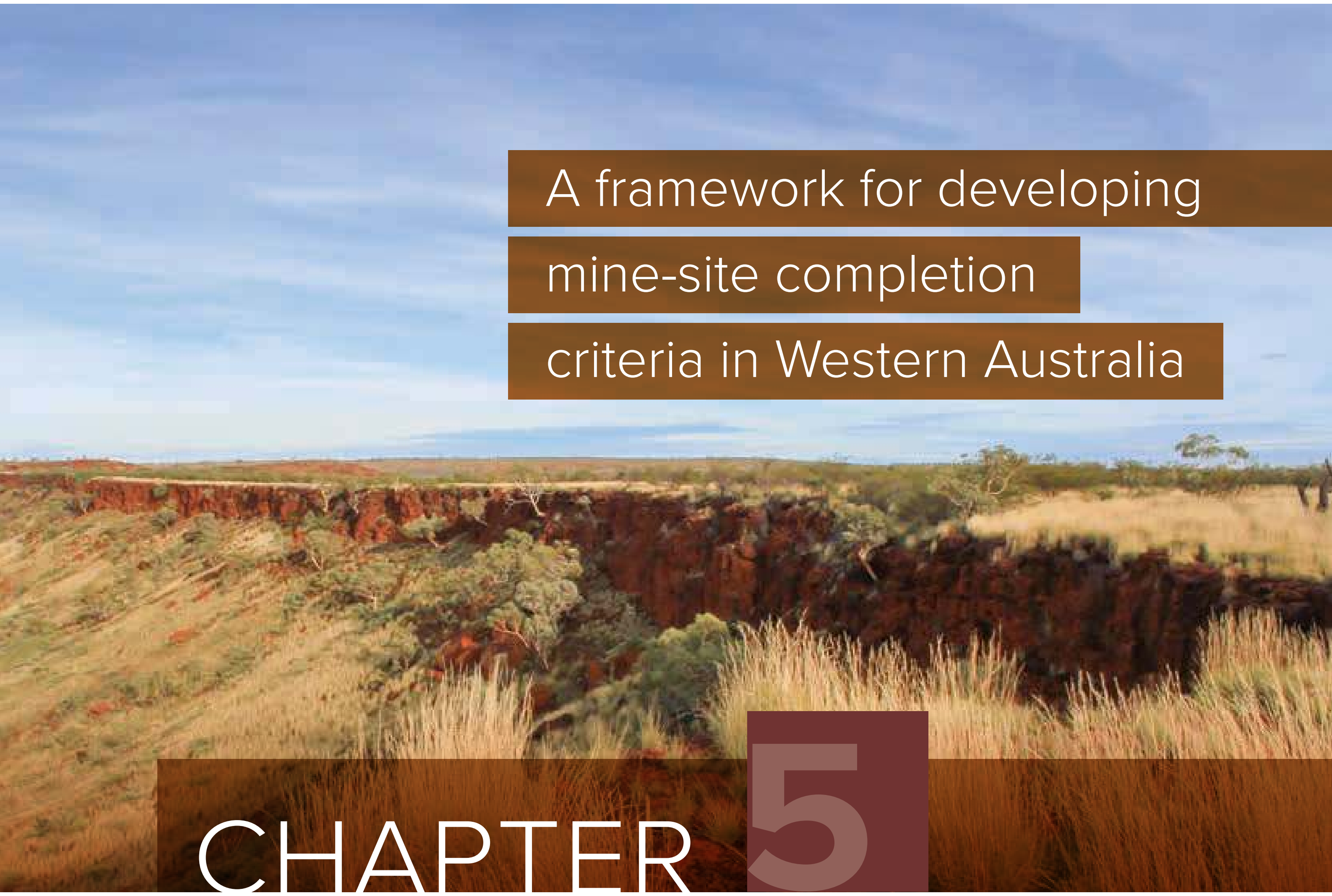

A framework for developing mine-site completion criteria in Western Australia

CHAPTER 5

Case Studies

(1 OF 7)

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The Western Australian Biodiversity Science Institute

5 CHAPTER

5 Case Studies

5.1 Introduction

Mine closure plans are publicly available but do not include the level of detail required to understand the context for, and history of, the development of completion criteria for mine rehabilitation. The purpose of this section is to present three case studies of mining operations in Western Australia. Specifically, the approach to, and experiences of, three mining companies in the development of completion criteria and monitoring outcomes appropriate to specific post-mining land uses is documented. This section provides some insights to industry, particularly to companies yet to embark on mine closure, by identifying examples of key challenges and opportunities for rehabilitation success. It also provides a record of what has been achieved to date within the current regulatory framework and availability of research to guide leading practice. Ultimately, by sharing lessons learned with industry, regulators, environmental consultants, researchers and other stakeholders, this report aims to increase efficiencies for best practice mine rehabilitation moving forward.

5.2 Selection of case studies

Case studies included in this section were selected through a stakeholder consultation process. Five key themes were identified, which would be used to select the case studies (Table 5.1). The first theme is bioregion, which defines mining activity according to underlying geology, and biophysical constraints to mine rehabilitation especially climate and diversity of native vegetation. There are at least 27 bioregions in Western Australia based on climate, geology, landform, native vegetation and species information (Thackway and Cresswell 1995). This Interim Biogeographic Regionalisation for Australia (IBRA) classification is more detailed than John Beard's original vegetation maps of the state, which include just seven regions: Kimberley, Great Sandy Desert, Great Victorian Desert, Nullarbor, Pilbara, Murchison and Swan (Beard 1990). Neither the IBRA nor Beard bioregions correspond to the nine socio-economic regions recognised by the Government of Western Australia (*Regional Development Commissions Act 1993*). Mining activity dominates the economy of six of the nine socio-economic regions: Kimberley (Diamonds, zinc, lead, nickel), Pilbara (iron ore, manganese), Gascoyne (salt, gypsum), Mid-west (iron ore, gold, nickel), Goldfields-Esperance (gold, nickel, platinum) and Peel regions (bauxite, mineral sands).

Photo courtesy: Mike Young

TABLE 5.1 Themes capturing key challenges for mine rehabilitation and closure in Western Australia

Theme	Theme categories
1. Biogeographic region	Between 7 and 27 bioregions depending on classification system
2. Socio-economic region	• Pilbara • Goldfields-Esperance • Peel or Mid-west • Other e.g. Kimberley
3. Company size	• Small • Divestment • Large
4. Type of mine	• Surface mining (e.g. mineral sands, bauxite) • Open cut (e.g. gold, iron ore)
5. Mine life stage	• Early stage (< 10 years) • Mature (>10 years) and sole operator • Mature (>10 years) and multiple consecutive operators

Besides geographic location, case studies were selected according to the characteristics of the company and mine (Themes 3 to 5 in Table 5.1), which typically impact their capacity and challenges in the development of completion criteria and rehabilitation. Unfortunately, despite approaching several companies in the Goldfields, the project research team was unable to recruit a case study. One company did not respond to the invitation and three declined, indicating lack of sufficient experience to serve as case studies on rehabilitation and closure planning.

The Pilbara Region was prioritised given the significant impact of iron ore mining on the state's economy and the capacity for industry in the region to set a state-wide standard for best practice rehabilitation. Thus, the Pilbara case study consisted of the BHP Billiton Goldsworthy Northern Area mining project.

The second case study, Mount Gibson's Tallering Peak in the mid-west, was selected as an example of a mid-size company with successful definition and achievement of completion criteria. Lastly, Alcoa was included given its vast, internationally recognised experience in mine site rehabilitation in the Northern Jarrah Forest. Alcoa is one of the few companies to have achieved mine closure and relinquishment in Australia.

For each case study, a template of information was completed pertaining to the development of completion criteria and the company's experience of mine closure. Details were extracted from the published and grey literature in the first instance. In a second phase, knowledge gaps were filled by conducting personal interviews with industry personnel.

Photo courtesy: Mike Young

5.3 Summary of case studies

The case study component reports how three mining companies have approached the development of their completion criteria and associated monitoring program. Each case study includes the context for mine rehabilitation and finishes with future opportunities (Table 5.2). This section contains case studies for:

- BHP — Goldsworthy Northern Areas
- Mount Gibson Iron — Tallering Peak
- Alcoa — Northern Jarrah Forest.

TABLE 5.2 Case study summary

Company	BHP Western Australia Iron Ore	Mount Gibson Iron	Alcoa of Australia
Size of company (per stock exchange)	AUD 3.21 billion	AUD 0.6 billion	AUS 16.15 billion (Global company worth)
Case study	Goldsworthy Northern Areas	Tallering Peak	Northern Jarrah Forest
Mineral resource	Iron ore	Iron ore	Bauxite
Mining activity	Open cut	Open cut	Surface
Economic region	Pilbara	Mid-west	Peel
Climate	Semi-arid	Semi-arid	Mediterranean
Soils	Shallow soils over banded ironstone formations	Shallow soils over banded ironstone formations	Lateritic (gravelly)
Native vegetation	Hummock grassland	Shrubland	Jarrah forest
Pre-mining land use	Livestock grazing	Livestock grazing	Selective logging, recreational, water catchment
Closest town or city	Port Hedland	Geraldton	Perth
Key stakeholders	Pastoralists, local Aboriginal communities	Pastoralists	City dwellers
History of mining in region	1960s (iron ore); 1890s (gold)	Iron ore discovered in Tallering Range in 1871	1960s (bauxite)
Inherited land use legacies	Grazing impacts	Grazing impacts	Large, old trees with nest hollows reduced by logging
Post-mining land use	Probably livestock grazing but yet to be confirmed	Livestock grazing	Conservation, recreational, water catchment
What needs to be rehabilitated?	Waste rock dumps, pit lakes, mesa landforms, vegetation, fauna, ecosystem functions	Waste rock dumps, pit lakes, vegetation, ecosystem functions	Landform, vegetation, fauna, ecosystem functions
Rehabilitation challenges	Altered hydrology, acid pit lakes, landform stability, spatial scale, limited topsoil, intermittent rainfall, remoteness	Altered hydrology, landform stability, spatial scale, limited topsoil, intermittent rainfall, acid pit lake, feral grazers	Altered hydrology, recalcitrant species, phytophthora
Achieved mine closure?	Pending	Pending	Yes
Achieved relinquishment?	Pending	Pending	Yes, to DBCA
Legislative framework	State agreement	*Mining Act 1978*	State agreement

5.4 Results

The selected case studies have been instrumental in informing the framework for definition of completion criteria. While each case study provides a unique set of lessons learnt (see sections below), several common themes emerged.

First, the definition of completion criteria needs to be based on a clear outcome, which will then dictate the rest of the process. In the case of BHP, this is referred to as 'outcome-based' hierarchy for closure and rehabilitation (Source: BHP Billiton (2017) Figure 5.4). The hierarchy or step-wise process, as it is defined in the framework, should be in line with the overarching guiding principles of ensuing the site is safe, stable, non-polluting and able to self-sustain the agreed post-mining land use (DMP & EPA 2015).

Second, the references against which completion criteria are defined should not necessarily be limited to baseline conditions or analogues sites, which are the two most commonly used references at present time in Western Australia. Instead, targets where appropriate should be informed by a suite of conditions, drawn from various sources which may include field and laboratory trials. For example, BHP set completion criteria based on a rehabilitation trial that demonstrated the ability to regenerate following burning, in terms of key parameters such as vegetation cover, richness and density (Table 5.4). Similarly, Mount Gibson conducted Landscape Function Analysis (LFA) and vegetation monitoring on a rehabilitation trial in the waste landforms. The purpose was to analyse soil chemistry, test rehabilitation techniques for supporting vegetation growth and determine optimal seed mix for rehabilitation (see Section 5.6.2). As part of its extensive research program, Alcoa used evidence from permanent monitoring plots and research trials to show that understorey cover density and richness are within the respective ranges observed in forest reference sites (see Section 5.6.3).

Besides the company's own knowledge base, it is important to consider the guidance from a broad range of sources for the definition of completion criteria. While the industry survey (Table 4.5) shows that most proponents only refer to one or two key guiding documents, a large number of guiding documents and polices exist that can be useful in the definition of completion criteria. A concise, yet informative list of such documents is presented in the Mount Gibson case study (see Section 5.6.2).

Interestingly, industry-driven research and regulatory requirements can be progressed in a mutually beneficial manner, whereby rehabilitation success is driven by innovation, rather than regulation. Each of the companies featured in our case studies show the positive outcomes of prioritising innovation and achievements beyond the minimum standard. For decades, Alcoa has heavily invested in its own cutting-edge research program to understand the opportunities and limitations in terms of rehabilitation of the mines in the Northern Jarrah Forest. The lessons learnt from such research have thus been key to inform rehabilitation standards in Western Australia, and internationally. While for most mining operators it is common practice to adhere to their minimum legal requirements, Alcoa has shown that aiming at the highest standards has allowed them to remain compliant in the long term, even as regulation become stricter overtime. In the Pilbara, BHP's investment in research has substantially improved rehabilitation outcomes for the Pilbara region.

A key benefit of rehabilitation research is its use in the development of leading indicators i.e. those that can be measured at early stages of rehabilitation and that provide an accurate estimation of future rehabilitation success. As noted by BHP (Section 5.6.1), closure outcomes are controlled by planning, design and execution activities and, thus, leading indicators should focus on provision of a suitable growth medium and local plant species. Some practical examples of leading indicators can be found in Mount Gibson's use of LFA (Section 5.6.2) or Alcoa's use of legume count as a proxy for soil nitrogen (Section 5.6.3).

The success of rehabilitation of mine sites is assessed on several indicators, although it is typically understood that some may be more critical than others. To make such distinction, BHP employs a risk-assessment process that ranks knowledge gaps based on their potential to negatively impact closure outcomes (see Section 5.6.1). Consequentially, high-priority knowledge gaps are associated with the necessary research programs in order to define detailed completion criteria that will ultimately support relinquishment.

Through the mine closure planning process, rehabilitation outcomes should be regarded as dynamic, and thus revised in successive version of mine closure plans as appropriate. The three case studies exemplify how closure objectives and completion criteria are revised in an iterative manner. As mining operations progress and change occurs, for example as a result of stakeholders' concerns or environmental factors, it is necessary that closure planning and rehabilitation practices adapt to such changes. For example, BHP employs an adaptive management approach (Source: BHP (2018) Figure 5.5), whereby knowledge gaps are repeatedly addressed as potential risks or impacts are better understood. Similarly, Alcoa carries out early assessments of rehabilitation status against the set completion criteria, which then trigger the undertaking of corrective actions, where needed (see Section 5.6.3).

In order to inform the need for corrective action, data monitoring should be carried out at regular intervals and be targeted at those indicators that serve to define rehabilitation success. Alcoa's accurate monitoring scheduling (e.g. at nine and 15 months — see Section 5.6.3) allows the tracking of progress along the desirable rehabilitation trajectory. In this way, the risk of non-fulfilment of completion criteria is minimised, as outcomes diverging significantly from the set targets can be addressed at early stages of rehabilitation. Advances in monitoring technology, as used by all three featured companies, are already providing dramatic improvements in the way data is collected and used for assessing rehabilitation success.

Finally, the three case studies feature in this report illustrate the need to assess rehabilitation success in a holistic manner, and not only as a compilation of independent criteria. For instance, BHP develops criteria across mine areas and domains in a way that failure to achieve a certain criterion in certain areas does not automatically mean that the land is unsuitable for its intended purpose (Section 5.6.1). Such a holistic approach becomes critical in situations such as that experienced by Mount Gibson's Tallering Peak. Although the mine was close to meeting all completion criteria in 2016, a dry spell throughout 2017 resulted in one vegetation criterion falling slighting below its agreed level in one particular area of the site.

5.5 Conclusions

The case studies highlight the different journeys companies undertake to rehabilitate their mining activities. Creating a framework to guide the development of completion criteria and risk-based monitoring programme for mine rehabilitation in Western Australia. Indeed, the experiences of the three mining companies reinforce the ample variation in rehabilitation contexts, including differences in minerals, extraction processes, landscape, climate and legislative requirements. Despite context dependencies evident in development of mine completion criteria, the three case studies provide some common lessons to guide future development of completion criteria for mine rehabilitation and closure. The methodology used could serve as a template for creation of additional case studies.

