Progressive Rehabilitation and Closure Planning using GIS-based Software at the Mungari Project, Western Australia.

S. Mackenzie *Outback Ecology Services, Australia*

I. Mitchell *Outback Ecology Services, Australia*

C. McGuire *La Mancha Resources Australia Pty Ltd, Australia*

Abstract

Closure planning at most mines is typically left until near the end-of-mine life, often leaving little time, financial provision or resources for effective planning and closure. This can present a major hurdle to the operating company because mine closure occurs at a time when the economic recovery of minerals has ceased, cash-flows are minimal or non-existent, and resources for earthworks are often no longer accessible. Early planning for closure takes commitment, resources and time, but can give increased financial return through effective planning and enhanced efficiency.

La Mancha Resources has been integrating progressive closure planning into their daily mining business at the Mungari project for five years. Outback Ecology worked with La Mancha to establish a progressive rehabilitation and closure system for the Mungari project in 2003. Since that time La Mancha has successfully used this system to facilitate rehabilitation and closure planning.

In 2006, Outback Ecology started developing GIS-based software to facilitate a shift from hardcopy to electronic management of rehabilitation and closure, to take advantage of the increasing capabilities of GIS-based systems to manage information. This software is known as the Progressive Rehabilitation and Closure (PRAC) System. In 2007 Outback Ecology was commissioned to review and update the Mungari progressive rehabilitation and closure system, and to re-format it into the electronic PRAC System.

The PRAC System is a web-based application, which means that it can be accessed securely from anywhere on a computer with internet access. The strength of the PRAC System is that tasks and documents can be managed in a spatial context, using standard GIS-information and aerial photography. The basis of the system is that the current knowledge base for any defined area forms the platform from which a rehabilitation and closure strategy for that area can be established. Through the process of gap analysis, tasks are identified to fill gaps and ultimately refine the rehabilitation and closure strategy for that area. Tasks are prioritised using risk-assessment and then scheduled over time in a logical order, rather than undertaken as a combined one-off activity at the time of mine closure.

1 Introduction

The mining industry makes an important economic contribution world wide. Australia is one of the world's leading mining nations and mining is our largest single export earner. A sustainable mining industry is considered vital for Australia's ongoing development and the future of the mining industry is likely to become more and more dependant on its reputation (Mackenzie *et al*., 2007).

La Mancha Resources Australia Pty Ltd (La Mancha) understands the benefits of integrating progressive closure planning into their daily mining business and has been actively engaged in this process at their Mungari project for five years.

Outback Ecology worked with La Mancha, formerly Mines and Resources Australia Pty Ltd, to establish a progressive rehabilitation and closure system for the Mungari project in 2003. Since that time La Mancha has successfully used this system to facilitate rehabilitation and closure

planning. After initial development and implementation in 2003, the Mungari progressive rehabilitation and closure system was reviewed and updated in 2004 and 2005.

In 2006, Outback Ecology started developing GIS-based software to facilitate a shift from hardcopy to electronic management of rehabilitation and closure, to take advantage of the increasing capabilities of GIS-based systems to manage large volumes of information, supporting documents and progressive closure tasks. This software is known as Progressive Rehabilitation and Closure (PRAC) System. In 2007 Outback Ecology was commissioned to review and update the Mungari progressive rehabilitation and closure system, and to re-format it into the electronic PRAC System.

This paper presents some background information on the Mungari project, including the history of mine closure planning, before detailing the concept and benefits of progressive rehabilitation and closure, and outlining the process of development and implementation of the Mungari PRAC System.

2 Mungari project

2.1 Location and background

The Mungari project is located in the Shire of Coolgardie, approximately 20 km north-east of Coolgardie and 22 km west of Kalgoorlie. The Mungari project consists of Frog's Leg and White Foil mines, both of which lie within the Mungari pastoral station. The Mungari pastoral station was de-stocked in 1998 (URS, 2001).

Frog's Leg is an operational underground mine and White Foil is an open pit mine under care and maintenance. All ore generated from the Mungari project is transported off-site for crushing, milling and processing.

2.2 Existing environment

2.2.1 Surface Hydrology

The Mungari project lies within a salt lake system that flows to the north-east, is classed as ephemeral, and fills only after significant rainfall (URS, 2001). Lakes Kopai and Kurrawang border Frog's Leg and White Foil mines respectively. A number of diversion drains and flood protection bunds were constructed to minimise the impacts of surface water on the mining operation, whilst aiming to maintain natural surface water flow (Townley and Associates, 2003).

