3.3	49.2	0.20	0.54	1.61	0.5-3						
Bare Soil	46.3							44.0	28.8	12.0	20.4	13.3	5.5
Tree-shrub complex	53.7							60.6	47.4	36.7	32.6	25.5	19.7
ER1		7.1	18.0	0.07	0.45	0.79	0.2-1.9						
Bare Soil	55.4							45.0	25.4	15.1	24.9	14.1	8.4
Plant hummock	32.0							56.0	29.9	20.2	17.9	9.6	6.5
Tree-shrub complex	12.7							65.0	36.5	31.4	8.2	4.6	4.0
ER2		1.5	259.6	0.43	0.75	3.00	0.6-7						
Bare soil	25.0							31.7	23.3	12.1	7.9	5.8	3.0
Plant hummock	37.0							44.0	48.7	55.5	16.3	18.0	20.6
Tree-shrub complex	38.0							44.0	34.5	28.0	16.7	13.1	10.6
MD1		0.7	596.6	0.78	0.36	9.76	0.6-27						
Open Thicket	36.3							55.1	36.9	31.8	20.0	13.4	11.5
Bare Soil	63.7							45.0	20.4	12.5	28.7	13.0	8.0
MI1		1.9	1884.3	3.61	0.71	1.70	0.2-4.8						
Open thicket	61.5							48.0	23.0	17.4	48.0	23.0	17.4
Bare soil	29.3							40.6	21.9	14.0	40.6	21.9	14.0
Plant hummock	9.2							44.3	26.5	16.5	44.3	26.5	16.5
MI2		0.5	787.4	0.78	0.23	15.60	5.7-31.1						
Open thicket	22.9							58.9	33.9	36.6	13.5	7.8	8.4
Bare soil	77.1							50.8	17.7	10.3	39.2	13.6	7.9
MR1		0.5	1385.6	0.92	0.55	13.46	4.2-19.6						
Open thicket	43.6							50.0	24.6	19.8	21.8	10.7	8.7
Bare soil	44.7							45.0	21.5	14.1	20.1	9.6	6.3
Plant hummock	11.7							47.9	23.4	15.8	5.6	2.7	1.8
MR2		0.8	630.5	0.85	0.26	10.90	0.8-23						
Open thicket	24.7							53.4	32.7	26.9	13.2	8.1	6.6
Bare soil	73.6							51.3	21.2	15.6	37.7	15.6	11.5
Plant hummock	1.6							45.0	29.8	22.5	0.7	0.5	0.4
SI1		8.3	9.6	0.16	0.73	0.33	0.2-0.6						
Plant hummock	72.5							52.5	27.7	27.7	38.1	20.1	20.1
Bare soil	27.5							41.5	20.7	18.8	11.4	5.7	5.2
SI2		7.6	13.7	0.15	0.51	0.64	0.3-1.2						
Plant hummock	51.1							61.6	34.0	27.5	31.5	17.4	14.1
Bare soil	48.9							46.1	24.6	12.8	22.5	12.1	6.3
SR1		2.0	178.9	0.71	0.81	0.97	0.4-1.4						
Plant hummock	80.7							74.0	46.8	51.1	59.7	37.8	41.2
Bare soil	19.3							58.5	27.1	23.9	11.3	5.2	4.6
SR2		5.4	15.7	0.17	0.38	1.16	0.4-2.8						
Plant hummock	37.6							70.6	47.4	42.0	26.6	17.8	15.8
Grass flat	62.4							65.0	36.2	33.8	40.5	22.6	21.1

4.5 Soil Sampling

Laboratory results from soil analyses undertaken by CSBP are summarised in Table 21.

4.5.1 Soil pH

Soil pH provides a measure of soil acidity and is typically measured in water or 0.1 M $CaCl_2$ (Hazelton and Murphy 2007). The latter is considered to more closely reflect concentrations with the natural soil solution; however, both measures are generally considered when assessing suitable conditions for plant growth.

Soil pH (H_20) across Mulga VMUs ranged from 5.4 (strongly acidic) to 8.2 (moderately alkaline), with MD1 generally recording lower pH values (5.2 and 5.7) than the other Mulga VMUs. Soil pH (H_20) across partially phreatophytic VMUs was relatively neutral ranging from 6.6-7.5. Soils within the Samphire VMUs ranged from 7.7 (mildly alkaline) to 9.3 (very strongly alkaline).

4.5.2 Electrical Conductivity

Electrical conductivity (EC) indicates the amount of soluble (salt) ions in soil or water. EC is typically categorised according to soil texture and is the most common measure of soil salinity. High salinity levels can adversely impact on plant growth and increase potential soil erosion.

EC values recorded for all Mulga and partially phreatophytic VMUs were extremely low, ranging from 0.018 dS/m at MR1 to 0.095 dS/m at ER2. Not surprisingly, EC values recorded within the Samphire VMUs were high across all samples and corresponded to elevated levels of exchangeable sodium in the surface profile. A similar correlation was observed during a preliminary soil survey of the Fortescue Marsh conducted by G. Kew in 2011, with common salt (NaCl) identified as the dominant soluble salt present.

4.5.3 Soil Nutrients

Nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) are the key macronutrients for plant growth and are largely derived from the soil and organic matter. Approximate values that may be considered typical for arid zone soils include nitrate and phosphorus values between 5-10 mg/kg, potassium values between 150-200 mg/kg and < 100 mg/kg sulphur (GHD 2010).

Levels of nitrate (i.e. plant available N) recorded from VMUs were generally low to moderate, with values ranging from <1 mg/kg to 11.5 mg/kg. Phosphorous levels were also low to moderate, with limited variability observed within VMUs. Potassium and sulphur levels were considerably higher within Samphire VMUs compare to other VMUs.

Table 21 Soil Data Summary of Partially Phreatophytic, Mulga and Samphire VMUs

Parameter / VMU[1]	ED1	ER1	ER2	MD1	MI1	MI2	MR1	MR2	SI1	SI2	SR1	SR2
pH Level (H2O)	6.9	7.75	7.75	5.45	7.7	6.1	7.4	6.3	9.25	8.65	8.65	7.8
Conductivity (dS/m)	0.023	0.058	0.095	0.040	0.051	0.032	0.031	0.018	5.093	5.644	3.107	2.501
Soil Nutrients												
Nitrogen (mg/Kg)	1	<1	8	5.5	2	11.5	0.5	1	0.5	<1	<1	0.5
Phosphorus (mg/Kg)	3	4.5	4.5	5	6	3.5	3	7.5	5.5	12	8.5	8
Potassium (mg/Kg)	192.5	580	397	288	359.5	358	359.5	356.5	2929	2085.5	2792.5	359
Sulphur (mg/Kg)	3.95	6	11.65	31.5	2.75	6.6	4	2.4	1105.05	1300.05	1330.85	4662.95
Organic Carbon (%)	0.29	0.93	0.47	0.43	0.41	0.23	0.18	0.36	0.21	0.33	0.35	0.37
Trace Elements												
Copper (mg/Kg)	1.07	2.39	1.96	1.81	2.34	2.50	1.86	3.07	2.41	2.76	3.16	0.66
Iron (mg/Kg)	3.84	8.79	5.4	6.50	6.59	3.30	2.20	25.0	7.86	3.35	3.93	5.53
Manganese (mg/Kg)	7.06	7.18	7.69	12.27	6.79	10.64	6.54	20.10	1.24	1.89	3.16	1.74
Zinc (mg/Kg)	0.51	0.73	0.35	0.64	0.52	0.40	0.22	0.68	0.95	0.47	0.95	0.16
Boron (mg/Kg)	0.22	0.63	0.84	0.52	0.62	0.37	0.59	0.28	14.19	6.52	22.76	1.05
Exc. Aluminium (meq/100g)	0	0	0	0.18	0	0.12	0	0.15	0	0	0	0
Exc. Calcium (meq/100g)	3.92	11.49	9.37	4.00	9.85	5.22	7.04	4.80	2.74	2.2	6.08	31.80
Exc. Magnesium (meq/100g)	1.34	2.93	2.13	0.99	4.44	1.61	3.55	3.01	2.19	5.14	6.43	0.72
Exc. Potassium (meq/100g)	0.44	1.01	0.95	0.68	0.86	0.84	0.92	0.84	5.89	3.78	5.25	0.90
Exc. Sodium (meq/100g)	0.05	0.95	0.24	0.45	0.20	0.02	0.12	0.03	34.64	29.48	16.99	2.08
Total Nitrogen (%)	0.01	0.05	0.03	0.05	0.03	0.04	0.04	0.05	0.03	0.02	0.04	0.01
Heavy Metals												
Arsenic (µg/Kg)	91600	11460	26340	19680	14760	20320	14160	29220	14440	23160	26720	29580
Cadmium (µg/Kg)	110	156	178	64	148	116	80	178	94	156	118	30
Chromium (µg/Kg)	164800	81400	138200	122400	108200	148600	119200	148000	88200	95600	86200	47100
Cobalt (µg/Kg)	10420	51800	23960	43760	5000	36840	22340	26040	20820	22000	48800	7120
Lead (µg/Kg)	30520	14780	21560	19180	18920	20560	18040	26220	17460	19800	22120	7960
Molybdenum (µg/Kg)	2678	846	1260	1738	1240	1754	1052	1782	1124	1368	1726	1844

[1]A total of two soil samples were taken at each VMU; values in the table represent the mean value for each soil parameter.

4.5.4 Trace Elements

Copper levels within partially phreatophytic and Samphire VMUs were generally low, ranging from 1.07-2.39 mg/kg and 0.66-3.16 mg/kg respectively. Soils within Mulga VMUs were all deficient in copper with most values recorded less than 3 mg/kg. Iron levels from topsoils within partially phreatophytic and Samphire VMUs were all within the optimal range of 2-20 mg/kg (Table 22). Iron levels within Mulga VMUs showed greater variability with MR2 recording a reading almost twice as high as the upper limit of the optimal range and the average greater than 20 mg/kg (Table 22). Manganese levels were also variable within Mulga VMUs and, as for iron, were recorded at high levels at MR2. Manganese levels within partially phreatophytic and Samphire VMUs showed far less variability and were generally within or slightly below the optimal range reported by Baker and Eldershaw (1993) (Table 22). Zinc levels recorded were typically low, with all values being less than 1 mg/kg. Although variable, Boron levels were very high at the majority of Samphire VMUs, with a maximum level of 32.8 mg/kg recorded at SR1. Such levels are well above the optimal range for many agricultural soils (Table 22). Boron levels within the partially phreatophytic and Mulga VMUs were much lower with all VMUs recording levels less than 1 mg/kg.

Table 22 Optimal Ranges for Micronutrients (Baker and Eldershaw 1993)

Trace Element	Optimum Range (mg/kg)
Copper (Cu)	3-6
Zinc (Zn)	2-4
Iron (Fe)	2-20
Manganese (Mn)	3-6
Boron (Bo)	0.3-0.5

4.5.1 Cat ion Exchange Capacity

Cat ion exchange capacity (CEC) is a measure of a soil's capacity to hold and exchange cat ion nutrients. It affects the buffering capacity of a soil, nutrient availability, calcium levels and soil stability (Hazelton and Murphy 2007). A low CEC value indicates that the soil has a low resistance to soil chemistry changes resulting from land disturbance (Hazelton and Murphy 2007).

CEC is commonly approximated by calculating the Effective CEC. The effective CEC values recorded for topsoils within Mulga and partially phreatophytic VMUs ranged from low to moderate. Soils with low CEC values are likely to have limited buffering capacity against sudden changes in nutrient levels or soil chemistry.

