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Planning for Rehabilitation and Closure of the Coburn Mineral Sand Mine at Shark Bay, Western Australia

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1 INTRODUCTION

Gunson Resources Limited (Gunson) is developing the Coburn Mineral Sand Project (the Project) in the Gascoyne region of Western Australia (Figure 1). The Project comprises the excavation and processing of a major low-grade mineral sand deposit immediately east of the Shark Bay World Heritage Property. Approximately 2.8 Mt of Heavy Mineral Concentrate will be dry-mined from nine pits and processed on site before transport to markets.

As part of the Environmental Impact Assessment (EIA) of the proposed Project, a Rehabilitation Benchmarking Study (RBS) was conducted to demonstrate whether rehabilitation was possible by providing examples of rehabilitation outcomes under similar conditions. This paper outlines the approach taken in relation to this study and discusses the key outcomes.

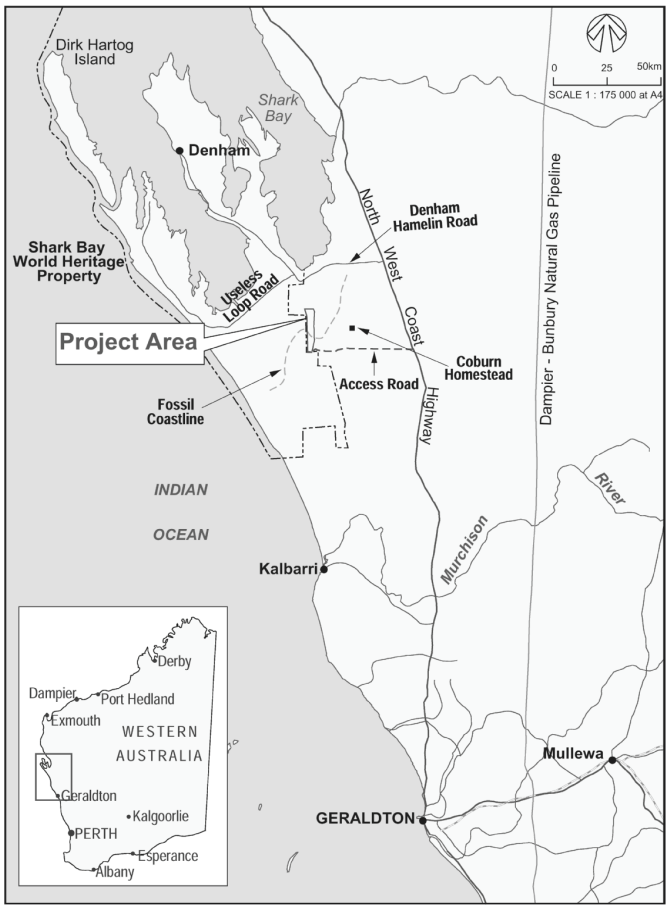

Figure 1 Location map

2 BACKGROUND

Most of the Coburn Project Area is located approximately 250 km north of Geraldton and 84 km southeast of Denham (Figure 1). The Project occurs primarily within Coburn Station, a pastoral lease held by Gunson and used for sheep grazing.

At a regional scale, the Project Area occurs within the Nanga, Nerren and Sandplain land systems, which are described by Payne et al. (1987) as comprising level to undulating sand plains and dunes with deep sand soils covered by moderately dense acacia and other shrublands, mallee woodlands or heathy scrublands. The Project is located in a transition zone from the arid Eremaean Botanical Province to the more Mediterranean conditions of the South West Botanical Province. It is expected that the Project will disturb approximately 3695 ha of land.

The Project proposal was subject to formal Environmental Impact Assessment (EIA), at the level of Public Environmental Review (PER) under Part IV of the Western Australian *Environmental Protection Act* 1986. In addition, the proposal is considered to be a "controlled action" under the *Environment Protection and Biodiversity Conservation Act* 1999. The controlling provisions are world heritage, listed threatened species and communities and listed migratory species. The environmental assessment was conducted in accordance with the "Agreement between the Commonwealth of Australia and Western Australia under Section 45 of the EPBC Act Relating to the Environmental Impact Assessment (the Bilateral Agreement) and in conformance with the Cooperative Arrangements to the Bilateral". This means that the Commonwealth accredited the WA environmental impact assessment process.

Approval by the State Minister for the Environment was issued in May 2006 and approval is expected from the Commonwealth Environment Minister in July 2006.

