

*Appendix E*  
*Rehabilitation Benchmarking Study*

**REHABILITATION BENCHMARKING STUDY**  
**Prepared for Gunson Resources Limited**  
**by URS Australia Pty Ltd**

## 1. INTRODUCTION

Rehabilitation of disturbed sites is now a standard component of mining operations. However, this process is not an exact science, as each specific site may require different methods of rehabilitation. Historically, rehabilitation success has been variable, often influenced by a range of site-specific factors.

Following a review of the Scoping Document for the proposed Coburn Mineral Sand Project, the EPA expressed concern over the capacity of the local ecosystem to rehabilitate. To address this concern, the Proponent, Gunson Resources, commissioned URS to undertake a Benchmarking Study. The aim of the study was to investigate the rehabilitation success of sites which had been previously disturbed in the region or in similar environmental settings. The study would also include the identification of factors which might impede the rehabilitation process, and determine a range of methods that may be used to combat these factors.

Very little information is available regarding mine site rehabilitation in the region of the proposed mine. In order to more effectively define the factors involved with the specific mineral sand mining process, a site visit was undertaken to investigate two other mineral sand mine sites that experience similar inhibitive environmental conditions.

In addition, a field evaluation of ten disturbed sites in the Gascoyne region was conducted in January 2005 to determine which local environmental factors were likely to pose a threat to the successful rehabilitation of the proposed Project.

This Benchmarking Study is intended as a stand-alone document, the findings of which have been used in preparation of a site-specific Rehabilitation Plan. This document presents a summary of the sites impacted, the methods used to assess revegetation success, and the lessons learned from each site inspected. A detailed case study is subsequently presented for each of the sites inspected during the Benchmarking Study.

## 2. METHODS

### 2.1 Mine Site Rehabilitation

#### 2.1.1 Site Introduction

Rehabilitation techniques and progress at two existing mineral sands mines were reviewed. These sites are:

- The North Stradbroke Island Mine, which is located off the Queensland coast.
- The Namakwa Sands Mine, which is located on the north-west coast of South Africa.

Both sites have a number of environmental similarities to the Project Area and conduct similar operations to those proposed by Gunson. The location of these sites is shown in Figure 1.



**Figure 1:** Location of the North Stradbroke Island and Namakwa Sands Mines

#### 2.1.2 Objectives

The objectives of this component of the Benchmarking Study were to:

- Identify examples where rehabilitation had been undertaken after similar disturbances to those likely to occur in the Amy Zone heavy mineral sand deposit on the Coburn Project, and under similar conditions to those experienced in the Project Area.
- Identify those factors that facilitate or constrain rehabilitation at those sites.

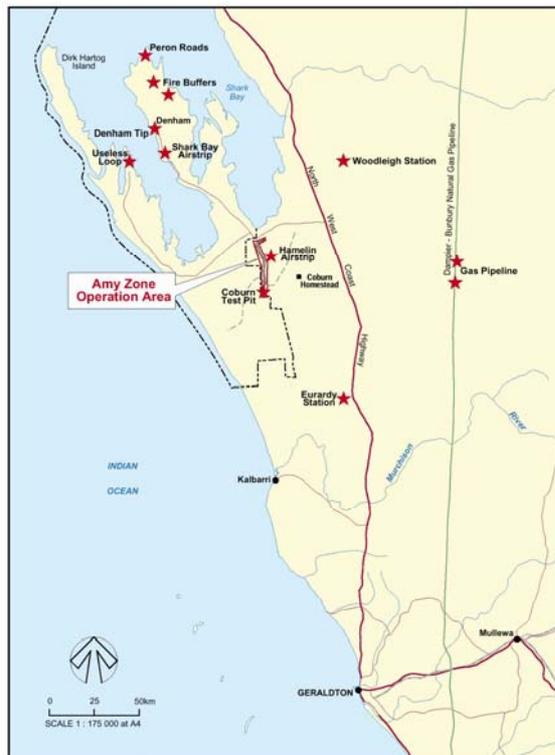
#### 2.1.3 Methods

A desktop review of available information and a site visit was conducted for each site. The Namakwa Sands site visit was conducted in November 2004 and the North Stradbroke Island site visit was conducted in January 2005. Rehabilitation areas were visited at both sites and discussions were held with environmental and other site personnel.

## 2.2 Gascoyne Rehabilitation Sites

### 2.2.1 Site Introduction

Prior to embarking on the Rehabilitation Benchmarking Study, ten sites were identified within the Gascoyne region that had sustained disturbances and/or conditions similar to those expected at the Amy Zone (Figure 2). Sites with a range of time since disturbance were also identified in order to indicate likely rehabilitation rates. The rehabilitation status of these sites was assessed during January 18-28, 2005.



**Figure 2:** Rehabilitation Sites in the Gascoyne Region

The ten sites comprised:

- The Coburn test pit, which is located in the southern portion of the Amy Zone. It was excavated and backfilled in March 2004 to allow Gunson to assess aspects associated with the mineability of the orebody. The site is being monitored to collect information on natural revegetation within the Nanga land system in the Project Area.
- Rehabilitated tracks on the Peron Peninsula, which are located approximately 80 km north-west of the Project Area and were rehabilitated by CALM in 2003/04. They were selected to provide information on the rehabilitation of areas experiencing similar environmental conditions and which have been compacted by vehicle movements.
- The Denham refuse tip, which is located approximately 80 km north-west of the Project Area. The tip was rehabilitated in 2003 and provides information on rehabilitation in similar environmental conditions to those within the Project Area.
- An area of natural revegetation on Eurardy Station, approximately 100 km south-east of the Amy Zone. This area was cleared in 1996 and used for a wheat crop in 1997 before being allowed to lie fallow and undergo natural revegetation. The site provides useful information on natural revegetation within the Nanga land system.
- Rehabilitated fire buffers on the Peron Peninsula, which are located approximately 120 km north-west of the Project Area. The fire buffers were rehabilitated by CALM in 1995 and provide information on rehabilitation in an arid area subject to grazing pressure.
- Gravel pits at the Shark Bay Salt Joint Venture, which is located approximately 85 km north-west of the Amy Zone. These areas provide information on gravel pit rehabilitation in a semi-arid environment.
- The proposed Shark Bay Airstrip, which is located approximately 80 km north-west of the Amy Zone. The area proposed for the airstrip was cleared and compacted in 1990, but was not developed further. No rehabilitation has been conducted at this site, which provides useful information on natural revegetation and vegetation succession.
- Rehabilitation sites along the Dampier-Bunbury Natural Gas Pipeline (DBNGP). These sites were rehabilitated approximately 25 years ago and provide information on rehabilitation of disturbances on the Nerren and Sandplain land systems, both of which occur in the Project Area.
- Sixteen sites on Woodleigh Station, which were disturbed in 1965 as part of a programme by National Aeronautics and Space Administration (NASA) to test visibility from space. These sites are located approximately 70 km north-east of the Amy Zone within the Sandplain land system (which also occurs within the Project Area). Little or no rehabilitation was conducted at these sites.
- An old airstrip which is located on the Hamelin pastoral lease approximately 5 km east of the Amy Zone. The L-shaped airstrip is located within the Nerren land system and has undergone natural revegetation.

A summary of the factors involved with each study site is presented in Table 1.

### 2.2.2 Objectives

The objectives of this component of the Benchmarking Study were to:

- Identify examples where rehabilitation had been undertaken after varying degrees of disturbance, occurring in areas within close proximity to the proposed Project Area.
- Identify those factors that facilitate or constrain rehabilitation at those sites.

### 2.2.3 Methods

The field study involved the comparison of two sites. These usually consisted of a disturbed area, and an adjacent undisturbed area. Notes on the

general site description for each area were taken, including factors such as GPS position, slope, aspect and landuse. Each tested area was divided into six randomly selected, 10m x 10m quadrats. Within each quadrat, a range of vegetation characteristics was measured.

The percentage cover of vegetation and vegetation litter were visually assessed within each quadrat, and the number of plant species present was counted. The maximum height of the vegetation was recorded along with the dominant community type. The four species providing the greatest percentage foliage cover were identified and recorded, including their individual cover values. The percentage cover provided by dead vegetation and litter was also recorded for each quadrat.

**Table 1**  
Case study sites summary

Site	Land systems	Years of rehabilitation	Disturbance	Rehabilitation Treatment
Coburn Mineral Sand mine	Nanga, Nerren, Sandplain.	-	Clearing, soil profile disturbance	-
Coburn test pit	Nanga	1	Clearing, soil profile disturbance	Replace subsoil, replace topsoil. Spread brush over half. Protected from grazing
Peron Peninsula road rehabilitation	Peron	1-2	Clearing, compaction	Some ripping, some brush
Denham tip	Peron	2	Clearing, soil profile disturbance	Some topsoil replacement, some brush
Eurardy Station	Nanga	7	Extensive clearing	None. 300 kg/ha superphosphate. Open to grazing
Namakwa Sands	-	1-10	Clearing, soil profile disturbance	Seed sowing, wind fencing, vegetation transplanting
Peron Fire Buffers	Peron	10	Clearing, burning	None
North Stradbroke Island	-	1-11	Clearing, soil profile disturbance	Topsoil replacement, soil emulsion, seed sowing, fertilizer, mulching, seedling planting, vegetation transplanting.
Shark Bay Salt Joint Venture	Edel	11	Clearing, soil profile disturbance	Some protection from grazing
Planned Shark Bay airstrip	Taillefer	15	Clearing, compaction	None
Gas pipeline	Sandplain and Nerren	25	Clearing, some compaction	Replace subsoil, replace topsoil. Spread brush
Woodleigh Station	Sandplain	40	Clearing, some compaction and topsoil removal	None. Occasional fire
Hamelin airstrip	Nerren	65	Clearing, unknown.	Unknown – none expected

Note: For details of original disturbance see individual Case Studies.

In order to determine a range of soil surface parameters of both disturbed and undisturbed sites, a methodology was designed based on the landscape function analysis (LFA) system devised by Tongway and Hindley (2004). LFA is a monitoring and assessment procedure that was recommended by the EPA for use in this benchmarking study. LFA uses rapidly acquired field assessed indicators to assess the biogeochemical functioning of landscapes (Tongway and Hindley, 2004).

A 1 m x 1 m quadrat was measured and defined in the centre of the vegetation assessment quadrat. Within this quadrat a range of indicators were measured in order to conduct a soil surface assessment. These indicators 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.

These values were then inserted into the software programme designed by Tongway and Hindley (2004) in order to calculate the three indices: soil stability, infiltration, and nutrient cycling. Each of the adjacent sites were then compared against each other with these three indices.

In one instance where the disturbance was recent (Coburn test pit), the differences between the disturbed and undisturbed sites were obvious. In this instance, a decision was made to compile data relating mainly to surface stability, so three transect lines were established and soil stability determined at 1 m intervals along the transects.

Soil profile was also assessed where possible by taking a 1 m core sample using an auger. Factors such as colour, soil texture, pH and calcrete content through the profile were recorded.

In some instances, time, space or privacy factors meant that the soil surface assessment methodology of LFA was inappropriate. In these instances photographic images were taken to show differences between sites, and a general visual overview of vegetation cover, dominant species and basic soil characteristics were taken.

The return of fauna was not studied due to time constraints (meaningful data at a site has to be conducted over many trapping days and over a range of seasons due to the temporal variations in species populations: Ninox 2005). The assumption was made that if the habitat returned to similar stability, species composition, density and diversity, then the original faunal diversity and abundance would also return.

The landforms, soils and vegetation of the Project Area have been described and mapped at the land system scale by Payne, Curry and Spencer (1987). The area of interest is comprised of the basically similar land systems, Nanga (about 90%), Nerren (5%) and Sandplain (5%). Three other similar systems Peron, Edel and Taillefer, occur in the same general area and have been examined as part of the attached case studies. The Nanga, Nerren, Sandplain, Peron and Edel systems consist of level to undulating sandy plains and occasional dunes with deep sand soils covered by moderately dense acacia and other shrublands, mallee woodlands or heathy scrublands. At the regional scale, these five systems fit into a broad land type, 'sandplains with acacias, mallee and heath'. The Taillefer system consists of plains of shrubby spinifex grasslands. It is included in the broad land type of 'sandplains and occasional dunes with spinifex grasslands'.

One benefit of the study being conducted in the middle of summer was that the percentage vegetation cover is expected to be at its lowest value for the year. The high temperatures and lack of rainfall discourage new growth and sometimes cause vegetation to drop physiologically expensive leaves in order to decrease stress. Further, the wind strength is at its greatest in summer, therefore the potential for wind erosion is likely to be at its highest.

### 3. RESULTS

The results of the desktop and field investigations are presented in a series of case study reports attached to this document. A summary of the disturbance outcomes for the Gascoyne case study sites is presented as Table 2.

### 4. DISCUSSION

#### 4.1 Soil Stabilisation

Nearly all of the Gascoyne Case Study sites visited in January 2005 had weak soil surface crusts that were able to confer stability to the sites. No accelerated wind erosion was recorded at any of the sites. Soil crusts are likely to begin forming with the addition of water during winter rainstorms. This

leads to the conclusion that wind erosion is unlikely to be a problem during the rehabilitation of the Project Area.