2.2.2 Flora

Approximately 20 plant communities were identified during pre-mining surveys at the Mungari project; these communities were dominated by *Eucalyptus* woodlands. Other plant communities include Samphire communities and *Eucalyptus yilgarnensis* (Dames and Moore, 1999) (Mattiske, 2002).

2.2.3 Fauna

Five fauna habitats were identified during a fauna survey in late-2002 (Townley and Associates, 2003):

- Tall *Eucalyptus* woodlands
- Mallee Woodlands
- Woodlands over Spinifex
- Scrublands and heathlands
- Chenopod heathlands.

2.2.4 Geology

Both Frog's Leg and White Foil mines are located within the Archaean Yilgarn Craton, on the western edge of the Norseman-Wiluna greenstone belt. The greenstone belt is generally considered to consist of Archaean komatiites, high-magnesium basalts, volcaniclastics and transported material intersected by gabbro-dolerite sills (URS, 2001).

The Mungari project was described as having varied thickness of transported material and as variably truncated laterite on Archaean basement (Townley and Associates, 2003).

2.3 White Foil mine

The White Foil mine comprises the following key features (Figure 1):

- White Foil open pit
- Waste rock landform
- Three Mile Hill and Paddington ROM pads
- Surface water diversion channel
- White Foil to Kundana dewatering pipeline and transfer dam
- Evaporation and storage ponds
- Workshop and fuel storage
- Access and haul roads
- Three Mile Hill haul road
- Hardstand and laydown areas
- Site offices and ablutions
- Exploration yard
- Explosives Magazine
- Re-injection borefield (decommissioned)

2.3.1 Mining

Mining of the White Foil open pit commenced in late 2001 and continued until mining was suspended in August 2003 due to issues with pit-dewatering. Dewatering of the White Foil open pit re-commenced in November 2006 and continued until September 2007 when dewatering rates stabilised. Dewatering at reduced rates has been ongoing since September 2007. Re-commencing mining of the White Foil pit will be subject to a feasibility study.

2.3.2 Rehabilitation

Rehabilitation of the White Foil waste landform commenced in 2004 and the majority of this was completed by 2006. Approximately 70% of the batter area of the landform has been rehabilitated; there is still a large area that needs to be filled and incorporated into the final landform design. The details of the final design will be determined by the outcomes of the feasibility study of White Foil. Landform batters were pushed down to 17-20 degrees and were covered with topsoil, deep-ripped and then seeded. The waste landform has not experienced significant erosion, most likely because of the competent and rocky nature of the subsurface materials.

2.4 Frog's Leg mine

The Frog's Leg mine comprises the following key features (Figure 2):

- Frog's Leg open pit

- Waste landform
- Surface water diversion channel
- Access and haul roads
- Pit flood protection bund
- ROM pad
- Dewatering and injection bores
- Frog's Leg to White Foil dewatering pipeline
- Transfer pond
- Hardstand and laydown areas
- Workshop and hydrocarbon storage areas
- Office buildings

2.4.1 Mining

The Frog's Leg project is a joint venture between La Mancha (51%) and Dioro Exploration (49%), known as the Mungari East Joint Venture (MEJV). La Mancha is the manager and operator of the Frog's Leg project. Development of the Frog's Leg open pit commenced in 2003 and the first ore was mined in March 2004. Open pit mining ceased in October 2005 (Areva, 2006). Underground mining from the Frog's Leg open pit commenced in June 2007 (La Mancha, 2007).

As the underground mine is still under development, waste rock will continue to be dumped on the waste landform. Waste rock will be used as underground backfill where practicable once production has commenced. The landform will be rehabilitated to final design.

2.4.2 Rehabilitation

The Frog's Leg waste landform is partially rehabilitated, with the lower batter on the western side having been pushed down to a slope angle of approximately 16 degrees and covered with topsoil. The lower batter has not been ripped or seeded, and vegetation establishment is limited. The upper batter on the western side of the waste landform has been pushed down to a slope of approximately 16 degrees, and is currently being covered with topsoil.

A single mid-slope berm, approximately two metres wide, separates the upper and lower western batter. The upper batter and mid-slope berm consist of primary waste rock, and it is likely that primary waste rock underlies the topsoil on the lower batter. The remainder of the waste landform, including a low grade stockpile adjoining the southern batter, remains at an angle of repose. This is currently being drawn from and allowing the final waste dump design to be achieved.