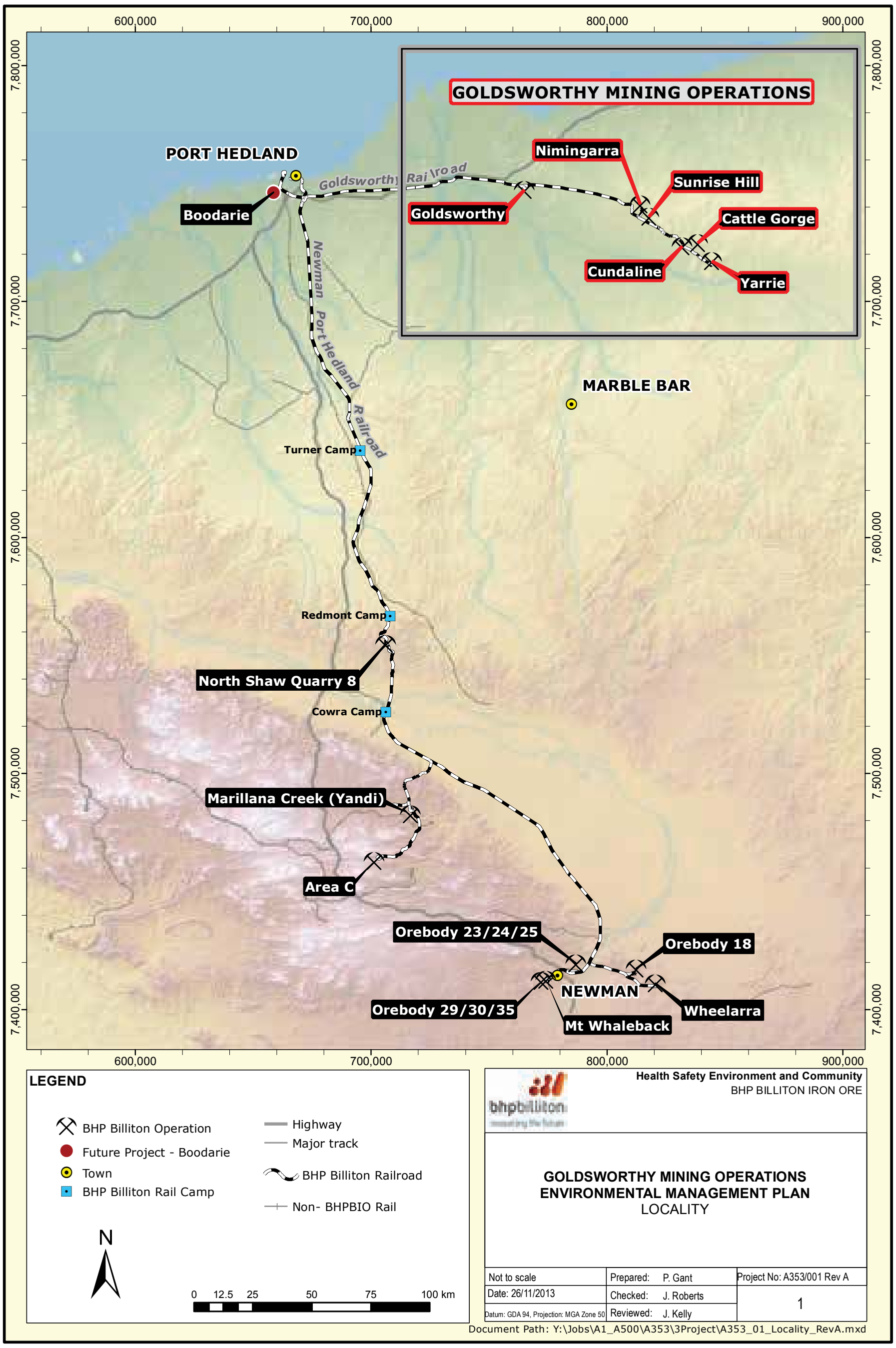
Photo courtesy: BHP

5.6 Appendices – Case studies

5.6.1 BHP – Goldsworthy Northern Areas (GNA)

Background

Goldsworthy Northern Areas (GNA) is located 178km east of Port Hedland (Source: BHP Billiton (2013) Figure 5.1). The GNA Hub consists of eight mines located in two areas; Yarrie (comprising Yarrie, Cattle Gorge, Cundaline and Callawa mines) and Nimingarra (comprising Nimingarra, Midnight Ridge, Shay Gap and Sunrise Hill mines). The Goldsworthy mine and associated former townsite are not part of the GNA Hub.



Source: BHP Billiton (2013)

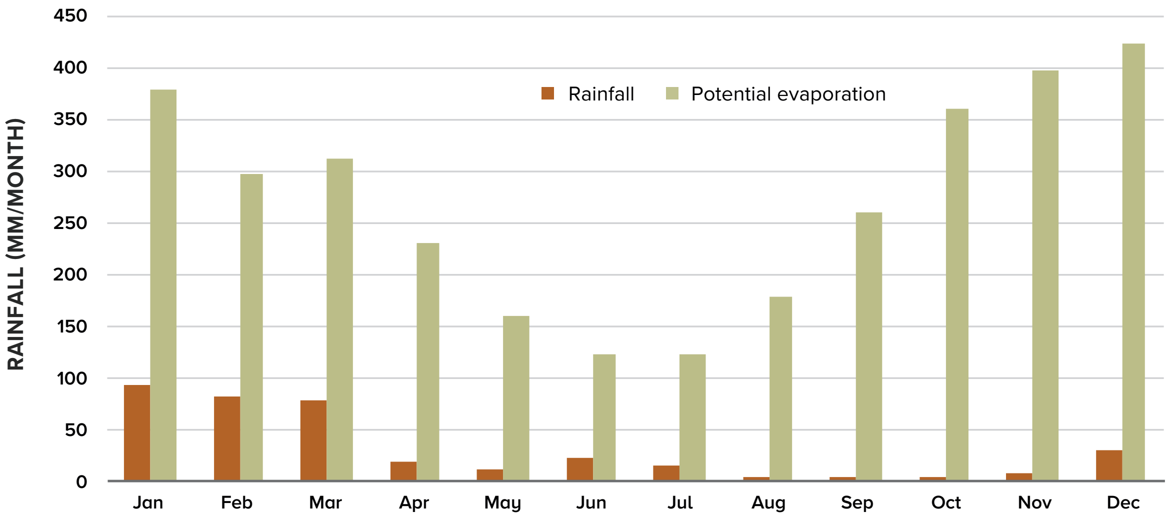
FIGURE 5.1 Location of Goldsworthy Northern Areas

ENVIRONMENTAL CONTEXT

The Goldsworthy-Nimingarra ores are predominantly high-grade microplaty hematite lode ores, distinct in character and origin from ore at other BHP mines in the region as they are developed within the approximately three-billion-year-old Archean granite-greenstone terrane. Deposits are distributed in a thick sequence of banded iron formation (BIF) in the Cleaverville Formation along the northern margin of the exposed Pilbara Craton (BHP 2011). The geomorphology consists of low rocky hills, plateaux and ridges with wide sandy plains containing ephemeral creeks (Dames & Moore 1992). Soils are skeletal, shallow, stony soils on the hills and ridges and sandier on the plains (Van Vreeswyk *et al.* 2004). As one of the oldest land surfaces on earth, it hosts exceptionally high biotic diversity and endemism (Pepper *et al.*, 2013), although much of the biodiversity and its conservation status still remain undescribed (EPA 2014).

The Pilbara has a semi-arid to arid climate with highly variable rainfall averaging 200mm to 350mm and an annual evaporation rate of over 4000mm (Johnson & Wright 2003). The Goldsworthy weather station recorded annual rainfall extremes of 72mm and 736mm, with an average of 329mm over 26 years of recording (BoM 2018). GNA experiences annual mean maximum temperatures of 28–40°C with extremes over 49°C (BoM 2018).

Rainfall events are infrequent, irregular and intense, with the majority of rain associated with tropical storms during summer (Source: DPIRD (2018) Figure 5.2). The boom and bust rainfall contributes to irregular seedling recruitment events and limits opportunities for vegetation establishment in mine rehabilitation, so the timing of rehabilitation events to coincide with expected rainfall is critical to their success (Lewandrowski et al. 2017a,b; Muñoz-Rojas *et al.* 2016b).



Source: DPIRD (2018)

FIGURE 5.2 Comparison of monthly rainfall to potential evapotranspiration for Marble Bar

Mining operations are situated at the north-east edge of the Fortescue botanical district which is a recognised biodiversity hot spot (Carwardine *et al.* 2015). Trees and shrubs are sparse except along watercourses and vegetation typically comprises 83% hummock grassland with 2% trees, 2% tall shrubs, 5% low shrubs and 8% tussock (Van Vreeswyk *et al.* 2004). In 1992, at the time of assessing the environmental impact of Yarrie mine, vegetation species were noted to be widespread across the area with no rare flora identified (Dames & Moore 1992).

Fauna surveys observed that birds, amphibians and reptiles present were common and widespread but the possible presence of conservation significant species were noted including the Pebble-mound Mouse (*Pseudomys chapmani*), Bilby (*Macrotis lagotis*), Mulgara (*Dasycerus cristicauda*), Lesser Stick-nest Rat (*Leporillus apicalis*), Grey Falcon (*Falco hypoleucos*), Pilbara Rock Python (*Moreila olivaceus barroni*), Peregrine Falcon (Falco peregrinus), Long-tailed Dunnart (Sminthopsis longicaudata), Woma Python (Aspidites ramsayi), Rothschild's Rock Wallaby (*Petrogale rothschildi*), Orange Horseshoe-bat (*Rhinonicteris aurantius*) and the Ghost Bat (*Macroderma gigas*) (Dames & Moore 1992). The relatively small land area affected by mining (270ha total disturbance at Nimingarra-Yarrie) (BHP Billiton 2013) may have protected native flora and fauna from the impacts of mining. However, the specific habitat requirements of some species make them especially vulnerable to mining impacts, such as bat roost destruction or disturbance (Armstrong 2010).

Photo courtesy: Lochman Transparencies

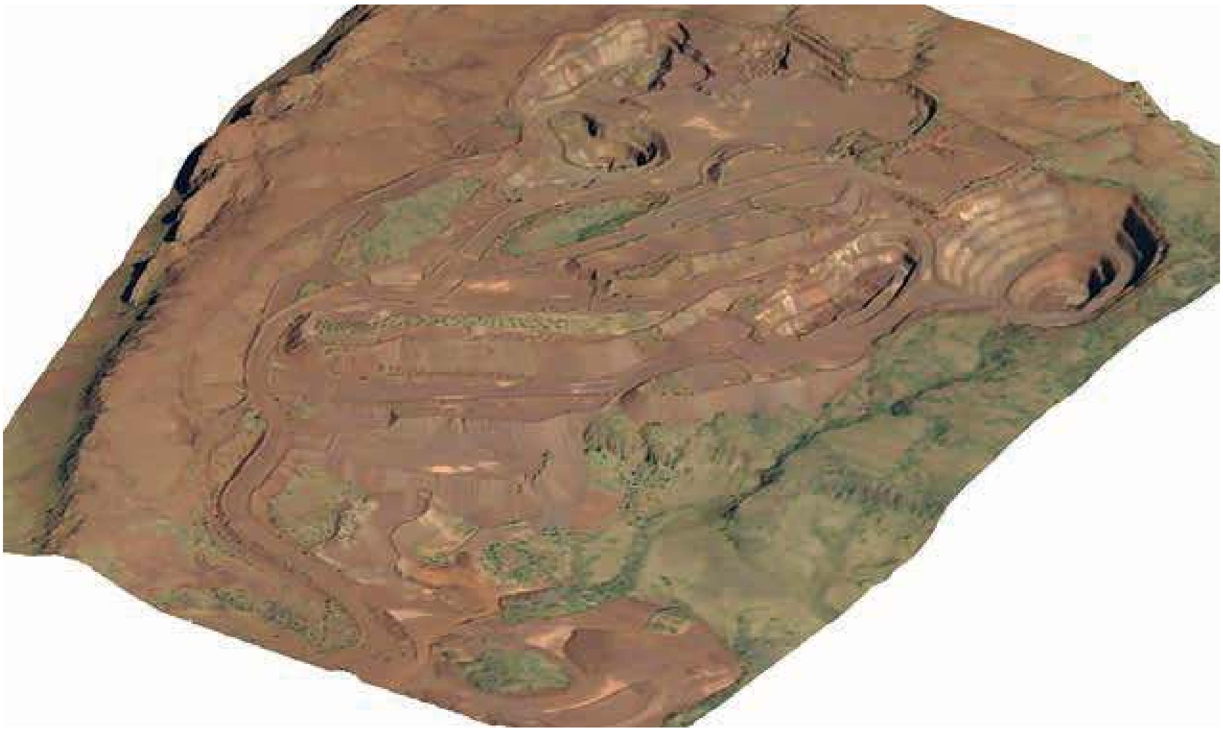
PREVIOUS LAND USE

The Goldsworthy region was originally home to the Njamal people, with the closely related Ngarla to the west. The Traditional Owners describe the area as good for hunting and ochre collection and state that spiritual obligations to country still exist despite mining activity (Brown (on behalf of the Ngarla People) v State of Western Australia 2010; Smith 2002). Njamal people continue to live in the area in the nearby towns of Marble Bar, Nullagine and Port Hedland and have been engaged in relation to mine closure planning (BHP Billiton 2013).

The mining leases (established 1964) are mostly located on the pastoral leases of Muccan Station (established 1879) and Yarrie Station (established 1888). These stations historically ran up to 20,000 sheep but now operate as cattle stations around the mines. The surrounding land comprises unallocated crown land and pastoral leases including the Pardoo, Warrawagine, Coongan and De Grey stations.

MINING OPERATIONS

Mining at Shay Gap and Sunrise Hill was approved in 1972 and at Nimingarra in 1986. BHP acquired full ownership of the mines from Mount Goldsworthy Mining in 1991 and developed the Yarrie, Cattle Gorge and Cundaline mines between 1992 and 2009. BHP commenced progressive rehabilitation in 1995. In 2014, mining operations were suspended and a stewardship program of ‘no regrets’ demolition and rehabilitation is currently underway. In 2016 Cattle Gorge was rehabilitated as part of this stewardship program and is the most recent example of rehabilitation at the GNA Operation (Figure 5.3).



BEFORE

AFTER

FIGURE 5.3 Cattle Gorge before (top image) and after (bottom image) rehabilitation

The mining method employed at GNA was conventional drill, blast and haul with overburden either backfilled or stored in overburden storage areas (OSAs) (BHP Billiton 2013).

TABLE 5.3 Key closure features

Features	Mining area	Characteristics (mine voids) and rehabilitation status (OSAs)
Mine voids	Nimingarra	Three pits above water table and seven below water table
	Midnight Ridge	Above water table
	Sunrise Hill	Thirteen pits above water table and four below water table
	Shay Gap	Three pits above water table and three below water table
	Cundaline	Three above water table pits
	Cattle Gorge	One pit backfilled to above the water table and two above water table pits
	Yarrie	Four backfilled pits, four partially backfilled, two below water table pits and remaining pits above water table
Overburden Storage Area (OSA)	Nimingarra	Several OSAs were rehabilitated in 1995. Some are yet to be rehabilitated.
	Midnight Ridge	Rehabilitated
	Sunrise Hill	Several OSAs were rehabilitated circa 1995. Some are yet to be rehabilitated.
	Shay Gap	Town site rehabilitated circa 1995
	Cundaline	Two OSAs not yet rehabilitated
	Cattle Gorge	OSAs rehabilitated 2016
	Yarrie	Rehabilitation campaigns in 1998, 2003, 2004, 2009, 2010-11. Some OSAs still to be rehabilitated.
Infrastructure	Includes process infrastructure (e.g. crusher, conveyors, stackers) and non-process infrastructure (e.g. workshops, fuel storage, offices, water and power supplies)	
Roads and access tracks		

Source: BHP (2018)

Methodology

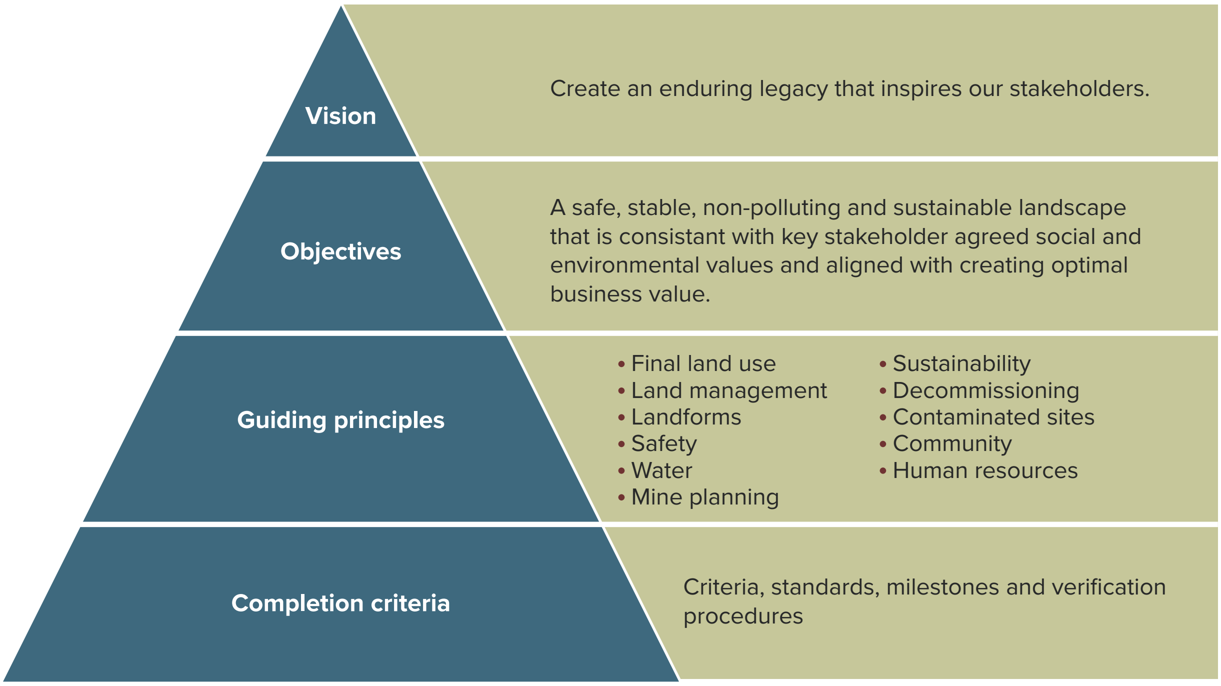
Research was split into three phases. Firstly, a site visit to Yarrie, Cattle Gorge, Nimingarra, Shay Gap and Goldsworthy was hosted by BHP staff on 7th–8th May 2018 to observe examples of rehabilitation completed over a 25 year period. Members of the WABSI Completion Criteria Project team travelled to site as guests of BHP.