The surface crust is likely to remain intact and confer continued soil stability to the site provided traffic and grazing animals do not cause significant disturbance. The protection afforded by the soil crust can also be improved with the provision of

material to decrease the critical shear velocity of wind (Blandford, 2004). This protection can be provided naturally with the re-establishment of annual and perennial vegetation, or artificially with the provision of dead vegetation (brush).

**Table 2**  
**Case study sites issues and rehabilitation summary**

Site	Years of rehabilitation	Issues	Present condition
Coburn Mineral Sand mine	-	Soil stability, grazing, revegetation rate, species composition, compaction	Undisturbed
Coburn test pit	1	Soil stability, initial colonizing species	Negligible perennial vegetation. Weed coloniser. Stable soils, no erosion
Peron Peninsula road rehabilitation	1-2	Compaction, initial colonizing species	Negligible colonizing vegetation on one site, vegetation establishing on another. Decompaction increases rehabilitation rate. Relatively stable soils, no erosion
Denham tip	2	Soil stability, affects of brushing, initial colonizing species	Colonizing vegetation (native and exotic). Stable soils where brushing occurred. Comparable vegetation cover between disturbed and undisturbed sites
Eurardy Station	7	Soil stability, vegetation composition, grazing	Stable soils, no erosion. Less vegetation cover, similar species diversity between disturbed and undisturbed sites
Namakwa Sands	1-10	Soil stability, vegetation composition	Stable soil after 4 years. Vegetation characteristics improving over time
Peron Fire Buffers	10	Vegetation composition, grazing	Grazing affects rehabilitation. Different dominant species, similar vegetation cover between disturbed and undisturbed sites
North Stradbroke Island	1-11	Soil stability, vegetation composition	Soil stabilizes with the addition of bituminous sprays and planting of cover crops. Substantial rehabilitation success.
Shark Bay Salt Joint Venture	11	Soil stability, grazing	Grazing affects rehabilitation
Planned Shark Bay airstrip	15	Vegetation composition, grazing	Different dominant species, similar soil characteristics, similar vegetation features between disturbed and undisturbed sites
Gas pipeline	25	Land system comparison	No difference in rehabilitation between land systems
Woodleigh Plots	40	Vegetation composition, grazing	No difference between between disturbed and undisturbed sites in any tested factors
Hamelin airstrip	65	Vegetation composition, grazing	Similar soil characteristics. Different dominant vegetation between disturbed and undisturbed sites

The erosion status of the Nanga, Nerren and Sandplain systems were previously assessed during the Carnarvon Basin rangeland survey (Payne *et al*, 1987) and the lower Murchison survey (Hennig and Leighton, in preparation). Negligible accelerated erosion was recorded (see Table 3). The systems were mostly under grazing (although grazing pressure on the Nanga system was low) and some restricted parts had been burnt in the previous two or three years.

D Thompson (*pers. comm.*) indicates that minor accumulations of wind-blown sand occurred widely in the first year after total clearing (in 1965) of 16x100 acre plots on the Sandplain land system on Woodleigh Station (Case Study 11). The area was not brushed and was open to grazing by sheep and goats. No erosion was evident in subsequent years and reasonable vegetative cover of mostly annuals was established by the end of the second winter after clearing.

#### 4.2 Colonising Species

The re-establishment of vegetation is likely to occur with initial colonizing by introduced annual weeds and native species. Trials within the proposed mining area showed that wild turnip (*Brassica tournefortii*) is likely to be the dominant colonizing species. This has a benefit of providing wind protection for the soil and other colonizing species, but potential negative attributes in being competitive with native species for water and nutrients.

Wild turnip was located in most Case Study sites, both disturbed and undisturbed, but in very low abundances. 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.

#### 4.3 Native Colonisers

Annual and perennial native colonizers were present in recently disturbed sites. Two species in particular, *Acacia ligulata* and *Stylobasium spathulatum*, were found in a number of disturbed areas. *A. ligulata*, in particular, was found to dominate some sites that had been disturbed 8-15 years prior. 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.

#### 4.4 Soil Compaction

However, colonizing by native or exotic species was not observed at all sites. Some rehabilitation sites that had been previously subject to compaction by vehicles showed low vegetation re-colonisation success. The comparison of two sites 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.

#### 4.5 Effects of Grazing

The rate of rehabilitation is likely to be decreased if there is significant loss of vegetation biomass through grazing pressure. Case Studies 7 and 8 show that sustained high levels of grazing, usually by exotic herbivores, has the ability to reduce species diversity and vegetation cover in rehabilitation areas. Very few herbivores were found during fauna surveys within the Project Area (Ninox, 2005), thus 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.

#### 4.6 Effects of Land System Characteristics

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.

The study sites that were visited all contained environmental or human induced factors that are likely to influence the rehabilitation of the proposed Project Area. The demonstrated ability of these sites to naturally overcome these factors is expected to be emulated by the Project Area due to their similar environmental conditions and locations on similar land systems.

**Table 3**  
**Erosion status of the Nanga, Nerren and Sandplain land systems**

Survey	Land System	No. of Observations	Erosion (% of obs)			
			nil	Minor	Moderate	Severe
Carnarvon Basin	Nanga	229	100			
	Nerren	264	100			
	Sandplain	1172	99.5	< 0.5		
Lower Murchison	Nanga	136	100			
	Nerren	228	100			
	Sandplain	70	100			

Sources: Hennig and Leighton (in prep.), Payne *et al.* (1987)

In conclusion, the rehabilitation of disturbed sites to a level of ecological functioning similar to their prior disturbance is likely. However, due to the local environmental constraints, this recovery period is expected to be lengthy. It is hypothesized that site rehabilitation over time will proceed as follows:

- Years 1-5: Soils stabilise and form a protective crust within an initial 6 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.

## 5. REFERENCES

Blandford, D. C. (2004). *Coburn Mineral Sand Project. Soils and Landforms of the Amy Zone Ore Body*. Report prepared for URS Australia Pty Ltd on behalf of Gunson Resources Limited.

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## CASE STUDY 1 NAMAKWA SANDS MINERAL SANDS MINE

### 1. LOCATION

Namakwa Sands, a Division of Anglo Operations Limited (Anglo), is a heavy minerals mining and beneficiation business operating along the west coast of South Africa. The operation comprises a mineral sands mine at Brand-se-Baai (385 km north of Cape Town), a Mineral Separation Plant (MSP) 7 km from Koekenaap and a smelter near Saldanha Bay (Diagram 1).



**Diagram 1: Location Map**

This case study focuses on the mineral sands mine at Brand-se-Baai. The mine covers an area of 14,892 ha of the Namakwaland coast. The 5 km long western boundary of the mine is located roughly parallel to, and approximately 300 m inland of the high water mark, whilst the eastern boundary is located almost 14 km inland.

### 2. ENVIRONMENTAL SETTING

The mine site is located on the Namakwaland coast, at the farm Graauwduinen. Prior to mining, the site was used for small stock farming.

The Namakwaland coast is situated in a transitional zone between the Namib Desert (to the north) and the Cape Mediterranean region (to the south). It forms part of a unique winter rainfall desert ecosystem which falls within the Succulent Karoo Biome, one of 24 biodiversity hotspots of the world (Hälbich, 2003).

The mine site has a Mediterranean climate with hot dry summers and cool wet winters. It has an average annual rainfall of 150 mm, which falls mainly in the winter months of April to July. The low rainfall is supplemented by sea fog (which occurs year round) and heavy dewfall (Hälbich, 2003).

The site experiences one of the strongest wind regimes in the world with wind speeds ranging from three metres per second (m/s) to 9.5 m/s and gusts up to 16 m/s. Anglo has estimated that wind speeds of 4 m/s are required to entrain and transport sand particles - these winds occur on 27% of all summer days and 8% of all winter days (Hälbich, 2003).

The mine site is characterised by vegetated sand dunes. There are no visible surface water features within the site and groundwater is scarce. The soil types present at the site vary according to the nature of the underlying bedrock, the position of the soil in the landscape and the annual rainfall, but tend to be saline and alkaline, with a pH greater than 8. The amount of water and nutrients available to the plants is affected by soil texture and salinity (Hälbich, 2003).

The vegetation of the Namakwaland region is categorised as Strandveld Succulent Karoo and Lowland Succulent Karoo. The Succulent Karoo is a low open shrubland (Plate 1) comprising chamaephytes (woody plants), geophytes (plants growing from bulbs) and therophytes (annuals).

There is also a rich diversity of succulents (Plate 2), many of which are endemic or near endemic (Cowling, 2001; Hälbich, 2003; Namakwa Sands, 2003).



Plate 1: Succulent Karoo



Plate 2: One of the succulent species in the rehabilitation areas.

Vertebrate fauna at the site includes 107 resident bird species, 35 species of mammals and 39 species of amphibians and reptiles. No rare or threatened species have been recorded at the site (Hälbich, 2003; Namakwa Sands, 2003).

### 3. TYPE OF ACTIVITY/DISTURBANCE

The heavy mineral deposits at Brand-se-Baai were discovered during the 1980s and mining commenced in 1994. There are two active mining areas, known as the east mine and the west mine. Strip mining is used to excavate the aeolian sand plains. The east mine excavates only the shallow Aeolian deposits whereas in the west mine the Aeolian sand and deeper feldspathic orebody is mined (Plate 3).

Seawater is added to the mined sand as part of the primary (gravity) separation process. The tailings from the primary separation plant are dewatered before being used to backfill mined-out areas of the pits. The clay fines (slimes) are disposed of to separate storage facilities (slimes dams). Rehabilitation processes are then implemented (see Section 4).



Plate 3: Open pit mining at the western mine.

Concentrate from the primary separation plant undergoes secondary (magnetic) concentration. Magnetic and non-magnetic concentrates are then trucked to the MSP, approximately 60 km south of the mine site (Namakwa Sands, 2003).

Namakwa Sands operates in accordance with an approved Environmental Management Programme Report, which includes a detailed closure plan. The mine site, along with the MSP and smelter sites, were awarded ISO 14001 certification in October 2003.

### 4. REHABILITATION TECHNIQUES

The objective of the Namakwa Sands rehabilitation programme is to return the land to its former use as small stock farming land (Hälbich, 2003). The rehabilitation programme has been developed based on the findings of research and small-scale field experiments conducted from 1995 to 1999, as outlined in Table 1.

Table 1  
Summary of Rehabilitation Trials

Experiment	Outcome
Sowing rye	Competes with local plant species
Rye under irrigation	Only effective in winter
Sorghum under irrigation	Established well in summer with irrigation
<i>Atriplex numularia</i>	Established well, but an invader species
Topsoil and vegetation removal	Organic matter and seeds are transferred
Mulching with reeds	Low profile and covered by sand
Emulsion binder	Does not trap seeds and easily damaged
Mulching with straw	Covered with sand
Shadecloth windbreaks	Most effective way to reduce wind speed

Source: (Hälbich, 2003)

Hälbich (2003) outlines the key objectives of Namakwa Sands' current rehabilitation programme as follows:

1. To ensure the successful re-establishment of a range of indigenous species in the mining area.
2. Manage the natural vegetation and rehabilitated vegetation so as to avoid the loss of species diversity and habitats by mining activities.
3. To ensure that rehabilitated land is stable in the long term, both in relation to soil erosion and self-sustaining vegetation cover, and can be used for sheep grazing.

Prior to mining, topsoil is cleared to a minimum depth of 50 mm. This depth was identified based on research conducted at the University of Pretoria, which found that 90% of the seed reserve occurs in the top 50 mm of soil in undisturbed areas (Hälbich, 2003). The topsoil is stockpiled for no more than three months to ensure the maintenance of soil and seed viability.

The method used to excavate the ore and backfill the mining areas with sand tailings results in a gently undulating landscape. Topsoil is profiled over these areas and shadecloth windbreaks are established. The windbreaks comprise shadecloth of 40% density supported by iron droppers erected every 2.5 m along the windbreak. The windbreaks are 230 m long and 750 mm high, and are installed 5 m apart and parallel to the prevailing winds. The windbreaks are removed once the sand has stabilised.



**Plate 4: Windbreaks installed in a rehabilitation area.**

The revegetation programme includes:

1. Sowing of seed from native Sandveld species. Seed from these species is vacuum harvested from adjacent undisturbed veld during the dry months of the year and immediately seeded in stabilised rehabilitation areas.

2. Transplanting of small-seeded perennials, mainly from the Mesembryanthemaceae family. The seeds of these species are not well adapted to long-range dispersal, so plants (and most of their root systems) are recovered from pre-mining areas using shovels. The plants are then transplanted during the wet season.
3. Planting of nursery cuttings. Cuttings of *Chrysanthemoides monilifera* are made and nurtured in a nursery with sprinkler irrigation. The cuttings are planted in rehabilitation areas during winter after the first good rains.

### Rehabilitation Backlog

A slightly different rehabilitation programme is implemented for the phase one mining operation at the western mine, as no topsoil was collected prior to mining in this area. In these areas the dorbank layer has been ripped, natural seed sown and windbreaks installed.

Backfilled areas are also sown with a pioneer species such as sorghum during the summer months and a local seed mix before the onset of the winter growth season. The pioneer species stabilise the sand and ameliorate soil conditions, which helps to create a micro-environment suitable for the establishment of native species. The growth of the sorghum also acts as a natural windbreak allowing movement of shadenets to newly backfilled areas.