The effective CECs recorded from within Samphire VMUs were high to very high, with sodium being the dominant cat ion recorded at all VMUs apart from SR2 whereby calcium was the dominant cat ion recorded. High calcium cat ion levels may potentially reflect the presence of gypsum or calcite in the profile.

4.5.2 Heavy Metals

All sites were measured for levels of the following heavy metals: arsenic, cadmium, chromium, cobalt, lead, molybdenum. Whilst the majority heavy metals recorded were considered to be at moderate levels, arsenic was commonly recorded at high levels across the Project Area.

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4.5.3 Soil Moisture

Mean soil moisture percentage was calculated for each VMU (Figure 9). The mean percentage moisture per VMU ranged from 2.67% ±0.35 at ED1 to 19.51% ± 1.85 at SR1. ED1 had a lower mean soil moisture percentage compared to other partially phreatophytic VMUs and this may be attributed to the location of soil sampling. Soil samples were collected from both the main and secondary channels at this VMU, whilst samples were collected only from the main channel at both other partially phreatophytic VMUs. Mulga VMUs had consistent percentages of soil moisture at all VMUs, whilst SI1 and SR1 both had consistently higher soil moisture percentages compared to other Samphire VMUs.

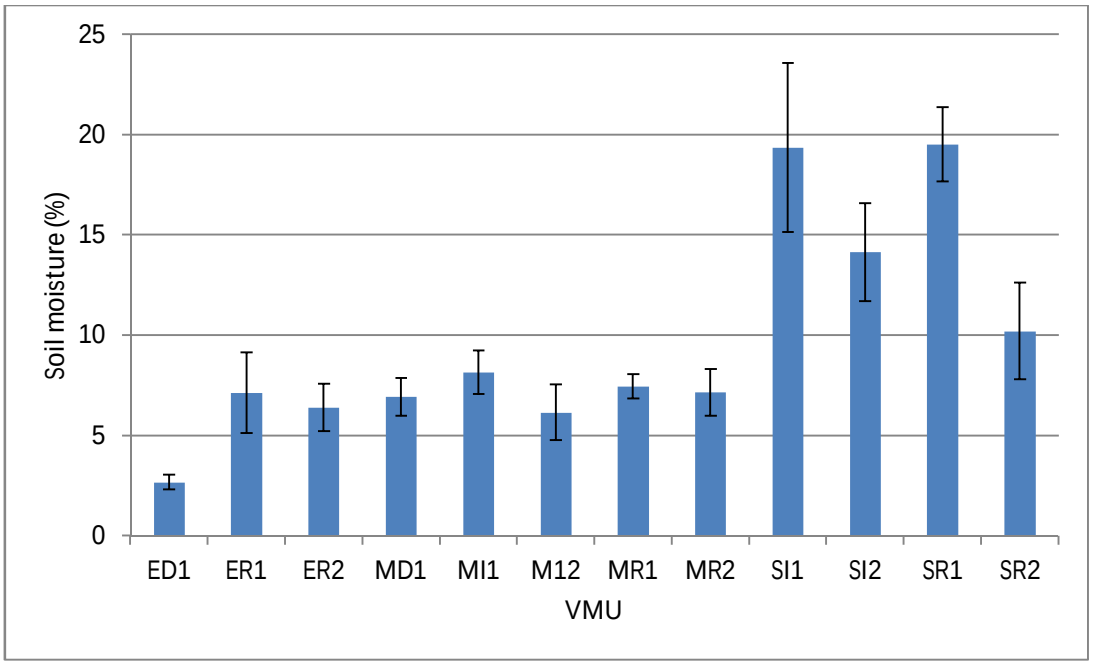

Figure 9 Mean soil moisture percentages calculated for partially phreatophytic, Mulga and Samphire VMUs.

4.6 Groundwater Monitoring

Groundwater data recorded from the Cloudbreak mine site is summarised for the period 1 August 2011 to 31 July 2012 and presented in Fortescue (2012e).

Groundwater bore details relevant to each VMU, including a summary of monitoring results are presented in Table 23. No trigger level exceedances were recorded for groundwater levels or water quality for any bores. However, no data was available for bores HEMB05_S and Kardardarrie.

Fortescue (2012c) also provides a graphical representation of water level in mAHD and water quality as EC µS/cm for bores within Zone A. Graphs of bore data collected from CBX04_S, CBX10a_WT, CBFMM02_S and CBFMM06_S show no or very little change in groundwater levels (<0.80 m).

A summary of zone C groundwater bore monitoring data for period June to July 2012 is provided in Table 24. All bores showed very little change in groundwater levels and were well below the water quality class 1 trigger, with the exception of bore HSMB29_S.

Table 23 Groundwater Bore Details and Monitoring Summary for Period 1 August 2011 to 31 July 2012

Site ID	Nearest Bore	Monitoring Frequency	Zone	Screening Interval	Groundwater Level Trigger		Water Quality Trigger	Monitoring Summary for Period 1 August to 31 October 2012
					Class 1	Class 2	Class 1	
ED1	HSMB03_WT	Monthly	C	12-18 m	3 mbgl	2.2 mbgl	17,595 µS/cm	No trigger level exceedances recorded
ER1	HSMB24_S	Monthly	C	22-24 m	3 mbgl	2.2 mbgl	9,000 µS/cm	No trigger level exceedances recorded
ER2	Kardardarrie							No data available
MD1	HSMB29_S	Monthly	C	18-30 m	3 mbgl	2.2 mbgl	16,558 µS/cm	No trigger level exceedances recorded
MI1	HEMB05_S	Monthly	C	27-32 m	3 mbgl	2.2 mbgl	9,000 µS/cm	No trigger level exceedances recorded
MI2	SCX02_S	Monthly	C	11-41 m	3 mbgl	2.2 mbgl	9,000 µS/cm	No trigger level exceedances recorded
MR1	SCX04_S	Monthly	C	14-38 m	3 mbgl	2.2 mbgl	9,000 µS/cm	No trigger level exceedances recorded
MR2	Kardardarrie							No data available
SI1	CBX10a_WT	Monthly	A	2-14 m	±0.65 m	±1 m	N/A	No trigger level exceedances recorded
SI2	CBX04_S	Monthly	A	6-18 m	±0.65 m	±1 m	N/A	No trigger level exceedances recorded
SR1	CBFMM06_S	Monthly	A	1-9 m	±0.65 m	±1 m	N/A	No trigger level exceedances recorded
SR2	CBFMM02_S	Monthly	A	0.5-9 m	±0.65 m	±1 m	N/A	No trigger level exceedances recorded

Table 24 Zone C Groundwater Bore Monitoring Summary for Period June to July 2012

Bore	Groundwater Level Range (m)	Mean EC (µS/cm)	Minimum EC (µS/cm)	Maximum EC (µS/cm)
Kardardarrie	0.04	No Data	No Data	No Data
HSMB29_S	0.57	11,068.75	8,270	13,269
HEMB05_S	0.18	1,767.75	1,616	1,960
SCX02_S	0.55	2,468.89	2,155	2,664
SCX04_S	0.18	2,399	2,201	2,613

5. Discussion

A summary of the key findings from baseline vegetation health and condition assessment is provided in Table 25.

5.1 Partially Phreatophytic Vegetation

Habitat characteristics of all partially phreatophytic VMUs were consistent across the Project Area, with all VMUs having vegetation in similar condition and containing a good spatial and age structure representation of the target keystone species. The significantly lower number of plant taxa recorded at ER1 compared to the other VMUs may be attributed to size of the drainage channel and the exclusion of any banks within ER1. Similarly, plant health scores showed all sample plants to be in similar condition during the June 2012 assessment, with no significant differences found between any VMUs. Significant differences were found in LWP and SWP measures between ER1 and other VMUs. However, this result may be attributed to different sampling times, with water potential measures on sample plants at ER1 undertaken mid-morning, and both ER2 and ED1 measures undertaken mid- to late afternoon.

All partially phreatophytic VMUs are located in different drainage lines and are widely spatially distributed across the Project Area. No significant differences in any monitoring parameters with the exception of LWP and SWP measures were observed for partially phreatophytic VMUs. These results would indicate that partially phreatophytic VMUs are of similar condition in their baseline state and are suitable for monitoring vegetation health and condition changes relating to changes in groundwater levels. Whilst it is envisaged that the direct impact VMU will ultimately be lost to mining as the Cloudbreak mine expands, the spatial distribution of reference VMUs across the Project Area will enable continued monitoring of vegetation health and condition.

5.2 Mulga Vegetation

Habitat characteristics of all Mulga VMUs were consistent across the Project Area, with all VMUs having vegetation in similar condition and containing a good spatial and age structure representation of the target keystone species. All VMUs comprised similar numbers of plant taxa with minimal weed incursion. As shown in the MDS ordination MI1 was shown to was to be distinctly different from all other VMUs. MI1 was dominated by Mulga group taxon *Acacia paraneura*, whereas all other VMUs were dominated by *Acacia aptaneura*. Both taxa are members of the Mulga group and would function similarly in the landscape (Maslin & Reid 2012).

Plant health scores showed all sample plants to be in similar condition during the June 2012 assessment. The significant differences in health scores reported between a number of Mulga VMUs can be attributed to the absence or presence of new tip growth on Mulga trees. Sample trees within Mulga reference VMUs had less new tip growth compared with sample plants from other VMUs. Furthermore, the Mulga reference VMUs also contained a greater number of mature trees (compared to adolescent and juvenile plants) which may also explain these results. No significant differences were found in LWP and SWP measures between any Mulga VMUs.

All Mulga VMUs are located in the eastern part of the Project Area with the exception of Mulga reference VMU, MR2, which is located west of the Cloudbreak mine site. The placement of direct impact, indirect impact and reference VMUs all within approximately 5 km of each other will enable monitoring to detect changes in vegetation health and condition from changes in groundwater levels with limited influence from other factors not controlled through the

monitoring program design (e.g. heterogeneity in rainfall, grazing pressures) which may vary per VMU.

No significant differences in any monitoring parameters with the exception of plant health scores were observed for Mulga VMUs. As with partially phreatophytic vegetation these results would indicate that Mulga VMUs are of similar condition in their baseline state and are suitable for monitoring vegetation health and condition changes relating to changes in groundwater levels.

5.3 Samphire Vegetation

Habitat characteristics of all Mulga VMUs were consistent across the Project Area, with all VMUs having vegetation in similar condition and containing a good spatial and age structure representation of the target keystone species. All VMUs comprised similar numbers of plant taxa with minimal weed incursion. As shown in the MDS ordination SI1 and SI2 were different from each other as well as the reference Samphire VMUs. This may be reflective of their landscape positions (i.e. on the fringes of the Fortescue March) compared with the reference VMUs (i.e. closer towards the centre of the Fortescue Marsh), as well as the complexity of the vegetation type. It is unlikely a reflection on the taxonomic resolution of the flora taxa within the Samphire VMUs; all taxa were identified to species level with the exception one *Maireana* species in SI2 which had <2% cover.

Plant health scores showed all sample plants to be in similar condition during the June 2012 assessment, with no significant differences found between any VMUs.