Secondly, a document review was completed, primarily involving internal documents supplied by BHP and regulatory documents. Lastly a semi-structured interview was conducted via telephone with key personnel from the mining company. The aim of the interview was to fill knowledge gaps evident after the document review or to provide more detail on specific emergent themes. Results from the multiple information gathering methods were synthesised into a report addressing the research objectives outlined above.

Results

REHABILITATION OBJECTIVES

BHP's outcomes-based hierarchy for closure and rehabilitation is outlined in (Source: BHP Billiton (2017)) Figure 5.4.



Source: BHP Billiton (2017)

FIGURE 5.4 Outcomes Based Hierarchy

BHP's overarching objective for closure is to develop a safe, stable, non-polluting and sustainable landscape that is consistent with key stakeholder agreed social and environmental values and aligned with creating optimal business value (BHP Billiton 2013).

This objective is supported by a number of guiding principles (BHP 2018):

- **Informed planning and design:** rehabilitation and decommissioning requirements are considered at a mine deposit and regional scale, upfront and integrated into mine plans to achieve optimal business value and a sustainable final land use.
- **Sustainable final land use:** Final land use and rehabilitated areas meet stakeholder expectations and consider the following:
  - Local land management practices
  - Ongoing management requirements (e.g. roads and tracks)
  - Closure landform integration, including visual impacts, landform stability (physical and geochemical) and hydrological regimes
  - Local baseline conditions (e.g. flora, vegetation, fauna and fauna habitat)
  - Ecosystem resilience in terms of flora, vegetation, fauna, and surface and groundwater hydrology
  - Infrastructure transfer or decommissioning
  - Management or remediation of contaminated sites
  - Amenity

- **Safety:** All mine rehabilitation and decommissioning is planned so that the risks to health and safety of people within the BHP Western Australian Iron Ore's (WAIO) area of influence are minimised. Unauthorised public access risk will be managed through the implementation of controls in accordance with regulatory requirements and consideration of industry guidance.
- **Effective stakeholder engagement:** Transparent and proactive stakeholder engagement occurs for all planned activities that may impact surrounding communities, including consideration of communities impacted by closure.

Post-mining land use

Post-mining land use is the one of BHP's key guiding principles and plays a significant role in closure and rehabilitation planning. Important factors that are considered in the planning process to determine post-mining land use include:

- Meaningful stakeholder engagement
- Capacity of the land to support potential post-closure land uses
- Long-term environmental and demographic trends
- Regulatory and tenure requirements
- Proximity to communities, major infrastructure, water sources, conservation estates and areas of high biodiversity (BHP Billiton 2017).

The post-mining land use has yet to be confirmed with stakeholders but, given that GNA is located predominantly on pastoral tenements, the overarching post-mining land use for the area is proposed to be 'low-intensity grazing'. However, taking into account the capacity of the land to support these uses, BHP acknowledges that, at this stage, residual mine voids may not support a specific land use due to ingress and egress restrictions (BHP Billiton 2013). The productive use of areas disturbed by mining (including mine voids) is an area that is rapidly evolving and there are a number of examples of productive uses of mine voids in Australia and overseas (for example, pumped hydro-electricity scheme at Kidston mine in Queensland (GENEX 2017) and the landfill bioreactor at Woodlawn in New South Wales (Veolia 2017)).

GNA is located in an area that is being independently assessed for other regional development opportunities such as irrigated agriculture (DPIRD 2018) and solar power generation (Mella *et al.* 2017). These potential uses have not been specifically factored into GNA's completion criteria, but the current pastoral end land use will not prevent alternative future uses from being implemented.

Completion criteria development

GENERAL PRINCIPLES

Completion criteria are 'agreed standards of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area ceases' (LPSDP 2016e). BHP's completion criteria cover the full scope of its guiding principles (see General Principles, above) and are progressively developed over the life of the mine with increasing detail and refined metrics over time (BHP Billiton 2017).

BHP recognises that closure outcomes are controlled by planning, design and execution activities. BHP's criteria, therefore, include both leading indicators describing the activities and designs necessary to achieve desired outcomes (e.g. landforms have been designed and constructed to take account of waste characteristics affecting stability), as well as lagging indicators which describe closure outcomes to be achieved (e.g. total native perennial vegetation cover to be ≥ 20%).

The land to which criteria are applied is altered fundamentally from its pre-existing condition. Criteria, therefore, need to be site specific and focus on what is required to make the land suitable for its end land uses rather than attempt to recreate a pre-mining environment. Not all criteria will apply to all areas of the site, particularly at a site like GNA that spans a wide area. The site may be split into sub-units to reflect different:

- Land capabilities
- Surrounding environmental conditions
- Stakeholder views and land use requirements.

One of the key challenges in developing and applying criteria is the inherently variable nature of the natural environment. Similar undisturbed areas often have different characteristics (spatially and temporally) and there have been instances where companies have developed numerical completion criteria that are not met by analogue sites. The Botanic Gardens and Parks Authority (BGPA) made the observation that the higher abundance of weed species in rehabilitation, relative to their abundance in analogues, could be a result of the unconscious selection of analogue sites that are unrepresentative of the broader rangeland landscape (BGPA 2017). The process of selection of analogue sites involves professional consultants reading the local landscape in the vicinity of planned rehabilitation and selecting undisturbed sites that are deemed to be appropriate analogues for a desired future state of the rehabilitation. This process would bias analogue sampling to be unrepresentative of the broad landscape and instead be representative of an ideal state. Analogues need to be used with care since the underlying structure of the mined landforms differs completely from natural landforms.

With this challenge in mind, BHP develops criteria which are intended to be viewed holistically across relevant domains and areas of the site such that failure to achieve certain criteria in some areas, does not automatically mean that the land is unsuitable for its intended purpose. The criteria are structured to:

- Clearly articulate the objective of each criterion — i.e. the intent of what should be achieved in closure.
- Describe the standard or milestone that is intended to be achieved. While a number of these standards may not be numerical, the qualitative descriptions define the expected actions or outcomes and are measurable through monitoring and audit. BHP's ongoing monitoring and research programs are designed to facilitate the development of numerical targets where these will add value to the assessment of closure outcomes.
- Define how BHP will demonstrate that a criterion has been met. The verification procedures outlined in BHP's criteria outline what is required to be measured to demonstrate achievement of each criterion.

Where specific criteria are not met, the objectives outlined for the criteria help to determine whether the standard of closure and rehabilitation may be acceptable when viewed holistically across the site.

Industry's understanding of closure and rehabilitation practice and achievable outcomes has improved over time and is still evolving. BHP's approach to developing criteria is, therefore, to start with criteria which are weighted towards leading indicators and qualitative descriptions of acceptable outcomes and to refine these with numerical targets as the results of trials and research become available.

One of the challenges of long-lived mining operations is that both the socio-economic context and natural environment surrounding the operation evolve over the life of the mine. This may necessitate a change in criteria to reflect different end land uses or changes to the natural environment. While BHP's approach maintains flexibility, there comes a point where certain approaches have been implemented and the range of outcomes that may be achieved by an area may be limited by the approaches applied. For example, at GNA a number of landforms were rehabilitated in the late 1990s to the leading practice standards of the day. The outcomes achieved by these landforms may be different to those achieved by more recently rehabilitated landforms. In recognition of this, early era completion criteria have been proposed for older areas of rehabilitation at GNA (Table 5.4).

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
1.1 Final Land Use	Agreed final land use has been determined in consultation with relevant stakeholders.	All	• End land use for the area is considered likely to revert to pastoral activity, or the inclusion in some form of natural conservation area. However, this would be determined in consultation with stakeholders, and approved by the administering authority during the life of the mine. • Specific rehabilitation objectives have been developed to ensure that, when met, areas will fulfil the post-mining land use requirements.	No variation proposed.	• Land use objectives are documented in the GNA MCP as reviewed and agreed by the key stakeholders.
2.1 Safety	There are no unsafe areas where members of the general public could gain inadvertent access.	All	• All hazards that could endanger the safety of any person or animal have been identified and eliminated, where practical. • All residual safety and health hazards have been identified and controlled in accordance with regulatory requirements and consideration of industry guidance.	No variation proposed.	• All relevant regulatory guidelines have been met unless otherwise agreed with the regulator. • All sites are assessed as acceptable with regards to safety by the District Mines Inspector.
2.2 Landform Safety	Final landforms are safe.	All	• Landforms are designed and constructed to address safety risks as described in criterion 2.1. They conform to DMIRS guidelines for structural stability, with no significant slumping or failure of accessible constructed slopes or berms. • No unacceptable hazards to humans or wildlife have developed thorough erosion, subsidence, Acid Mine Drainage (AMD) or otherwise.	No variation proposed.	• Report on landform construction methods (not applicable to early era landforms), and any additional maintenance works undertaken. • Rehabilitation inspections (including undertaken on maintenance earthworks) confirm earthworks have met final landform designs. • Rehabilitation monitoring results (including erosion monitoring). • Report on performance in relation to design criteria and DMIRS guidelines. • Inspections of the rehabilitated landforms have been conducted to monitor their stability over time, with monitoring conducted after each significant rainfall season.

Table 5.4 continues following page...

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
3.1 Visual Amenity	Visual amenity of constructed landforms is compatible with that of local Pilbara landforms.	All except mine voids	Within the constraints imposed by aspects such as the physical nature of the materials available, tenement boundaries, and proximity to water courses, landforms have been constructed to blend into the surrounding landscape. Landforms are consistent with the agreed final land use (criterion 1.1).	No variation proposed.	• Report on rehabilitation works confirms landform construction undertaken according to WAIO relevant procedure. • Rehabilitation inspections confirm earthworks have met final landform designs.
3.2 Waste Characterisation	Materials with poor physical or chemical properties do not compromise rehabilitation (landforms stability and revegetation).	Anywhere problem materials present	• An overburden storage plan for any new OSA is developed and incorporated into the life of mine plan prior to the commencement of ex-pit dumping activities. • All overburden placement in new OSAs has been undertaken in accordance with this plan. Mine waste material likely to provide a poor growth medium (e.g. dispersive and incompetent material), has been placed appropriately in the OSA.	• OSAs have already been constructed and there is limited information on 'as constructed' design. A suggested criterion is therefore: • The landform is stable and there are no areas where mine waste material placed at the surface is resulting in unacceptable outcomes to landform stability.	• Waste characterisation report available for review (not applicable to early era landforms). • Report on landform construction methods (not applicable to early era landforms). • Rehabilitation inspections confirm earthworks have met final landform designs.
3.3 Landform Stability	Constructed landforms are structurally stable.	All	Post-mining landforms have been designed and constructed with consideration of waste characteristics affecting stability (physical and chemical). The design and construction methods conform to DMIRS guidelines for structural stability such as residual pit voids have been left as run-of-mine (ROM) where geotechnically stable.	• Landforms have already been constructed and there is limited information on 'as constructed' design. A suggested criterion is therefore: • Landforms are stable and show no significant slumping or failure of accessible constructed slopes or berms.	• Report on rehabilitation works at construction confirms safety and geotechnical guidelines have been met and sites constructed according to WAIO relevant procedure (not applicable to early era rehabilitation). • Rehabilitation Inspections confirm: • Earthworks have met final landform designs (not applicable to early era rehabilitation). • Landforms are stable.

Table 5.4 continues following page…

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
3.4 Surface Stability	The constructed surface is stable and showing no signs of significant erosion.	All	• Post-mining landforms have been designed and constructed taking into consideration the waste characteristics (physical and chemical). • Slope surfaces are stable, with no dispersive material on the surface; rock armouring is present as required and no areas are exposed to the risk of significant erosion which may be defined as having: • Channelised flow resulting in extensive active gullies; • Failure of banks, berms or bunds; and • Evidence of ongoing significant sheet erosion (including large accumulation of silt at base of slope, exposed subsoil, poor seedling establishment).	Landforms have already been constructed and there is limited information on 'as constructed' design. It is, therefore, suggested that the criterion focuses only on the outcomes i.e. that the landform is stable and does not have significant erosion, as defined in the criterion for recent rehabilitation.	• Report on landform construction methods (not applicable to early era rehabilitation), and any additional maintenance works undertaken. • Rehabilitation inspections (including undertaken on maintenance earthworks) confirm earthworks have met final landform designs (not applicable to early era rehabilitation). • Visual assessment and monitoring, taking into consideration the slope, available materials and vegetation cover and relevant research projects on surface stability of comparable rehabilitated landforms. • Rehabilitation monitoring results (including erosion monitoring) indicate gullies and rills are stabilising.
3.5 Landform Surface	Landform surface material promotes water infiltration and reduces erosion and crusting.	All (exc. mine voids and PAF material encapsulation OSAs)	Surface treatments (including ripping) undertaken to rehabilitated surfaces to maximise water infiltration, to reduce erosion potential and support establishment of vegetation.	• Not applicable. • Landforms have already been constructed and there is limited information on 'as constructed' design. Refer to outcome criteria in 3.4, 4.1 and 4.2.	• Report on landform construction methods. • Rehabilitation inspections confirm earthworks have met final landform designs.
4.1 Sustainability	Rehabilitation is sustainable, and the land capability and groundwater are suitable for the agreed end land use.	All where relevant	Monitoring, research data and site inspections indicate that the rehabilitation will be sustainable and will continue to fulfil rehabilitation objectives relating to the agreed final land use in terms of flora, vegetation, fauna, and surface and groundwater hydrology.	No variation proposed.	Documented in relevant monitoring and research reports; site inspections.

Table 5.4 continues following page...

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
4.2 Resilience	Vegetation is sustainable and resilient to likely impacts such as fire, drought and grazing (where applicable, if managed according to agreed guidelines)	All where relevant	• Monitoring and/or research results have shown that recruitment of native perennial species is occurring, or is likely to occur, on the site (e.g. evidence of flowering, fruiting, soil seed bank or second-generation seedlings). • Research trials in rehabilitation representative of the same age and technique have demonstrated its ability to regenerate following burning (in terms of key parameters such as cover, richness and density); rehabilitation has reached the age where plants are likely to tolerate fire or regenerate/reseed. • Monitoring has shown that the rehabilitation can survive one or more seasons of low rainfall.	Under development.	• Review of progress and performance of rehabilitation monitoring results, and related rehabilitation monitoring procedures. • Monitoring results reported in the AER. • Research findings from trials on representative rehabilitated areas investigating post-disturbance recovery of revegetation.
4.3 Growth Media	A suitable growth medium has been identified to facilitate plant establishment and growth	All where revegetation is planned	• Material placed on the outer surface of landforms takes into consideration the growth media characteristics required to support sustainable vegetation development. • The depth and characteristics of newly constructed landforms, surface soils and subsoils are suitable for plant growth in terms of their structure, water holding capacity and lack of materials that might affect plant growth or survival (i.e. they are suitable for establishing target vegetation communities and supporting the agreed final land use). • Soil stripping has been undertaken in accordance with the WAIO Rehabilitation Standards and Procedures. • Topsoil stockpiles have been managed following the WAIO Rehabilitation Standard and Procedures, and the relevant plans and databases have been prepared, updated and maintained. • Where available and appropriate to meet the landform design requirements, topsoil has been used to provide a suitable medium for plant establishment and a source of propagules.	• Not applicable. • Landforms have already been constructed and there is limited information on 'as constructed' design. Refer to outcome criteria in 3.4, 4.1 and 4.2.	• Topsoil reconciliation information available. • Review of baseline soil report (where available) and site waste characterisation report. • Report on landform construction methods. • Rehabilitation inspections confirm earthworks have met final landform designs. • Rehabilitation monitoring results provide feedback to determine suitability of growth medium.

Table 5.4 continues following page...

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
4.4 Provenance	Vegetation is locally endemic	All	All seeded/ selected plant species to be indigenous species of local provenance	Under development	• Site Rehabilitation Report including seed mix summary. • Seed Database. • Rehabilitation monitoring results.
4.5 Vegetation Development	Vegetation is suited to the agreed final land use	All with revegetation	• Established vegetative cover should be self-sustaining and similar to the surrounding undisturbed vegetation. • Monitoring of rehabilitated areas has been undertaken until it can be demonstrated that the landscape and vegetation are progressing towards a self-sustaining state. • Rehabilitation development stage density or cover target still to be developed. • The number of native perennial species shall be no less than the number recorded in comparable nearby vegetation that has not been disturbed. • Total native perennial vegetation cover to be ≥ 20%.	Under development	• Monitoring of vegetation reestablishment using WAIO Rehabilitation Monitoring Procedures. • Monitoring results reported in the AER. • Report on performance in relation to rehabilitation methods, using site inspection and rehabilitation monitoring sites to assess whether criteria have been met.
4.6 Weeds	Potential for rehabilitation to meet the agreed post-mining use is not limited by the presence of weeds	All areas with revegetation	• No Declared Pests (as defined under the Biosecurity and Agriculture Management Act 2007) are present in greater abundance than surrounding nearby vegetation. • Populations of environmental weeds have been monitored and controlled based on risk.	Under development	• Review of weed monitoring and control undertaken to ensure compliance with the WAIO Weed Management Procedure. • Report on weed monitoring and control records. • Measurement of weed abundance compared to representative reference sites, using cover or counts (as appropriate according to the species). • Monitoring and visual inspection of vegetation establishment and representative reference areas.