Currently, the areas in the west mine which have already been mined for the shallow Aeolian sand and are awaiting deep mining are not being rehabilitated. The topsoil that was stripped prior to the shallow mining has been placed in topsoil blocks approximately 1m deep and shade nets erected to prevent the loss of this topsoil resource.

## 5. REHABILITATION OUTCOMES

Namakwa Sands' rehabilitation monitoring programme comprises flora biodiversity audits of control and stabilised areas. The audits commenced in 2001 and are conducted annually to provide an indicator for rehabilitation progress. The parameters measured are species composition, crown cover and basal cover. Monitoring has demonstrated encouraging results with good basal area and species composition recovery (Hälbich, 2003).

Much of the rehabilitation programme's success can be attributed to the use of recently cleared topsoil as a source of seed and nutrients, and the use of windbreaks to reduce wind erosion. Field observations suggest that vegetation initially becomes established adjacent to the windbreaks (Plate 5) before colonising the areas between the

windbreaks (Plate 6). It is suggested that, in addition to reducing wind speed and sand mobilisation, the shadecloth used to construct the windbreaks captures moisture from dew and fog, which drains to the base of the windbreak, encouraging germination and plant growth adjacent to the windbreak.



**Plate 5: One year old rehabilitation.**



**Plate 6: Two year old rehabilitation.**

With time, soil stabilisation improves and revegetation progresses. It was observed in the field that a thin crust was present on the sand supporting four-year old rehabilitation, which facilitates stabilisation. Once the soil has been stabilised, the windbreaks are removed and reused in other rehabilitation areas at the site (Plates 7 and 8).

Monitoring of the rehabilitation sites continues until the rehabilitation objectives agreed to for the site have been achieved and accepted by all concerned parties including government regulators.



**Plate 7: Four year old rehabilitation prior to removal of windbreaks.**



**Plate 8: Four year old rehabilitation following removal of windbreaks.**

## **6. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT**

This case study was triggered by a request from the Western Australian Environmental Protection Authority to find examples of where rehabilitation has worked under similar conditions to those that the Coburn Project is expected to encounter. Despite being on different continents, there are a number of similarities between Namakwa Sands and the Coburn Project, as follows:

- Both sites are located in the transition zone between arid/desert conditions and more Mediterranean conditions. They have similar climates, though the Namakwa Sands site has a lower average annual rainfall and a higher occurrence of sea fog than the Coburn site.
- Both sites regularly experience strong winds. The Namakwa Sands site has one of the strongest wind regimes in the world with average wind speeds of 3 - 9.5 m/s and gusts of up to 16 m/s. During summer in the Shark Bay area, southerlies consistently blow over 25 km/hr (approximately 7 m/s) for several days.

- There are similarities in landform and surface soil characteristics. Both sites comprise dunal systems with surface aeolian sands. However, the southern portion of the Coburn Project Area has a more hilly terrain than the Namakwa Sands site Area.
- The mining and processing operations proposed for the Coburn Project are similar to those conducted by Namakwa Sands at the mine site, and will result in similar tailings. However, Namakwa Sands' use of seawater in the primary and secondary concentrators means that the tailings produced at this site are significantly more saline than those expected to be produced by the Coburn Project.

It is recognised that there are differences between the sites (such as the difference in the vegetation types and proximity to the ocean), but these do not preclude the transfer of information and lessons learned about rehabilitation under these conditions. The key aspects in this regard are:

- Rehabilitation can occur successfully in windy areas if appropriate wind erosion controls are implemented. Shadecloth windbreaks are used effectively at Namakwa Sands, but field maintenance is labour-intensive.
- Topsoil is an important source of seed and nutrient reserves, and should be conserved for use in rehabilitation.
- Topsoil should not be stockpiled for more than three months. Stockpiling this resource for longer periods of time results in a loss of soil and seed viability. Direct return of topsoil to rehabilitation areas is preferred.
- Most of the seed reserve occurs in the uppermost layer (5 cm) of topsoil at Namakwa Sands.
- Disposal of clay fines (slimes) with the sand tailings is preferable to disposing of this material in separate storage facilities due to difficulties associated with rehabilitating these facilities.

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Namakwa Sands (2003) Namakwa Footprint 2003. Sustainability Report.

## 8. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank Anglo Operations Limited and Namakwa Sands for the opportunity to visit the mine site and prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 2

### NORTH STRADBROKE ISLAND MINERAL SANDS MINE

#### 1. LOCATION

North Stradbroke Island is one of a chain of sand islands which extend along the coast of South East Queensland between the Gold Coast and Brisbane. It is approximately 35 km long and 4 to 10 km wide. It is accessed by ferry from the Town of Cleveland on Moreton Bay. The coastal parts of the island are principally a holiday resort for the people of Brisbane, with fishing, boating, 4-wheel driving and camping, swimming and surfing being the major recreational activities.

Apart from tourism, the major industry on the island is mineral sand mining, which has occurred on the island since before the Second World War. Consolidated Rutile Limited (CRL) is the largest of the two miners currently operating on the island. Mines currently operated by CRL include the Ibis/Enterprise and Yarraman mines.

The case study focuses on operations at the Ibis/Enterprise mine.



**Diagram 1: Location Map**

#### 2. ENVIRONMENTAL SETTING

North Stradbroke Island is a sub-tropical environment which experiences a distinct dry and wet season. The wet season occurs usually between December and April when moderate to fresh South East trade winds prevail. The annual rainfall is 1500 mm with a minimum rainfall during this season of 900 mm. During the dry season (July to November), winds are moderate from the NW to NE. Lighter winds prevail from the W and SW during the intervening period (May-June).

The island also supports a number of internationally recognized wetlands and associated fauna (Brown Lake, Blue Lake and Eighteen Mile Swamp). The dunes of the island contain a large freshwater aquifer which provides the Town of Cleveland with potable water via a borefield on the west side of the island and submarine pipe connection to the mainland.

The vegetation on the higher sandy parts of the island is principally a dry sclerophyll forest (Plate 1) of *Banksia* and *Eucalyptus* colonizing fine sands (< 200 micron).



**Plate 1.** Existing landform and vegetation height.

#### 3. TYPE OF ACTIVITY/DISTURBANCE

CRL undertake both dry and wet mining operations on North Stradbroke Island, although wet mining is the main form (Plates 2 and 3). Wet mining is carried out by a large dredge floating on an artificial pond which is maintained at the desired level by a complex groundwater pumping, pumping from trenches in swamps and water recycling system of fresh water. A submerged rotating cutter is used to loosen the sand which is then pumped through pipelines to a floating concentrator plant at a rate of about 3000 tonnes per hour. In the concentrator a gravity separation process extracts the heavy mineral sands (about 1% of the mined material).



**Plate 2.** Dry mining process.



**Plate 3.** Wet mining process.

Heavy mineral concentrates are transported by barge to a separation plant at Pinkenba on the mouth of the Brisbane River, for final separation into various raw materials. The residue sand from the primary concentrator is stacked behind the pond to fill previously mined areas.

#### 4. ENVIRONMENTAL MANAGEMENT

An Environmental Impact Statement is required for mine approval incorporating all forms of the mining impact. Prior to mining, flora and fauna surveys are conducted to identify the species present in the area to be mined, and topographic surveys are undertaken to record the dune shape. The land is then cleared, vegetation chipped, or used as brushmatting, large logs retained in stockpiles and topsoil removed and stockpiled.

Mined areas are filled with wet tailings and then re-shaped to approximate the pre-mining topography (Plate 4). Stockpiled topsoil is then spread over the reshaped tailings. Native seeds collected by CRL, together with a temporary cover crop of sorghum are sown between January and June when the rainfall is consistent (80 wet days in a six month period). Brushmatting, windbreaks and a soil stabilizer are then used to control wind erosion.



**Plate 4.** Mining disturbance. Original landform is being reproduced in background.

#### 5. REHABILITATION DETAILS

The main constraints to successful rehabilitation at North Stradbroke Island are wind erosion, regular rain while the plants are establishing and weeds. Hence the rehabilitation program aims to prepare the surface (ie shape and spread topsoil) prior to the onset of the wet season.

At the start of the wet season, the land is fertilized and seeded with a mixture of native seeds and sorghum and then stabilized by spraying a dilute bituminous substance known as Terolas. The Terolas stabilizes the soil while the cover crop of Sorghum develops. The sorghum provides protection from wind erosion plus organic matter to the soil within the first growing season. Native seeds also develop during the first wet season. The sorghum cover crop dies out after the first season.



**Plate 5.** Soil covered in Terolas, with sorghum crop growing through. Undisturbed vegetation in background.

Subsequently, CRL provide a “top up” fertiliser application after six months, and then plant out nursery grown plants after two years in gaps in the revegetation which have been identified by monitoring the area when 12 months old. The area is then left to develop

naturally with only minor maintenance to problems areas.

Rehabilitation costs approximate to \$20,000 per ha, with half of that amount being the cost of the earthworks. The Terolas costs about \$1500 per ha and the seed and fertiliser costs \$500 per ha. The remainder (~\$8,000) is primarily labour cost.

CRL operate their own nursery which produces about 140,000 plants per annum. They also have developed their own native seed harvesting facilities and have developed a seed bank for the area (Plate 6). CRL also remove grass-trees from the mining area and transplant them back into rehabilitated mined areas.



**Plate 6.** Native species seeding facility.

Stockpiled logs from cleared areas are transferred to mined rehabilitation areas to provide windbreaks and fauna habitat. Larger tree trunks with 1-3 branches are buried on end to provide roosting perches for birds.

Terolas is sprayed onto the soil surface via tanks mounted on two four-wheel drive tractors. Terolas is a proprietary product sold by Pioneer. It costs about 50c per litre and requires approx 3000 litres per ha (dependant on sand grain size). It is comprised of Potassium hydroxide, water, bitumen and kerosene, is inert and not classified as hazardous. It rapidly weathers to produce an inert crust.

CRL mix 1 part Terolas to 9 parts water and spray at a rate of 1.8 litres per square meter. Spraying is preferable during the wet season as moist ground gives an even cover. With the equipment set-up that they have, CRL can spray between 2 and 3 ha per day. Results indicate that the Terolas provides an effective soil stabilizer for 12 – 18 months, and retains about 50 % cover up to two years after spraying.

There are six types of emulsion available depending on the type of soils being treated (anionic or cationic) and the drying time required (fast , medium, slow).

## 6. REHABILITATION OUTCOMES

Inspection of the rehabilitated areas of the Ibis Mine indicated substantial success in achieving return of native species and ground cover (Plates 7 and 8). However no data was available for review.



**Plate 7.** Three year old rehabilitation area.



**Plate 8.** Eleven year old rehabilitation area.

Much of the rehabilitation programs success can be attributed to the use of Terolas as a soil stabilizer, good quality topsoil and the native seed harvesting system developed by CRL.

## 7. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

Whilst the two sites occur in different climates, and North Stradbroke benefits from a reliable and reasonably sizeable rainfall season, they are both coastal areas involving sand dunes. Wind erosion is a major problem at both sites. Both sites are sensitive internationally recognized conservation areas. Both sites have a groundwater resource that is used by others.

The acceptable use of the bitumen emulsion (Terolas) in an area which provides potable water to the town of Cleveland, is probably the major lesson for the Coburn Project.

## **8. ACKNOWLEDGEMENTS**

Gunson Resources Limited and URS thank Consolidated Rutile Limited for the opportunity to visit the mine site and prepare this case study for use in developing the Coburn Mineral Sand Project Rehabilitation Plan.

## CASE STUDY 3

### COBURN TEST PIT

#### 1. LOCATION

In March 2004, Gunson Resources excavated a pit within the proposed Coburn Mineral Sand mine lease to determine the commercial viability of mining in the area (Diagram 1). The test pit site was identified as a difficult section to mine due to a thick layer of calcrete below the surface.

The aim of the test pits were three-fold:

1. to determine the strength of the calcrete layer;
2. to conduct a range of tests on the test pit's mineral sands; and,
3. to determine the ability of the project area to rehabilitate.



Diagram 1. Test Pit site.

#### 2. ENVIRONMENTAL SETTING

The disturbed site is located within the Coburn pastoral lease, which primarily runs sheep and goats. The Project Area was granted to Gunson Resources as a mining lease.

As part of the Shark Bay region, the Project Area is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall believed to be significantly greater than that of Denham (B. Wake *pers comm.*; Denham average rainfall - 226 mm). Approximately 70% of this falls between May and August. Average temperatures are likely to be more extreme than those at Denham due to its location away from the tempering maritime influence (Denham range 5.5 - 47°C). Dew often forms overnight.

The test pit site is located within the S2 vegetation community (Mattiske, 2004): Tall open shrublands with overstorey predominantly *Acacia*, *Eucalyptus*,

*Calothamnus* and *Hakea* species over *Lamarchea*, *Baeckea* and *Triodia* species. This vegetation is living on sand dunes and sandplains (Nanga land system).

The soils at the site are red sands, with slight clay accumulation at depth. The pH is 6 at the surface, tending to 6.5 at the bottom of the profile (1m).

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

The Coburn test pit is located within the southern end of the Coburn Project Area. The method of mining and soil disturbance and replacement replicated that which will occur during the mining of the Amy Zone mineral sands.