No significant differences in any monitoring parameters were observed for Samphire VMUs. Similarly, as with other vegetation communities these results would indicate that Samphire VMUs are of similar condition in their baseline state and are suitable for monitoring vegetation health and condition changes relating to changes in groundwater levels. Whilst no Samphire VMUs are located within predicted mounding impact areas or the predicted drawdown impact area, Samphire impact VMUs represent some of the most northern occurrences of Samphire vegetation within the Project Area. Samphire species zonation occurs from the fringes to the centre of the Fortescue Marsh and is reflective of the varied edaphic and water quality conditions, and varied tolerance levels of the species to salt concentration, ground water levels and drainage. Monitoring these northern occurrences of Samphire vegetation may detect changes in Samphire vegetation health and condition where habitat conditions are near thresholds.

Table 25 Summary of Baseline Vegetation Health and Condition Monitoring Results

Monitoring Parameter	Partially Phreatophytic VMUs	Mulga VMUs	Samphire VMUs
Habitat Characteristics	Vegetation condition similar between all VMUs.	Vegetation condition similar between all VMUs.	Vegetation condition similar between all VMUs.
	Cow pats only recorded at ER2.	Cow pats recorded at all VMUs.	No cow pats recorded.
	No ant nests recorded.	Ant nests recorded at all impact VMUs (e.g. MD1, MI1, MI2).	No ant nests recorded
	ED1 and ER1 most similar VMUs, but degree of similarity not strong.	MD1 and MI2 most similar, MI1 significantly different from all other VMUs.	Impact VMUs different from each other and reference VMUs. SR1 and SR2 showed some similarity.
Plant Health	No significant differences were found between any VMU.	Significant differences were found between impact and reference VMUs.	No significant differences were found between any VMU.
LWP	Significant differences between ER1 and other VMUs	No significant differences were found between any VMU.	N/A
SWP	Significant differences between ER1 and other VMUs	No significant differences were found between any VMU.	N/A
LFA	Variable between and within vegetation types. Limited inferences can be made regarding VMUs in the absence of temporal data.		
Soil sampling	All soil parameters were found to be within acceptable ranges compared to other studies in similar environments. Differences in soil properties between vegetation types and VMUs are a reflection of subtle changes in topography and geology.		
Groundwater	Groundwater levels and water quality exhibited very little change during the June-July 2012 period. One water quality Class 1 trigger exceedance recorded.		

5.4 Monitoring Parameters

The selection of parameters chosen for monitoring vegetation health and condition include a range of quantitative and qualitative measures. In this initial baseline assessment the results of each parameter has been statistically compared between VMUs of the same vegetation types to determine status of the overall health and condition of sample plants' and suitability for monitoring. Temporal replication (i.e. repeat-measures) will enable differences in each parameter within each VMU to be examined over time. This replication will produce a long-term data set and allow VMU specific changes in vegetation health and condition to be inferred. Additionally, the results of each parameter can be compared between VMUs of the same vegetation type to examine differences between impact and reference VMUs. However, ultimately temporal replication of parameters within VMUs will be more important in assessing vegetation health and condition change over the long-term.

5.4.1 Water Potential

The water status of a plant is controlled by the relative rates of water loss and water uptake (Klepper 1968). During periods of increased heat and light the LWP of plant will often increase as water uptake through the roots is unable to match water loss occurring via evaporation in the leaves. Water potential sampling was undertaken to obtain a baseline measure of the water status of partially phreatophytic and Mulga sample plants. These measures will help to determine the natural variation in the plants' water status, as well as detect levels of water stress through a 'repeat-measure' monitoring design. In potential drawdown impact areas a significant decrease in either LWP and/or SWP in partially phreatophytic sample plants may indicate increased water stress due to changes in the water table.

Very large LWP and SWP values were obtained for Mulga sample plants indicating that the plants need to exert significant pressure to obtain water from the surrounding soil. A significant positive increase in these high negative values will indicate water logging events when soil water becomes more freely available and the trunk becomes saturated. However, like with partially phreatophytic vegetation a significant decrease in either LWP and/or SWP in Mulga sample plants may indicate increased water stress.

5.5 Landscape Function Analysis

Limited inferences can be made regarding VMUs in the absence of temporal data, and similarly limited comparisons can be made between vegetation communities. The significance of a particular numerical value comes from comparing disturbed sites with analogue sites or single sites over time (Tongway and Hindley 2004a). Similarly, index values do not absolutely indicate the functional state as these are dependent on the biome; an index value may represent a highly functional landscape, whilst a comparable value may represent a dysfunctional landscape in a different biome (Tongway and Hindley 2004a).

5.6 Soil Sampling

Soil sampling was undertaken to obtain a baseline measure of soils at each VMU. All soil parameters were found to be within acceptable ranges compared to other studies in similar environments (e.g. Baker and Eldershaw 1993, Hazelton and Murphy 2007, GHD 2010, Kew 2011). However, heavy metal arsenic was commonly recorded at high levels across the Project Area; this is most likely a reflection of the geology of the broad area. Differences in soil properties between vegetation types and even VMUs are a reflection of subtle changes in topography and geology between all VMUs.

5.7 Groundwater

Baseline groundwater data showed all bores to exhibit very little change in groundwater levels and water quality during the June-July 2012 period. However, the exception was bore HSMB29_S, which experienced a water quality Class 1 trigger exceedance. Groundwater bore HSMB29_S is the monitoring bore for Mulga VMU MD1. This VMU and its sample plants were not significantly different in any measure to any other Mulga VMUs, with the exception of plant health scores compared with reference Mulga VMUs. The groundwater data recorded is currently not impacting any vegetation type or sample plant negatively in relation to health and condition as shown by the collected vegetation monitoring data.

6. Conclusions

A baseline vegetation health and condition assessment has been undertaken at the Cloudbreak mine site. This assessment conforms to the monitoring program and procedures outlined in Fortescue (2013), which addresses Condition 6.2 and 6.3 of MS 899 and is consistent with Fortescue (2012b) allowing for synergies in monitoring across the Chichester's. As part of the baseline assessment direct impact, indirect impact and reference VMUs have been established in partially phreatophytic, Mulga and Samphire vegetation communities. Additionally, keystone plant species have been identified and the current state of the vegetation health and condition measured and reported here.

The assessment has shown that all VMUs for each vegetation community are in similar condition and their baseline states are suitable for monitoring vegetation health and condition changes relating to changes in groundwater levels. Continued monitoring of each VMU will enable differences in each monitoring parameter to be examined over time. This temporal replication will produce a long-term data set and allow VMU specific changes in vegetation health and condition to be detected over time.

Similarly, groundwater data including groundwater level and water quality from appropriate bores have been collected by Fortescue and is considered most appropriate to satisfy the second part of Condition 6-3(3) of MS 899. The groundwater data showed all bores to exhibit very little change in groundwater levels and water quality during the June-July 2012 period; however, one bore recorded a water quality Class 1 trigger exceedance. The baseline groundwater data collected and reported during the period June-July 2012 shows no negative impact to partially phreatophytic, Mulga and Samphire vegetation health and condition as shown by the baseline vegetation health and condition assessment.

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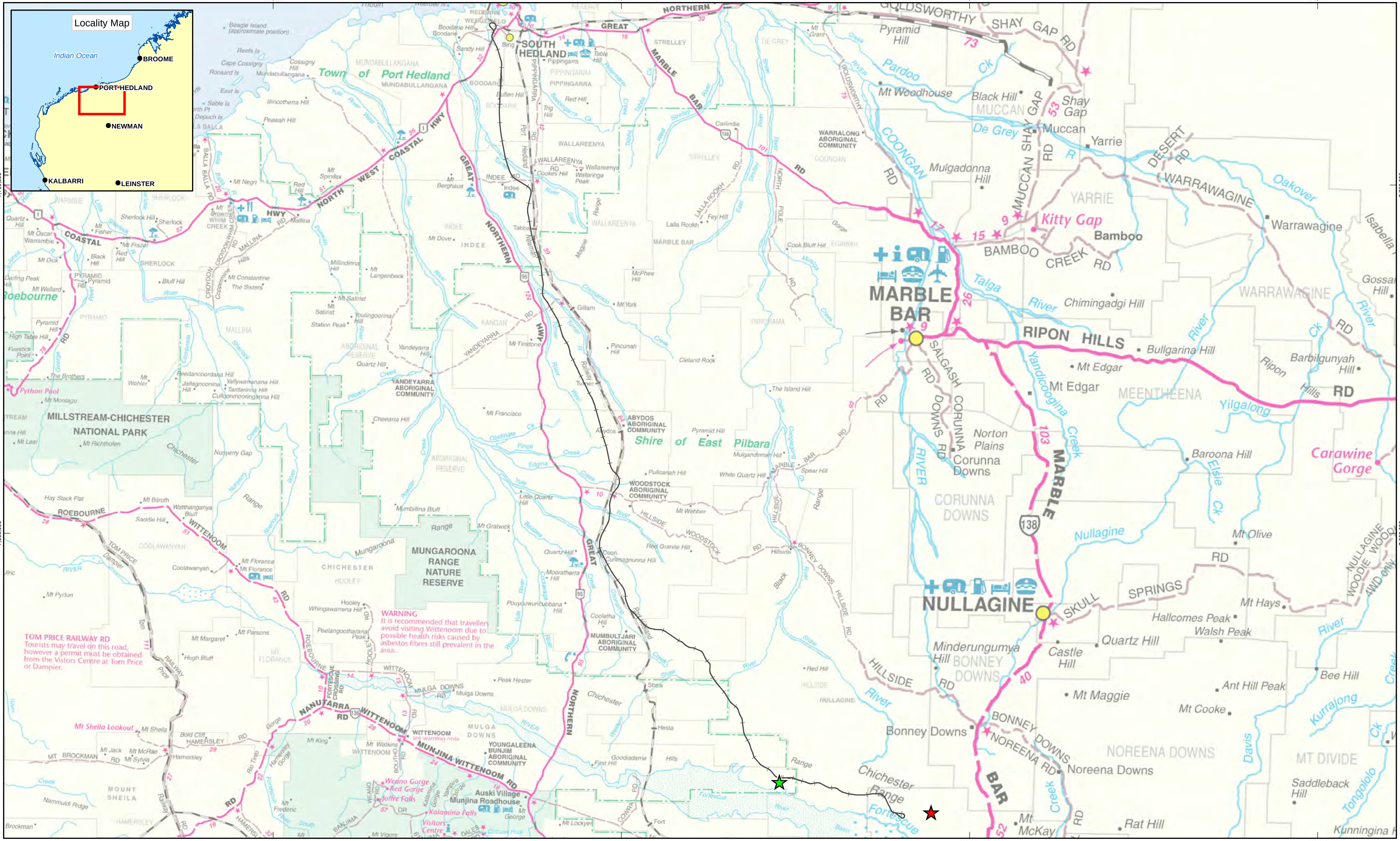
Appendices

Appendix A – Map Figures



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0 10 20 30 40 50

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone50

N

LEGEND

FMG Minesite

- Christmas Creek
- Cloudbreak

FMG Rail

Fortescue Metals Group Ltd
Cloudbreak Vegetation
Heath Monitoring

Job Number 61-28112
Revision 0
Date 12 Mar 2013

Locality

Figure 1

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Data source: FMG: FMG Rail - 2012, FMG Minesite - 2012; Landgate: Travellers Atlas 2004 - 20120806. Created by: cagilbert, jrutherford

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

715,000 732,500 750,000 767,500

7,540,000

7,522,500

MR2
Kardardarrie
ER2
ED1
HSMB03_WT
SR2
CBFMM02_S
CBX04_S
SI2
SR1
SI1
CBFMM06_S
CBX10a_WT
ER1
HSA08
MD1
HSMB29_S
MI1
HEMB05_S
MI2
MR1
SCX04_S
SCX02_S