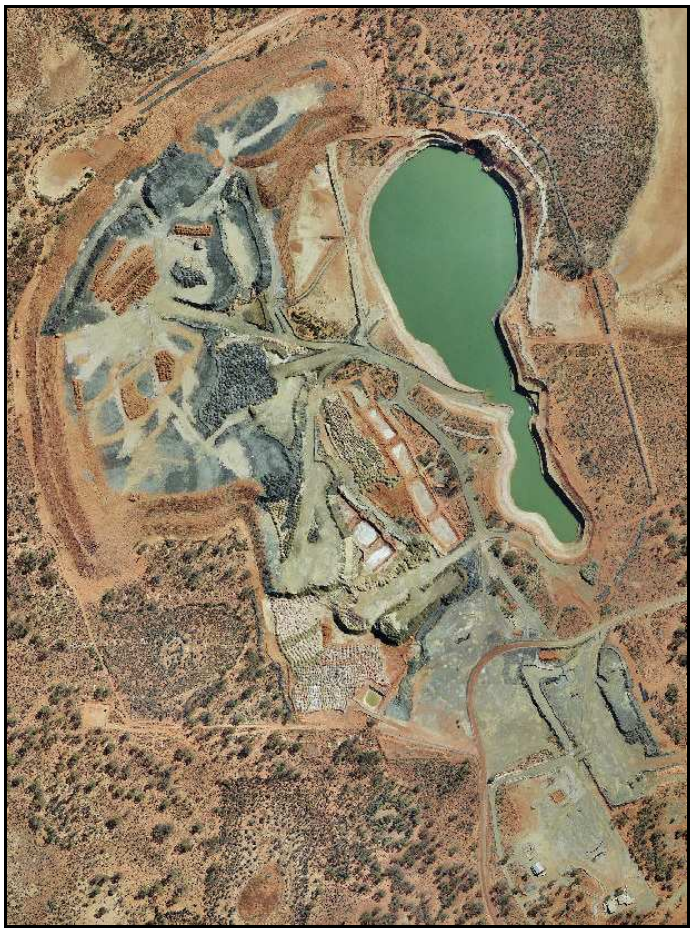

Figure 1 White Foil mine

Figure 2 Frog's Leg mine

3 Progressive Rehabilitation and Closure Planning

3.1 Background

Closure planning at most mines is typically left until near the end-of-mine life, often leaving little time, financial provision or resources for effective planning and closure. This can present a major hurdle to the operating company because mine closure occurs at a time when the economic recovery of minerals has ceased, cash-flows are minimal or non-existent, and resources for earthworks are often no longer accessible. The end of mine-life is clearly not the optimal time to be planning and undertaking the bulk of rehabilitation and closure activities (Mackenzie *et al*., 2006).

Early planning for closure takes commitment, resources and time, but can give increased financial return through effective planning and enhanced efficiency. Some of the benefits of planned closure include (Mackenzie *et al*., 2006):

- Identification of high risk priorities for research or rehabilitation
- Reduction of ongoing environmental liabilities by progressive rehabilitation
- Allocation of rehabilitation and closure costs to the productive phase of mining rather than deferral to the end of mine-life
- Increased efficiency through reduced double handling of waste rock and rehabilitation materials
- Ongoing feedback, through monitoring, of the effectiveness of rehabilitation designs
- Anticipated closure outcomes are more reliable as they are the product of considered decisions, scientific trials and investigation
- Opportunity to refine potentially costly closure strategies through research and trials
- Facilitation of timely bond recovery and tenement relinquishment
- Early confirmation of rehabilitation and closure costs so that sufficient financial and material resources can be set-aside
- Improved access to capital from lending institutions
- Lower risk of regulatory non-compliances and less regulatory interest
- Improved access to land resources from governments
- Greater acceptance by key stakeholders, and
- Reduced period of post-closure monitoring and maintenance period, areas rehabilitated earlier during the life of mine.

3.2 Progressive Rehabilitation and Closure; the concept

The concept of progressive rehabilitation and closure promotes a shift away from conventional ‘static’ closure plans towards a systematic approach that makes provision for planning and closure as life-of-mine processes. The concept has been developed in accordance with the principles of the ‘Strategic Framework for Mine Closure’ developed by the Australian and New Zealand Minerals and Energy Council and the Minerals Council of Australia (ANZMEC/MCA, 2000).

The basis of the concept is that the current knowledge base for any defined area forms the platform from which a rehabilitation and closure strategy for that area can be established. Through the process of gap-analysis, tasks are identified to fill-gaps and ultimately refine the rehabilitation and closure strategy for that area. Tasks are prioritised using risk-assessment and then scheduled

over time in a logical order, rather than undertaken as a combined one-off activity at the time of mine closure.