#### 4. TYPE OF DISTURBANCE

On March 4 and 5, 2004, vegetation and topsoil was cleared in an area of approximately 100 m x 100 m, and stockpiled in windrows for re-spreading following completion of the pit. The test pit was dug to a depth of 15 m by bulldozers and a backhoe excavator. Tests were completed, the pit refilled, and the topsoil returned. On March 6 the dead vegetation (brush) was pushed back over the surface of approximately 50% of the disturbed area, with the other 50% being left devoid of brush cover.

#### 5. REHABILITATION TECHNIQUES

In late August 2004, an area of 20 m x 30 m was fenced using wire with a hole shape of approximately 15 cm x 25 cm. The fencing was 1 m high. In addition, acting upon a request from the Department of Industry and Resources, the test pit area was sprayed for weeds on the 6th and 7th of September 2004. A mixture of Roundup (Glyphosate) at a dose rate of 1 L/ha and Ally (Met Sulstran) at a dosage of 5gm/ha were sprayed on the Test Pit area. This was mixed with a 2% solution of wetting agent.

#### 6. SAMPLING METHODOLOGY

No vegetation sampling was completed at this site due to a very obvious difference in species composition and density between the disturbed and analogue sites (Plate 1). Therefore, emphasis was placed upon soil stability. To assess this factor, three transect lines, of 30 m each, were measured,

and soil stability analysis completed at 1 m intervals (Plate 2).



**Plate 1.** Coburn test pit site after herbicide treatment.



**Plate 2.** 30 m transect line through the Coburn test pit.

## 7. REHABILITATION ASSESSMENT

A study was completed to determine the extent of soil stability at the Coburn test pit site over the 10 months since disturbance. There was very little surviving vegetation located on the test pit site during the case study. High temperatures, and lack of rainfall, may have attributed to a lack of vegetation recolonisation since the herbicide spraying.

The dominant species present at the site was wild turnip (*Brassica tournefortii*), although all individuals were dead: almost certainly due to the herbicide spraying. A number of native species were also deceased. These included *Acacia ligulata*, *Ptilotus* spp, and *Triodia* spp. Few species had germinated since the spraying (Plate 3), although

occasional individuals of *Triodia* spp, *Acacia ligulata* and *Stylobasium spathulatum* had returned.

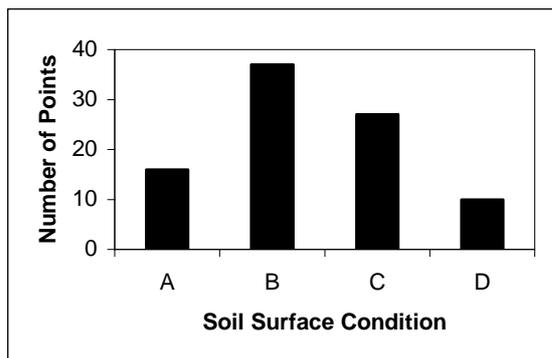


**Plate 3.** *Acacia ligulata* seedling on the Coburn test pit site, with dead *Brassica tournefortii* in the foreground and background.

There was no evidence of wind erosion at the site. Much of the soils on the test pit site had formed a weak surface crust (n = 37, 41%; Plate 4, Diagram 2). A further 30% (n = 27) of the area had formed a crust that was located under a thin layer (2-10mm) of mobile sand. A total of 11% (n = 10) of the area had not formed a crust, with the remaining area being covered by brush (dead vegetation).

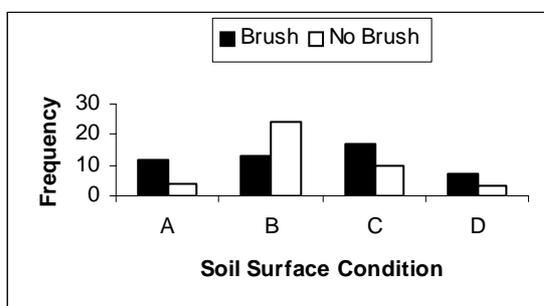


**Plate 4.** Crust formed on the sand surface.



**Diagram 2.** Condition of soil surface determined using 3 x 30 m (n = 90) transects on the Coburn Test Pit site. Soil Surface Condition key. A = litter, B = crust, C = crust under loose sand, D = loose sand.

When the soil stability results from brushed and unbrushed areas were compared (Diagram 3), less litter cover was found on the unbrushed areas, as might be expected. The unbrushed sites were also found to have a larger area where the soils have formed a surface crust. In addition the amount of area in which the soil is unstable (no crust) is greater in the brushed area than the unbrushed areas. However the brushing may have an alternative positive effect on seedling germination and growth.



**Diagram 3.** Comparison of soil surface condition between areas that were covered with brush and those that remained uncovered. Soil Surface Condition key. A = litter, B = crust, C = crust under loose sand, D = loose sand.

Due to the lack of surface water in the area, no sheep and goats had recently used the test pit site during the case study period in January, 2005. The main herbivore tracks encountered included kangaroo and emu.

The fencing on the fenced area was considered to be adequate to exclude only sheep. There was no observable difference between the vegetation or soil stability between the fenced and unfenced areas.

## 8. REHABILITATION OUTCOMES

Results from the Coburn test pit site suggest the disturbed soil surface will bind to form a thin crust within a period of one year. It is likely that this crust forms with the addition of water, therefore may form after rain in the winter period. Brushing is not required in order for the soil to form this crust. Wild turnip is likely to provide the majority of the foliage cover within the first year of rehabilitation.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study is applicable to the proposed Coburn Mineral Sand Mine as it is located within the mining lease, and sustained similar disturbance to that which is expected to occur during the mining process. The period of one year since disturbance also allows for the identification of issues that may inhibit the initial stages of rehabilitation.

The lessons learnt from the Coburn test pit case study include:

- Soil will form a thin crust within a one-year period after disturbance. It seems likely that this occurs after rain. This would decrease the likelihood or severity of wind erosion events.
- Brushing is not required in order for the soil to form a crust.
- Wild turnip (*B. tournefortii*) is likely to be the dominant coloniser within the first year of rehabilitation.

## 10. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.
- Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.

## 11. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank the managers of Hamelin and Coburn Stations for allowing access to the property, which was required in order to prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 4

### PERON PENINSULA ROAD REHABILITATION

#### 1. LOCATION

The two road rehabilitation sites are situated on the Peron Peninsula, Shark Bay. One site is located on the outskirts of the Denham township, the other is located on the northern tip of the Peron Peninsula. These sites are located approximately 80 and 100 km (respectively) north-west of the proposed Coburn Mineral Sand Project Area.



**Diagram 1.** Peron Peninsula road rehabilitation sites.

#### 2. ENVIRONMENTAL SETTING

The peninsula upon which the rehabilitation sites are located is classed as having a hot semi-desert Mediterranean climate (Beard 1976), with an average yearly rainfall of 226 mm: approximately 70% of this falls between May and August. Temperatures range between 5.5 - 47°C and dew often forms overnight. The vegetation ranges from heath and low scrub to tall open shrubland comprising mixed *Acacia* species and patches of spinifex grass (*Triodia* sp.), living on sand dunes and sandplains (Peron land system). This vegetation is similar to that found within the Project Area (Mattiske, 2004).

The soils at the Denham road site are red/brown calcareous sand. The pH is 8.5 at the surface, tending to 9 at the bottom of the profile (1m). The Peron road site contained soil comprising of red sand with a pH of 6 at the surface, tending to 7 at the bottom of the profile (1m).

The Peron Peninsula was a pastoral station prior to 1990. Since then, sheep have been removed from the area, while goats, rabbits, kangaroos and emus are the only remaining larger herbivores.

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

There are a number of similarities between the Peron Peninsula road rehabilitation sites and the proposed mining site. These similarities include:

- Average wind speeds expected at 21.9 km/hr, with gusts of up to 81.4 km/hr for the Peron Peninsula sites. The Project Area is also likely to experience similar high wind speeds, although they are liable to be less extreme due to its greater distance from the coast and protection by land topography.
- All sites have similar vegetation and soil characteristics, as well as similar environmental extremes.

#### 4. TYPE OF DISTURBANCE

Both rehabilitation sites were used as roads prior to their decommissioning. Soil compaction due to vehicle weight and disturbance would have been significant at both sites. The Peron road was left to rehabilitate in March 2003, while the Denham road began rehabilitation in March 2004.

#### 5. REHABILITATION TECHNIQUES

The road at the Peron site was ripped with three tynes mounted on a grader at 1m intervals. No brushing was provided for rehabilitation.

The Denham road site was more comprehensively ripped than the Peron site. It also had brush laid over the surface upon completion of the decompaction exercise.

Both areas were then left to rehabilitate with no protection from grazing animals.

#### 6. REHABILITATION ASSESSMENT

A visual and photographic assessment of the sites were conducted. The Peron road site had a vegetative cover of <1% (Plate 1). Only two species had established on the site: *Brassica tournefortii* and *Ptilotus divaricatus*. These species were present at the site in very small populations.

The soil was found to have formed a thin crust in places, although large areas of soil retained a thick crust (approximately 20cm), which was likely to have been caused by previous compaction. No vegetation was found growing on these compacted areas.



**Plate 1.** Peron road rehabilitation site showing the low vegetation cover and ripped soil.

The Denham road site had a vegetative cover of 20% (Plate 2). Approximately 3% of this cover was provided by brush (dead vegetation).



**Plate 2.** Denham road site showing rehabilitation over a 12 month period.

Buffel grass (*Cenchrus ciliaris*) provided the majority of the cover (15%) with pebble bush (*Stylobasium spathulatum* – 1%; Plate 3).



**Plate 3.** Denham road rehabilitation site showing brushing and 12 month growth of *Stylobasium spathulatum* and *Cenchrus ciliaris*.

The Denham road site appeared to be more comprehensively ripped and graded, showing significantly less compacted soil.

The vegetation at an adjacent site contained *C. ciliaris*, but no *S. spathulatum* was visible locally.

## 7. REHABILITATION OUTCOMES

Comparison of the rehabilitation results from the two sites suggests that compaction relief influences the success of rehabilitation. The Denham road site contains more advanced regrowth than the Peron road site, even though it has had 12 months less growth time. It is likely that this difference in success is assisted by the more substantial compaction relief provided at the Denham road site.

However, there are a range of other potential influences. The disparity in early rehabilitation success may also be due to differences such as soil pH, brushing provision, and the presence of disturbance colonising weed species.

## 8. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study is applicable to the proposed Coburn Mineral Sand Mine as it is exposed to comparable environmental issues that may hamper rehabilitation efforts. It is understood that the method of disturbance on the Peron Peninsula sites are significantly different to that expected for the Project Area. However, the period of 1-2 years since disturbance also allows for the prediction of likely vegetation regrowth rates for the mine rehabilitation area.

The lessons learned from the Peron Peninsula roads case study include:

- Comprehensive relief of compaction is likely to significantly increase the rate of vegetation establishment at a disturbed site. This may be particularly important for the rehabilitation of the haul roads within the Project Area.

## **9. REFERENCES**

Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.

Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.

## **10. ACKNOWLEDGEMENTS**

Gunson Resources Limited and URS would like to thank the Shark Bay Shire and The Department of Conservation and Land Management (Denham) for allowing access to their property, as well as a range of information pertaining to the site disturbance. This assistance was required in order to prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 5

### DENHAM TIP

#### 1. LOCATION

In April 2002 the Shark Bay Shire closed down the refuse site that had been used by the residents of Denham for a number of years previous. Located on the outskirts of the township, the site is open to the prevailing south-westerly winds (Diagram 1).

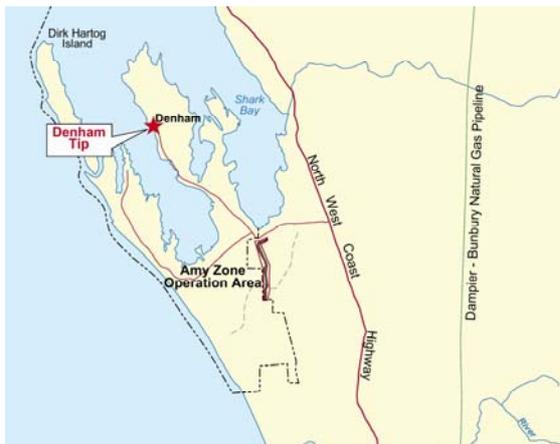


Diagram 1: Location Map

#### 2. ENVIRONMENTAL SETTING

The peninsula upon which the tip site is located is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall of 226 mm: approximately 70% of this falls between May and August. Temperatures range between 5.5 - 47°C and dew often forms overnight. The vegetation is predominantly heath and low scrub comprising mixed *Acacia* species and patches of spinifex grass (*Triodia* sp.), living on sand dunes and sandplains (Peron land system).

The soils at the site are red/brown calcareous sand, with a pH of 8 at the surface, tending to 9 at depth (1 m).

#### 3. COMPARISON WITH THE COBURN MINERAL SAND PROJECT AREA

Despite being located approximately 80 km north-west of the Coburn Mineral Sand Project Area, there are a number of similarities between the refuse tip and the proposed mining site. These similarities include:

- Average wind speeds of 21.9 km/hr, with gusts of up to 81.4 km/hr for the airstrip site. The Project Area is also likely to experience similar high wind speeds, although there are liable to

be less extreme due to its distance from the coast and protection by land topography.