Table 5.4 continues following page...

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
4.7 Fauna Recolonisation	Revegetated areas provide suitable fauna habitat	All where opportunities exist	• As per the WAIO Rehabilitation Standard and Procedures include, where practical, the creation of habitat features similar to those found in the GNA Hub area prior to mining. Habitat creation initiatives include, but are not limited to, the following: • Creation of rock piles in OSAs and/or mine void areas to provide potential habitat opportunities for reptiles and mammals; • Return of vegetation debris, logs and rocks to areas which have been disturbed to provide microhabitats for recolonising fauna; • Creation of rocky cliff features, which may include small hollows and cracks suitable for reptiles and mammals; • Vegetation includes locally endemic species of known importance to fauna. • Signs of fauna recolonisation are apparent including (but not limited to) scats and presence of invertebrates; • Vertebrate pests (rabbit, dingo, donkey, goat and cat) have been controlled, where necessary.	• Landforms have already been constructed. A suggested criterion is therefore: • Signs of fauna recolonisation are apparent including (but not limited to) scats and presence of invertebrates. • Vertebrate pests (rabbit, dingo, donkey, goat and cat) have been controlled, where necessary.	• Rehabilitation inspections confirm earthworks have met final landform designs (not applicable to early era rehabilitation). • Fauna habitat assessment using site inspection and evaluation of vegetation monitoring results. • Vertebrate pest species have been controlled, as required.
5.1 Surface Water	Rehabilitation drainage patterns have been established and impacts on natural surface water flows are acceptable at key receptors	All where relevant	• There are no significant, physical off-site impacts at key receptors as a result of WAIO's operations. • Baseline conditions for surface water quality and flow regimes in Eel Creek, Egg Creek and the De Grey River have been maintained to an acceptable level. • Surface water quality should fall within guidelines for specific-end land use (e.g. stock watering requirements).	No variation proposed	• Documents reviewed and signed off as required. • Surface water sampling results from within Eel and Egg Creeks and the De Grey River indicate no significant impact from the GNA Hub. • Monitoring results reported in the AER and Annual Aquifer Review (as required). • Site inspection to verify no unplanned impacts on surrounding natural drainage patterns.

Table 5.4 continues following page...

TABLE 5.4 Goldsworthy Northern Areas completion criteria

Criterion	Criterion objective	Domain	Criterion standard or milestone	Proposed variation to criterion for early era rehabilitation	Verification procedure
5.2 Groundwater	Mining-related impacts on groundwater (levels, quality and soil moisture) have been minimised	All where relevant	• There are no significant, physical off-site impacts at key receptors as a result of WAIO's operations. • Baseline conditions for groundwater regime (levels and quality) have been maintained to an acceptable level. Water resource quality is managed within predetermined criteria based on ANZECC & ARMCANZ (2000a).	No variation proposed	• Groundwater monitoring results indicate no significant impact from the GNA Hub. • Monitoring results reported in the AER and Annual Aquifer Review (as required).
6.1 Infrastructure	Infrastructure has been decommissioned and removed where transfer to a third party is not agreed	All where infrastructure exists	Agreement has been reached with Government regarding whether any infrastructure is required to remain post-mine closure. Infrastructure not required has been removed (and recycled/reused where practicable) and the site rehabilitated.	No variation proposed	Site inspection and documentation of infrastructure removal and rehabilitation operations.
7.1 Contaminated Sites	Contaminated sites have been documented and addressed	All where relevant	All commitments relating to the identification and management of contaminated sites, as per *Contaminated Sites Act (2003)* have been fulfilled.	No variation proposed	Report documenting compliance with specific requirements
8.1 Land Management	Long-term management requirements have been addressed	All	At the time mine closure is considered complete, site land management requirements will be no greater than those of areas prior to mining (or comparable unmined areas); alternatively, where additional management actions are required, these will be identified in agreement with regulators, and WAIO will make adequate provisions so that this additional management can be undertaken.	No variation proposed	Reports into sustainability and long-term management requirements identified in the monitoring and research carried out as per Criterion 4.

Source: BHP (2018)

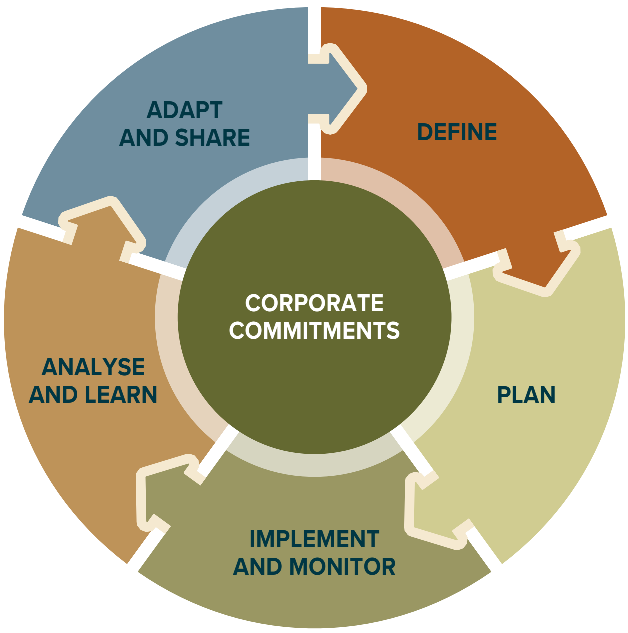
RISK MANAGEMENT

The physical and biological challenges to rehabilitation in the Pilbara include harsh temperatures, unpredictable rainfall, limited topsoil, hostile waste materials and poorly understood seed ecology (Risbey 2016).

As described above, BHP's approach is to refine completion criteria over time through research and monitoring. BHP uses the criteria framework to assist in identifying key knowledge gaps for each site which need to be addressed in order to develop more detailed criteria to support relinquishment. The knowledge gaps and associated research programs are prioritised through BHP's risk assessment process. The risk assessment process helps to identify those areas where there is a high potential for impact if a knowledge gap is not addressed. For example, in an instance where the local geology is known to contain erodible materials, having an inadequate understanding of the sources and quantities of competent waste at the outset of mining would be likely to have a significant impact on closure outcomes and the knowledge gap would be rated as a high priority.

The inclusion of planning and design criteria into the criteria framework prompts early consideration of the key issues that need to be addressed during these stages to enable outcome criteria to be achieved.

BHP employs an adaptive management approach to mine closure planning (Source: BHP (2018) Figure 5.5). As knowledge gaps are addressed during a mine's life and potential risks or impacts are better understood, BHP refines its management approach. In instances where potential impacts cannot be entirely avoided, the adaptive management approach allows for an evaluation of potential mitigation options and progressive refinement of preferred options over time to optimise eventual closure outcomes. As preferred options are honed, completion criteria are updated.



Source: BHP (2018)

FIGURE 5.5 BHP's adaptive management approach

GNA COMPLETION CRITERIA

The completion criteria for GNA are provided in Table 5 4. A brief description of selected criteria follows to illustrate how BHP has applied the principles described above, and some of the key challenges that have been encountered during the development and application of the criteria.

Criterion 3.1 Visual Amenity

A criterion for visual amenity is one that is difficult to apply numerical measures to as visual amenity is subjective. BHP's visual amenity criterion describes the outcomes as:

- Constructed landforms are compatible with that of local Pilbara landforms (objective)
- Landforms have been constructed to blend into the surrounding landscape (standard).

At GNA, BHP's landform design principles, which include preserving ridgelines and softening sharp edges, have achieved landforms that blend with natural landforms (Figure 5.6).

FIGURE 5.6 Cattle Gorge constructed landform (foreground), natural landform (background)

Sometimes optimal visual amenity outcomes are constrained by the physical nature of the materials available, tenement boundaries and proximity to water courses, particularly at older sites where closure considerations were not integrated into up front mine planning in the way that occurs now. In these instances, there may be a trade-off between visual amenity in terms of landform geometry and long-term landform stability (which may also have a visual impact). BHP's criterion recognises that there is a balance between short-term and long-term outcomes and acknowledges that there may be constraints to achieving a landform geometry with optimal visual outcomes within the criterion standard:

> *"Within the constraints imposed by aspects such as the physical nature of the materials available, tenement boundaries and proximity to water courses, landforms have been constructed to blend into the surrounding landscape"*

Criteria 3.2 to 3.5 Waste characterisation and landform stability

Criteria 3.2 to 3.5 have a strong focus on leading indicators as the outcomes of non-polluting and stable landforms are strongly influenced by whether problematic materials have been identified early and their placement has been incorporated in the mine plan such that impacts will be minimised.

The leading criteria mandate that:

- Materials characterisation is taken account of during landform designs
- An overburden storage plan be developed prior to commencement of ex-pit dumping activities
- Construction of landforms is in accordance with designs.

These criteria are all auditable and the criteria framework identifies the information that should be available to confirm conformance with the criteria (e.g. material characterisation reports and reports that confirm landforms have been constructed in accordance with designs).

In the case of the early era rehabilitation at GNA, it may be difficult to assess conformance with these leading indicators as there are limited records on materials characterisation and 'as constructed' designs. BHP, therefore, can only apply outcome criteria to these landforms.

The outcome criterion for erosion at GNA comprises a qualitative description of an acceptable outcome:

> *"Slope surfaces are stable, with no dispersive material on the surface; rock armouring is present as required; and no areas are exposed to the risk of significant erosion which may be defined as having:*
>
> - *Channelised flow resulting in extensive active gullies*
> - *Failure of banks, berms or bunds*
> - *Evidence of ongoing significant sheet erosion (including large accumulation of silt at base of slope, exposed subsoil, poor seedling establishment)".*

Erosion is a natural process and all the natural landforms in the Pilbara have been shaped by an erosion or deposition process. It is, therefore, a certainty that mine landforms will erode over time. The challenge in developing completion criteria is defining the acceptability of the erosion. To assist in further defining meaningful and relevant erosion criteria, BHP has contributed to a Pilbara Research Group project aimed at defining acceptable erosion rates for mine waste landform modelling in the Pilbara (Landloch 2018). In determining the impact of erosion and acceptable erosion rates, the project considered a wide range of factors including:

- Rates of soil formation
- Maintenance of soil quality, which may include considerations of:
  - Plant/crop productivity
  - Effective soil depth
  - Soil organic matter and nutrient stores
  - Rates of natural erosion in adjoining areas
  - Water quality impacts and
  - Potential for gully development.

The project recognised that different circumstances would apply to different sites and developed a risk matrix for assessing the risk of erosion from different landforms.

BHP broadly used guidance behind these criteria to design a concave slope landform at GNA with the available capping materials.

Criteria 4.2 to 4.6 Vegetation development and outcomes

There are a number of challenges in achieving revegetation of landforms in the Pilbara. These include:

- The Pilbara's arid climate and rainfall patterns which are characterised by isolated thunderstorms or cyclones during the summer months. These dramatic fluctuations in rainfall in the Pilbara mean that traditional revegetation methods, such as using nursery seedlings, are unlikely to succeed.
- Certain vegetation species seed only once every few years, which hinders annual revegetation works (BHP Billiton 2017).

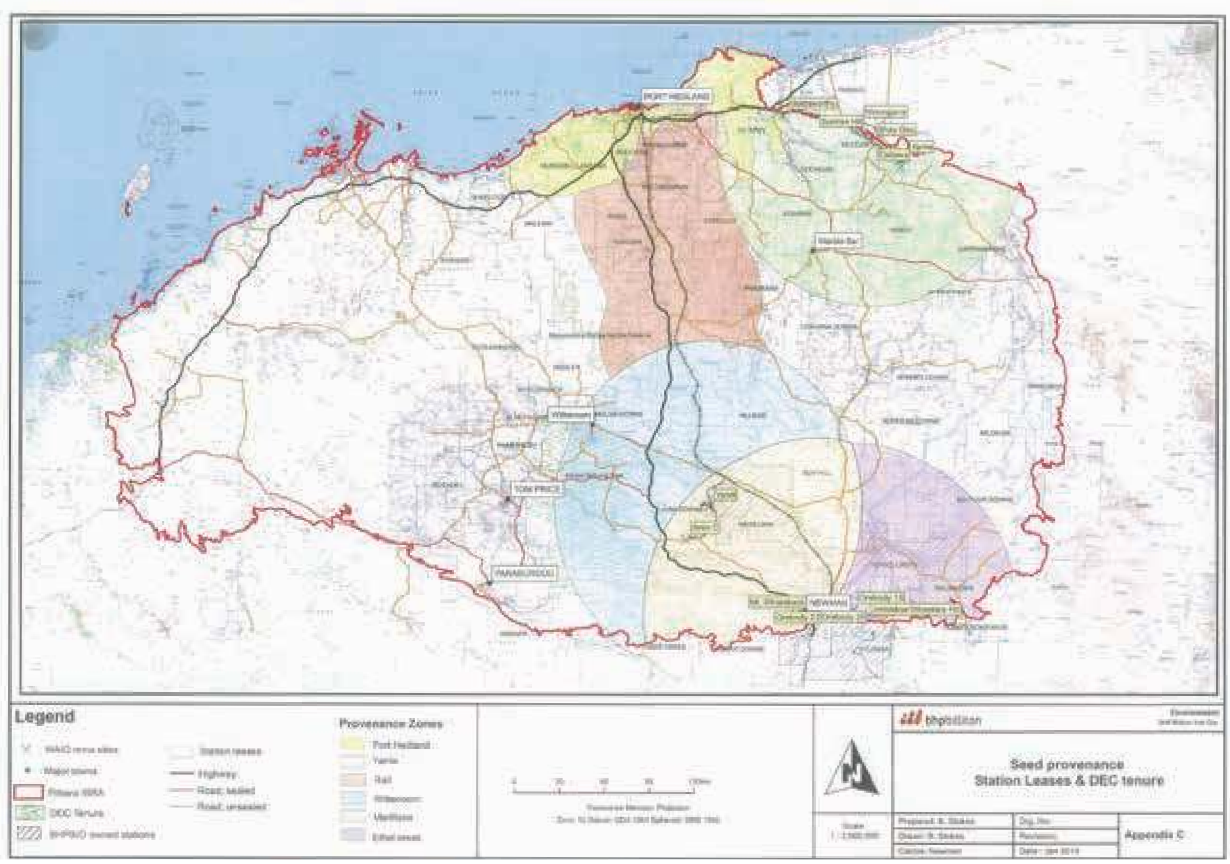
As part of its risk assessment program, BHP has recognised these challenges and has invested in research to improve its understanding of how best to use seed to revegetate the land. Over the past five years, the program has led to significant improvements in all facets of seed management, including identifying seed requirements, availability, viability, collection, storage, treatment, germination and species knowledge that informs rehabilitation programs (BHP Billiton 2017).

Research is ongoing and the Restoration Seed Bank Initiative, a five-year research partnership between BHP Billiton, BGPA and the University of Western Australia (UWA), is focused on resolving key seed propagation challenges such as dormancy and germination (Kaur *et al.* 2017; Lewandrowski *et al.* 2017b; Muñoz-Rojas *et al.* 2016a; Ritchie *et al.* 2017; Shackelford *et al.* 2013; Turner *et al.* 2017). The initiative is also aimed at the development of seed enablement technologies, new approaches to topsoil management and alternative growth media to overcome limitations to seedling establishment and plant growth (BHP Billiton 2017). It is expected that information arising from this initiative will result in future refinements to BHP's completion criteria and associated measurement framework.

As with the waste characterisation and landform stability criteria, the vegetation completion criteria for GNA comprise a mixture of leading and lagging indicators. The leading indicators focus on the identification, management and placement of a suitable growth medium and the selection of local provenance plant species.

Development of a seed provenance map in consultation with the Department of Parks and Wildlife (now Department of Biodiversity Conservation and Attractions) (Source: BHP Billiton (2013) Figure 5.7) enabled the provenance criterion to be included in BHP's criteria framework and provided a basis for auditing conformance with the criterion.

Photo courtesy: BHP



Source: BHP (2013)

FIGURE 5.7 Seed provenance map for Western Australian Iron Ore mine sites

The lagging criteria aim to describe the key aspects of a successful vegetation community at GNA including:

- Resilience to likely impacts such as fire, drought and grazing
- Self-sustaining system suitable for the agreed final land use
- The post-closure land use will not be limited by the presence of weeds.

BHP has been working with BGPA to develop a set of draft vegetation completion criteria for a general conservation end use (BGPA 2017). The criteria are designed to be science-based, quantifiable, attainable within a realistic time frame and acceptable to all stakeholders. The work used data collected from 360 transects over a six-year period in rehabilitated sites as well as analogue and post-fire unmined landscapes.

Based on two key guidance documents (EPA 2006; SERA 2017), BGPA developed a list of quantifiable vegetation parameters that assess desired rehabilitation attributes and are capable of supporting completion criteria (Table 5.5). The parameters were then ranked by considering the:

- Extent to which each parameter addressed the desired attribute
- Uniqueness of parameters, redundancy or co-variation among parameters
- Sensitivity of parameters to seasonal or successional drivers
- Sensitivity of parameters to the typical extent of changes to landforms, soils and hydrology that arise through mining
- Ease and accuracy of standard monitoring protocols for assessment
- Complementarity in assessment techniques
- Capacity to develop quantitative targets that unambiguously reflect the desired attribute.