Early in the EIA process, concerns were raised about the feasibility and effectiveness of rehabilitation at Coburn. It was recognised that there was limited experience in mine site rehabilitation in the region, and that the windy conditions, irregular rainfall, high evaporation rates and slow-growing vegetation at the site would present significant challenges to the rehabilitation programme. Therefore, the WA Environmental Protection Authority (EPA) requested that Gunson demonstrate that successful rehabilitation was possible by providing examples of rehabilitation outcomes under similar conditions. This was a challenging request as there are no other mineral sands mines operating in the Shark Bay district or operating elsewhere under exactly the same conditions.

In response to the EPA's concerns, Gunson commissioned URS Australia Pty Ltd (URS) to undertake a Rehabilitation Benchmarking Study (RBS) which examined ten sites in the Gascoyne region of WA, a mineral sands mine in Queensland and a mineral sands mine in South Africa.

3 METHODOLOGY

3.1 Objectives

The objectives of the RBS were to:

- Investigate the rehabilitation success of sites located in the Gascoyne region or in similar environmental settings elsewhere.
- Identify the factors that might constrain or enhance rehabilitation success.
- Develop rehabilitation methods that may be used to address these factors.

3.2 Site Selection

Twelve sites were selected as case studies for the RBS. These comprised two mineral sand mines operating in relatively similar conditions to those at Coburn, and ten sites in the Gascoyne region that have undergone disturbance and occur in conditions similar to those expected at Coburn. These sites are described below:

- Namakwa Sands mineral sands mine. Namakwa Sands operates a mineral sands mine at Brand-se-Baai on the west coast of South Africa (Figure 2). Mining commenced in 1994 and is conducted using "dry" mining methods. Rehabilitation is conducted on a progressive basis.
- North Stradbroke Island (NSI) mineral sands mine. Consolidated Rutile Limited (CRL) conducts both dry and wet mining of mineral sands on North Stradbroke Island, on the east coast of Australia (Figure 2). Mining has occurred at the site since pre-1945 and progressive rehabilitation has been conducted.