- Both sites are located within semi-arid Shark Bay region, experiencing similar vegetation and soil characteristics, as well as similar environmental extremes.
- The refuse tip site has experienced the removal of topsoil and its associated seed bank, loss of vegetation biomass and thus loss of wind protection, and soil compaction. The soil profile has been dramatically altered to five metres, and essentially not replaced. It is likely that this disturbance provided greater difficulty for rehabilitation than is expected for the planned Coburn mining project.

#### 4. TYPE OF DISTURBANCE

The refuse tip site comprises an area of approximately 2 ha and was cleared of vegetation and excavated to a depth of five metres in order to provide the necessary space for refuse from the town of Denham and its surrounds.

#### 5. REHABILITATION TECHNIQUES

Once decommissioned, the walls of the refuse tip site were battered and the soil was spread over the waste. There were no other immediate treatments. However, when vegetation did become available due to council vegetation pruning programmes, or from vegetation removal from private property, council employees would place this brush over the rehabilitation site. This practice is still continuing.

#### 6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

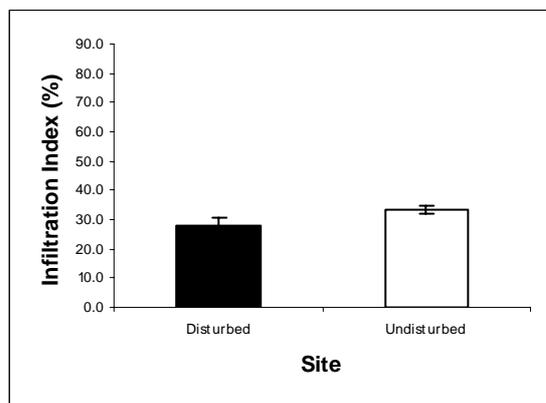
- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

#### 7. REHABILITATION ASSESSMENT

The study aimed to determine the extent of rehabilitation at the refuse tip site over the 3 years

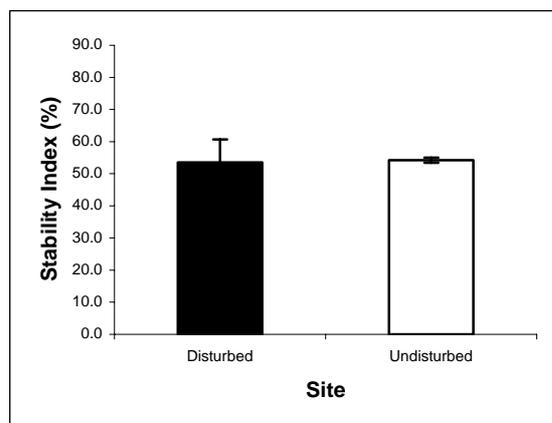
since closure. These results were compared with those gained at an adjacent, undisturbed site.

The undisturbed sites showed greater infiltration indices than the disturbed sites (Diagram 2). Therefore, the undisturbed sites showed a greater ability to infiltrate water, and therefore decrease water, soil and nutrient loss from the local area, than the disturbed sites.



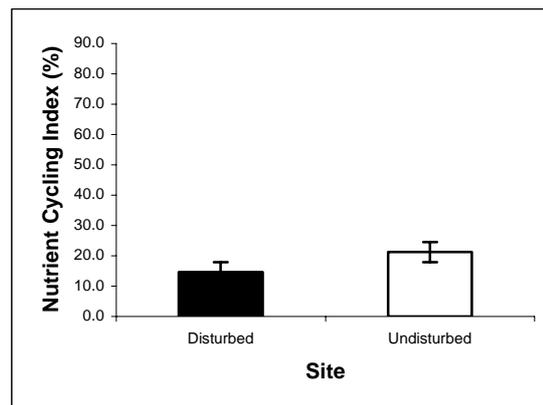
**Diagram 2.** Zone Infiltration comparison for disturbed refuse tip site and undisturbed analogue site.

A comparison of soil stability between the two sites showed no difference (Diagram 3).



**Diagram 3.** Zone Stability comparison for disturbed refuse tip site and undisturbed analogue site.

The potential for nutrient cycling differed between sites (Diagram 4), with the undisturbed sites showing a greater ability to return organic matter and nutrients to the soil.



**Diagram 4.** Zone Nutrients comparison for disturbed refuse tip site and undisturbed analogue site.

No difference was found in the amount of vegetation covering the soil (mean %  $\pm$  SE) between disturbed (n=4;  $61 \pm 5.2$ ) and undisturbed sites (n=6;  $67 \pm 3.2$ ). The vegetation on the sites differed in maximum height, with the vegetation in the undisturbed quadrats ( $110 \text{ cm} \pm 5.8$ ) found to be taller than that in the disturbed plots ( $78 \text{ cm} \pm 11.8$ ).

There was also a difference in species diversity between disturbed sites ( $10 \pm 0.7$ ) and undisturbed sites ( $18 \pm 1.2$ ). In addition, the dominant species between sites differed. The disturbed area had a high prevalence of dead vegetative cover (34%) due to the brushing programme implemented by the Shark Bay Shire. *Salsola kali* provided the highest average amount of foliage cover (4%). A range of weed species also inhabited this area, including species such as *Cenchrus ciliaris* (buffel grass), *Rumex vesicarius* (ruby dock), and *Mesembryanthemum crystallinum* (iceplant). (Plate 2).



**Plate 2.** The disturbed refuse tip site showing the brushing laid by the Shark Bay Shire and the subsequent vegetation regrowth.

In contrast, the undisturbed sites were dominated by *Cenchrus ciliaris* (8.8%), *Ptilotus divaricatus* (7.3%), *Atriplex bunbyana* (5.3%), with dead vegetation and litter (12.5%) providing further soil protection (Plate 3).



**Plate 3.** Undisturbed site adjacent to the refuse tip rehabilitation site.

Not all the rehabilitation area had been provided with brush (dead vegetation). One area of note was a section of approximately 50 metres on top of one battered wall on the southern side of the refuse tip site (Plate 4). This area is particularly open to wind and had the steepest slope of approximately 30°. Where brushing had been provided no evidence of soil erosion was found and the vegetation was of a comparative growth to the rest of the rehabilitation site. However, where no brush had been laid there was evidence of slight wind erosion and a noticeable lack of vegetation growth.



**Plate 4.** Refuse tip site with battered wall showing signs of slight wind erosion and lack of vegetation establishment.

Both disturbed and undisturbed sites are likely to have undergone grazing pressure over the three-year period, with rabbits particularly common throughout the area during the case study field research.

## 8. REHABILITATION OUTCOMES

The disturbed refuse tip site has shown to return to a soil stability comparable with the adjacent undisturbed region over the three-year rehabilitation period. However, the vegetation has not returned to a comparable density and diversity,

with the dominant species also varying between sites.

A range of weed species have colonized the rehabilitation area, along with some native species. Due to the close proximity to Denham town the undisturbed site also had a variety of weed species present, although not in the same abundance.

This result suggests that weeds are likely to be a primary colonizer at disturbed sites in the region, however the same weed dominance or species diversity may not occur at the Project Area due to its greater distance from human habitation.

This case study has shown that vegetation can return to an area that has been significantly disturbed. The soil has the ability to stabilize quickly, although it is likely that the addition of brush provides protection for seeds and seedlings. It is not known whether this disturbed area will return to the species dominance and vegetation height shown by the analogue sites, however it currently retains significant value by retaining nutrients and providing protection for soil, fauna, and seedlings.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was identified as being applicable to the proposed Coburn Mineral Sand Mine due to the soil profile at the disturbed site having undergone more severe transformation, being subject to more extreme wind conditions, and being located on a similar sandplain land system. The site was also of interest as it may provide some insight into what form the rehabilitated areas of the proposed mine might take after a period of three years.

Though the similarities between this case study site and the Project Area have been identified, it is important to recognize that there remain some differences that may influence rehabilitation success on the Amy Zone.

The lessons learnt from the Denham tip include:

- Vegetation can colonise a severely disturbed area with minimal assistance. However, after a period of three years post-disturbance the rehabilitated area is not likely to have comparable vegetation structure and dominance to analogue communities.
- Many weed species are primary colonizers and disturbance specialist, and are thus likely to be found at the rehabilitation sites within the Project Area. However, the cover and protection they provide are likely to improve soil stability.

- Protection from grazing is not a prerequisite for return of vegetation, although grazing protection may have improved or changed the rate of rehabilitation of the current vegetation community.
- The provision of brush may improve soil stability as the dead vegetation can decrease the critical shear velocity of wind flow, thus decreasing wind erosion potential (Blandford, 2004). Decreasing wind velocity is also likely to improve vegetation establishment success.

## 10. REFERENCES

Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.

Blandford, D. C & Associates Pty Ltd (2004). *Coburn Mineral Sands Project – Soils and landforms of the Amy Zone Ore Body*. Report prepared for URS Australia Pty Ltd.

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## 11. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank the Shark Bay Shire for their support in providing information on the history of the Denham refuse tip site, which assisted in preparing this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 6

### EURARDY STATION

#### 1. LOCATION

In 1998 the manager of Eurardy Station released an area of land from wheat cropping. Located on the same land system as the proposed Coburn Mineral Sand mine, and approximately 100km south-east (Diagram 1), the rehabilitation of this area is likely to provide valuable information for the revegetation of the Project Area.



Diagram 1: Location Map

#### 2. ENVIRONMENTAL SETTING

Eurardy Station is classed as having a dry warm Mediterranean climate (Beard, 1976), with an average yearly rainfall likely to be similar to that of Kalbarri (369 mm): approximately 75% of rainfall occurs between May and August. Temperatures range between  $-0.4 - 46.3^{\circ}\text{C}$  and dew often forms overnight. The vegetation is predominantly heath and low scrub comprising mixed *Melaleuca* and *Thryptomene* species and grasses, living on sand dunes and sandplains (Nanga land system).

The soils at the site are yellow sand, with a pH of 6 through to 1m.

#### 3. COMPARISON WITH THE COBURN MINERAL SAND PROJECT AREA

Despite being located approximately 100 km south-east of the Project Area, there are a number of similarities between Eurardy Station and the proposed mining site. These similarities include:

- Average wind speeds of 16.5 km/hr, with gusts of up to 92.5 km/hr for the nearby Kalbarri township. Both the Eurardy site and the Project Area are likely to experience similar high wind

speeds, although these are liable to be less extreme due to its distance from the coast and protection by land topography.

- Both sites are located within the Nanga land system (Payne *et al*, 1987).
- The Eurardy Station site has experienced the removal of all original vegetation and its associated seed bank and thus loss of wind protection.

#### 4. TYPE OF DISTURBANCE

The Eurardy Station site comprises an area of approximately 3,000 m<sup>2</sup>. In 1996 the virgin land was ploughed twice, the vegetation scrub raked and pushed into windrows where it was burnt. In 1997, 300kgs of superphosphate was put on the soil, before being sown to wheat and the crop harvested when mature.

#### 5. REHABILITATION TECHNIQUES

In April 1998 the area was sprayed with the herbicide simazine (825g/ha). This product is designed to prevent growth of shallow rooted vegetation, which is the case with the many introduced weed species. It was then decided not to crop the area again. No rehabilitation procedures were conducted at this site.

#### 6. SAMPLING METHODOLOGY

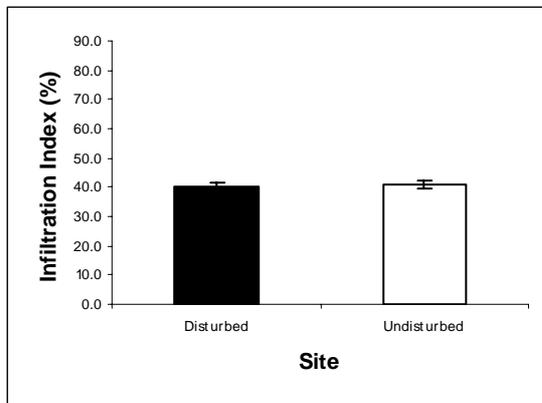
When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

#### 7. REHABILITATION ASSESSMENT

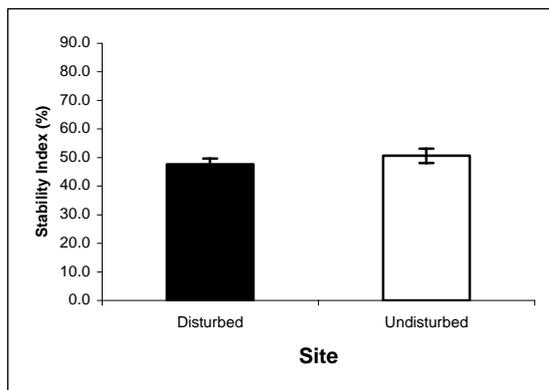
The study aimed to determine the extent of rehabilitation at the Eurardy Station site over the 7 years since rehabilitation began. These results were compared with those gained at an adjacent, undisturbed site.

No difference was found between the infiltration indices of the disturbed and undisturbed sites (Diagram 2). This indicated that the sites showed a similar ability to infiltrate water, and therefore decrease water, soil and nutrient loss from the local area.