The parameters with the highest scores (in bold in Table 5.5) were developed as criteria.

TABLE 5.5 Vegetation parameters

EPA (2006) Criteria	SERA (2017) Attribute	Class	Measurable parameter	Priority
9. Abundance or density **12. Canopy and keystone species** **16. Habitat diversity**	Community structure	Quantity	Cover	Highest
			Density	Medium
			Biomass	Low
		Structure	Bare areas	High
			Patchiness/ connectivity	Medium
			Strata	High
8. Species diversity **10. Genetic diversity** **11. Ecosystem diversity** **13. Effective weed control** **15. Animal diversity**	Species composition	Composition	Indigenous species (yes/no)	Highest
			Dominant species (yes/no)	Highest
			Native species richness	High
			Weeds (cover)	High
			Significant species/communities	High
			Floristic similarity / turnover	Medium
7. Self-sustaining and resilient	Ecosystem function	Reproduction	Flowering/fruiting	High
		Recruitment	Seedlings/survival	High
		Recovery	Recovery (e.g. from fire, drought)	High

Source: BGPA (2017)

To date, the following criteria have been adopted for the GNA site:

- All plant species to be locally indigenous species (sensu BGPA 2017) of local provenance
- The number of native perennial species shall be no less than the number recorded in comparable nearby vegetation that has not been disturbed
- Total native perennial vegetation cover to be ≥ 20%.

The total native perennial vegetation cover criterion is based on the minimum cover values observed in analogue survey data, which is 20%. In practice, BHP intends to develop a range of cover that reflects the range and variation of cover found in the reference system. The minimum analogue value was employed to avoid setting a standard that is higher than occurs in natural systems. As 20% is a base threshold, rehabilitation must be designed to exceed this cover. Comparison of perennial cover between rehabilitation and analogue sites shows that while the average values differ, the range of variation is similar between both. So, for all rehabilitation sites to exceed the minimum analogue threshold, including the worst performing, it is likely that maximum and average cover of rehabilitation sites will reflect the average and range observed in the natural system. This approach works best when initiating a collection of sites with the same criteria, rather than just one at a time, and only when aware that achieving the target involves aiming above the target. Also, if rehabilitation capability improved so that variation in cover outcomes is reduced, whether the average increases or not, the logic of this approach would no longer be valid.

Targets have yet to be developed for:

- Hummock grass cover
- Size of bare areas

Developing appropriate revegetation outcome criteria can occasionally have competing objectives for an area, depending on land use. For example, in the past BHP has consulted pastoral station owners about the control of the weed Kapok (*Aerva javanica*) and has been informed that it is one of the preferred feedstocks for cattle. Control is not favoured, as would be the case with a general conservation end land use criteria. However, it should be noted that pastoralists, as temporary land managers, do not hold authority to approve closure outcomes. Instead, this lies with the Pastoral Lands Board — a statutory authority established under Section 94 of the *Lands Administration Act 1997*. Issues such as these require further consideration of an appropriate criteria, acceptable to both landholders and other stakeholders.

Criterion 4.7 Fauna recolonisation

One of the challenges in developing criteria for fauna is that fauna presence can change temporally in response to many factors which may not be related to the quality of rehabilitation. BHP's fauna criterion is, therefore, weighted towards leading indicators that describe the conditions that would be expected to attract the return of fauna such as:

- Creation of habitat features such as rock piles
- Inclusion of locally endemic species of known importance to fauna in revegetation
- Control of vertebrate pests, where necessary.

The lagging indicator currently refers to signs of fauna recolonisation including (but not limited to) scats and presence of invertebrates.

At Cattle Gorge, both rock piles (Figure 5.8) and bat habitat (Figure 5.9) were incorporated into rehabilitation. Three different species of bats were acoustically recorded in the bat habitat structure three days after practical completion.

No Declared Pests (as defined under the *Biosecurity and Agriculture Management Act 2007*) are present in greater abundance than surrounding nearby vegetation.

FIGURE 5.8 Example of a rock pile at Goldsworthy Northern Areas

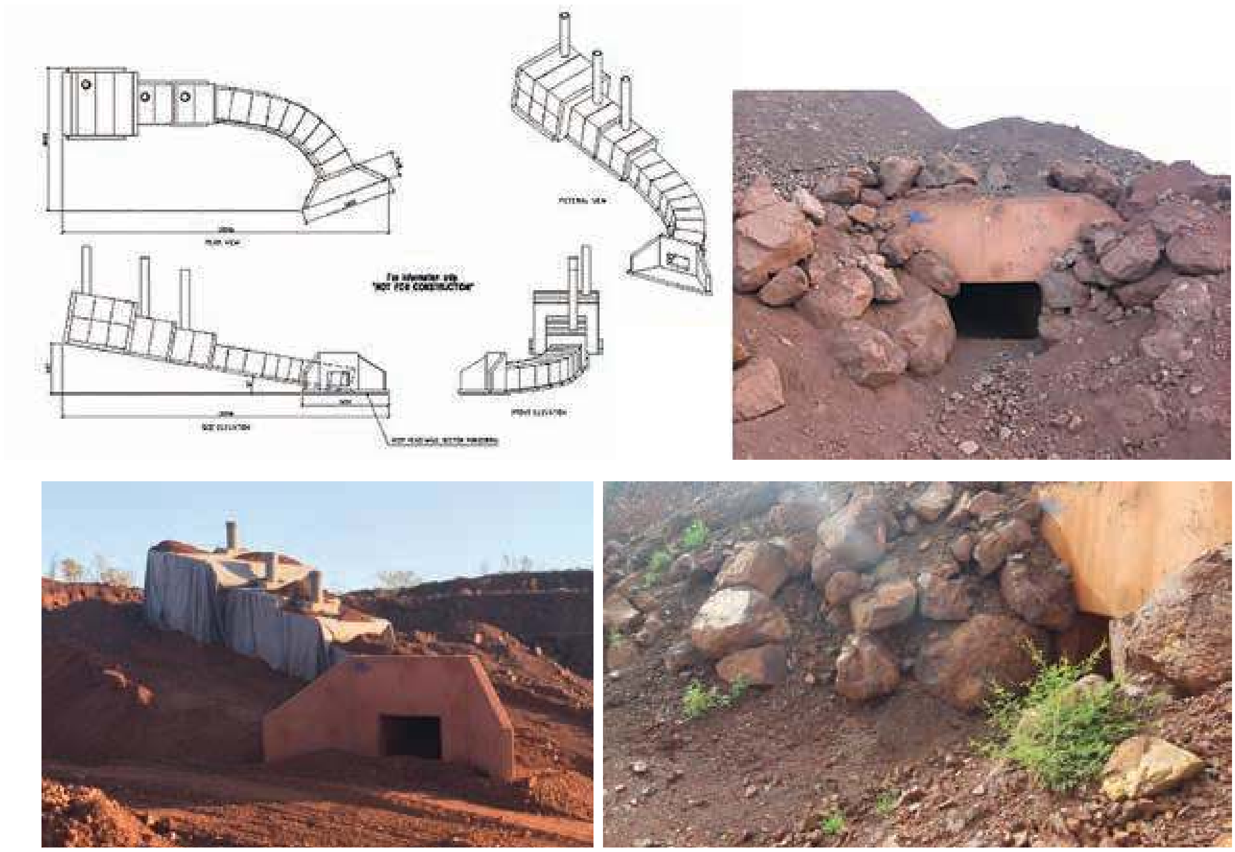


FIGURE 5.9 Bat habitat at Cattle Gorge

Criteria 5.1 and 5.2 water

Mining activities have the potential to change surface water and groundwater conditions. The key focus of BHP's water criteria is, therefore, on controlling changes so that there are no unacceptable impacts on key receptors.

One of the key lessons learned in using recognised generic standards for water quality is that in mineralised zones the background water quality may not meet these standards. At older sites where collection of baseline environmental data prior to development was not always rigorously undertaken, background data may need to be analysed to infer pre-mining conditions. This data may then be used as the basis for defining appropriate site-specific water quality completion criteria.

Monitoring and evaluation

BHP's criteria framework clearly outlines the information that will be used to verify achievement of each criterion and a monitoring and inspection program supports the collection of the information. The frequency and complexity of monitoring is risk based. For instance, where AMD risks have been identified, water quality is monitored to confirm predictions, update AMD modelling and allow for adaptive management in the case of unacceptable results (BHP 2017).

Revegetated landforms are monitored to establish the success of rehabilitation. Previous rehabilitation monitoring used Ecosystem Function Analysis. However, a review of the rehabilitation monitoring system was undertaken during 2011 and resulted in the establishment of an improved three-stage monitoring process:

- Rehabilitation Establishment Assessment (3 to 24 months of age) to provide feedback on the stability and erosion of rehabilitation areas and an assessment of vegetation establishment.
- Rehabilitation Development Monitoring comprising an in-depth assessment of rehabilitation involving Landscape Function Analysis, erosion monitoring and quadrat vegetation monitoring using existing monitoring transects. It is applied to maturing rehabilitated areas.
- Rehabilitation Landform Appraisal to provide a summary of the status of large scale rehabilitated landforms and areas not covered by Rehabilitation Development Monitoring (BHP 2018).

While changes in monitoring techniques can be problematic in terms of being able to compare the performance of rehabilitation from previous years, it is sometimes necessary to make changes to enable more meaningful and representative data to be collected. For example, BGPA (BGPA 2017) noted that species richness is scale-dependent, so vegetation monitoring transects have been modified from linear 50m x 1m plots to larger 50m x 50m plots to provide more representative data.

Remote sensing monitoring is being implemented, with annual research undertaken and monitoring methods modified to take advantage of new technologies. Remote methods can be applied to all phases of waste dump rehabilitation using laser scanning, LiDAR, aerial imagery, 3D reconstruction and multispectral analysis.

Future opportunities

Successful, effective and cost-efficient ecosystem recovery will more likely be achieved through targeted multidisciplinary research programs and knowledge transfer (Cross *et al.* 2018b). BHP will continue to explore collaborative research opportunities through avenues such as industry workshops, the Pilbara Rehabilitation Group and other industry partnerships such as the Global Innovation Linkages Project.

Further research, trials and analysis of monitoring data will facilitate the refinement of completion criteria. Advances in monitoring technologies are enabling efficient capture and analysis of data at a wider landscape scale including whole rehabilitation sites. The strongest promise of this technology is in its ability to track progress of rehabilitation against vegetation completion criteria on a broad scale. It is likely that hummock grass cover can also be effectively assessed using this technique and capacity to measure cover of other strata is also feasible. Adoption of these assessment tools would enable refinement of criteria relating to total vegetation cover, hummock cover and bare ground. It is likely that criteria relating to vertical structure could also be supported (BGPA 2017).

While the targeted end land use at GNA is appropriate to the current local socio-economic conditions, BHP regularly reviews these criteria. This takes into consideration any changes in stakeholder expectations that may involve re-purposing parcels of the mining area to an alternate end land use to better meet community expectations.

5.6.2 Mount Gibson Iron — Tallering Peak

Background

Mount Gibson Iron is a Perth-based independent iron ore producer established in 1996. Since 2002, it has been listed in Australian Stock Exchange and, over the financial year 2016-17, had a total sales revenue of AUD 173 million (Mount Gibson Iron 2017). Mount Gibson Iron currently operates three mine sites in Western Australia: Koolan Island (Kimberley coast), Extension Hill/Iron Hill and Tallering Peak, both in the Mid-West region (Source: Mount Gibson Iron (2017) Figure 5.10). Tallering Peak was the company's first mine to commence operations and the subject of this case study. Mining operations at Tallering Peak commenced in 2004 and ceased in 2014. The company is currently progressing mine closure to achieve site relinquishment.

The Tallering Peak mine is located 125km northeast of Geraldton and approximately 500km northeast of Perth. The closest population centre is Mullewa (63km south), with a population of 935. During operations, direct shipping ore (DSO) was transported by road to the Mullewa Rail transfer station, and then by rail to the Geraldton Port where it was stockpiled prior to being loaded onto ships and exported. The Tallering Peak Hematite Project consists of three entities of operation;

- Tallering Peak Iron Ore Mine;
- Mullewa Rail Transfer Station; and
- Hematite Storage and Loading Facilities at the Geraldton Port.

Mount Gibson's operations at the Geraldton Port are in accordance with an agreement with Mid-West Ports who, accordingly, dictate specifications for closure of the Hematite Storage and Loading Facilities. Therefore, the approved Mine Closure Plans (MCP) elaborated by Mount Gibson Iron include Tallering Peak Iron Ore Mine and the Mullewa Rail Transfer Station, but not the facilities at the Geraldton Port.

Source: Mount Gibson Iron (2017)

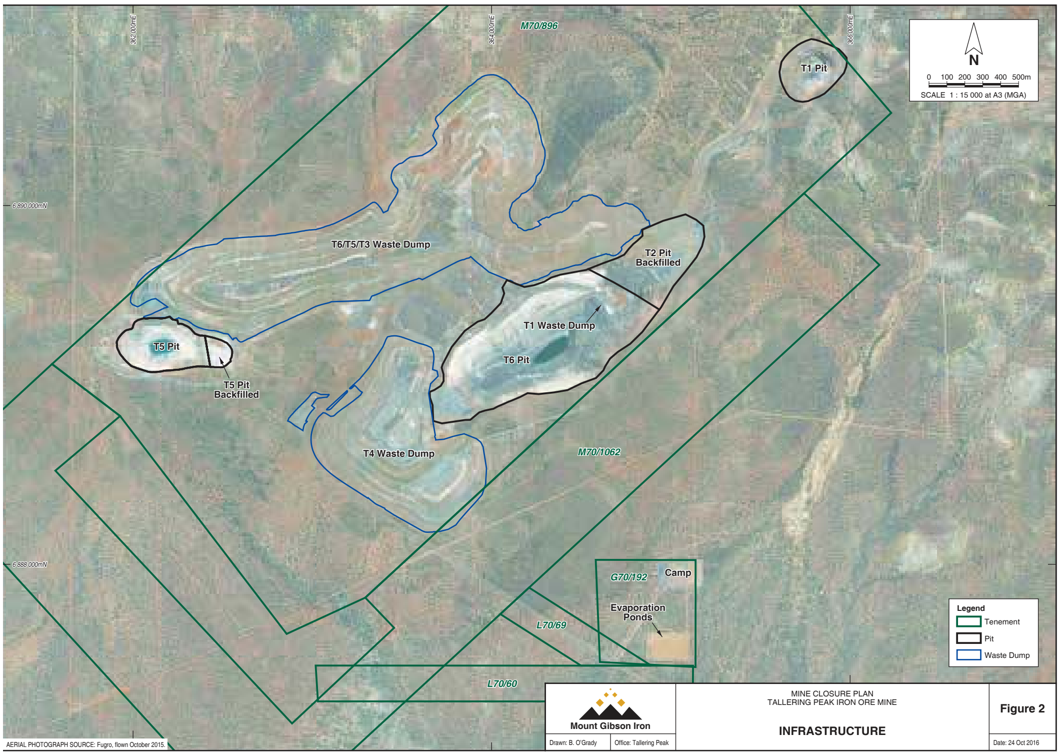
FIGURE 5.10 Location of Mount Gibson mining operations

The Tallering Peak Iron Ore mine site consists of three open pits: T6 (combining former T2, T2, T3, T6 and T4 pits), T5 and T1. The mine has three waste dumps: T2, T4 and a combined T3/T6/T5. Characteristics of pits, waste dumps and other key infrastructure are summarised in Table 5.6. A site plan of the Tallering Peak Iron Ore mine is depicted in Source: Mount Gibson Iron (2016) Figure 5.11.

The mining tenements coincide with the Wandina Station pastoral lease. An agreement with the pastoralist has determined what built infrastructure is retained.

TABLE 5.6 Key infrastructure at Tallering Peak Iron Ore mine

Infrastructure	Characteristics and rehabilitation	Area of disturbance (ha)
Open pits	• Backfilling has partially filled the T5 and T6 pits, as well as the northern T2 section of the main pit	81.2
Waste dumps	• T2 rehabilitated to pre-mining use (sloping hillside) • T4 annual Landscape Function Analysis (LFA) monitoring regime established in 2008. Currently rehabilitated. • T3/T5/T6 was progressively rehabilitated	230.5
ROM pad and crusher	• Decommissioned in late 2014. A stockpile of crushed low-grade fines and a stockpile of crushed low-grade lump hematite iron ore were removed from the load out area in 2017 and subsequently rehabilitated	18.8
Mullewa Rail Transfer Facility	• Under the operational control of the Ruvidini Registered Manager and left in place for possible future use	2.5
Offices and workshop	• Decommissioned in late 2014	8.4
Services (power, water, wastewater treatment)	• Decommissioned in late 2014/ early 2015	5.5
Explosives and diesel storage areas	• Decommissioned in late 2014	N/A
Transportation corridors	• Mine access roads were transferred to Wandina Station in 2015. • Mullewa Bypass Road was constructed by the Mullewa Shire prior to the opening of the mine and will remain under the City of Greater Geraldton's control post-mine closure	42.0
Accommodation village (Camp)	• Progressively decommissioned during late 2014. The fence around the village remains as an additional asset on the Tallering Station	3.8
Landfill	• Decommissioned and rehabilitated in early 2015	N/A



Source: Mount Gibson Iron (2016)

FIGURE 5.11 Tallering Peak iron ore mine site

ENVIRONMENTAL CONTEXT

Physical environment

Tallering Peak is part of the Tallering Range, which is an elevated feature rising 150m above the surrounding plains. The range is visible from the surrounding areas, with a picnic area and viewpoint located off the Carnarvon-Mullewa Road. However, public access to the viewpoint is now restricted via the Wandina Station homestead.