1:175,000 (at A3)

0 1.75 3.5 5.25 7 8.75

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone50

N

LEGEND

Vegetation Monitoring Units (VMU)

- Eucalyptus
- Mulga
- Samphire

FMG Bore

Project Area

Contours greater than 1m

- Mounding
- Drawdown

Fortescue Metals Group Ltd
Cloudbreak Vegetation
Heath Monitoring

Job Number	61-28112
Revision	0
Date	12 Mar 2013

Monitoring Locations and Impact Areas

Figure 2

G:\61\28112\GIS\Maps\MXD\6128112_G005_Fig2_Rev0.mxd

Data source: FMG: FMG Bore - 20120606, Chichester Mosaic 2011, Project Area - 2020510, Contours - 2012; GHD: Vegetation Monitoring Units - 20120621; Landgate: Mount Marsh 2008 Mosaic - 20120625, Warrie 2008 Mosaic - 20120625. Created by: cagilbert, jrutherford

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Appendix B – Flora Data

VMU Flora Data Sheets

Raw Data For Monitoring Parameters –Excel Spreadsheet Format

Cloudbreak – Life of Mine **Site** ED1
Described by JR&JH **Date** 16/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: HSMB03_WT (453 m due SE)
MGA Zone 50 734214 **mE** 7532607 **mN** 119.273383 **E** -22.296274 **S**
Habitat *Eucalyptus victrix* Open Woodland
Soil Red sandy loam to silt loam
Rock Type Stones, 20%
NVIS vegetation description (Level VI – sub-association) U1 *Eucalyptus victrix*/7/i; U2 *Eucalyptus victrix*/*Atalaya hemiglauca*/*Acacia coriacea*/6/i; M1 *Grevillea wickhamii*/*Acacia tumida* var. *pilbarensis*/*Atalaya hemiglauca*/2/i; M2 *Tephrosia rosea*/*Acacia tumida* var. *pilbarensis*/*Acacia pyrifolia*/3/i; M3 *Grevillea wickhamii*/*Acacia tumida* var. *pilbarensis*/*Pterocaulon sphacelatum*/2/i; G1 *Triodia longiceps*/*Triodia epactia*/*Cenchrus ciliaris*/2/r; G2 *Pluchea dentex*/*Hybanthus aurantiacus*/*Stemodia viscosa*/1/bi.
Veg Condition Very Good
Fire Age Old (5-20 years)
Notes Topography & aspect: Riparian zone, main channel, 2%
Bare ground: 80%
Logs: 10%
Twigs: 10%
Leaves: 10%
Disturbances: Pastoral (cattle), mining and exploration adjacent

Species	Cover class	Height (m)
Acacia arida	1	1
Acacia coriacea	1	2
Acacia pyrifolia	1	1
Acacia tetragonophylla	1	2
Acacia trachycarpa	1	3
Acacia tumida var. *pilbarensis*	3	2
Alternanthera nodiflora	1	0.4
Amphipogon sericeus	1	0.4
Atalaya hemiglauca	2	4
**Bidens bipinnata*	1	0.3
Boerhavia coccinea	1	0.4
**Cenchrus ciliaris*	1	1
Cleome viscosa	2	0.5
Corchorus lasiocarpus subsp. *lasiocarpus*	1	0.5
Cucumis maderaspatanus	1	2
Dicladanthera forrestii	1	0.5
Digitaria brownii	1	0.5

Species	Cover class	Height (m)
Dodonaea petiolaris	1	1
Dodonaea viscosa	1	2
Duperreya commixta	1	0.8
Elytrophorus spicatus	1	0.2
Eragrostis tenellula	2	0.4
Eucalyptus victrix	3	6
Euphorbia biconvexa	1	0.5
Evolvulus alsinoides var. *villosicalyx*	1	0.2
Gomphrena affinis subsp. *pilbarensis*	1	0.3
Goodenia lamprosperma	1	0.4
Goodenia nuda (P4)	1	0.5
Grevillea wickhamii	2	3
Hybanthus aurantiacus	1	0.5
Indigofera monophylla	1	0.5
Ipomoea muelleri	1	0.2
Isotropis atropurpurea	1	0.5
Panicum effusum	1	0.8
Petalostylis labicheoides	2	3
Phyllanthus erwinii	1	0.3
Pluchea dentex	1	0.5
Pluchea rubelliflora	1	0.5
Polycarpaea longiflora	1	0.4
Pterocaulon sphacelatum	1	1
Ptilotus nobilis	1	1
Stemodia grossa	1	1
Stemodia viscosa	1	0.4
Tephrosia rosea var. *glabrior*	1	1
Themeda triandra	1	1
Trichodesma zeylanicum	1	0.5
Triodia epactia	1	0.4
Triodia longiceps	1	1
Wahlenbergia tumidifructa	1	0.2

Cloudbreak – Life of Mine **Site** ER1
Described by JR&JH **Date** 14/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: HSMB24_S (4.1 km due SE)
MGA Zone 50 761305 **mE** 7528667 **mN** 119.536795 **E** -22.327938 **S**
Habitat Eucalyptus victrix Open Woodland
Soil Red sandy clay loam to sandy clay
Rock Type Stones, 10%
NVIS vegetation description (Level VI – sub-association) U1 *Eucalyptus victrix*/7/c; U2 *Atalaya hemiglauca*/*Acacia coriacea*/*Corymbia hamersleyana*/6/bi; M1 *Acacia trachycarpa*/*Acacia pyrifolia*/4/i; M2 *Indigofera monophylla*/*Vachellia farnesiana*/2/r; M3 *Indigofera monophylla*/*Pterocaulon sphacelatum*/2/i; G1 *Triodia longiceps*/*Cenchrus ciliaris*/*Cyperus vaginatus*/3/d; G2 *Pluchea dentex*/*Rhynchosia minima*/1/c.
Veg Condition Excellent
Fire Age Very Old (>20 years)
Notes Topography & aspect: Valley bottom, <1%
Bare ground: 10%
Logs: 20%
Twigs: 20%
Leaves: 30%
Disturbances: Pastoral (cattle), mining and exploration adjacent, weeds

Species	Cover class	Height (m)
Acacia bivenosa	1	1
Acacia coriacea	1	2
Acacia pyrifolia	1	1.9
Acacia trachycarpa	1	2
Atalaya hemiglauca	1	2
Bonamia media	1	0.1
**Cenchrus ciliaris*	5	1.1
Corymbia hamersleyana	1	3
Crotalaria medicaginea	1	0.2
Cucumis maderaspatanus	1	2
Cyperus vaginatus	4	1.2
Digitaria brownii	1	0.8
Eragrostis tenellula	1	0.1
Eucalyptus victrix	4	10
Indigofera monophylla	2	0.8
Pluchea dentex	2	0.5
Pluchea rubelliflora	1	0.5
Pterocaulon sphacelatum	1	0.5
Rhynchosia minima	1	0.1
Sida sp. spiciform panicles (E. Leyland s.n. 14/8/1990)	1	1
Stemodia grossa	1	1
Tephrosia rosea	1	0.8
Themeda triandra	2	0.5

Species	Cover class	Height (m)
Triodia longiceps	1	0.75
Vachellia farnesiana	1	1

Cloudbreak – Life of Mine **Site** ER2
Described by JR&JH **Date** 15/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: Kardardarrie (2.6 km due NW)
MGA Zone 50 716449 **mE** 7532198 **mN** 119.101096 **E** -22.302291 **S**
Habitat *Eucalyptus victrix* Open Woodland
Soil Red-brown silty clay to heavy clay
Rock Type Stones, 10%
NVIS vegetation description (Level VI – sub-association) U1 *Acacia xiphophylla*, *Eucalyptus victrix*, *Acacia distans*/6/c; M1 *Acacia tetragonophylla*/*Acacia synchronicia*/*Acacia xiphophylla*/4/i; M2 *Acacia synchronicia*/*Rhagodia eremaea*/3/r; M3 *Rhagodia eremaea*/*Salsola tragus*/2/r; G1 **Cenchrus ciliaris*/*Evolvulus alsinoides*/*Alternanthera nodiflora*/2/r; G2 *Bulbostylis barbata*/2/bi.
Veg Condition Excellent
Fire Age Old (5-20yr)
Notes Topography & aspect: Riparian zone, <1%
Bare ground: 50%
Logs: 10%
Twigs: 10%
Leaves: 10%
Disturbances: Pastoral (cattle), mining and exploration adjacent, weeds

Species	Cover class	Height (m)
Abutilon dioicum	1	1
Acacia distans	4	4
Acacia aptaneura ms	1	1
Acacia coriacea	1	4
Acacia disphana	4	4
Acacia synchronicia	1	2
Acacia tetragonophylla	1	2
Acacia xiphophylla	1	2
Alternanthera nodiflora	1	0.5
Amaranthus cuspidifolius	1	0.4
Atalaya hemiglauca	1	0.5
Blumea tenella	1	0.2
Bulbostylis barbata	1	0.1
Calandrinia schistorhiza	1	0.2
**Cenchrus ciliaris*	4	1
Centipeda minima subsp. *macrocephala*	1	0.2
Chloris pectinata	1	0.5
Cleome viscosa	1	1
Corchorus aestuans	1	0.1
Digitaria brownii	1	0.4
Duperreya commixta	1	3
Dysphania melanocarpa	1	0.4
**Echinochloa colona*	1	0.2
Enchylaena tomentosa	1	0.4

Species	Cover class	Height (m)
Enneapogon caerulescens	1	0.2
Eragrostis falcata	1	0.2
Eragrostis leptocarpa	1	0.5
Eragrostis tenellula	1	0.3
Eucalyptus victrix	4	10
Euphorbia biconvexa	1	0.4
Euphorbia boophthona	1	0.2
Evolvulus alsinoides	1	0.2
**Flaveria trinervia*	1	0.4
Goodenia muelleriana	1	0.2
Ipomoea muelleri	1	1
**Malvastrum americanum*	1	1
Notoleptopus decaisnei	1	0.5
Operculina aequisepala	1	0.2
Phyllanthus erwinii	1	0.3
Pluchea dentex	1	0.4
Pluchea rubelliflora	1	0.3
Polycarpaea corymbosa	1	0.2
**Portulaca oleracea*	1	0.1
Pterocaulon sphacelatum	1	1
Ptilotus gomphrenoides	1	0.3
Rhagodia eremaea	1	1.5
Rostellularia adscendens var. *pogonanthera*	1	0.2
Salsola tragus	1	1
Senna artemisioides subsp. *oligophylla*	1	0.5
**Setaria verticillata*	1	0.4
Sida fibulifera	1	0.3
Sporobolus australasicus	4	0.2
Streptoglossa bubakii	1	0.5
Themeda triandra	1	0.8
Trianthema triquetra	1	0.4

Cloudbreak – Life of Mine **Site** MD
Described by JR&JH **Date** 14/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: HSMB29_S (202 m due E)
MGA Zone 50 771160 **mE** 7523518 **mN** 119.633267 **E** -22.372880 **S**
Habitat Mulga Low Open Forest
Soil Red-brown sandy clay loam to sandy clay, no cracking clay
Rock Type Ironstone stones (1-50 mm), 80%
NVIS vegetation description (Level VI – sub-association) U1 *Acacia aptaneura*/*Acacia aneura* var. *intermedia*/6/c; M1 *Acacia aptaneura* /4/c; M2 *Sida* sp. dark green fruits (S. van Leeuwen 2260)/*Eremophila forrestii*/3/i; M3 *Enchylaena tomentosa*/1/i; G1 *Aristida contorta*/*Enneapogon polyphyllus*/*Polycarpaea corymbosa*/1/c.
Veg Condition Excellent - Very Good
Fire Age Old (5-20 years)
Notes Topography & aspect: Bottom of slope, flat, <1%
Bare ground: 50%
Logs: 10-30%
Twigs: 10-30%
Leaves: 2-10%
Disturbances: Adjacent tracks, weeds, grazing.