3.3 Mungari mine closure planning

La Mancha understands the benefits of integrating closure planning into their daily mining business. Since 2003 La Mancha has used innovative tools to assist them in this process.

A progressive rehabilitation and closure system was developed for White Foil in 2003 by Outback Ecology and Aquaterra in conjunction with La Mancha. La Mancha has used this system to facilitate rehabilitation and closure planning from 2003 until the present. La Mancha reviewed and updated the system internally in 2004 and 2005.

In 2007, Outback Ecology was commissioned to review and update the Mungari rehabilitation and closure system for both Frog's Leg and White Foil mines, and to re-format it into the GIS-based PRAC System.

3.4 The PRAC System

Outback Ecology teamed with a Microsoft Certified software development company to customize GIS-based software to 'bring-to-life' the concept of progressive rehabilitation and closure. The software facilitates a shift from hardcopy to electronic systems to integrate the benefits of GIS-based data management into mine closure planning. This software is known as the PRAC System.

The PRAC System is a web-based application, which means that it can be accessed securely from anywhere on a computer with internet access. The strength of the PRAC System is that tasks and documents can be managed in a spatial context, using standard GIS-information and aerial photography.

3.4.1 Task Management

The PRAC System manages tasks (eg investigative, monitoring or rehabilitation tasks) for each area of interest or 'project area' on a mine. Once established, tasks can be scheduled logically over time. Tasks can be managed via the GIS-interface or through an interactive Gantt chart. Tasks are marked as 'not-complete', 'in-progress' or 'completed', allowing effective tracking of achievements over time and re-establishment of planning priorities. When viewed through the Gantt chart, tasks can be sorted by the project area they relate to, their status and/or their category. Task queries can be generated for reporting requirements. In addition, tasks can be emailed or printed by a project manager for the personnel responsible for their completion.

3.4.2 Document Management

Missing documents are one of the challenges in mine closure planning. The PRAC System hosts electronic copies of all relevant documents including monitoring data, historic approvals documents and related reports. Copies of the documents are held in a secure register. Links to specific documents are established for each project area. Registered documents in the Mungari PRAC System are accessible through a global search function. This function allows the user to search and access all documents hosted within the PRAC System.

3.5 PRAC System; Mungari Project

There were two stages in establishing the Mungari PRAC System, development and implementation.

3.5.1 Development

The Mungari PRAC System consists of two core components. The first is the *Closure Framework* which contains all the overarching information that provides the context for the closure planning process. The second is the *Progressive Rehabilitation and Closure Strategy* which details the

strategy for application of the system achieving the closure objectives. The format of the Mungari PRAC System is as follows:

Closure Framework	Introduction and background
	Legal compliance register
	End land use, closure objectives and draft closure criteria
	Bond reconciliation and relinquishment framework
	Stakeholder engagement strategy
	Risk assessment
Progressive Rehabilitation and Closure Planning	Project areas and current knowledge base
	Gap identification
	Progressive rehabilitation and closure strategy; including progressive rehabilitation and closure tasks
	Closure cost estimates

Interaction between various elements of the Mungari PRAC System is facilitated through a geo-referenced detailed aerial photograph.

3.5.2 Implementation

The Mungari PRAC System is administered by the La Mancha environmental department in consultation with the management team and service and planning departments. Many of the tasks identified for each area can be managed directly by the environmental department, with assistance from specialist consultants or internal departments where required.

The primary driver for the PRAC System is the process of review, which involves scheduled updates. Periodical reviews can be undertaken at less frequent intervals early in the operation's history (biennially) and more frequently closer to the end of mine life (annually or more often if required).

An important tool in managing the Mungari PRAC System is the annual environmental report (AER). The AER is used as a transparent reporting document to describe accomplishment of progressive rehabilitation and closure tasks, and to establish objectives for the coming reporting period.

4 Summary

Closure planning at most mines is left until near the end-of-mine life, often leaving little time, financial provision or resources for effective planning and closure. This can present a major hurdle to the operating company because mine closure occurs at a time when the economic recovery of minerals has ceased, cash-flows are minimal or non-existent, and resources for earthworks are often no longer accessible. Early planning for closure takes commitment, resources and time, but can give increased financial return through effective planning and enhanced efficiency.

Progressive closure planning reduces the risk of a company suffering many of the consequences of unplanned closure. La Mancha understands this and through the development, implementation

and maintenance of the Mungari PRAC System, La Mancha has engaged in and realised the rewards of progressive mine closure planning.

Acknowledgements

The authors would like to acknowledge La Mancha Resources Australia Pty Ltd for allowing their data to be presented in this paper.

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