The Tallering Range is about 8km long and is composed of banded iron formations (BIF) which are especially resistant to erosion from long-term weathering (Mount Gibson Iron 2016). Each of the Tallering iron ore deposits occurs within a BIF unit, with the principal iron ore mineral being hematite (Fe_2O_3). The Mount Gibson Tallering Peak mine is based on the exploitation of one major and one minor massive hematite deposit in the northwest side of the Tallering Range.

The climate of the region is semi-arid, characterised by hot summers (mean monthly maximum temperature in January of 37°C) and mild winters (mean monthly maximum temperature in July of 19°C). The average annual rainfall, measured at Mullewa, is 337.4mm, with most of the rain concentrated in two wet seasons: May–August (frontal systems from the South-West) and January–March (summer thunderstorms and tropical lows).

Water bodies

There is no permanent surface water within the Tallering Peak mine site. However, a number of temporary streams are generated from flows off the Tallering range, chiefly on the Central and North ridges, forming the main catchment within the mining leases. These streams may provide recharge to the T5 borefield, as well as inflows into the Greenough River, which is proclaimed under the *Rights in Water and Irrigation Act 1914*.

Drilling campaigns and dewatering at the Tallering Peak mine showed that groundwater is located at depths greater than 25 m and that hydraulic connectivity is highly variable. The Mine held a licence for the abstraction and use of groundwater, prescribed under the *Rights in Water and Irrigation Act 1914*, although this was surrendered in 2015 because mining had ceased and water was no longer required. Water used for stock supply is generally fresh to slightly brackish and obtained from shallow depths in small quantities. A 200ML/yr groundwater license was granted to the previous (pastoral lease) owner. The current pastoral leaseholder is free to obtain their own 5C licence.

Flora

The Tallering Peak mine site comprises three main land systems (Tallering, Nerramyne and Tindelarra), each of which is associated with a certain characteristic vegetation community. Overall, vegetation communities are characterised by shrubs (e.g. *Acacia* shrubs), with greater plant diversity on the hill slopes (e.g. *Thryptomene decussata*, *Eriostemon sericeus*, *Eremophila* spp.) compared with flats and hill tops.

Over the life of mine (2004 to 2014), extensive surveys were conducted to identify and map significant flora species. Significant ecological communities were classified according to the Department of Environment and Conservation (DEC) Conservation Codes for Declared Rare and Priority Flora. These include two codes for Declared Rare Flora (DRF) — Presumed Extinct and Extant — and four Priority levels: P1, P2, P3 and P4. DRF species were not known to occur within the mine footprint nor surrounding the mine area. Four priority species were found, including P1: *Eremophila* sp. and *Hemigenia* sp.; P3: *Micromyrtus placoides* and *Prostanthera petrophila*.

Flora surveys carried out in 1994 and 1998 identified several weed species that were listed under the Agriculture and Related Resources Protection Act 1976 (WA). In accordance with Mount Gibson Iron's (MGI's) Weed Management Plan, weeds were controlled by occasional manual removal and spraying.

Fauna

Fauna surveys conducted in 1995, 2003 and 2012 in the Tallering area identified 101 vertebrate species, which consisted mainly of birds and reptiles, as well as few mammals, fish and amphibian species. A list of significant fauna species possibly present in the Tallering Peak mine area was compiled drawing from data available through the EPBC Act Protected Matters Search Tool (Australian Government 1999) and the DPaW (Department of Parks and Wildlife) database (Government of Western Australia 2016). Fourteen listed species of conservation significant vertebrate fauna had distributions that overlapped the mine site. However, due to lack of suitable habitat, 12 of the 14 species were considered unlikely to occur on site.

Surveys of invertebrate fauna conducted in 2008 and 2012 found 11 taxa, including spider, snail, millipede and slater species. Out of these 11, four were considered significant because of restricted ranges or listing under the *Wildlife Conservation Act 1950* (Government of Western Australia 1950).

A large population of the feral goat (*Capra hircus*) has been present at different times throughout the Wandina Pastoral lease, where the mine is located. Grazing of feral goats is known to be detrimental to the vegetation of the Tallering Peak area, including both the rehabilitated waste landforms and the analogue sites (see Mining Operations and Rehabilitation below).

PREVIOUS LAND USE

Tallering Peak Mine is located within the Shire of the City of Greater Geraldton. Formerly, the land where the mine site lies was part of the Wandina and Tallering Pastoral Stations where low-intensity grazing of rangeland goats was the primary land use. Subsequently, the station boundaries were modified by the previous lease holder, resulting in the Tallering Peak mine being contained within Wandina Station. Currently, the Wandina Station still exists under the granted tenements and, thus, goat grazing is able to occur within the tenement areas that are outside the mine's fenced perimeter (see Source: Mount Gibson Iron (2016) Figure 5.11). The current pastoral lease holder has re-stocked Wandina station with approximately 1000 cattle. Additional cattle will be added to the station lease in the coming months.

MINING OPERATIONS AND REHABILITATION

In 2003, Mount Gibson Iron commenced the development of iron ore hematite deposits in the Mid-West Region of Western Australia, with commencement of the Tallering Peak hematite project in February 2004 (Mount Gibson Iron 2016). The mine reached its target production rate of three-million tonnes per annum in the first quarter of the 2006 financial year.

The Tallering Peak mine ceased operations in May 2014 after 10 years of uninterrupted production, having generated over 25 million tonnes of iron ore over the lifetime of mining operations. Since the site was closed in September 2014, facilities have been decommissioned and removed in accordance with the mine closure and rehabilitation plan (Mount Gibson Iron 2016).

Progressive rehabilitation of the Mine was undertaken with the long-term aim '*to re-establish productive land surface that required minimal ongoing maintenance and management (i.e. stable and safe)*'. For this purpose, revegetation of disturbed areas was undertaken with a self-sustaining system of native species, with similar diversity, density and cover to the pre-mined ecosystem. As a result of progressive rehabilitation, the age of the vegetation in rehabilitated areas varies from one to 11 years old.

Closure tasks and final rehabilitation activities were completed in 2015 with rehabilitation of all areas disturbed by mining in the ten years of operation completed. The latest version of the Mine Closure Plan (MCP) was submitted in October 2016 and, along with the 2017 Annual Environment Report (AER), demonstrate that all important completion criteria were substantively met. However, after the annual report of 2017 was drafted, a dry spell of 160 days without rain affected the revegetation in the two younger waste landforms with reduced plant richness and density. Consequently, the completion criteria for vegetation cover were not met in all areas in 2017, despite these same areas having met the targets in 2016 and, additionally, despite similar drops in vegetation indicators in the analogue site due to the drought conditions.

Rehabilitation and associated completion criteria (e.g. species diversity) had appeared to be impacted by grazing pressure from goats in the rehabilitated waste landforms and, similarly, on the vegetation at the analogue sites. Grazing pressure was noted in the Ecosystem Function Analysis (EFA) reports of 2011 and 2012 as one of the potential factors hampering adequate vegetation growth towards achievement of completion criteria. Subsequent to the 2012 finding, around 400 goats were captured and moved out of the fenced mine area, which resulted in reduced grazing pressure and increased species diversity, as noted by the following annual EFA monitoring. These observations are relevant to the proposed post-mining land use and suggest careful management of goat grazing pressure will be necessary to sustain the condition of the rehabilitation sites in the longer term.

The full final relinquishment report was made by MGM in Jan 2019, based on agreed completion criteria to the Department of Mines, Industry Regulation and Safety (DMIRS) with a decision expected later in the year.

Methodology

The Mount Gibson Iron Tallering Peak case study was developed in two phases: data collection and analysis. The data collection phase consisted of first, a desktop review of mine closure plans (MCP); and second, a personal interview with two advisors at Mount Gibson Iron. The data analysis phases consisted of reviewing and summarising the information obtained to understand the process followed by Mount Gibson in the development of completion criteria for their Tallering Peak site.

Results

CLOSURE OBJECTIVES

According to *Guidelines for Preparing Mine Closure Plans* (DMP & EPA 2015), closure objectives for rehabilitated mines are to be safe, stable, non-polluting/non-contaminating and capable of sustaining an agreed post-mining land use; and for premises to be decommissioned and rehabilitated in an ecologically sustainable manner. Closure objectives proposed by mining companies must be site specific, consistent with post-mining land uses and defined for each of the various attributes present within the mine site.

The Mount Gibson Iron closure objectives, which are consistent with the above guidelines, can be summarised as follows:

- To ensure closure occurs in a timely (i.e. five to 12 years), orderly and cost-effective manner, and its associated costs are adequately represented in company accounts;
- To ensure accountability and availably of resources for the implementation of the closure plan;
- To define a suite of indicators that will demonstrate successful mine completion to the satisfaction of the Responsible Authority; and
- To engage with stakeholders and have their interest considered during the closure process.

CLOSURE GUIDELINES AND OBLIGATIONS

In the Tallering Peak mine, Mount Gibson Iron followed several other policies and guideline documents including:

- Guidelines for Preparing Mine Closure Plans (DMP & EPA 2015)
- Leading Practice Sustainable Development Program for the Mining Industry: Mine Closure and Completion (LPSDP 2006d)
- Leading Practice Sustainable Development Program for the Mining Industry: Mine Rehabilitation (LPSDP 2006e)
- Leading Practice Sustainable Development Program for the Mining Industry: Managing Acid and Metalliferous Drainage (LPSDP 2007)
- Safety Bund Walls around Abandoned Open Pit Mines DIR 1997)
- Contaminated Sites Management Series - Reporting of Known or Suspected Contaminated Sites (DEC 2006)
- Contaminated Sites Management Series - Potentially Contaminating Activities, industries and Land Uses (DEC 2004).

Numerous legal obligations also applied to the Tallering Peak mine, in accordance with tenement conditions and legislation. A summary of legal closure obligations is provided in Table 5.7. While the Tallering Peak Hematite Project was not under Ministerial Statement, it was a “prescribed premises”, thus triggering regulation under the *Environmental Protection Act 1986* (DER 2016).

TABLE 5.7 Legal closure obligations

Legislation	Section	Requirement relevant to closure
Aboriginal Heritage Act 1978	Part IV	Heritage sites are not to be altered, excavated, damaged, concealed or any portion of the site removed in anyway, unless granted via Section 16 or 18 under the Aboriginal Heritage Act 1978.
Contaminated Sites Act 2003	Part I, Section	The proponent or individuals are to report known or suspected areas of contaminated sites.
Contaminated Sites Regulations 2006	Part II (6)	
Contaminated Sites Act 2003	Part III, (23)	Sites classified as Contaminated –Remediation Required as described under the Contaminated Sites Act 2003 are to be remediated.
Environmental Protection (Controlled Waste) Regulations 2004	Part III, (6) (44)	Disposal of asbestos is to be separated, wrapped and labelled and disposed in accordance with Part III (6) (44)
		The proponent is to treat all products listed in schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004 as a controlled waste.
Environmental Protection Act 1986	Part V, (49)	Proponent shall not cause pollution or an unreasonable emission of noise, odour or electromagnetic radiation.
	Part V, (51)	The proponent shall not clear native vegetation without the relevant approval (e.g. clearing permit) in place.
Health Act 1911	Part IV (2) (87)	The proponent shall ensure (stagnant) pools, ponds, open ditches, and drains do not become offensive to the public or allow these areas to become prejudicial to human health.
Health Act 1911	Part IV (3) (95)	Removal of sewerage systems are to be conducted in accordance with Local Government Law and by a Licensed contractor Environmental Protection (Controlled Waste) Regulations 2004.
Environmental Protection (Controlled Waste) Regulations 2004	Part III	
Mining Act 1978	Part IV (84AA)	A mine closure plan is required to be approved by the Department and reviewed every three years, or as specified by the Department.
	Part III (1) (20) (3a)	Make safe all holes, pits, trenches and other disturbances on the surface of the land which are likely to endanger the safety of any person.
	Part III (1) (20) (3b)	Take all necessary steps to prevent fire.
Mining Regulations 1981	Part V (6) (97)	Avoid activity that obstructs any public thoroughfare or undermines any road, railway, dam or building in such manner as to endanger the public safety.
	Part V (6) (98)	The proponent shall not allow detritus, dirt, sludge, refuse, garbage, mine water or pollutant from the tenement to become an inconvenience to the holder of any other mining tenement or to the public, or in any way injure or obstruct any road or thoroughfare or any land used for agricultural purposes.
Mines Safety and Inspection Act 1994	Part IV (42)	The principal employer or manager of a mine must, in accordance with the regulations, notify the district inspector for the region in which the mine is situated before mining operations are suspended.
Soil and Land Conservation Act 1945	Part V (32)	The proponent shall take adequate precautions to prevent or control soil erosion, salinity or flooding; or the destruction, cutting down or injuring of any tree, shrub, grass or any other plant on land where land deregulation is occurring or likely to occur.
Wildlife Conservation Act 1950	(16 and 23F)	A person may not take for any purpose protected fauna or flora without a licence, or rare and endangered flora without the written consent of the Minister.

POST-MINING LAND USE

Land use at the Tallering Peak Hematite Project area will revert to pastoral grazing of native vegetation, once mining ends and rehabilitation is completed. Prior to mining, the area was under sheep, cattle and goat grazing, which still occurs within the tenement area adjacent to the mining domain (Wandina Station). Pastoral grazing was agreed for post-mining land use through a stakeholder consultation process involving the former Department of Mines and Petroleum (DMP, now DMIRS), Department of Environment and Conservation (DEC, now DBCA), local councils, residents and the mine site's previous pastoral lease holder.

Any improvements or infrastructure left on site post-mining, for the use of the land holder, would require advice from the Pastoral Land Board. A key condition is that the mine site will remain free from grazing until vegetation on rehabilitation areas reaches an agreed level of similarity with undisturbed vegetation at analogue sites. Analogue (control) sites were set within the tenement areas where grazing was ongoing, including three sites on the southern face of the Tallering Ridge and two on the northern face of a small nearby ridge.

These comparative sites were used as references for the definition of completion criteria. All sites were analysed using EFA annually (at the same time each year e.g. spring) to monitor the progress of the rehabilitation program.

Other options for future land use that have been considered previously include tourism and nature conservation. The Mullewa Shire suggested developing the rehabilitated mine into a tourist attraction, yet the pastoral landholder rejected the idea and proposed to direct tourists to the existing operation on Wandina Station. The Tallering Range hosts several priority species of native plants for conservation, yet nature conservation was not pursued as a post mining land use as this would result in the permanent removal of the pastoralists from the site. In addition, Mount Gibson Iron did not receive any requests from the Department of Parks and Wildlife (now DBCA) to add the Tallering Range and rehabilitated mine site to the conservation estate.

Completion criteria development

CLOSURE DOMAINS

To facilitate the process of mine closure planning, the Tallering Peak mine site was divided into 'closure domains', which are defined as areas of similar characteristics. The four separate domains included open pits, waste dumps, industrial-plant and infrastructure, and rail transfer facility. In general, open pits were managed for acid contamination or back-filled, waste dumps were rehabilitated with native vegetation for grazing and the remaining two domains were left as is or decommissioned and rehabilitated with native vegetation not-for-grazing (Table 5.8). Each domain was subdivided into 'elements' that outline the specific areas requiring management for closure. For example, within the 'waste dump' domain, each of the three waste dumps (T2, T4 and T3/T6/T5) constitute a separate element. Likewise, within the 'industrial-plant and infrastructure' domain, distinct elements include workshops, explosive storage areas, roads and accommodation village, among others. Given the agreed post-mining land use of pastoralism, final configurations for each closure element were developed, as summarised in Table 5.8.

TABLE 5.8 Rehabilitation actions by domain and element

Domain	Element	Rehabilitation action
Open pits	T2 pit	Backfill T2 and rehabilitate
	T6 pit	Leave open and establish abandonment bund around the pit
Waste dump	T4 Waste dump	Rehabilitate
Plant and infrastructure	Workshops	Decommission, reuse/recycle where possible and rehabilitate
	Services	Retain elements (bores, pipes) for pastoral use, rehabilitate others
Rail transfer facility	Workshop	Workshop Decommission, reuse/recycle where possible and rehabilitate to required post-mining land use

COMPLETION CRITERIA

Mount Gibson's methods for establishing completion criteria are in line with guidelines provided by DMP and EPA (2015). These state that completion criteria should follow the S.M.A.R.T. principle and be Specific, Measurable, Achievable, Relevant and Time-bound. Thus, the Tallering Peak MCP defines completion criteria that are specifically tailored in consideration of the mine's i) post-mining land use; ii) analogue sites; iii) closure domains; and iv) closure objectives.

In each version of the Mine Closure Plan (MCP), completion criteria were defined in further detail, from indicative criteria to final criteria. Detail on each criterion was provided in response to the regulators' request.