Species	Cover class	Height (m)
Abutilon otocarpum	1	0.15
Acacia aneura var. *intermedia*	3	5
Acacia aptaneura	4	5
Acacia ayersiana	2	1.6
Acacia pruinocarpa	1	2.1
Aristida contorta	4	0.3
Aristida obscura	2	0.4
Aristida pruinosa	2	1.2
**Bidens bipinnata*	3	0.1
Boerhavia sp.	1	prostrate
Cleome viscosa	1	0.3
Convolvulaceae sp.	1	creeper
Cucumis maderaspatanus	1	creeper
Cymbopogon ambiguus	1	0.6
Digitaria brownii	1	0.5
Dodonaea petiolaris	1	0.7
Dysphania melanocarpa	1	0.5
Enchylaena tomentosa	3	0.4
Enneapogon polyphyllus	4	0.35
Eremophila forrestii	1	1.1
Eriachne obtusa	2	0.4
Eriachne pulchella subsp. *dominii*	1	0.05
Evolvulus alsinoides var. *villosicalyx*	1	0.05
Gomphrena affinis subsp. *pilbarensis*	1	0.1

Species	Cover class	Height (m)
Gomphrena canescens	1	0.4
Goodenia microptera	1	0.3
Goodenia prostrata	1	0.01
Hakea chordophylla	1	0.5
Hakea lorea	1	2.8
Hibiscus burtonii	1	0.5
Indigofera brevidens	1	0.5
Lepidium muelleri-ferdinandii	1	0.05
Maireana ?melanocoma	1	0.25
Panicum ?effusum	1	0.4
Paraneurachne muelleri	2	0.4
Polycarpaea corymbosa	1	0.05
**Portulaca oleracea*	1	prostrate
Psydrax latifolia	1	3.2
Psydrax rigidula	1	1.2
Pterocaulon sphacelatum	1	0.3
Ptilotus fusiformis	1	0.1
Ptilotus macrocephalus	1	0.4
Ptilotus nobilis	1	0.4
Ptilotus obovatus	1	0.9
Ptilotus polystachyus	1	0.4
Salsola tragus	1	0.4
Sclerolaena cuneata	1	0.25
Senna artemisioides subsp. *helmsii*	1	0.8
Senna artemisioides subsp. *oligophylla*	1	0.8
Senna glutinosa subsp. *luerssenii*	1	1.9
Senna notabilis	1	0.3
Sida fibulifera	1	prostrate
Sida sp. dark green fruits (S. van Leeuwen 2260)	3	1
Solanum horridum	1	0.2
Solanum phlomoides	1	0.6
Sporobolus australasicus	1	0.05
Themeda triandra	1	0.6
Trianthema glossostigma	1	prostrate
Trichodesma zeylanicum	1	1.4

Cloudbreak – Life of Mine **Site** MI1
Described by JR&JH **Date** 13/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: HEMB05_S (405 m due SE)
MGA Zone 50 774226 **mE** 7523659 **mN** 119.662993 **E** -22.371121 **S**
Habitat Mulga Low Open Forest
Soil Red-brown sandy loam to silt loam
Rock Type Ironstone stones, 80%
NVIS vegetation description (Level VI – sub-association) U1 *Acacia paraneura*/*Acacia synchronicia*/6/c; M1 *Acacia paraneura*/4/r; M2 *Senna artemisioides* subsp. *oligophylla*/3/r; M3 *Senna artemisioides* subsp. *oligophylla*/*Acacia synchronicia*/2/r; G1 *Aristida contorta*/*Aristida inaequiglumis*/1/c.
Veg Condition Very Good - Good
Fire Age Old (5-20 years)
Notes Topography & aspect: Broad floodplain, flat, <1%.
Bare ground: 45%
Logs: 0%
Twigs: 2-10%
Leaves: 2-10%
Disturbances: Adjacent road, cattle grazing.

Species	Cover class	Height (m)
Abutilon otocarpum	1	0.3
Acacia paraneura	4	4
Acacia synchronicia	2	4
Acacia tetragonocarpa	1	0.4
**Aerva javanica*	1	0.15
Amaranthaceae sp.	1	0.1
Amyema fitzgeraldii	1	creeper
Aristida contorta	4	0.4
Aristida inaequiglumis	3	0.5
Boerhavia coccinea	1	0.3
Chloris pectinata	1	0.5
Chrysopogon fallax	2	1.2
Corchorus tridens	1	0.3
Enneapogon robustissimus	1	0.3
Eragrostis setifolia	1	0.1
Eragrostis tenellula	1	0.15
Eremophila lanceolata	1	0.4
Eremophila latrobei subsp. *latrobei*	1	0.4
Eriachne obtusa	2	1.2
Eriachne pulchella subsp. *dominii*	2	0.45
Eulalia aurea	1	0.4
Evolvulus alsinoides var. *villosicalyx*	1	0.15
Gomphrena affinis subsp. *pilbarensis*	1	0.2
Gomphrena kanisii	1	0.1
Goodenia muelleriana	1	0.4
Hibiscus leptocladus	1	0.15

Species	Cover class	Height (m)
Iseilema eremaeum	1	0.3
Lepidium muelleri-ferdinandii	1	0.15
**Malvastrum americanum*	1	0.5
Marsilea hirsuta	1	0.05
Pluchea ferdinandi-muelleri	1	0.2
**Portulaca oleracea*	1	0.05
Pterocaulon sphacelatum	1	0.3
Ptilotus fusiformis	1	0.15
Ptilotus gomphrenoides	2	0.15
Ptilotus nobilis	1	0.25
Rhagodia eremaea	1	0.5
Rhynchosia minima	1	prostrate
Salsola tragus	2	0.4
Sclerolaena cuneata	2	0.5
Senna artemisioides subsp. *helmsii*	1	0.6
Senna artemisioides subsp. *oligophylla*	2	1.5
Sida fibulifera	1	prostrate
Solanum horridum	2	0.15
Solanum lasiophyllum	2	0.5
Sporobolus australasicus	3	0.05
Streptoglossa bubakii	2	0.7
Tephrosia clementii	1	0.4

Cloudbreak – Life of Mine **Site** MI2
Described by JR&JH **Date** 14/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: SCX02_S (345 m due E)
MGA Zone 50 769369 **mE** 7522362 **mN** 119.616083 **E** -22.383595 **S**
Habitat Mulga Low Open Forest
Soil Red-brown sandy clay loam to sandy clay
Rock Type Ironstone stones, 85%
NVIS vegetation description (Level VI – sub-association) U1 *Acacia aptaneura*/6/d; M1 *Acacia aptaneura*/4/i; M2 *Acacia aptaneura*/3/c; M3 *Eremophila forrestii*/*Pterocaulon sphacelatum*/2/i; G1 *Sclerolaena cuneata*/*Eremophila lanceolata*/2/i; G2 *Aristida contortai*/*Enneapogon polyphyllus*/**Cenchrus ciliaris*/1/i.
Veg Condition Very Good
Fire Age Very Old (>20 years)
Notes Topography & aspect: Bottom of hillslope, flat, <1%
Bare ground: 30-70%
Logs: 10-30%
Twigs: 10-30%
Leaves: 10-30%
Disturbances: Pastoral (cattle), mining and exploration

Species	Cover class	Height (m)
Abutilon dioicum	1	1
Abutilon otocarpum	1	0.5
Acacia aptaneura	4	8
Acacia pruinocarpa	1	2
Ammannia baccifera	2	0.2
Aristida contorta	3	0.3
Aristida obscura	1	0.4
**Bidens bipinnata*	3	0.3
Boerhavia coccinea	1	0.2
**Cenchrus ciliaris*	1	0.5
Cheilanthes sieberi subsp. *sieberi*	1	0.3
Cleome viscosa	1	0.5
Corchorus lasiocarpus subsp. *lasiocarpus*	1	1
Cucumis maderaspatanus	1	creeper
Cymbopogon ambiguus	1	0.5
Cymbopogon obtectus	1	1
Digitaria brownii	1	1
Enneapogon polyphyllus	3	0.4
Eremophila forrestii	2	1
Eremophila lanceolata	3	0.6
Eremophila latrobei	1	1
Euphorbia australis	1	0.1
Euphorbia biconvexa	1	0.4
Euphorbia myrtoides	1	0.3

Species	Cover class	Height (m)
Evolvulus alsinoides var. *villosicalyx*	1	0.2
Gomphrena affinis subsp. *pilbarensis*	1	0.4
Goodenia prostrata	1	0.1
Hibiscus sturtii var. *campylochlamys*	1	0.5
Lepidium muelleri-ferdinandii	1	0.5
Maireana melanocoma	2	0.3
Mollugo molluginea	2	0.3
Panicum effusum	1	0.3
Perotis rara	1	0.4
Polycarpaea corymbosa	1	0.3
**Portulaca oleracea*	1	0.2
Psydrax latifolia	2	2.5
Psydrax rigidula	1	1
Pterocaulon sphacelatum	3	1
Ptilotus aervoides	1	0.2
Ptilotus calostachyus	1	1
Ptilotus fusiformis	1	0.2
Ptilotus macrocephalus	1	1
Ptilotus nobilis	1	0.5
Ptilotus obovatus	2	1
Rhagodia eremaea	1	1
Salsola tragus	1	0.5
Sclerolaena cuneata	2	0.5
Senna artemisioides subsp. *helmsii*	1	1
Senna notabilis	1	0.5
Sida fibulifera	2	0.2
Sida sp. dark green fruits (S. van Leeuwen 2260)	1	0.4
Solanum horridum	1	0.2
Solanum lasiophyllum	1	0.8
Sporobolus australasicus	3	0.2
Streptoglossa decurrens	1	1
Tephrosia clementii	1	0.3
Themeda triandra	2	1

Cloudbreak – Life of Mine **Site** MR1
Described by JR&JH **Date** 13/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: SCX04_S (308 m due N)
MGA Zone 50 771221 **mE** 7522268 **mN** 119.634071 **E** -22.384151 **S**
Habitat Mulga Low Closed Woodland
Soil Red-brown sandy clay loam to sandy clay
Rock Type Ironstone stones (1-10 mm, but up to 50 mm), 65%
NVIS vegetation description (Level VI – sub-association) U1 *Acacia aptaneura*/6/d; M1 *Psydrax latifolia*/4/r; M2 *Senna artemisioides* subsp. *helmsii*/3/r; M3 *Sida* sp. dark green fruits (S. van Leeuwen 2260)/2/r; G1 *Aristida nitidula*/*Enneapogon polyphyllus*/*Streptoglossa bubakii*/2/c.
Veg Condition Very Good
Fire Age Old (5-20 years)
Notes Topography: Bottom of slope, flat, <1%
Bare ground: 30%
Logs: 10-30%
Twigs: 10-30%
Leaves: 30-70%
Disturbances: Pastoral (cattle), mining and exploration