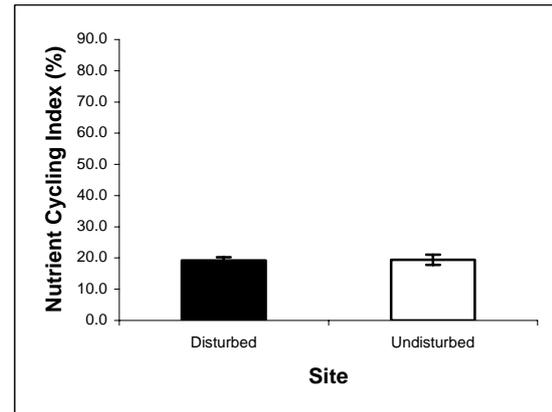
**Diagram 2.** Zone Infiltration comparison for disturbed Eurardy Station site and undisturbed analogue site.

A comparison of soil stability between the two sites showed no difference (Diagram 3), which suggests that the soil of the disturbed site has similar stability to that of the undisturbed site.



**Diagram 3.** Zone Stability comparison for disturbed Eurardy site and undisturbed analogue site.

The potential for nutrient cycling did not differ between sites (Diagram 4), with the disturbed sites showing a similar ability to return organic matter and nutrients to the soil.



**Diagram 4.** Zone Nutrients comparison for disturbed Eurardy Station site and undisturbed analogue site.

Vegetation in the disturbed site was found to provide less surface cover ( $n = 6$ ; mean %  $\pm$  SE;  $48 \pm 3.8$ ) than that in the undisturbed site ( $67 \pm 2.5$ ). The vegetation on the sites differed in maximum height, with the vegetation in the disturbed quadrats ( $167 \text{ cm} \pm 19.8$ ) found to be smaller than that in the undisturbed plots ( $215 \text{ cm} \pm 5.0$ ).

There was no difference in species diversity between disturbed sites ( $14 \pm 0.6$ ) and undisturbed sites ( $14 \pm 0.8$ ). However, the dominant species within the quadrats differed slightly. The disturbed area had a high prevalence of *Thryptomene* species (15.3%), and cover provided by dead vegetation, much of which were deceased annual species (15.2%; Plate 2).



**Plate 2.** The disturbed Eurardy Station site showing the dominant cover provided by *Thryptomene* species.

The undisturbed sites also had high percentage cover provided by *Thryptomene* species (11.7%). It was predominantly competing with *Mesomelaena tetragona* (12.2%) and *Melaleuca* spp. (8.8%). Cover was also provided by dead vegetation (12%), with a noticeable lack of annual species (Plate 3).



**Plate 3.** Undisturbed site adjacent to the Eurardy Station rehabilitation site.

Both disturbed and undisturbed sites are likely to have undergone high grazing pressure over the 7 year period as the Station also runs sheep, which use the site as feeding areas. Signs of use by rabbits and kangaroos were also common throughout the area during the case study field research.

The presence of sheep on the property may have influenced the soil surface assessments as their presence increased the amount of regular soil disturbance (Plate 4). Very little soil was found to have formed a crust, however, no evidence of wind erosion was found, and the property manager did not report any significant loss of topsoil through wind erosion (B. Quicke, *pers comm.*, 2005).



**Plate 4.** Cropped and grazed area on Eurardy Station showing soil surface disturbance that regularly occurs due to the presence of sheep (centre picture).

## 8. REHABILITATION OUTCOMES

The disturbed Eurardy Station site has shown that soil characteristics can return to that comparable with the adjacent undisturbed region over the seven-year rehabilitation period. The vegetation has returned to a comparable diversity over that period, however, the dominant species did vary between sites. The cover provided by the vegetation and litter was also found to be greater in the undisturbed

sites, although it had less cover provided by annual species.

This case study has shown that vegetation can return to an area that has been significantly disturbed seven years prior. This revegetation has occurred in the presence of heavy grazing pressure, and regular soil surface disturbance. The growth and dominance of native colonizers may be related to the spraying of herbicide prior to the rehabilitation stage. It is not known whether this disturbed area will return to the species dominance and vegetation height shown by the analogue sites, however it currently retains significant value by retaining nutrients and providing protection for soil, fauna, and seedlings.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was identified as being applicable to the proposed Coburn Mineral Sand Mine due to the soil profile at the disturbed site having undergone significant transformation, being located on the same Nanga land system, and being subject to similar wind conditions. The site was also of interest as it may provide some insight into what form the rehabilitated areas of the proposed mine might take after a period of seven years in the presence of sustained grazing pressure.

Though the similarities between this case study site and the Project Area have been identified, it is important to recognize that there remain some differences that may influence rehabilitation success on the Amy Zone.

The lessons learnt from Eurardy Station include:

- Vegetation can colonise a severely disturbed area with minimal assistance. However, after a period of seven years post-disturbance the rehabilitated area is not likely to have comparable vegetation structure and dominance to analogue communities, although perennial species composition is likely to be similar.
- Protection from grazing is not a prerequisite for return of vegetation, although grazing protection may have improved or changed the rate of rehabilitation of the current vegetation community.

## 10. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.
- Payne, A. L., Curry, P. J. and Spencer, G. F. (1987). *An inventory and condition survey of rangelands in the Carnarvon Basin*,

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Tongway D. J. and Hindley, N. L. (2004). *Landscape Function Analysis: Procedures for monitoring and assessing landscapes with special reference to Minesites and Rangelands*. CSIRO Sustainable Ecosystems, Canberra, ACT.

## **11. ACKNOWLEDGEMENTS**

Gunson Resources Limited and URS would like to thank the managers of Eurardy Station for their support in providing information on the history of their property, which assisted in preparing this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 7

### PERON FIRE BUFFERS

#### 1. LOCATION

The Peron fire buffers are located within Francois Peron National Park, on the northern tip of the Peron Peninsula. Two sites were looked at during this study: the 10 and 18 mile buffers. These sites are approximately 150 km from the Coburn Mineral Sand (CMS) Project Area.



**Diagram 1.** Peron fire buffer sites.

#### 2. ENVIRONMENTAL SETTING

The disturbed site is located within the Francois Peron National Park. Prior to becoming a National Park in 1990, the area had formed part of the Peron pastoral lease, which primarily ran sheep and goats. Sheep have since been removed from the area and goat presence significantly reduced. Rabbits, kangaroos and emus are the only other remaining larger herbivores.

Francois Peron National Park is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall of 226 mm. Approximately 70% of this falls between May and August. Average temperatures range from 5.5 - 47°C. Dew is likely to form overnight.

The Peron fire buffer sites contain a vegetation community that is similar to the S7 vegetation community found within the CMS Project Area (Mattiske, 2004). The undisturbed plant community was described as tall open shrublands with overstorey comprising of *Acacia ramulosa*, *Acacia sclerosperma*, and *Acacia tetragonophylla* over *Scaevola* and *Ptilotus* spp. This vegetation is living on sand dune and sandplains (Peron land system).

The soils at the site are red sands. The pH is 6 at the surface, tending to 7 at the bottom of the profile (1m).

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

Despite being located approximately 150 km north-west of the Coburn Mineral Sand (CMS) Project Area, there are a number of similarities between the Peron fire buffers and the proposed mining site. These similarities include:

- Average wind speeds of 21.9 km/hr, with gusts of up to 81.4 km/hr for the fire buffer sites. The CMS Project Area is also likely to experience similar high wind speeds, although they are liable to be less extreme due its greater distance from the coast and protection by land topography.
- Both sites are located within semi-arid Shark Bay region, experiencing similar vegetation and soil characteristics, as well as similar environmental extremes.

#### 4. TYPE OF DISTURBANCE

In 1995, the Department of Conservation and Land Management (CALM) established two buffers designed to protect parts of the National Park from a single, large scale fire. In order to create these buffers, approximately 40 ha of vegetation was scrub-rolled in two parallel lines. Unsuccessful attempts were made to burn the vegetation once it had been disturbed. Staff returned approximately 12 months later and burnt the now dry brush.

#### 5. REHABILITATION TECHNIQUES

Thirteen pairs of experimental plots were fenced off from both within the disturbed area, and in an adjacent undisturbed area by CALM in the mid 1990's. This experimental project was designed to determine the effect of grazing on vegetation rehabilitation, and was studied over a number of years by research scientists within CALM (Ward 2002).

#### 6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

## 7. REHABILITATION ASSESSMENT

The results of the herbivore exclusion experiment conducted by CALM found that the vegetation within the exclusion plots had a 70% greater species diversity and abundance than those that were unfenced over a period of approximately five years (Ward 2002).

Ward (2002) also concluded that vegetation recovery is dependant on rainfall. An increase in rainfall during the period 1998-2000 was found to favour the development of plant species.

The research conducted during the rehabilitation benchmarking exercise aimed to determine the extent of rehabilitation at the Peron fire buffer site over the 10 years since disturbance (Plate 1). These results were compared with adjacent undisturbed sites (analogue; Plate 2).

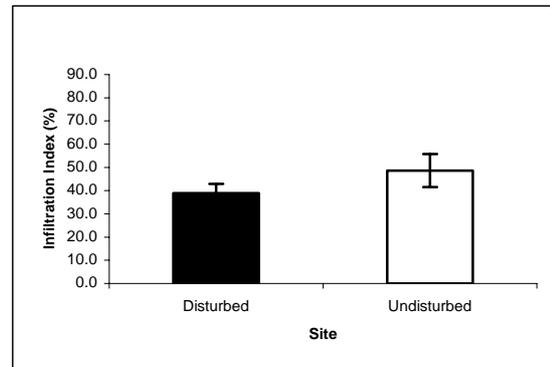


**Plate 1.** Peron fire buffer site. Exclusion plot located in the centre of the photograph.



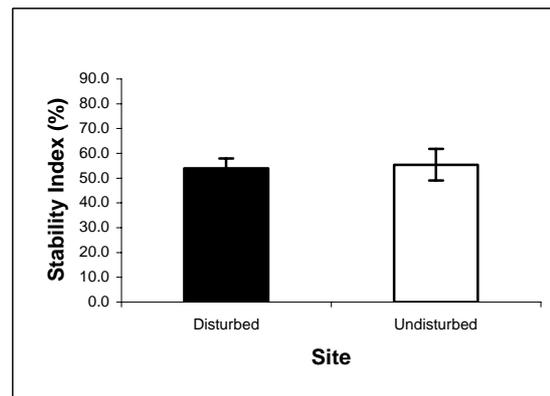
**Plate 2.** Undisturbed analogue site.

The soils in the undisturbed sites were better able to transfer rainfall into soil-water than those at the disturbed sites (Diagram 2). However, due to the sandy nature of the soils involved, little water loss through runoff is expected at either site.



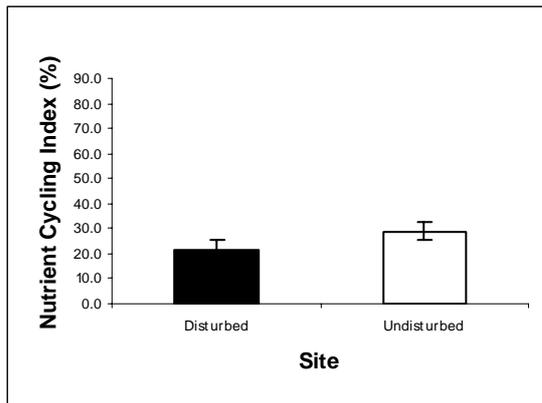
**Diagram 2.** Zone infiltration comparison for disturbed plots and undisturbed analogue sites.

A comparison of soil stability between the two sites showed no difference (Diagram 3). No erosion was observed at either site suggesting that the soils were able to withstand the environmental pressures.



**Diagram 3.** Zone Stability comparison for disturbed plots and undisturbed analogue sites.

The undisturbed site showed a slightly greater ability to cycle nutrients (Diagram 4). This suggests that the analogue sites are better able to return organic matter and nutrients to the soil.



**Diagram 4.** Zone nutrients comparison for disturbed plots and undisturbed analogue sites.

No difference was found in the amount of vegetation covering the soil (mean %  $\pm$  SE) between disturbed ( $n=6$ ;  $47 \pm 6.8$ ) and undisturbed sites ( $n=6$ ;  $58 \pm 7.6$ ). The vegetation on the sites differed in maximum height, with the vegetation in the undisturbed quadrats ( $223 \text{ cm} \pm 12.3$ ) found to be taller than that in the disturbed plots ( $172 \text{ cm} \pm 15.8$ ).

Species diversity in disturbed sites ( $10.3 \pm 1.2$ ) was less than that in undisturbed sites ( $12.7 \pm 0.9$ ). However, the dominant species between sites differed.

The disturbed sites showed two distinctive communities. Some sites showed dominant overstorey species consisting of *Acacia ligulata* and *Acacia sclerosperma* (eg. Plate 1). Other sites contained very little overstorey, with the vegetation dominated by understorey species such as *Scaevola* spp., *Ptilotus* spp. and *Solanum* spp., as well as a range of annual species (eg. Plate 3).



**Plate 3.** Peron fire buffer site. Vegetation at this site is dominated by *Solanum* spp., *Ptilotus* spp., *Scaevola* spp., and a range of annual species.