The Tallering Peak MCP defines closure objectives for the following 12 attributes:

- Compliance
- Closure Administration
- Access and Security
- Environmental Monitoring
- Landform Stability
- Flora and Fauna
- Surface Water
- Groundwater
- Acid Mine Drainage:
- Site Contamination
- Air Quality, Noise and Vibration
- Infrastructure.

For each of the 12 attributes (and corresponding closure objective) at least one indicative completion criterion and one completion criterion are defined. Some attributes, like flora and fauna, have more than one criterion. An example of the latest completion criteria, as per Mount Gibson's October 2016 MCP, is presented in Table 5.9.

Photo courtesy: Mount Gibson Iron

TABLE 5.9 Examples of Tallering Peak completion criteria

Closure objectives	Indicative completion criteria	Completion criteria	Measurement tools	Applicable closure domains
Landform Stability: To achieve a final landform that remains stable long term and meets the end land use objectives	Concept level engineering designs and specifications for landforms, which will not be prone to slumping, mass movement or significant erosion	Demonstrated landform stability under representative climatic conditions	Visual monitoring / regular inspection of landform stability during the post closure monitoring and maintenance period. Analysis of site-specific meteorological data to demonstrate representative climatic conditions have occurred since landforms were constructed	Waste dump
Flora and Fauna: To establish a self-sustaining ecosystem commensurate with pastoral land use	Vegetation composition on rehabilitated areas is representative of the pastoral land use ecosystem and vegetation community requirements	Vegetation composition on rehabilitated areas is representative of the pastoral land use ecosystem and vegetation community requirements (diversity ≥ 75%, cover ≥ 15%, stems / hectare ≥ 50% and declared weed cover ≤ 10% of comparative analogues). (Government of Western Australia 2007)	Annual quantitative survey of vegetation through Ecosystem Function Analysis (EFA) in rehabilitated areas in comparison to local control survey sites	All
Access and Security	All roads (apart from those retained for station owner use) rehabilitated with natural drainage lines re-established	All roads (apart from those retained for station owner use) rehabilitated with natural drainage lines re-established	Rehabilitation records. Stakeholder consultation records identifying agreement on infrastructure retention.	Infrastructure
Surface Water Management: To maintain the natural quality and quantity of surface water to ensure that existing and potential uses, including ecosystem maintenance are protected consistent with the ANZECC &ARMCANZ 2000a water quality guidelines	Measurements of pH, EC and TSS in runoff leaving the mine site are consistent with measurements in Bangemall Creek or the Greenough River for the same flow event	Interpretation of measurements of pH, EC and TSS in runoff leaving the mine site to check consistency with measurements in Bangemall Creek or the Greenough River for the same flow event	Surface water analysis using accredited laboratory analysis and field measurements during the post-closure monitoring and maintenance period	All
Acid Mine Drainage: To minimise the potential for acid mine drainage (AMD) from the waste rock dumps	Appropriate waste dump designs generated to minimise the potential for AMD	Appropriate records to demonstrate that approved designs have been implemented	Visual assessment of area for any signs of AMD (seepage staining, iron precipitates, vegetation die off) during post-closure monitoring and maintenance period	Waste dump
Air Quality, Noise and Vibration: To manage dust emissions to ensure potential impacts on vegetation are minimised	Depositional dust levels post closure return to pre-mining levels	Depositional dust levels post closure return to pre-mining levels	Depositional dust records (post closure (<5 years) and analogue)	All
Infrastructure: No infrastructure left on site unless agreed to by regulators, key stakeholders and post-mining pastoral lease holder	Stakeholder consultation with regulators, key stakeholders and post-mining pastoral lease holder regarding remaining infrastructure	Stakeholder consultation records identify agreement with regulators, key stakeholders and pastoral lease holder regarding remaining infrastructure	Stakeholder consultation records. Copy of formal approval letter from Pastoral Lands Board to station lease holder	Infrastructure

Monitoring and evaluation

SOIL AND WASTE MATERIAL CHARACTERISATION

The soils in the Tallering Peak mine site vary between land systems in the following manner:

- Tallering Land System: lithosols, shallow sands and loams; slightly acidic (pH ranging from 5.5 to 6.0).
- Nerramyne Land System: gravelly loamy sands (east of the ridge); siliceous sands or sandy clay-loams over granite (on the gravelly plains); and clayey or loamy sand over clays (in the drainage zone).
- Tindelarra Land System: sandy clay-loams and red earths (in the wash plains); duplex or clay over hardpan (alluvial plains); and hardpan loams over granite or hardpan (surfaced plains).

Soil stability and erodibility on waste rock landforms were assessed by a consultant through the annual Ecosystem Function Analysis (EFA) monitoring since 2008. The reports indicated that erosion was minimal, rock cover was good and all the EFA indices had achieved completion criteria targets. However, some erosion appeared on the T3/T5/T6 waste dump and this was subsequently repaired by a specialist earthworks contractor. All waste dumps were shaped and prepared for rehabilitation. Reclaimed topsoil was applied to all waste dumps.

FLORA AND VEGETATION

Mount Gibson Iron completed a series of surveys (1992–2013) and rehabilitation trials (2008–2012), which served to identify the most effective rehabilitation practices and define achievable closure objectives specific to the Tallering Peak site. The challenges to vegetation rehabilitation include limited topsoil, landform instability, low rainfall and soil erosion (T. Collie, pers. comm. Oct 2018).

Native habitat and vegetation surveys were carried out prior to mining, between 1992 and 2000. The aims of these baseline surveys were to a) identify flora of conservation significance; and b) collect data to characterise the native vegetation of the area. The information obtained from these baseline surveys were used to determine the seed mix for rehabilitation of Tallering Peak mine site. During mine operations, further flora surveys were completed between 2006 and 2013, to identify locations of conservation significant flora species within the Tallering Peak region.

Landscape Function Analysis (LFA) and vegetation monitoring were conducted on a rehabilitation trial, first established on the T4 waste landform (2008–2011), and then also applied to T3/T4/T6 waste dump in 2012. It has been repeated on all dumps in every year since. The purpose of the trial was to analyse soil chemistry, test rehabilitation techniques for supporting vegetation growth and determine optimal seed mix for rehabilitation.

LFA monitoring revealed that levels of all three LFA indices (stability, infiltration and nutrient cycling) were between 54% and 72% of levels at the analogue sites. Based on these results, and the fact that analogue sites benefit from established vegetation, it was understood that high levels of LFA indices (i.e. >75%) would not be attainable in the rehabilitated areas. Thus, a target was set whereby waste landforms would have a median LFA stability rating of ≥50%, infiltration rating of ≥20% and nutrient cycling rating of ≥15% and compare favourably with natural analogue site trends.

Results of the flora and vegetation surveys served to design the seed mix around the dominant species, as well as the likely best availability of seed. The seed list was updated based on the success of the species that established in rehabilitation (identified from the early vegetation monitoring). Consequently, rehabilitated vegetation tended to be comprised of common native species that were able to establish in the surface cover conditions that characterised the waste dumps.

HERITAGE

Archaeological and ethnographic surveys were undertaken in 1992, with further heritage surveys carried out in 2002. Information obtained during these surveys served to define Aboriginal Heritage Exclusion Zones that are in place on the mine. In 2009, further surveys were completed ahead of an intensive exploration drilling program. In 2012, archaeological and ethnographic surveys were undertaken to enable submission of an application under the *Aboriginal Heritage Act 1972* for exploration drilling in the T1 area and the issue of Ministerial consent for the ground disturbances. All heritage surveys at the Tallering Peak mine site were reported in accordance with the *Aboriginal Heritage Act 1972* (Government of Western Australia 1972).

There are no known sites of European heritage significance on or near the mine site.

Risk analysis

Risk analysis at the Tallering Peak mine site was developed taking into consideration pastoralism as the post-mining land use and incorporating relevant closure issues identified by stakeholders. Risk analysis was done following the principles outlined in the AS/NZ ISO 31000:2009 Risk Management and Australian Standard IS014001 (ISO 2015).

As the life-of-mine progressed, the risk analysis in each version of the MCP was reviewed based on updated risks and mitigation measures across the site. The 2014 risk analysis was updated in 2016, based on post-closure monitoring information. 'Post-closure' refers to the window after finalisation of closure activity but before closure is attained. The 2016 update resulted in the reclassification of 'groundwater contamination from acid in T5 pit' from unknown risk to low risk because of evidence of the pit water operating as an evaporative sink. Moreover, several items were downgraded from high residual risk to low risk level, including erosion of dumps and erosion of backfilled pits.

Photo courtesy: Mount Gibson Iron

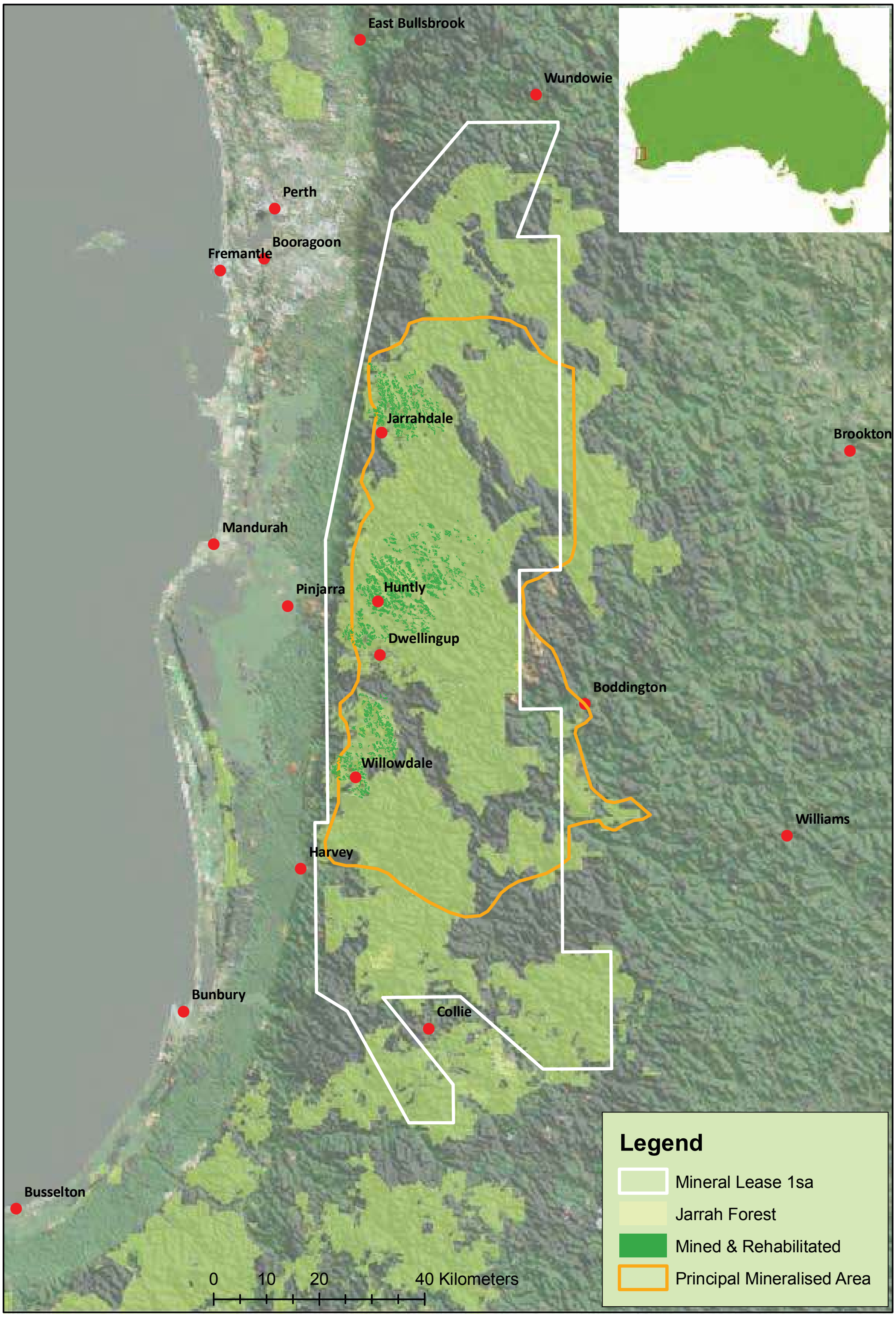
Photo courtesy: Alcoa

5.6.3 Alcoa — Northern Jarrah Forest

Background

Alcoa's mining operations in the Northern Jarrah Forest in south-west Western Australia comprise the Huntly and Willowdale bauxite mines, located approximately 100km south-east of Perth (Source: Alcoa (2018c) Figure 5.12). Established in 1976, Huntly is currently the world's second largest bauxite mine, supplying 26 million tonnes of bauxite in 2016 (Alcoa 2018a). Willowdale mine was established in 1984 and in 2017 supplied 10 million tonnes of bauxite (Alcoa 2018b). Across Huntly and Willowdale, approximately 600 hectares of mined land is rehabilitated each year, with the long-term objective of establishing a self-sustaining jarrah forest ecosystem (Koch 2007a). A third mine at Jarrahdale ceased operations in 1998, having been open for 35 years and producing 160 million tonnes of bauxite ore in its lifetime. The closure of Jarrahdale mine, including decommissioning of infrastructure and final rehabilitation of haul roads and pits, was completed in 2001 (Mining Atlas 2018).

Alcoa's mining operations are overseen by the Mining and Management Program Liaison Group (MMPLG), an interagency government group responsible for the review of mine plans on a rolling annual basis. The MMPLG also provided oversight for the development and implementation in the 1990s of Alcoa's completion criteria for its bauxite mine rehabilitation (Elliott *et al.* 1996). This included a process of assessment leading to the issuing of Certificates of Acceptance for areas that have met all appropriate criteria (Alcoa 2018d). The completion criteria are reviewed on a periodic basis, with the latest revision completed in 2015.



Source: Alcoa (2018c)

FIGURE 5.12 Map of Alcoa's mineral lease ML1SA

ENVIRONMENTAL CONTEXT

The Northern Jarrah Forest is part of the South-West Botanical District, characterised by high plant and animal diversity and comprised of more than 780 native plant species, 235 vertebrate terrestrial species and invertebrates species in the order of tens of thousands (Grant & Koch 2007). The vegetation is defined as open forest, with its overstorey dominated by jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*). The midstorey includes bull banksia (*Banksia grandis*) and snottygobble (*Persoonia longifolia*) and is typically sparse, while a diverse understorey is dominated by four native plant families: Fabaceace, Proteaceae, Myrtaceae and Mimosaceae (Bell & Heddle 1989).

The climate is typically Mediterranean, characterised by hot, dry summers and cool, wet winters. Summer droughts are common, often lasting up to four to six months (Gardner & Bell 2007). Occasional cyclones during hot periods may bring rain, but also thunderstorms and lightning, thus greatly increasing the risk of wildfires. The average rainfall in the region of bauxite mining is between 900 and 1,300 mm per year, 60% of which falls between June and August.

PREVIOUS LAND USE

Most of the Northern Jarrah Forest lies within State Forest which has been managed for multiple uses including water catchment, conservation, timber production and recreation (Nichols *et al.* 2005). The forest was selectively logged prior to mining activity (Grant & Koch 2007).

MINING OPERATIONS AND REHABILITATION

Alcoa's bauxite mining occurs in shallow 'pods', averaging 4 to 5m deep and is typically located less than one metre below the soil surface (Grant & Gardner 2005). The mine pits range in size from 2ha to 60ha, with an average size of 10ha. Each mine pit is prepared by harvesting trees for timber, clearing the mid and understorey vegetation, salvaging the topsoil (upper 15cm) and underlying overburden (10 to 80cm deep) layers for use in rehabilitation (Grant 2006). Bauxite extraction involves blasting of an indurated layer where present, which is removed together with the friable material below.

Mine pits are rehabilitated. The first step consists of reshaping or landscaping the mine pit by battering down the pit faces to blend with the surrounding topography, along with deep ripping of compacted areas to 1.5m depth to facilitate percolation and root exploration. Overburden and topsoil materials are returned in sequence and, finally, a second shallow (0.8m) ripping along the contour assists in reducing erosion, promoting rainfall infiltration and preparing a seedbed for applied seed. Because topsoil contains a seedbank important for plant establishment, and is enriched in organic matter, nutrients and microorganisms, it is immediately transferred from stripping areas to rehabilitate nearby pits whenever possible. Logs and rocks are also returned to provide habitat for native fauna. Seed of more than 60 species is collected from the forest ensuring local provenance and applied within a week of contour ripping to supplement plant species established from the soil seedbank. All soil return, contour ripping and seeding is carried out during the drier summer months. Plant species that are difficult to return via topsoil or collected seed are propagated under nursery conditions and seedlings are planted during the winter months. A one-off application of fertiliser by helicopter occurs in the second spring after establishment, to replace soil nutrients lost in the clearing and mining steps and to encourage early plant growth.

Rehabilitation is a progressive operation, with approximately 600 a of forest cleared for mining and subsequently rehabilitated each year. Approximately 20,000ha of rehabilitation has been established since the first rehabilitation was completed in 1966. An example of Alcoa's rehabilitation is illustrated in (Source: Grant and Gardner (2005)) Figure 5.13. The images depict an area of the jarrah forest where, after bauxite mining, all rehabilitation objectives were met.