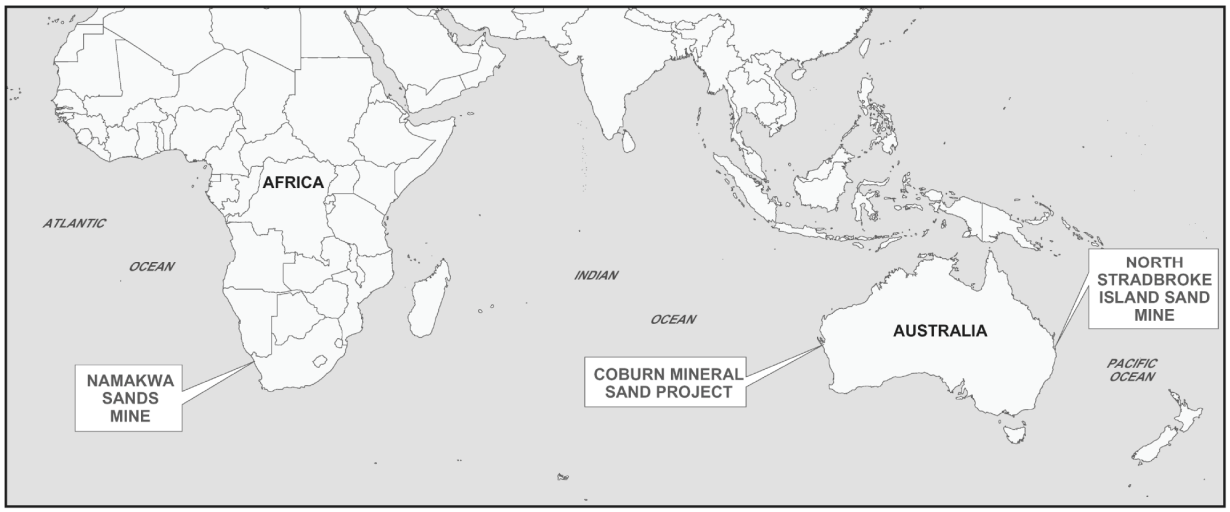

Figure 2 Location of the Namakwa Sands and North Stradbroke Island mine sites

- Coburn test pit. The test pit is located at the southern end of the Coburn Project Area (Figure 3) and was developed to assess aspects associated with the mineability of the ore. The site is located within the Nanga land system and was excavated and backfilled in March 2004.
- Peron Peninsula roads. This site comprises selected tracks and roads on the Peron Peninsula, approximately 100 km northwest of the Project Area (Figure 3). The tracks and roads were ripped by the Department of Conservation and Land Management (CALM) in 2003/04.
- Denham refuse disposal site. The Denham refuse disposal site is located approximately 80 km northwest of the Coburn Project Area (Figure 3). Earthworks were conducted to rehabilitate the site in 2003.
- Eurardy Station. This site comprises an area within the Nanga land system on Eurardy Station, approximately 100 km southeast of the Coburn Project Area (Figure 3). The area was cleared in 1996 and used for a wheat crop in 1997 before being allowed to lie fallow. A herbicide was applied and the site left to revegetate naturally.
- Peron Peninsula fire buffers. The fire buffers are located approximately 120 km northwest of the Project Area (Figure 3) and were cleared by CALM in 1995.
- Useless Loop gravel pits. Development of the Shark Bay Salt Joint Venture, approximately 84 km northwest of the Project Area (Figure 3), included the use of several gravel pits. These pits were rehabilitated in 1994.
- Proposed Shark Bay airstrip. The proposed airstrip is located approximately 80 km northwest of the Project Area (Figure 3). Clearing of vegetation and compacting of soil was conducted at the proposed airstrip site in 1990, but no further development occurred. No active rehabilitation has been conducted at this site.

- Dampier-Bunbury Natural Gas Pipeline (DBNGP). Two sites along the DBNGP to the east of the Project Area (Figure 3) were included in the RBS. These sites are located in the Nerren and Sandplain land systems and were cleared approximately 25 years ago.
- Woodleigh Station. Woodleigh Station is located approximately 70 km northeast of the Project Area (Figure 3). Sixteen sites in the station were disturbed in 1965 as part of a programme by the American National Aeronautics and Space Administration (NASA) to test visibility from space. The sites are located within the Sandplain land system and have been subject to little or no active rehabilitation.
- Old Hamelin Airstrip. The airstrip is located on the Hamelin Station, to the north of Coburn Station (Figure 3). The L-shaped airstrip is located within the Nerren land system and has undergone natural revegetation.