The undisturbed sites consisted of overstorey species such *Acacia ramulosa* (11%) and *Lamarchea hakeifolia* (5%). Understorey consisted

primarily of *Ptilotus* species (7%) and dead vegetation and litter (12%).

## 8. REHABILITATION OUTCOMES

Results from the Peron fire buffer site suggest that the disturbed area will require more than 10 years to return to a similar vegetation composition as the original site. However, over a 10 year period the soils should return to a comparable stability, and the vegetation height will be approaching the heights of vegetation within the undisturbed sites.

In addition, results from the grazing exclusion plots conducted by CALM show that the elimination of grazing pressure on rehabilitation sites increases species diversity and abundance.

Very few herbivores were found during fauna surveys within the CMS Project Area (Ninox, 2005), so exclusion fencing may not be required. 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.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study is applicable to the proposed Coburn Mineral Sand Mine as it is located in reasonable proximity to mining lease and is exposed to comparable environmental issues that may hamper rehabilitation efforts. It is understood that the method of disturbance for the fire buffers are significantly different to that expected for the CMS Project Area, however, the period of 10 years since disturbance allows for the prediction of vegetation regrowth rates.

The lessons learnt from the Peron fire buffer case study include:

- Monitoring of rehabilitation sites should include observations on the abundance of herbivores. If populations of grazers (particularly rabbits and goats) increase significantly from that found prior to disturbance, thought should be given to fencing the rehabilitation sites.
- Although a different vegetation community to the original may return during the initial 10 years of rehabilitation, the soils retain the capacity to return to their original stability.

## 10. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.

- Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.
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- Ward, B. 2002. *Review of Vegetation Succession Following Fire at Francois Peron National Park, Shark Bay*. Internal report, Department of Conservation and Land Management.

## 11. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank the managers of the Department of Conservation and Land Management for allowing access to the property, as well as a range of information pertaining to the site disturbance. This assistance was required in order to prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 8

### SHARK BAY SALT JOINT VENTURE

#### 1. LOCATION

The Shark Bay Salt Joint Venture mine is located on Useless Loop, Heirrisson Prong, and has been producing salt since the mid-1960s. They currently produce 1.2 million tonnes of salt per annum for the overseas market. Along with the salt pans required to create the salt, the mining area also has infrastructure and housing for an average of 60 employees. This industry has created a range of disturbances on the local environment. Although they are not required to rehabilitate these areas until mine closure, the mine has decided to become proactive in restoring some of these areas. These sites are approximately 85 km north-west of the Coburn Mineral Sand Project Area.



**Diagram 1.** Shark Bay Salt Joint Venture mine site.

#### 2. ENVIRONMENTAL SETTING

Heirrisson Prong is classed as having a dry warm Mediterranean climate (Beard, 1976), with an average yearly rainfall expected to be similar to that of Denham (226 mm). Approximately 70% of this falls between May and August. Average temperatures are expected to range from 5.5 - 47°C. Dew is likely to form overnight.

The Useless Loop undisturbed community contained vegetation classified as scattered to closed shrublands (Payne *et al.*, 1987). Most species present are also found within the Project Area (Mattiske, 2004). The vegetation is living on sand dunes and sandplains of the Edel land system.

The soils at the sites are pale brown calcareous sands. The pH is 8 at the surface, tending to 9 at the bottom of the profile (1m).

Sheep have been removed from the area, while goats, rabbits, kangaroos and emus are the only remaining larger herbivores. Signs of rabbit presence were particularly common.

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

Despite being located approximately 85 km north-west of the Coburn Mineral Sand Project Area, there are a number of similarities between the Useless Loop sites and the proposed mining site. These similarities include:

- Average wind speeds expected at 21.9 km/hr, with gusts of up to 81.4 km/hr for the Useless Loop sites. The Project Area is also likely to experience similar high wind speeds, although they are liable to be less extreme due its greater distance from the coast and protection by land topography.
- Both sites experience similar vegetation and soil characteristics, as well as similar environmental extremes.

#### 4. TYPE OF DISTURBANCE

In 1994, the Shark Bay Salt Joint Venture mine began rehabilitation on about 2 ha of land which had previously been used as a quarry for the maintenance of roads and pond walls. Disturbance would have been locally extreme, with the complete removal of vegetation and topsoil, and loss of soil profile due to the removal of material for structural maintenance purposes.

#### 5. REHABILITATION TECHNIQUES

The walls of the quarry were battered, and the soil overburden pushed over the mined area in order to restore, as much as possible, the site's natural profile. Areas that had undergone compaction were relieved through a ripping process. The entire rehabilitation area was hand seeded, using a mixture of species. An experimental procedure was attempted, whereby one section (approximately 900m<sup>2</sup>) was surrounded by a rabbit resistant fence (Plate 1). Both areas were then left to rehabilitate. After a period of five years, part of the fenced area was opened to allow grazing. This experiment could then determine the affect of grazing on established vegetation.



**Plate 1.** Useless Loop rehabilitation site showing rabbit proof fencing in foreground.

## 6. REHABILITATION ASSESSMENT

A visual and photographic assessment of the unfenced rehabilitation area (Plate 2) was conducted. It was found to have an average vegetation cover of 10%. Ten different species were found at the site, with the most dominant being *Acacia ligulata* (7% cover). All other species comprised <1% cover.



**Plate 2.** Useless Loop rehabilitation site showing the low vegetation cover and dominance of *A. ligulata*.

The rabbit exclusion experiment, conducted by the Shark Bay Salt Joint Venture mine, showed positive vegetation results. Where the rabbit proof fence had been removed after five years, the vegetation cover averaged 60%, with a species diversity of 10 (Plate 3). *A. ligulata* was the most dominant, averaging 20% cover. The site where the fence remained in place had a vegetative cover of 70% (Plate 1). *A. ligulata* was again the most dominant species, with a percentage cover of 35%. The site was found to contain 11 different species.



**Plate 3.** Useless Loop rehabilitation site where the rabbit resistant fencing had been removed after a five year period.

The original vegetation at the site looked to be relatively different to the vegetation at the rehabilitation sites (Plate 4). Percentage cover was similar to the fenced rehabilitation sites (70%), however the dominant species differed. Although *A. ligulata* was present at the analogue site (10%), it did not show the same dominance as that found in the rehabilitation sites.



**Plate 4.** Analogue vegetation for Useless Loop rehabilitation sites.

## 7. REHABILITATION OUTCOMES

Results from the Useless Loop site suggest that providing rabbit proof fencing to a rehabilitation area significantly increases the vegetative cover of the area. Further photographic evidence highlights this result, showing vegetation hanging over the fenced area to have been severely grazed (Plate 5). Due to the height of the grazing, rabbits are presumed to be responsible.



**Plate 5.** Useless Loop fenced rehabilitation site showing grazing on Acacia species growing over the rabbit proof fencing.

Hand seeding was also deemed successful, as lines where seeding was conducted were still visible 11 years later (Plate 6).



**Plate 6.** Fenced rehabilitation areas at Useless Loop showing lines where seeding initially occurred.

## 8. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study is applicable to the proposed Coburn Mineral Sand Mine as it is located in reasonable proximity to the mining lease and is exposed to comparable environmental issues that may hamper rehabilitation efforts. It is understood that the method of disturbance for the Useless Loop sites are significantly different to that expected for the Project Area. However, the period of 11 years since disturbance also allows for the prediction of vegetation regrowth rates.

The lessons learnt from the Useless Loop case study include:

- Monitoring of rehabilitation sites should include observations on the abundance of herbivores. This case study has shown that high populations of grazers (particularly rabbits) can cause significant decreases in rehabilitation success. If grazing populations

are found to increase from their current negligible numbers (Ninox, 2005), thought should be given to fencing the rehabilitation sites.

- Seeding of vegetation during the initial stages of rehabilitation may improve the rate of return of vegetation cover.

## 9. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.
- Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.
- Ninox Wildlife Consulting (2005). *Vertebrate fauna survey – Coburn Mineral Sands Project*. Report prepared for URS Australia Pty Ltd.
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## 10. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank the managers of the Shark Bay Salt Joint Venture for allowing access to the property, as well as a range of information pertaining to the site disturbance. This assistance was required in order to prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 9

### PLANNED SHARK BAY AIRSTRIP

#### 1. LOCATION

In 1990 the Shark Bay Shire identified a site on the Peron Peninsula, Shark Bay, which was to be designated as an airstrip. Located approximately 2 km from the coast, and approximately 10 km south of Denham, it is open to the prevailing south-westerly winds (Diagram 1).



**Diagram 1:** Location Map

#### 2. ENVIRONMENTAL SETTING

The airstrip site was historically part of the Peron pastoral lease, which was a property primarily stocked with sheep and goats. In 1990, the Department of Conservation and Land Management (CALM) purchased the lease to the property. The land was integrated into the state-wide conservation project “Western Shield”, whereby all sheep were removed and a goat de-stocking programme was initiated.

The peninsula is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall of 226 mm: approximately 70% of this falls between May and August. Temperatures range between 5.5 - 47°C and dew often forms overnight. The vegetation is predominantly low heath and scrub comprising mixed *Acacia* species and patches of spinifex grass (*Triodia* sp.), living on sand dunes and sandplains (Taillefer land system).

The soils at the site are a red/brown calcareous sand, with slight loam accumulation at depth. The pH is 8 at the surface, tending to 8.5 at the bottom of the profile (1 m).

#### 3. COMPARISON WITH THE COBURN MINERAL SAND PROJECT AREA

Despite being located approximately 80 km north-west of the Coburn Mineral Sand Project Area, there are a number of similarities between the decommissioned airstrip and the proposed mining site. These similarities include:

- Average wind speeds of 21.9 km/hr, with gusts of up to 81.4 km/hr for the airstrip site. The Project Area is also likely to experience similar high wind speeds, although there are liable to be less extreme due to its distance from the coast and protection by land topography.
- Both sites are located within semi-arid Shark Bay region, experiencing similar vegetation and soil characteristics, as well as similar environmental extremes.
- The airstrip site has experienced the removal of topsoil and its associated seed bank, loss of vegetation biomass and thus loss of wind protection. It is likely that this disturbance provided greater difficulty for rehabilitation than is expected for the planned Coburn mining project.

#### 4. TYPE OF DISTURBANCE

The airstrip site comprises an area of 2,000 m x 100 m, and was cleared of vegetation (chained), raked and graded in order to provide the necessary surface for large aeroplane traffic. All mobile topsoil was removed and no vegetation roots or debris remained on the surface. However, once this element of the construction was completed, the requirement for an airstrip at that site was downgraded, and the designed airstrip was no longer required. At that stage, all that was required to complete the airstrip was the removal of windrows of vegetation, and placing an erosion retardant on the ground surface.

#### 5. REHABILITATION TECHNIQUES

Once decommissioned, the site was then left in its completed state and subsequently abandoned with no management programme, nor assistance, for rehabilitation.

## 6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

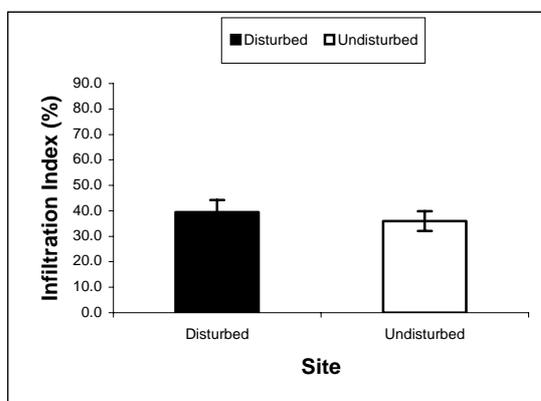
## 7. REHABILITATION ASSESSMENT

The study aimed to determine the extent of rehabilitation at the airstrip site over the 15 years since disturbance. These results were compared with those gained at an adjacent, undisturbed site (Plate 1).



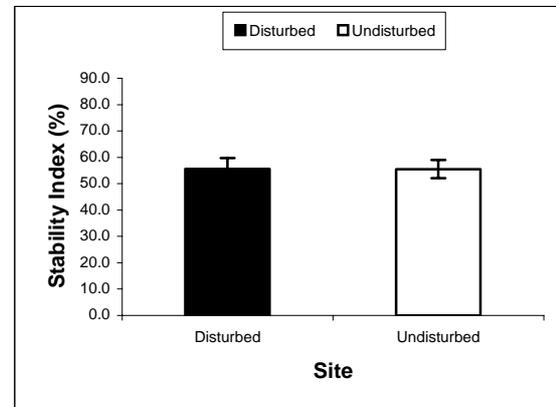
**Plate 1.** Windrow down the centre of photo. Rehabilitated site to the left, undisturbed site to the right.

There was no difference between infiltration indices at the disturbed and undisturbed sites (Diagram 2). Both sites contain sandy soils that allow rapid water infiltration and therefore decrease water, soil and nutrient loss from the local area.



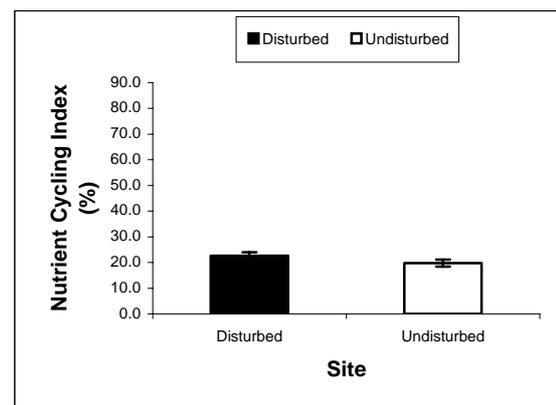
**Diagram 2.** Zone Infiltration comparison for disturbed airstrip and undisturbed analogue site.