Species	Cover class	Height (m)
Abutilon otocarpum	1	0.25
Acacia aptaneura	5	6
Aristida contorta	4	0.3
Aristida nitidula	1	1.2
Aristida pruinosa	1	0.4
**Bidens bipinnata*	1	0.05
Cheilanthes sieberi subsp. *sieberi*	1	0.01
Chrysopogon fallax	1	1.3
Cleome viscosa	1	0.5
Cucumis maderaspatanus	1	creeper
Cymbopogon obtectus	1	0.4
Dysphania kalpari	1	0.1
Enchylaena tomentosa	4	0.3
Enneapogon polyphyllus	2	0.2
Eremophila forrestii	1	0.9
Eremophila lanceolata	1	0.3
Eremophila latrobei subsp. *latrobei*	1	1
Euphorbia biconvexa	1	prostrate
Euphorbia myrtoides	1	0.01
Gomphrena canescens	1	0.2
Hibiscus leptocladus	1	0.2
Iseilema eremaeum	1	0.05
Lepidium muelleri-ferdinandii	1	0.05
Maireana planifolia	1	0.6

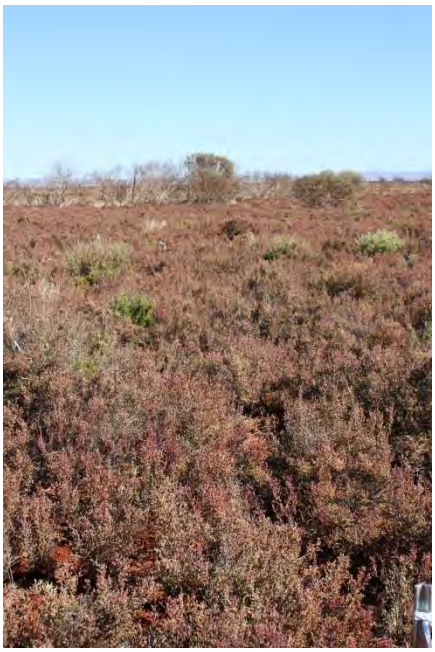
Species	Cover class	Height (m)
Perotis rara	1	0.1
Polyalthia holtzeana	1	0.02
Polycarpaea corymbosa	1	0.02
**Portulaca oleracea*	1	prostrate
Psydrax latifolia	2	2.4
Psydrax rigidula	1	0.5
Pterocaulon sphacelatum	1	0.4
Ptilotus fusiformis	1	0.35
Ptilotus macrocephalus	1	0.3
Ptilotus nobilis	1	0.4
Ptilotus polystachyus	1	1
Ptilotus schwartzii	1	0.4
Rhagodia eremaea	1	0.4
Salsola tragus	1	0.5
Sclerolaena cornishiana	1	0.4
Senna artemisioides subsp. *helmsii*	2	1.7
Sida sp. dark green fruits (S. van Leeuwen 2260)	2	0.4
Sida sp. verrucose glands (F.H. Mollemans 2423)	1	0.2
Solanum phlomoides	1	0.4
Sporobolus australasicus	4	0.05
Streptoglossa bubakii	2	0.5

Cloudbreak – Life of Mine **Site** MR2
Described by JR&JH **Date** 17/06/2012 **Type** Quadrat 100 m x 25 m
Client Fortescue Metals Group
Location Closest bore: Kardardarrie bore (1.4 km due S)
MGA Zone 50 714815 **mE** 7535440 **mN** 119.084808 **E** -22.273226 **S**
Habitat Mulga Low Closed Woodland
Soil Red-brown sandy clay loam to sandy clay
Rock Type Ironstone stones, 45%
NVIS vegetation description (Level VI – sub-association) U1 *Acacia aptaneura*/6/d; M1 *Acacia aptaneura* ms/*Acacia tetragona*/4/c; M2 *Sclerolaena cuneata*/*Abutilon otocarpum*/*Eremophila forrestii*/2/r; G1 *Sporobolus australasicus*/*Aristida contorta*/Enneapogon polyphyllus/1/r.
Veg Condition Very Good
Fire Age Old (5-20 years)
Notes Topography & aspect: Broad floodplain, flat, <1%
Bare ground: 70%
Logs: 10-30%
Twigs: 10-30%
Leaves: 10-30%
Disturbances: Pastoral (cattle), mining and exploration

Species	Cover class	Height (m)
Abutilon dioicum	1	1
Abutilon otocarpum	2	0.5
Abutilon oxycarpum	1	0.1
Acacia aptaneura	5	6
Acacia synchronicia	2	2
Acacia tetragonocarpa	2	4
Ammannia baccifera	1	0.2
Aristida contorta	2	0.3
**Bidens bipinnata*	1	0.2
Boerhavia coccinea	1	0.1
**Cenchrus ciliaris*	1	1
Cheilanthes sieberi subsp. *sieberi*	2	0.1
Chloris pectinata	1	0.5
Cleome viscosa	1	1
Corchorus aestuans	1	0.1
Cucumis ?melo	1	0.1
Cullen cinereum	1	0.4
Dysphania kalpari	1	0.4
Dysphania melanocarpa forma *melanocarpa*	1	0.5
Enchylaena tomentosa	1	0.5
Enneapogon caerulescens	1	0.4
Enneapogon polyphyllus	2	0.4
Eragrostis falcata	1	0.2
Eremophila forrestii	2	1

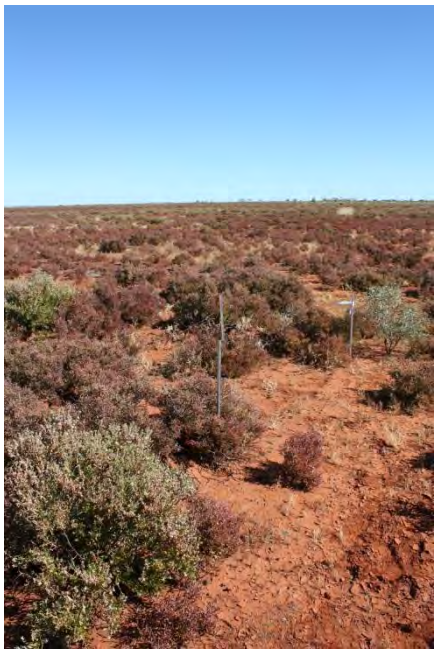
Species	Cover class	Height (m)
Eremophila latrobei	1	0.5
Eriachne obtusa	1	0.5
Eriachne pulchella subsp. *dominii*	1	0.2
Euphorbia australis	1	0.1
Euphorbia biconvexa	1	0.3
Evolvulus alsinoides var. *villosicalyx*	1	0.2
Goodenia prostrata	1	0.2
Hibiscus leptocladus	1	0.4
**Malvastrum americanum*	1	0.5
Pluchea dentex	1	0.4
Pluchea ferdinandi-muelleri	1	0.5
Polyalthia holtzeana	1	0.2
Polycarpaea corymbosa	2	0.3
**Portulaca oleracea*	1	0.2
Psydrax latifolia	1	2
Psydrax rigidula	1	0.5
Pterocaulon sphacelatum	1	1
Ptilotus gomphrenoides	1	0.4
Rhagodia sp. Hamersley (M. Trudgen 17794) (P3)	1	2
Salsola australis	1	1
Sclerolaena cornishiana	1	0.4
Sclerolaena cuneata	3	0.5
Senna artemisioides subsp. *helmsii*	1	1
Senna artemisioides subsp. *oligophylla*	1	1.5
Sida fibulifera	1	0.4
Sporobolus australasicus	4	0.2
Tribulus macrocarpus	1	0.1

Cloudbreak – Life of Mine **Site** SI1
Described by JR&JH **Date** 15/06/2012 **Type** Quadrat 40 m x 5 m
Client Fortescue Metals Group
Location Closest bore: CBX10a_WT (2 km due E)
MGA Zone 50 742535 **mE** 7524646 **mN** 119.355306 **E** -22.366983 **S**
Habitat Samphire
Soil Sandy loam to silt loam
Rock Type Mara Mamba Formation overlain by tertiary detritals and alluvium
NVIS vegetation description (Level VI – sub-association) M1 *Tecticornia indica*/*Eremophila spongiocarpa* (P1)/2/d; G1 *Eragrostis falcata*/*Sporobolus australasicus*/1/r.
Veg Condition Good
Fire Age Very Old (>20 years)
Notes Topography & aspect: Edge of salt marsh, flat
Bare ground: 60%
Logs: 0%
Twigs: 10-30%
Leaves: 2-10%
Disturbances: Pastoral (cattle), mining and exploration adjacent



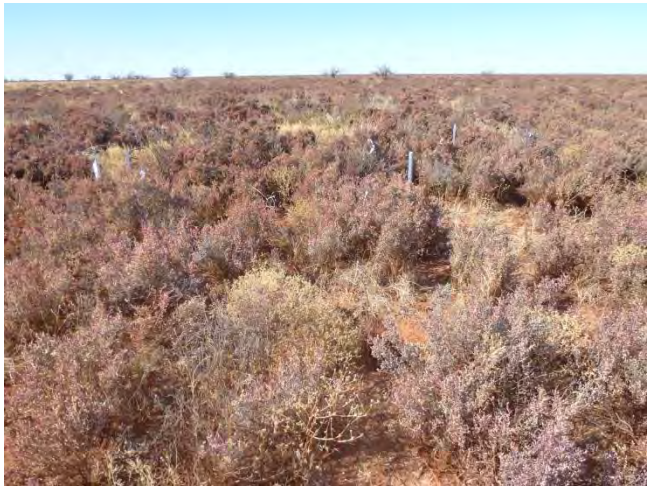
Species	Cover class	Height (m)
Cullen cinereum	1	0.4
Dactyloctenium radulans	2	0.2
Eragrostis falcata	1	0.2
Eremophila spongiocarpa (P1)	2	0.9
Maireana luehmannii	1	0.3
Nicotiana heterantha (P1)	1	0.4
Portulaca pilosa	1	0.2
Pterocaulon sphacelatum	1	0.4
Sporobolus australasicus	1	0.4
Streptoglossa bubakii	1	0.4
Tecticornia indica	5	0.9
Threlkeldia diffusa	1	0.2
Trianthema triquetra	1	0.2
Xerochloa laniflora	1	0.2

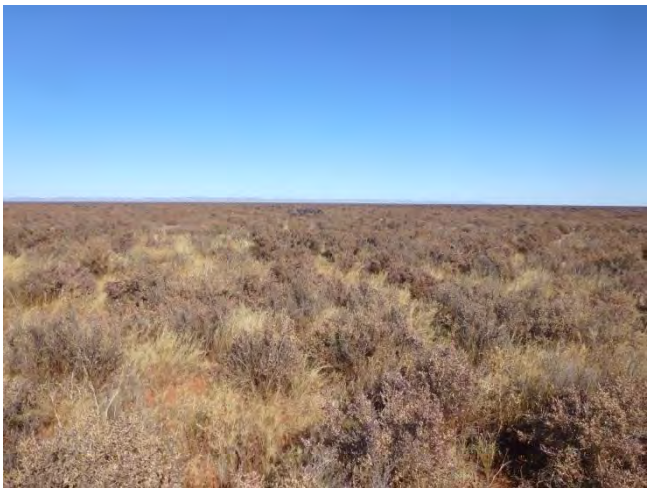
Cloudbreak – Life of Mine **Site** SI2
Described by JR&JH **Date** **Type** Quadrat 5 m x 40 m
Client Fortescue Metals Group
Location Closest bore: CBX04_S (824 m due NW)
MGA Zone 50 734644 **mE** 7527519 **mN** 119.278300 **E** -22.342145 **S**
Habitat Samphire
Soil Silty clay to heavy clay, presence of salt crust on soil surface
Rock Type Unknown detritals
NVIS vegetation description (Level VI – sub-association) M1 *Tecticornia indica/Eremophila spongiocarpa* (P1)/*Eremophila youngii*/3/d; M2 *Tecticornia indica/Eremophila spongiocarpa* (P1)/*Eremophila youngii*/2/i; G1 *Eragrostis falcata*/2/bi; G2 *Nicotiana heterantha* (P1)/1/r.
Veg Condition Excellent
Fire Age Very Old (>20 years)
Notes Topography & aspect: Edge of salt marsh, flat,
Bare ground: 10-30%
Logs 0%
Twigs: 10-30%
Leaves: 10-30%
Disturbances: Pastoral (cattle), mining and exploration adjacent