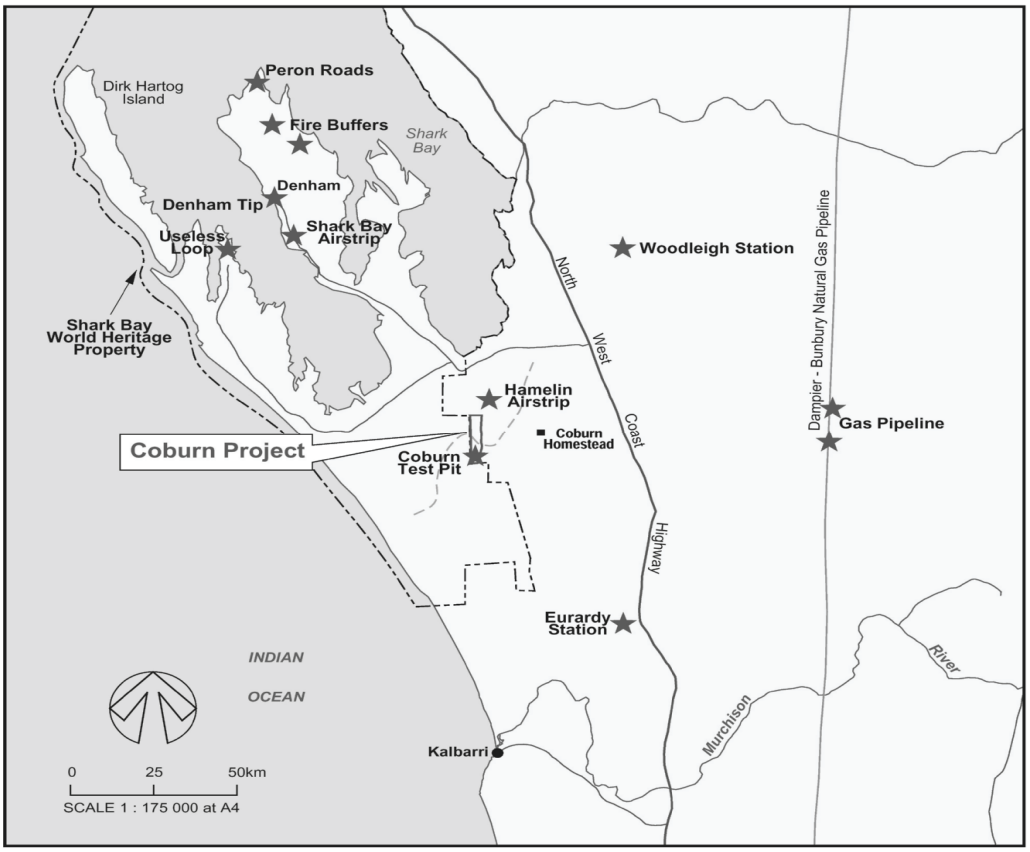

Figure 3 Location of Gascoyne region sites

There are many similarities between the case study sites and the Coburn Project Area. Of course, there are also differences, but these do not preclude the transfer of information and lessons learned about rehabilitation under these conditions. Each case study site was chosen specifically as it contained at least one similarity to the disturbance expected by mining operations. The applicability of each case study to the Project is summarised in Table 1.

Table 1 Summary of case study sites

Case Study Site	Applicability to Coburn Project
Namakwa Sands mineral sands mine	• Both sites are located in the transition zone between arid/desert conditions and more Mediterranean conditions. They have similar climates though Namakwa Sands has a lower average annual rainfall and a higher occurrence of sea fog. • Both sites experience a strong wind regime. Namakwa Sands experiences one of the strongest wind regimes in the world, with average wind speeds of 3 – 9.5 m/s. Summer southerlies at Shark Bay consistently blow over 7 m/s for several days. • Both sites are characterised by vegetated sand dunes, though the vegetation is different. • Neither site has visible surface water features. • Both sites occur in the vicinity of sensitive internationally-recognised conservation areas. • The mining and processing operations proposed for the Coburn Project are similar to those conducted by Namakwa Sands.
NSI mineral sands mine	• Both sites comprise vegetated sand dunes. • NSI experiences a different climate regime, but both sites experience a strong wind regime. CRL uses a bitumen emulsion to reduce wind erosion. • Both sites occur in the vicinity of sensitive internationally-recognised conservation areas. • The operations proposed for the Coburn Project are similar to the dry mining and processing operations conducted by CRL.
Coburn test pit	• The site is located within the Coburn Project Area. • Direct return of topsoil and subsoil was conducted during site rehabilitation. • The site provides an example of natural revegetation within the Nanga land system. • A period of one year has occurred since rehabilitation, providing information on any issues arising during the initial stages of rehabilitation.
Peron Peninsula roads	• The site is located within the Shark Bay area and has similar environmental conditions. • The site is located within the Peron land system, which is similar to the land systems within the Coburn Project Area. • The site provides information on revegetation of areas previously compacted by vehicle movements.

Case Study Site	Applicability to Coburn Project
	• One to two years has occurred since ripping, providing information on any issues arising during the initial stages of rehabilitation.
Denham refuse disposal site	• The site is located within the Shark Bay area and has similar environmental conditions. • The site is located within the Peron land system, which is similar to the land systems within the Coburn Project Area. • The site provides information on landfill rehabilitation and the use of brush in rehabilitation. • A period of three years has occurred since rehabilitation, providing information on any issues arising during the initial stages of rehabilitation.
Eurardy Station site	• The site has many similar environmental conditions. • The site provides an example of natural revegetation within the Nanga land system and provides information on the use of herbicides to restrict exotic weeds and the impact of sustained grazing pressure. • A period of seven years has occurred since rehabilitation, providing information on the impact of grazing after this time.
Peron Peninsula fire buffers	• The sites are located within the Shark Bay area and have similar environmental conditions. • The sites occur within the Peron land system, which is similar to the land systems within the Coburn Project Area. • The sites provide information on natural revegetation in an arid area subject to grazing pressure. • Ten years have occurred since disturbance, providing information for prediction of revegetation rates.
Useless Loop gravel pits	• The sites are located within the Shark Bay area and have similar environmental conditions. • The sites occur within the Edel land system, which is similar to the land systems within the Coburn Project Area. • The sites provide information on the use of rabbit resistant fencing to improve revegetation. • Eleven years have occurred since rehabilitation, providing information for prediction of revegetation rates.
Proposed Shark Bay airstrip	• The site is located within the Shark Bay area and has similar environmental conditions.