Source: Grant and Gardner (2005)

FIGURE 5.13 Mining at Alcoa's Huntly operation in 1980 (left) and after restoration in 2001 (right)

Methodology

Research for this case study was split into two phases. Firstly, a document review was completed, primarily involving internal reports supplied by Alcoa and regulatory documents. Second, a semi-structured interview was conducted in person. The aim of the interview was to fill knowledge gaps evident after the document review or to provide more detail on particular emergent themes. Results were synthesised into a report addressing the research objectives outlined above.

Results

REHABILITATION OBJECTIVES

The rehabilitation objective is '… to establish a stable, self-regenerating jarrah forest ecosystem, planned to enhance or maintain water, timber, recreation, conservation and/or other nominated forest values'. Rehabilitation objectives and, consequentially, completion criteria are based on the following five key principles:

- **Land use:** rehabilitated areas meet the land use objectives
- **Integrated landscape:** rehabilitated areas are integrated into the landscape
- **Sustainable growth and management:** rehabilitated areas exhibit sustained plant growth and ecosystem development
- **Resilience:** rehabilitated vegetation is as resilient as jarrah forest to disturbances such as drought and fire
- **Integrated management:** rehabilitated areas can be integrated into broader forest management plans.

POST-MINING LAND USE

The selected post-mining land use must be compatible with surrounding forest values and uses, protect biodiversity, meet community expectations, and fulfil all governmental regulation requirements (Gardner & Bell 2007). Occasionally, certain sites may have elevated historical, recreational or other values where closure objectives differ from those outlined in the standard completion criteria. In these cases, specific area management plans are developed by Alcoa and subsequently approved by the MMPLG (Alcoa 2015).

5

CHAPTER

COMPLETION CRITERIA DEVELOPMENT: HISTORY

Prior to 1971, rehabilitation at the Jarrahdale mine consisted of plantations of either Pinus or Eucalyptus species native to the eastern states of Australia which were chosen for their resistance to 'dieback' disease, caused by the soil-borne pathogen *Phytophthora cinnamomi*. Subsequent efforts up to 1977 introduced ground preparation treatments (e.g. landscaping), while rehabilitation in the period 1978-1987 broadened the range of native understorey species. The time period prior to 1988 is known as the Early Era, during which the key objective was to establish a functioning and self-sustaining eucalypt forest. Completion criteria for Early Era rehabilitation were developed retrospectively and approved in 2002. The criteria were based on assessments at later stages of development and include rehabilitated using outdated methods (Nichols *et al.* 2005).

From 1998 onwards (the period known as the 'Current Era'), rehabilitation has been undertaken using only species native to jarrah forest, including the canopy dominants jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) trees. The objective for the Current Era is to restore a self-sustaining jarrah forest ecosystem planned to enhance or maintain water, timber, recreation, conservation and/or other nominated forest values (Nichols *et al.* 2005). The specific conservation goal is to encourage the development of floral, faunal and soil characteristics similar to those of the indigenous jarrah forest ecosystem. Completion criteria for the Current Era include areas rehabilitated using methods as summarised in Standish *et al.* (2015).

Given the evolution of rehabilitation practices and procedures over time, Alcoa's rehabilitation areas are assessed against a different set of criteria depending on the year when rehabilitation was established. For the 1998–2004 period, criteria were approved in 1998. Rehabilitation between 2005 and 2015 had criteria reviewed and approved by MMPLG in 2007. The latest criteria are defined in the 2015 revision of Alcoa's rehabilitation program (Alcoa 2015) and comprise the period from 2016 until today. Both Current and Early Era completion criteria are required to be reviewed at five-yearly intervals (Nichols *et al.* 2005).

Photo courtesy: Alcoa

COMPLETION CRITERIA DEVELOPMENT: ROLE OF RESEARCH

The definition, achievement and monitoring of closure objectives and specific completion criteria has been possible as a result of Alcoa's long-standing and comprehensive research program, which started in the early 1980s. Since then, Alcoa's Environmental Research Group has collaborated with universities, CSIRO, Government departments and individual experts on a range of aspects related to ecosystem establishment and recovery in rehabilitated areas (Alcoa 2015). Key research areas have included the re-establishment of flora and fauna diversity, successional processes, nutrient cycling, soil development and resilience to disturbance (Nichols *et al.* 2005). Further detail regarding these and other research questions can be found in numerous studies available in the published literature including a special issue of the journal Restoration Ecology that summarised two decades of research (Volume 15(S4), 2007) and other publications (e.g. Bell 2001; Bell & Heddle 1989; Brennan 2003; Gardner & Bell 2007; Grant 2003; Grant & Koch 2007; Grant *et al.* 1997; Jasper 2007; Koch 2007a; Nichols 1998; Nichols *et al.* 2005; Nichols & Nichols 2003; Smith *et al.* 2004a; Smith *et al.* 2000; Ward *et al.* 1990; Ward *et al.* 1993).

Alcoa's commitment to biodiversity restoration in the jarrah forest has been driven by the need to preserve the interest of the local community, as well as those of the natural environment (Grant & Gardner 2005). Such commitment has led Alcoa's research and rehabilitation achievements to be recognised by numerous national and international awards (Grant & Gardner 2005). Among others, outstanding awards include the Western Australian Department of Mines and Petroleum Golden Gecko Award (2007 and 2002), Society for Ecological Restoration International Award (2003) and the United Nations Environmental Program Global 500 Honour Roll (2003), which made Alcoa of Australia the first mining company worldwide to be recognised for its rehabilitation excellence (Alcoa 2018d).

COMPLETION CRITERIA DEVELOPMENT: IN PRACTICE

Alcoa has developed a suite of internal standards, including environmental policy, restoration objectives and completion criteria, that exceed regulatory requirements (Grant & Gardner 2005). These standards are based on extensive research and development activities, aimed at returning biodiversity to the mined areas. Some of these experiences are unique to Alcoa, while others have the potential to be applied to mining operations elsewhere.

The company follows a set of internal guidelines in the development of completion criteria.

First, criteria should include both *prescriptive* and *performance* indicators. The former confirm that actions have been carried out, while the latter refer to attainment of agreed standards or milestones. This distinction is similar to that made by risk management frameworks (ICMM 2012) distinguishing between *leading* (measuring circumstances preceding an event) and *lagging* indicators (measuring final outcomes).

Second, completion criteria are based on the five key principles outlined in Section 5.6.3 'Rehabilitation objectives'. Third, Alcoa divides its completion criteria into four time-bound stages. This approach reflects that certain criteria need to be met at early stages of rehabilitation, while others become relevant later and, therefore, depend on the successful completion of previous criteria. For example, correct re-landscaping (i.e. earthworks) needs to be achieved as a first step, which will then allow adequate plant growth and fauna return. By contrast, poorly-conducted earthworks may lead to excessive erosion due to water flows, thus preventing the desired rehabilitation outcomes. The four stages for the definition of completion criteria and their relevant aspects are as follows:

1. **Planning:** land use and management priority; existing environment; sustainable growth and development; integrated landscape; integrated management.
2. **Rehabilitation earthworks (landform and soil re-establishment):** integrated landscape; sustainable growth and development; catchment protection.
3. **Early establishment (first 5 years):** vegetation establishment; resilience of vegetation to weeds, dieback, other forest diseases, fire, insects and drought.
4. **Vegetation (12 years and older):** resilience of vegetation; land use (including timber production).

RISK MANAGEMENT

Alcoa manages short and longer-term risks of failure to meet completion criteria. In the short term, the staged approach to setting and achieving completion criteria facilitates the management of risk. Monitoring (as described in the next section) serves to identify whether remedial action may be necessary and, if so, the extent of reworking required. In the longer term, completion criteria are based on research and monitoring to determine what outcomes may or may not be achievable. In this way, completion criteria have become more complex while managing risk of failure.

MONITORING

As part of the rehabilitation certification process, completed rehabilitation is assessed and monitored at several stages. The first evaluation is carried out at the end of the rehabilitation season and is aimed at assessing criteria related to landform earthworks and ground preparation, soil return and seeding (Table 5.10). Second, early monitoring undertaken towards the end of the first year is aimed at ensuring an adequate density of trees for future timber production and other forest values, establishment of leguminous understorey species important for long-term soil nitrogen supply, and the presence of any weed infestations. Any erosion arising from winter rains is also identified at this stage. This early monitoring step enables aspects that do not meet specifications to be quickly addressed, triggering remedial earthworks, infill planting or reseeding (Source: Grant (2006, p. 30) Figure 5.14).

TABLE 5.10 Summary of completion criteria self-certification monitoring

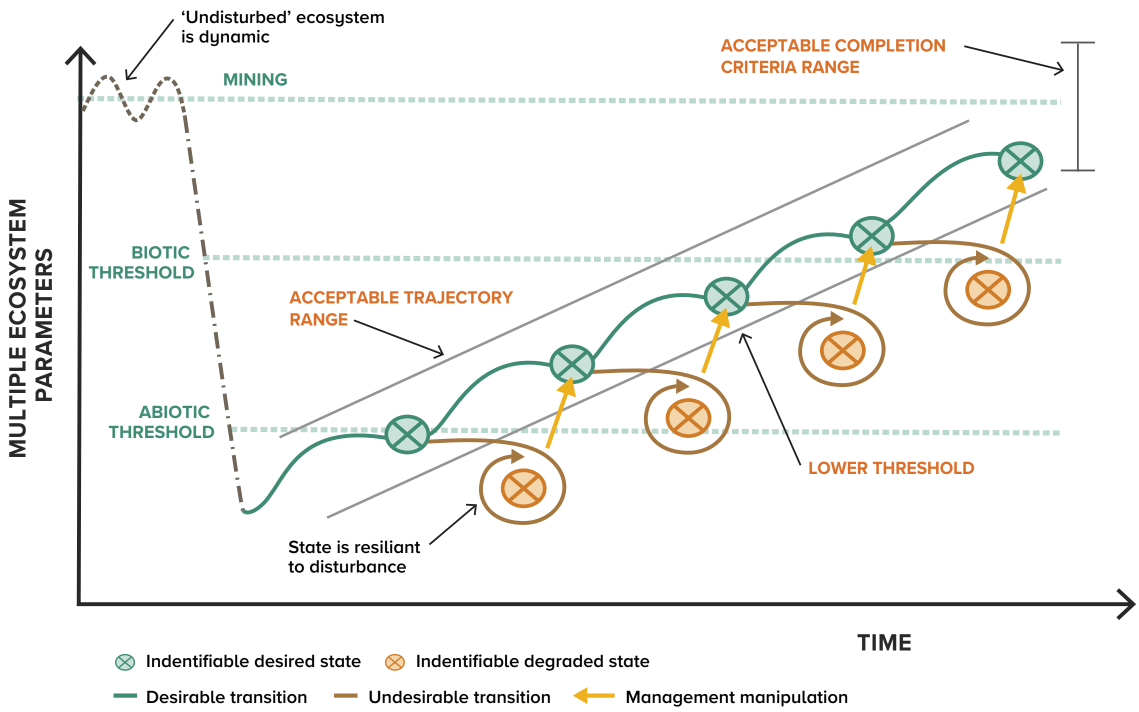
Domain	Rehabilitation action
July — End of first rehabilitation season	• Landscaping: earthworks, pit slopes, burring rocks, pit water holding capacity, access tracks • Soil Return and Fauna: Topsoil cover, fauna habitat, pit level • Contour Ripping • Seeding
March/April — 9 months after rehabilitation initiated	• Plant Density: legumes, jarrah, marri. • Weeds • Erosion • Bare areas
October/November — 15 months after rehabilitation initiated	• Species richness

Source: Adapted from Alcoa (2015)

Thirdly, in the second year after establishment at 15 months of age, monitoring is conducted to measure plant species richness. Results from monitoring plots in rehabilitation are compared with similar plots in the reference unmined forest to obtain a percentage species richness return. Alcoa set a target of 100% species richness return in 1996, which was first achieved in 2001 (Koch 2007b).

A subset of plots assessed for species richness in the second year are retained as permanent plots. These are re-monitored at increasing intervals to assess longer-term ecosystem development, providing confidence that the regenerating forest is tracking on a satisfactory trajectory and able to meet the requirements of various future forest uses. Long-term plot data are also useful inputs for research studies investigating various aspects of ecosystem development and function (e.g. Grant 2003; Grant 2006; Grant & Koch 2007; Source: Grant (2006, p. 30) Figure 5.14).

In addition to flora monitoring, a long-term program monitoring fauna return and use of rehabilitated areas is conducted on a periodic basis. Designed in 1991, the program surveys the return of mammals, birds, reptiles, frogs and ants in healthy upland forests, in stream zone vegetation and in rehabilitated areas of increasing age (Nichols & Nichols 2003). The program provides information on patterns of recolonisation, identifies species that are slow to recolonise rehabilitated areas (which may become subjects for further research) and monitors fauna population dynamics in the surrounding unmined forest.



Source: Grant (2006, p. 30)

FIGURE 5.14 Key states in the rehabilitation process including transitions that require remedial action

EVALUATION

Alcoa's completion criteria are reviewed on a periodic basis. Such reviews consider the latest research and monitoring results, as well as advances in technology, including cost-effective rehabilitation techniques (Nichols *et al.* 2005). In this way, Alcoa is able to both meet current regulatory standards, and anticipate and influence higher standards across the broader industry (Grant & Koch 2007). Two revisions of completion criteria for jarrah-dominant rehabilitation have been completed to date. The format and examples of completion criteria for current rehabilitation are given in Table 5.11.

For example, early research showed the importance of fresh topsoil for rehabilitation of diverse jarrah forest (Tacey & Glossop 1980) which has influenced practice thereafter. More recently, research on P-fertiliser effects on vegetation development has resulted in Alcoa reducing rates of P-fertiliser application from 80 to 40kg per ha (e.g. Daws *et al.* 2015). Where relevant, revision is conducted by mutual agreement between Alcoa and the regulatory authority. In the case of reduced P-fertiliser, DBCA has requested more research into the long-term effects on jarrah forest restoration (e.g. Daws *et al.*, 2019) before ratifying it as standard practice. Efforts to restore not only plant species richness but also similar species composition to reference forest are ongoing and may eventually inform the development of new completion criteria.

Completion criteria are supported by formalised Working Arrangements between Alcoa and the DBCA. The Working Arrangements describe in greater detail how mine operations, including rehabilitation, may be conducted. The intent is to maintain a coordinated approach to the management of mining operations and the protection of biodiversity and water resources (Alcoa 2015). Working Arrangements were first developed in 1979 and are regularly updated in part to maintain consistency with revisions to the completion criteria.

TABLE 5.11 Examples of completion criteria established from 2016 onwards

Stage	Criteria and intent	Guidelines for acceptance	Standard	Corrective action
Planning	**Flora and fauna surveys** Flora surveys and fauna assessments have been completed prior to clearing	Plant species and community management plans have been prepared and endorsed by Parks and Wildlife (DBCA) for State and Federally listed flora species and Threatened Ecological Communities.	Field flora surveys have been completed to agreed standards as set in the Alcoa/Parks and Wildlife Working Arrangements for all areas intended to be cleared for mining or infrastructure.	Undertake survey to agreed standards
Rehabilitation Earthworks	**Landscape design** The mine pit areas are landscaped to be stable and to blend in with the surrounding forest	Landscaping must be completed to ensure effective surface water management. Landscape design will not cause an impediment to access for DBCA Parks and Wildlife's operations or be an ongoing financial or management liability. Self-certification by Alcoa annually and / or inspection by Parks and Wildlife confirm landscape design is acceptable. Landform design that meets the standard will be deemed acceptable unless Parks and Wildlife writes to Alcoa within three months of self-certification to advise otherwise.	Slopes must always be less than 18 degrees. No landscaped pit is to have a slope greater than 15 degrees for more than 20 metres unless it is on contour of the surrounding forest floor.	Alcoa to provide documentation and advice to Parks and Wildlife, where self-certification has resulted in non-standard outcomes. Completion criteria checklists will be completed by Alcoa and may be checked by Parks and Wildlife. If Parks and Wildlife finds that any rework is required based on occasional random inspections, then they will state this in writing to Alcoa within 3 months of the completed inspection. Alcoa will undertake remedial works to ensure areas meet the landscape design standard.
Early Establishment	**Establishment of understorey** There is an adequate legume density early in regeneration.	Alcoa must submit 9-month monitoring data to DBCA Parks and Wildlife annually. Parks and Wildlife must review and advise Alcoa of acceptance or request corrective actions. Vegetation establishment monitoring to occur as defined in the Alcoa/Parks and Wildlife Working Arrangements.	Minimum legumes 0.5 per square metre averaged over a pit assessed at 9-months. Monitoring as defined in the Alcoa/Parks and Wildlife Working Arrangements.	Rehabilitated areas that do not meet the standard will be inspected by Parks and Wildlife and planted or seeded if required and re-monitored.
Vegetation 12 years and older	**Management of understorey** There is an adequate understorey layer in the regenerated pit.	Understorey vegetation meets the expected species richness, density and cover.	Evidence from permanent monitoring plots, and research trials that understorey cover density and richness are within the respective ranges observed in forest reference sites.	Rehabilitated areas that do not meet the expectations will be inspected by DBCA Parks and Wildlife and a plan for remedial action will be negotiated with Alcoa and Parks and Wildlife.

Source: Adapted from Alcoa (2015).

(END OF CHAPTER 5)