Species	Cover class	Height (m)
Acacia synchronicia	1	0.4
Bulbostylis barbata	1	<0.5
**Cenchrus ciliaris*	1	0.5
**Chloris virgata*	1	0.4
Eragrostis falcata	1	0.2
Eremophila spongiocarpa (P1)	2	1
Eremophila youngii	1	1
Maireana sp.	1	0.5
Nicotiana heterantha (P1)	1	0.3
Pluchea dentex	1	0.2
**Portulacaria afra*	1	0.2
Pterocaulon sphacelatum	1	0.4
Salsola tragus	1	0.4
Sporobolus australasicus	1	0.2
Streptoglossa bubakii	1	0.4
Tecticornia indica	5	1.2
Trianthema turgidifolia	1	0.4

Cloudbreak – Life of Mine **Site** SR1
Described by JR&JH **Date** 15/06/2012 **Type** Quadrat 40 m x 5 m
Client Fortescue Metals Group
Location Closest bore: CBFMM06_S (440 m due NE)
MGA Zone 50 740803 **mE** 7524802 **mN** 119.338473 **E** -22.365818 **S**
Habitat Samphire
Soil Silty clay to heavy clay, presence of salt crust on soil surface
Rock Type Mara Mamba Formation overlain by tertiary detritals and alluvium
NVIS vegetation description (Level VI – sub-association) M1 *Tecticornia auriculata*/3/bi; M2 *Tecticornia indica*/2/d; G1 *Eragrostis falcata*/1/c; G2 *Nicotiana heterantha* (P1)/*Cullen cinereum*/1/d.
Veg Condition Excellent
Fire Age Very Old (>20 years)
Notes Topography & aspect: Edge of salt marsh, flat
Bare ground: 20%
Logs: 0%
Twigs: 10-30%
Leaves: 10-30%
Disturbances: Pastoral (cattle), mining and exploration adjacent





Species	Cover class	Height (m)
Alternanthera nodiflora	1	0.3
Cullen cinereum	1	0.3
Eragrostis falcata	4	0.3
Eragrostis tenax	1	1
Eremophila spongiocarpa (P1)	1	1
**Flaveria trinervia*	1	0.5
Nicotiana heterantha (P1)	1	0.3
Pluchea dentex	1	1
Pterocaulon sphacelatum	1	1
Streptoglossa bubakii	1	0.5
Tecticornia auriculata	1	1
Tecticornia halocnemoides	1	1
Tecticornia indica	5	1
Tecticornia glomerata	1	1

Cloudbreak – Life of Mine **Site** SR2
Described by JR&JH **Date** 16/06/2012 **Type** Quadrat 40 m x 5 m
Client Fortescue Metals Group
Location Closest bore: CBFMM02_S (58 m due SW)
MGA Zone 50 727638 **mE** 7527992 **mN** 119.210246 **E** -22.338817 **S**
Habitat Samphire
Soil Sandy clay loam to sandy clay, presence of salt crust on soil surface
Rock Type Mara Mamba Formation overlain by tertiary detritals and alluvium
NVIS vegetation description (Level VI – sub-association) M1 *Tecticornia indica*/*Muellerolimon salicorniaceum*/*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)/2/d; G1 *Eragrostis falcata*/1/c; G2 *Nicotiana heterantha* (P1)/1/3.
Veg Condition Excellent
Fire Age Very Old (>20 years)
Notes Topography & aspect: Edge of salt marsh, flat
Bare ground: 50%
Logs: 0%
Twigs: 2-10%
Leaves: 2-10%
Disturbances: Pastoral (cattle), mining and exploration adjacent
Comments: Many samphire seedlings (mainly *Tecticornia*)


Species	Cover class	Height (m)
Cyperus bifax	2	0.3
Eragrostis falcata	4	0.2
Eremophila spongiocarpa (P1)	2	0.9
Frankenia ambita	1	0.2
Muellerolimon salicorniaceum	3	0.9
Nicotiana heterantha (P1)	3	0.2
Swainsona kingii	2	0.3
Tecticornia auriculata	1	0.9
Tecticornia disarticulata	1	0.3
Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	4	0.9
Tecticornia indica	5	0.9

Appendix C – Landscape Function Analysis Data

LFA Patch and Inter-patch References

VMU LFA Data Sheets

Landscape Function Analysis (LFA) patch and inter-patch references

Mulga vegetation

The landscape is characterised by patches (mulga groves) consisting of open thicket complexes interspersed by bare ground areas. Sheet flow appears to be a significant driver of ecosystem function with open thicket complexes acting as depositional zones for sediment and transported woody debris. Open thicket mulga complexes are generally banded across the slope thereby intercepting overland flow. The groves themselves increase landscape roughness and rainfall interception. The landscape is organised into distinct patches and inter-patches. Patches form the primary zone of biological function with a fair amount of litter accumulation, sediment and litter deposition. Inter-patches are primarily armoured and embedded, stony sheet-flow zones with little biological function. Mulga habitat is actively grazed.

On site investigations suggested that an approach for patch and inter-patch classification which suitably describes the nature and extent of mulga thickets relative to inter-patch or sheet-flow zones was adopted. The following patch types were identified:

Mulga patch and inter-patch characteristics

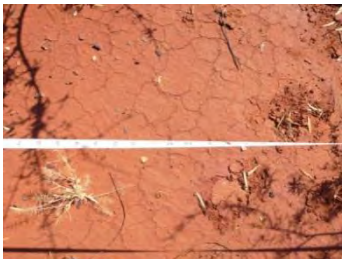
Patch/Inter-patch	Description	Photograph
Open Thicket (Patch)	Mulga Grove characterised by a mix of transported sediment, woody debris both local and transported, annual grasses, trees (adult and juvenile) and shrubs. Generally forming extensive bands connected by debris bridges forming a depositional zone.	
Plant Hummock (Patch)	Mix of perennial and annual grass and shrub hummocks, generally less extensive but appear to act as a sediment store/depositional zone	
Bare Soil (Inter-patch)	Bare ground characterised by a stoney surface with little deposition present. This surface is generally armoured and appears to be dominated by sheetflow.	

Partially Phreatophytic vegetation

Partially phreatophytic vegetation tends to dominate river channels and the riparian zone. The landscape is characteristically a transition zone from river channel up onto a flooded bench inundated during flow events greater then bankful discharge. Partially phreatophytic habitat appears to be driven by episodic stream/channel flow events rather than overland flow/sheetflow events. Partially phreatophytic habitat in the upper catchments appears to be relatively stable confined to highly vegetated river channel. On the lower slopes partially phreatophytic species are growing in very active channels characterised by large amounts of gravel and sediment transport. Closer to the salt marsh partially phreatophytic vegetation are confined to primary channels forming part of extensive depositional zones (silts and gravels) associated with reduced channel gradient and alluvial fan development. Partially phreatophytic species do not appear to be associated with well-defined patch or inter-patch zones. The partially phreatophytic habitat is actively grazed.

LFA transects were oriented perpendicular to channel flow making the assumption that resources are moving from the riparian zone into the ephemeral channel. Transects' describe the first terrace associated with flows in excess of bankful discharge and not the active river channel itself. The following patch types were identified:

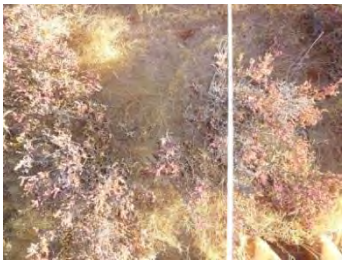
Partially phreatophytic patch and inter-patch characteristics

Patch/Inter-patch	Description	Photograph
Tree Shrub Complex (Patch)	Characterised by a mix of transported sediment, woody debris both local and transported, perennial and annual grasses, trees (adult and juvenile) and shrubs. Generally inclusive of Coolibah adjacent to the river channel but less so with distance from the channel.	
Plant Hummock (Patch)	Mix of perennial and annual grass and shrub hummocks, generally less extensive but appear to act as a sediment store/depositional zone.	
Bare Soil (Inter-patch)	Bare ground characterised by a stony surface with little deposition present. This surface is generally armoured and appears to be dominated by sheetflow.	

Samphire vegetation

Samphire VMUs represent the edge of the salt marsh community and a substantial depositional zone. Due to the low gradient of these sites, sheet-flow appears to occur during episodic events possibly corresponding with lake filling events resulting in a low velocity depositional environment. Substantial silt deposits were evident at all sites. Samphire vegetation was well organised into characteristic patch and inter-patch zones. Size and distribution of the zones appears to be dependent on the level of sheet-flow activity i.e. larger inter-patches in locations with active sheet-flow. Samphire VMUs were actively grazed and soils appear poorly structured and prone to erosion.

Samphire patch and inter-patch characteristics

Patch/Inter-patch	Description	Photograph
Plant Hummock (Patch)	Mix of perennial and annual grass and shrub hummocks; appear to act as a sediment store/depositional zone. In some cases they formed mounds up to 300 mm above the general ground surface. Generally dominated by Samphire shrubs.	
Grassy Flat (Inter-patch)	Characterised by a bare soil surface or covered with annual grasses. Occasional gravel and substantial silt deposits were evident at some sites. Sheet flow was evident at some but not all sites resulting in some gravel deposits.	