Case Study Site	Applicability to Coburn Project
	• The site occurs within the Taillefer land system, which is similar to the land systems within the Coburn Project Area. • The site provides an example of natural revegetation of a compacted area.
DBNGP sites	• The sites are located within the Gascoyne area and have many similar environmental conditions. • The sites provide a comparison of natural revegetation on the Nerren and Sandplain land systems.
Woodleigh Station sites	• The sites are located within the Gascoyne region and have many similar environmental conditions. • The sites provide an example of natural revegetation of a compacted area within the Sandplain land system. • Forty years have occurred since disturbance, providing information for prediction of revegetation rates.
Old Hamelin Station airstrip	• The site is located in the vicinity of the Coburn Project Area and has the same environmental conditions. • The site provides an example of natural revegetation within the Nerren land system, although the disturbance characteristics remain unknown. • Sixty years have occurred since disturbance, providing information for prediction of revegetation rates.

3.3 Assessment of Mine Sites

A desktop review of available information was conducted for the Namakwa Sands and NSI mines. URS visited the Namakwa Sands mine in November 2004 and the NSI mine in January 2005. Rehabilitation areas were visited at both sites and discussions were held with environmental and other site personnel.

3.4 Assessment of Gascoyne Sites

The rehabilitation status of the ten sites located in the Gascoyne region was assessed during a field survey in January 2005. At each site, both disturbed and undisturbed areas were inspected. General site characteristics were described including slope, aspect and land use. Up to six randomly placed 10 m x 10 m quadrats were established in each of the disturbed and undisturbed areas, and vegetation characteristics were measured or observed. Within each quadrat, the vegetation type, maximum height of the vegetation, number of plant species and percentage cover of live vegetation, dead vegetation and vegetation litter were recorded. The four species providing the greatest percentage foliage cover within each quadrat were identified and their individual cover values were recorded.

Soil parameters were recorded using a methodology based on the Landscape Function Analysis (LFA) system developed by Tongway and Hindley (2004). A 1 m x 1 m quadrat was placed in the centre of the vegetation quadrat and a range of indicators was measured. These included rainsplash protection, perennial vegetation cover, litter, cryptogram cover, crust brokenness, soil erosion type and severity, deposited materials, soil surface roughness, surface nature (resistance to disturbance) and texture. The soil data were entered into the software programme designed by Tongway and Hindley (2004) to calculate soil stability, infiltration and nutrient cycling.

Where possible, an auger was used to sample the soil up to 1 m deep. Data were recorded in relation to soil colour, texture, pH and calcrete content.

The above soil assessment methodology was used for most sites. In some instances, site-specific factors prevented the use of the LFA methodology so photographs were taken to allow a visual assessment of the sites. At the Coburn test pit, there was a marked difference between disturbed and undisturbed areas due to the short period of time since disturbance, so a decision was made to compile data relating mainly to surface stability. Three transects were established across the site, and soil stability was determined LFA techniques at 1 m intervals along the transects.

One benefit of conducting the study during summer was that the extent of live vegetation cover was expected to be at its lowest. The high temperatures and lack of rainfall (except during cyclonic events) discourage new growth and sometimes cause plants to drop physiologically-expensive leaves in order to decrease stress. Further, the wind strengths are greatest in summer, so the potential for wind erosion is higher than at other times of the year.

4 RESULTS

The results of the RBS are presented in a series of case study reports appended to the PER (URS, 2005). The key outcomes are summarised in Table 2 below.

Table 2 Summary of case study outcomes

Site	Years since disturbance/rehabilitation (at time of BRS)	Observations
Coburn test pit	1 year since rehabilitation earthworks and brushing	Negligible perennial vegetation present. Weeds (in particular *Brassica tournefortii*) appear to be dominant primary colonisers. Soils appear to be stable, with no signs of erosion. A crust at the surface of the soil profile is evident, that is likely to assist with soil stabilisation.
Peron Peninsula roads	1-2 years since ripping	Negligible colonising vegetation on one site, vegetation establishing on another. Improved revegetation at site where de-compaction has occurred. Relatively stable soils with no erosion.
Denham refuse disposal site	2 years since rehabilitation earthworks and brushing	Colonising vegetation present (both native and exotic species). No significant difference between zone stability in disturbed and undisturbed sites, with stable soils particularly evident where brushing has occurred. Comparable zone infiltration indices, zone nutrient indices and vegetation cover between disturbed and undisturbed sites.
Eurardy Station site	7 years since herbicide application	Stable soils with no erosion evident. Less vegetation cover at disturbed site than undisturbed site, but similar species diversity. No difference in weed abundance, zone infiltration, zone stability or zone nutrients between disturbed and undisturbed sites. Protection from grazing is not a prerequisite for the successful return of native vegetation.

Site	Years since disturbance/rehabilitation (at time of BRS)	Observations
Namakwa Sands mineral sands mine	Mining commenced in 1994, with progressive rehabilitation occurring as mining progresses	Stable soil after four years. Vegetation characteristics are improving over time. Shadecloth windbreaks can provide successful wind erosion control but windbreaks are labour intensive. Topsoil should not be stockpiled for more than three months, with direct return preferable. Most seed reserve exists in top 5 cm of topsoil.
Peron Peninsula fire buffers	10 years since rehabilitation	Fenced areas show improved rehabilitation, suggesting that grazing affects the rate of revegetation. Different dominant species present, but similar vegetation cover is evident between disturbed and undisturbed sites. Undisturbed sites showed higher water infiltration and nutrient cycling indices than disturbed sites, although no difference was observed in soil stability.
NSI mineral sands mine	1-11 years since rehabilitation	Soil stabilises with the addition of bituminous sprays and planting of cover crops. Substantial rehabilitation success has been achieved at this site.
Useless Loop gravel pits	11 years since rehabilitation	Fenced areas show improved rehabilitation, suggesting that grazing affects that rate of revegetation. Seeding of vegetation during initial stages of rehabilitation may improve the rate of return of vegetation cover.
Proposed Shark Bay airstrip	15 years since disturbance, no active rehabilitation	Dominant vegetation species differ between disturbed and undisturbed sites, although all other vegetation features are comparable. *Acacia ligulata* was the dominant coloniser. Protection from grazing is not a prerequisite for the return of native vegetation. No significant difference was found between sites in soil stability, nutrient cycling or zone infiltration.
DBNGP sites	25 years since rehabilitation	No difference is evident in rehabilitation between the Nerren and Sandplain land systems. Tested parameters including zone infiltration, zone stability and zone nutrients were similar between sites.
Woodleigh Station sites	40 years since disturbance, with little or no active rehabilitation	No significant difference noted between disturbed and undisturbed sites in any tested factors. After 40 years, the disturbed vegetation appears to have returned to its “natural” state.
Old Hamelin Station airstrip	65 years since disturbance, with no active rehabilitation	Tested indices including zone infiltration, zone stability and zone nutrients were similar between sites. Dominant vegetation species differ between disturbed and undisturbed sites.

5 DISCUSSION

The RBS was successful in identifying a range of factors that have the potential to affect the rehabilitation success of the Project. The main factors that were identified as follows:

- Topsoil is an important source of seed and nutrients, and should be conserved for use in rehabilitation. Experience suggests that stockpiling topsoil for less than three months is preferable.
- Nearly all of the case study sites had weak soil surface crusts that were able to confer stability to the sites. No accelerated wind erosion was recorded at any of these sites. Soil crusts are likely to begin forming with the addition of water during winter rainstorms. This suggests that wind erosion is unlikely to be a significant problem during the rehabilitation of the Project Area.
- The surface crust is likely to remain intact and confer continued soil stability provided that traffic and grazing animals do not cause significant disturbance. The protection afforded by the soil crust can also be improved through the provision of vegetative material to decrease the critical sheer velocity of wind (Blandford, 2004). This protection can be provided naturally with the re-establishment of annual and perennial vegetation, or artificially with the clearing of cleared vegetation (brush).
- The re-establishment of vegetation is likely to occur with initial colonising by introduced annual weeds and native species. Trials within the Coburn test pit showed that wild turnip (*Brassica tournefortii*) is likely to be the dominant colonising species. This species may benefit rehabilitation by providing wind protection for the soil and other colonising species, but will compete with native species for water and nutrients.
- Wild turnip occurred at most case study sites, both disturbed and undisturbed, but in low abundance. This abundance seemed to decrease as time since disturbance increased, suggesting that as sites become more stable, native species dominate and this weed species becomes scarce.
- Annual and perennial native colonisers were present in recently disturbed sites. Two species in particular, *Acacia ligulata* and *Stylobasium spathulatum*, were found at a number of disturbed areas. *A. ligulata*, in particular, was found to dominate some sites that had been disturbed 8-15 years prior to the RBS. Due to its lack of dominance in rehabilitated sites older than 15 years, we expect that *A. ligulata*'s dominance decreases after this time period, allowing the slower growing climax vegetation to re-establish.
- Revegetation was not observed at all sites. Some rehabilitation sites that had been previously subject to compaction by vehicles showed low plant re-colonisation. A comparison of rehabilitated roads on Peron Peninsula that had been subject to similar conditions and disturbances suggested that ineffective de-compaction methods may have been the cause. This lesson is particularly important for the rehabilitation of haul roads within the Project Area, and suggests that comprehensive compaction relief is required.
- The rate of rehabilitation is likely to be decreased if there is significant loss of vegetation biomass through grazing pressure. The Peron Peninsula fire buffers and Useless Loop gravel pits show that sustained high levels of grazing, usually by introduced herbivores, have the ability to reduce plant species diversity and vegetation cover in rehabilitation areas. Very few herbivores were found during fauna surveys within the Project Area, so high levels of grazing are not likely to be an issue. However, the addition of water to the area through the mining process, as well as the growth of young nutrient-rich vegetation, may attract herbivores to the region. If this occurs, exclusion fencing or some form of exotic species population management may need to be implemented.
- The Nanga, Nerren and Sandplain systems (in contrast to many rangeland systems) are resilient and 'non-leaky' in that they retain water and nutrients within the system. Sand soils with high infiltration rates and relatively dense vegetation means that patch and inter-patch partitioning of resources, although obvious, is not as marked as in many other systems. The systems are not historically susceptible to wind erosion. If vegetation is completely removed by fire or clearing, there may be moderate to high risk of wind erosion for a short period until vegetation and soil crusts are re-

established or artificial protection elements (eg. brush) are applied to soil surfaces. There was no appreciable difference in rehabilitation rates between similar land systems.

The RBS indicates that rehabilitation of disturbed sites to a level of ecological functioning is likely. However, due to the local environmental constraints, the recovery period is expected to be lengthy. It is hypothesised that, depending on a range of environmental and operational conditions, site rehabilitation over time may proceed as follows:

- Years 1-5: Soils stabilise and form a protective crust within an initial six month period with minimal wind erosion occurring. Early colonisers include weed species such as wild turnip.
- Years 5-10: Stable soils. Native species form the majority of the vegetative cover, with species such as *S. spathulatum* and *A. ligulata* being most prevalent.
- Years 10-15: Vegetative cover and ecosystem function return to levels similar to that found in adjacent, undisturbed environments. Vegetation still dominated by native disturbance colonisers.
- Years 15-20: Slow return of climax vegetation species begins. Increasing species diversity and comparative vegetative cover allows for the return of most faunal species.
- Years 20-40: Slow return of climax vegetation, species diversity and fauna continues.
- Years 40+: Ecosystems comparable with analogue sites in most factors.

The data and conclusions from the RBS were integral to the design of the draft Rehabilitation Plan, draft Closure Plan and other Management Plans included in the PER and subject to public review.

As indicated previously, by the Western Australian Minister for the Environment has issued environmental approval for the Project, subject to a range of conditions and proponent commitments. These include the development of a Progressive Rehabilitation Programme (that includes a soil management plan, a revegetation management plan and a weed management plan) and a Preliminary Closure Plan. In addition, Gunson is developing a research and development programme to address factors that may enhance or limit rehabilitation success.

The Progressive Rehabilitation Programme will be reviewed regularly and updated with information provided by the research and development programme, monitoring data, stakeholder feedback and other sources including industry benchmarking.

6 CONCLUSION

The principal aim of the Rehabilitation Plan is to stabilise the disturbed soils and return a sustainable vegetative cover over the mined areas. Gunson has expended substantial effort in determining the most appropriate rehabilitation strategies by investigating examples of rehabilitation in the region and other similar areas, and seeking independent peer advice. On the basis of this advice, the company is confident that the mined areas can be successfully rehabilitated and that the technology and experience required is available.

In conclusion, the RBS was successful in identifying potential opportunities and constraints for the rehabilitation of the Coburn Mineral Sand Mine, and will allow for the development of a range of rehabilitation methods that can be used to address these factors.

ACKNOWLEDGEMENTS

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