Site name & ID:	Eucalyptus Direct 1; ED1	LFA ID:	ED1_LFAJuly2012
Observers:	JEF	Date:	3/07/2012
Start position (GPS):	734160E; 7532689N	Length:	28 m
Compass bearing:	90°		
Position in landscape:	Riparian zone, secondary channel adjacent to main channel		
Slope and Aspect:	2 %		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy loam to silt loam		
State of Soil Surface:	Stony/armored		
Vegetation type:	*Eucalyptus* and *Acacia* Open Woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:			

Tree-shrub complex

Bare Soil

General Site photo

Site name & ID:	Eucalyptus Reference 1; ER1	LFA ID:	ER1_LFAJuly2012
Observers:	JEF	Date:	1/07/2012
Start position (GPS):	761231E; 7528607N	Length:	25 m
Compass bearing:	150°		
Position in landscape:	Riparian zone to channel base (valley bottom)		
Slope and Aspect:	<1 %		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy clay loam to sandy clay		
State of Soil Surface:	Stony/armored (minimal)		
Vegetation type:	*Eucalyptus victrix* Open woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:			

Bare Soil at 0.4-1.5m

Plant Hummock

Tree-shrub complex

General Site photo

Site name & ID:	Eucalyptus Reference 2; ER2	LFA ID:	ER2_LFAJuly2012
Observers:	JEF	Date:	4/07/2012
Start position (GPS):	716385E; 7532253N	Length:	60 m
Compass bearing:	210°		
Position in landscape:	Riparian zone		
Slope and Aspect:	n/a		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Silty clay to heavy clay		
State of Soil Surface:	Eroded		
Erosion type:	Sheetflow zone		
Vegetation type:	*Eucalyptus victrix* Open Woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:			

Bare Soil

Plant Hummock

Tree-shrub complex

General Site photo

Site name & ID:	Mulga Direct 1; MD1	LFA ID:	MD1_LFAJuly2012
Observers:	JEF	Date:	1/07/2012
Start position (GPS):	771043E; 7523566N	Length:	76.6 m
Compass bearing:	135°		
Position in landscape:	Bottom of slope, sheet flow area		
Slope and Aspect:	<1%		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy clay loam to sandy clay		
State of Soil Surface:	Armored/stony (1-50 mm)		
Vegetation type:	Mulga woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	Elevation 433m		

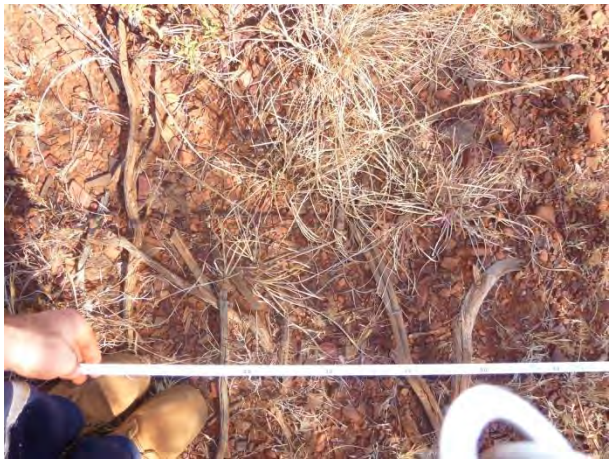
Bare Soil

Open Thicket

General Site photo

Site name & ID:	Mulga Indirect 1; MI1	LFA ID:	MI1_LFAJuly2012
Observers:	JEF	Date:	1/07/2012
Start position (GPS):	774272E; 7523572N	Length:	52.2 m
Compass bearing:	270°		
Position in landscape:	Broad floodplain		
Slope and Aspect:	Mid-slope		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy loam to silt loam		
State of Soil Surface:	Stony/armored		
Vegetation type:	Mulga woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:			

Bare Soil



Open Thicket

Plant Hummock

General Site photo

Site name & ID:	Mulga Indirect 2; MI2	LFA ID:	MI2_LFAJuly2012
Observers:	JEF	Date:	2/07/2012
Start position (GPS):	769371E; 7522351N	Length:	101.2 m
Compass bearing:	240°		
Position in landscape:	Bottom of hillslope		
Slope and Aspect:	<1%		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy clay loam to sandy clay		
State of Soil Surface:	Finds (silts) settle out below open thicket at downstream end		
Vegetation type:	Mulga woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	Bare ground areas are typically free of finds and significantly amoured, open thicket areas have substantial debris (branches) both local and transported. Bare ground areas are mostly free of woody debris material. Open thicket boundaries have smaller less extensive groves (e.g. 1 to 2 trees) but some sediment deposited is evident.		

Bare Soil

Open Thicket

General Site photo

Site name & ID:	Mulga Reference 1; MR1	LFA ID:	MR1_LFAJuly2012
Observers:	JEF	Date:	1/07/2012
Start position (GPS):	771221E; 7522268N	Length:	105 m
Compass bearing:	214°		
Position in landscape:	Bottom of slope		
Slope and Aspect:	<1%		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy clay loam to sandy clay		
State of Soil Surface:	Stony/armored (1-10 mm, but up to 50 mm)		
Vegetation type:	Mulga woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	Mulga groves intersected by stony bare ground areas with some annuals (grasses) on the bare ground areas. Mulga groves characterized by an increase in soil surface undulations/roughness.		

Bare Soil

Open Thicket

Plant Hummock

General Site photo

Site name & ID:	Mulga Reference 2; MR2	LFA ID:	MR2_LFAJuly2012
Observers:	JEF	Date:	4/07/2012
Start position (GPS):	714815E; 7535440N	Length:	74 m
Compass bearing:	300°		
Position in landscape:	Broad floodplain		
Slope and Aspect:	<1%		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy clay loam to sandy clay		
State of Soil Surface:	Strong with areas of silt deposition		
Vegetation type:	Mulga woodland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	Sheetflow area, Depositional zone		

Bare Soil

Open Thicket

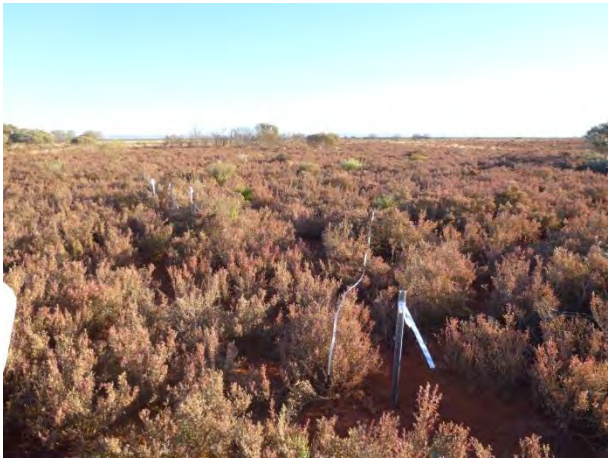
Plant Hummock

General Site photo

Site name & ID:	Samphire Indirect 1	LFA ID:	SI1_LFAJuly2012
Observers:	JEF & JER	Date:	2/07/2012
Start position (GPS):	742526E; 7524648N	Length:	6 m
Compass bearing:	240°		
Position in landscape:	Edge of salt marsh		
Slope and Aspect:	Flat		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy loam to silt loam		
State of Soil Surface:			
Vegetation type:	Samphire shrubland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	Elevation 406 m		

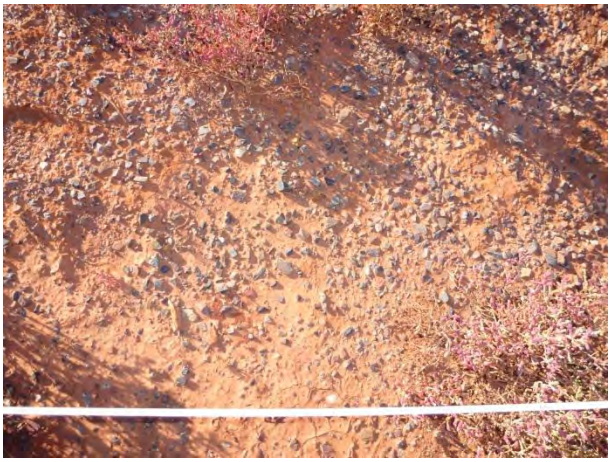
Bare Soil

Plant Hummock



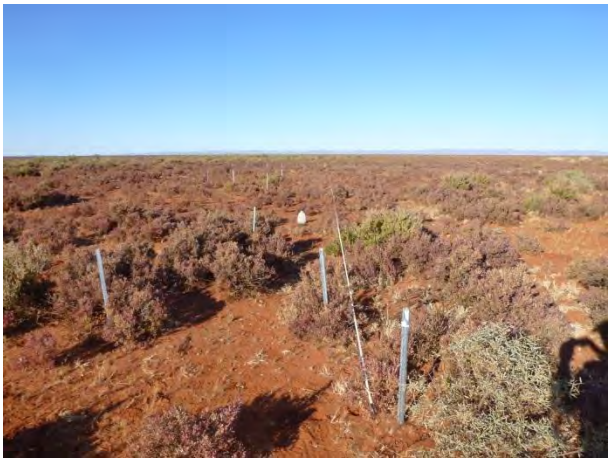
General Site photo

Site name & ID:	Samphire Impact 2; SI2	LFA ID:	SI2_LFAJuly2012
Observers:	JEF & JER	Date:	5/07/2012
Start position (GPS):	734644E; 7527519N	Length:	9.2 m
Compass bearing:	150°		
Position in landscape:	Edge of salt marsh		
Slope and Aspect:	Flat		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Silty clay to heavy clay		
State of Soil Surface:	Presence of salt crust on soil surface		
Vegetation type:	Samphire shrubland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	The site is characterized by sheetflow and plant hummocks (elevated) 300 mm above general ground surface (mounds on sediment which are represented by samphire patches. Sheet flow is predominant between the mounds with gravel up to 50 mm transported. Soil surface is soft in patches and breaks up when walked on. The zone is a depositional zone with active sheetflow.		



Bare Soil

Plant Hummock

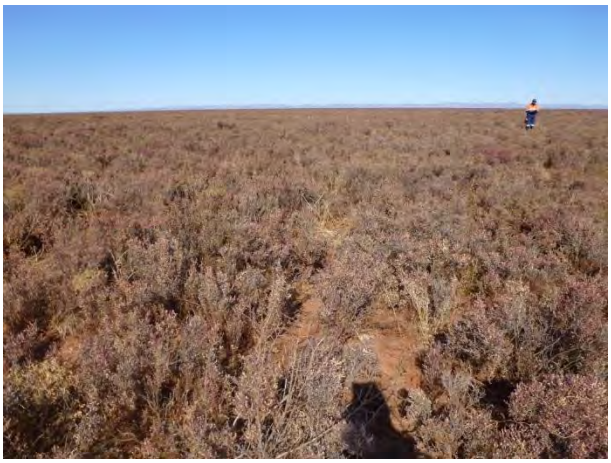


General Site photo

Site name & ID:	Samphire Reference 1; SR1	LFA ID:	SR1_LFAJuly2012
Observers:	JEF & JER	Date:	5/07/2012
Start position (GPS):	740803E; 7524802N	Length:	25.15 m
Compass bearing:	220°		
Position in landscape:	Edge of salt marsh		
Slope and Aspect:	Flat		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Silty clay to heavy clay		
State of Soil Surface:	Presence of salt crust on soil surface		
Vegetation type:	Samphire shrubland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	Very dense Samphire community, interpatches generally correspond with animal pathways. No sheetflow is evident and site appears to be in a stogle (very stable) condition. There is lots of woody material present.		

Bare Soil

Plant Hummock



General Site photo

Site name & ID:	Samphire Reference 2; SR2	LFA ID:	SR2_LFAJuly2012
Observers:	JEF & JER	Date:	4/07/2012
Start position (GPS):	727638E; 7527994N	Length:	9.3 m
Compass bearing:	212°		
Position in landscape:	Edge of salt marsh		
Slope and Aspect:	Flat		
Lithology:	Mara Mamba Formation overlain by tertiary detritals and alluvium		
Soils:	Sandy clay loam to sandy clay		
State of Soil Surface:	Presence of salt crust on soil surface		
Vegetation type:	Samphire shrubland		
Landuse:	Pastoral (cattle), mining and exploration adjacent		
Comments:	No overland flow is evident. This appears to be a salt flat possibly with very low flows of low velocity. This area experiences inundation (occasionally) (?rather than flowing).		

Plant Hummock

Grass Flat

General Site photo

Appendix D – Soil Data

Raw VMU Soil Data – Excel Spreadsheet Format.

GHD

GHD House, 239 Adelaide Tce. Perth, WA 6004
P.O. Box 3106, Perth WA 6832
T: 61 8 6222 8222 F: 61 8 6222 8555 E: permail@ghd.com.au

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	J Reid	J Hurter		A Napier		
B	J Reid	J Hurter		A Napier	A. C. Napier	25/3/2013

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