A comparison of soil stability between the two sites showed no difference (Diagram 3). No erosion was observed at either site suggesting that the soils were able to withstand the environmental pressures.



**Diagram 3.** Zone Stability comparison for disturbed airstrip and undisturbed analogue site.

The potential for nutrient cycling did not differ between sites (Diagram 4), suggesting that both sites retain similar abilities to return organic matter and nutrients to the soil.



**Diagram 4.** Zone Nutrients comparison for disturbed airstrip and undisturbed analogue site.

No difference was found in the amount of vegetation covering the soil (mean %  $\pm$  SE) between disturbed ( $n=6$ ;  $56.7 \pm 5.7$ ) and undisturbed sites ( $n=6$ ;  $65 \pm 3.2$ ). The vegetation on the sites differed in maximum height, with the vegetation in the undisturbed quadrats ( $131.7 \text{ cm} \pm 15.4$ ) found to be taller than that in the disturbed plots ( $63.3 \text{ cm} \pm 7.2$ ).

There was no difference in species diversity between disturbed sites ( $7 \pm 0.5$ ) and undisturbed sites ( $8 \pm 0.6$ ). However, the dominant species within the quadrats differed. The disturbed area had a high prevalence of *Acacia ligulata*, which had an average foliage cover of 45.8% (Plate 2). The understorey was predominantly *Triodia plurinervata* (3.8%), with the topsoil containing a low litter cover (2.8%).



**Plate 2.** Disturbed site showing a predominance of *Acacia ligulata*.

In contrast, the undisturbed sites were dominated by *T. plurinervata* (25%), with *A. ligulata* (12.3%) and *Thryptomene baeckeacea* (8.3%) providing further soil protection (Plate 3).



**Plate 3.** Undisturbed site.

Both sites are likely to have undergone high grazing pressure over the 15-year period, with rabbits particularly common throughout the area during the case study field research. Fresh echidna tracks, scats and diggings were also present within the disturbed area.

## 8. REHABILITATION OUTCOMES

The disturbed airstrip site has shown to have returned to a soil stability comparable with the adjacent undisturbed region. The vegetation has also returned to a similar density and diversity, although the dominant species vary between sites.

The dominance of *A. ligulata* in the disturbed area, together with its lack of dominance in the undisturbed area, suggest that this species is an effective primary colonizer that prefers disturbed soils for germination and survival.

This case study has shown that comparable vegetation can return to an area that has been significantly disturbed, and that it does not require

assistance to rehabilitate. It is not known whether this disturbed area will return to the species dominance and vegetation height shown by the analogue sites, however it currently retains significant value by retaining nutrients and providing protection for soil, fauna, and seedlings.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was identified as being applicable to the proposed Coburn Mineral Sand Mine due to the soil at the disturbed site having undergone significant degradation, extreme wind conditions, and being located on a similar sandplain land system. The vegetation on the proposed airstrip location was similar to Community S3 (Mattiske, 2004), which is found throughout a large area of the proposed Project Area. The site was also of interest as it may provide some insight into what form the rehabilitated areas of the proposed mine might take after a period of 15 years.

Though the similarities between this case study site and the Project Area have been identified, it is important to recognize that there remain some differences that may influence rehabilitation success on the Amy Zone.

The lessons learnt from the disturbed airstrip include:

- Vegetation can colonise a severely disturbed area without assistance. However, after a period of 15 years post-disturbance the rehabilitated area is likely to have a different vegetation structure and dominance to analogue communities.
- *Acacia ligulata* is a primary colonizer and disturbance specialist. The cover and protection it provides is likely to improve soil stability.
- Protection from grazing is not a prerequisite for return of vegetation, although grazing protection may have improved or changed the rate of rehabilitation of the current vegetation community.

## 10. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.
- Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.
- Tongway D. J. and Hindley, N. L. (2004). *Landscape Function Analysis: Procedures*

*for monitoring and assessing landscapes with special reference to Minesites and Rangelands.* CSIRO Sustainable Ecosystems, Canberra, ACT.

## **11. ACKNOWLEDGEMENTS**

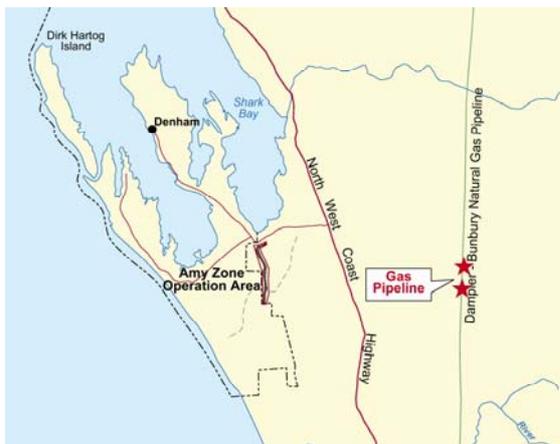
Gunson Resources Limited and URS would like to thank the Shark Bay Shire for their support in locating the proposed airstrip and providing information on its history, which assisted in preparing this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 10

### DAMPIER – BUNBURY GAS PIPELINE

#### 1. LOCATION

Located approximately 80 km east of the proposed Coburn Mineral Sand Project Area, two sites were sampled from two different land systems. Situated along the Dampier – Bunbury Gas Pipeline, the sites were chosen as they have undergone the same disturbance and have had the same rehabilitation period since disturbance.



**Diagram 1.** Gas pipeline site locations.

#### 2. ENVIRONMENTAL SETTING

The disturbed sites are located within the Tooloonga Nature Reserve.

This area is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall believed to be about 220mm. Approximately 70% of this falls between May and August. Average temperatures are likely to be more extreme than those at Denham due to its location away from the tempering maritime influence (Denham range 5.5 - 47°C). Dew is likely to form overnight.

One site was located on the Sandplain land system (Payne *et al*, 1987) and supported vegetation similar to community S8, which is found within the Project Area (Mattiske, 2004). The plant community was described as tall open shrublands with overstorey predominantly *Acacia* species over *Ptilotus obovatus* and *Scaevola spinescens*.

The other site was located on the Nerren land system and supported tall open shrubland communities with emergent mallee and tree form eucalypts. Overstorey consisted of *Eucalyptus* and *Acacia* species over *Ptilotus*, *Eremophila* and *Thryptomene* species. The majority of the species

found were also located within the Project Area (Mattiske, 2004).

Both sites had red sand soil, with a pH of 5.5 throughout the profile (1m).

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

The gas pipeline sites were located approximately 80 kilometres east of the centre of the Project Area. The similarities between these sites and the proposed mine site include:

- Both sites experience similar rainfall, wind, and temperature patterns.

#### 4. TYPE OF DISTURBANCE

Between 1982-1984 a gas pipeline was constructed in the area as part of the 1473km long Dampier-Perth section of pipeline. Vegetation of less than 200mm diameter was cleared from a 30m wide easement, processed through a chipper, and then spread back over the easement after the pipeline was excavated and pipe laid. Vegetation greater than 200mm diameter was removed and stockpiled on the side of the easement. The easement would have suffered from compaction by heavy equipment driving over the route (SEC, 1979).

#### 5. REHABILITATION TECHNIQUES

When the pipe construction had passed, the stockpiled vegetation was returned to the disturbed easement area.

#### 6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (Landscape Function Analysis, CSIRO, 2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

#### 7. REHABILITATION ASSESSMENT

This study aimed to compare the extent of rehabilitation at the Gas Pipeline site over the 25

years since disturbance, and provide additional information as to what the rehabilitated mine site may look like after a similar period of time. Disturbed sites were studied in two different land systems (Sandplain and Nerren; Plates 1 and 2) in order to determine whether rehabilitation success is influenced by land systems.

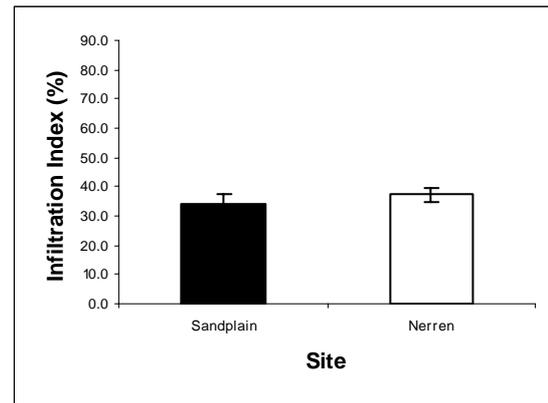


**Plate 1.** Gas pipeline site. Sandplain land system.



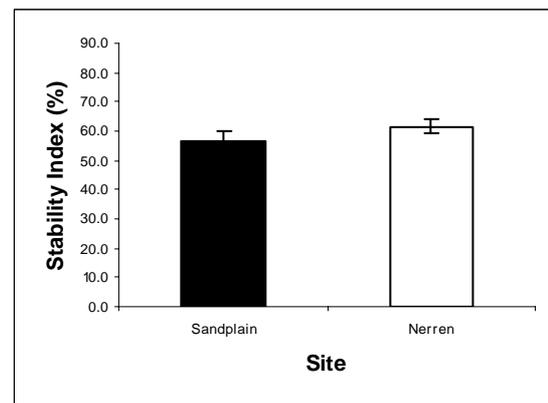
**Plate 2.** Gas pipeline site. Nerren land system.

There was no difference in any of the soil surface assessment characteristics tested. Soils in both the Sandplain and Nerren sites showed that same ability to transfer rainfall into soil-water (Diagram 2).



**Diagram 2.** Zone infiltration comparison for disturbed Sandplain and Nerren sites.

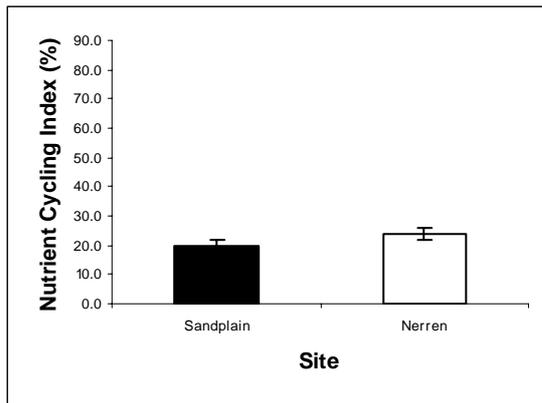
A comparison of soil stability between the two sites showed a similar soil stability index (Diagram 3). No erosion was observed at either site suggesting that the soils were able to withstand the environmental pressures.



**Diagram 3.** Zone Stability comparison for disturbed Sandplain and Nerren sites.

The potential for nutrient cycling did not differ between sites (Diagram 4), indicating that both sites retain similar abilities to return organic matter and nutrients to the soil.

No difference was found in the amount of vegetation covering the soil ( $n = 6$ ; mean %  $\pm$  SE) between Sandplain ( $35 \pm 3.1$ ) and Nerren sites ( $43 \pm 6.3$ ). The vegetation on the sites differed in maximum height, with the vegetation in the Sandplain quadrats ( $192 \text{ cm} \pm 11.4$ ) found to be shorter than that in the Nerren plots ( $255 \text{ cm} \pm 19.6$ ).



**Diagram 4.** Zone nutrients comparison for disturbed Sandplain and Nerren sites.

Species diversity in Sandplain sites ( $8 \pm 0.5$ ) did not differ to that at the Nerren sites ( $7.7 \pm 0.3$ ). However, the dominant species differed between sites. The Sandplain rehabilitation sites had a high prevalence of *Acacia* species (5.7%) over wanderrie grass (*Monachather paradoxa* – 4.5%). The Nerren land system sites were dominated by *Acacia* species (10.5%) over *Stylobasium spathulatum* (6.5%) and *Monachather paradoxa* (2.8%). Due to the brushing provided shortly after disturbance, the dead litter cover for the Sandplain (19.3%) and Nerren sites (17.7%) were high.

Few visual signs of herbivores were located, suggesting that these rehabilitation areas may not have significant pressure applied by grazing animals.

## 8. REHABILITATION OUTCOMES

The Sandplain and Nerren land systems are essentially similar systems with similar topography and soils but somewhat different vegetation (A. Payne, *pers comm.*). Results from this case study imply that rehabilitation is likely to be similar on similar types of land systems. The two Sandplain systems tested here showed similar rehabilitation patterns after undergoing the same disturbance at a similar time.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study is applicable to the proposed Coburn Mineral Sand Mine as it is located in reasonable proximity to the mining lease and is exposed to comparable environmental issues that may hamper rehabilitation efforts.

The lessons learnt from the gas pipeline case study include:

- Methods used on one land system should also be applicable to rehabilitation attempts on another similar land system.

## 10. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.
- Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.
- Payne, A. L., Curry, P. J. and Spencer, G. F. (1987). *An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia*. Technical Bulletin No. 73. Western Australian Department of Agriculture.
- SEC (1979). *Dampier – Perth Natural Gas Pipeline: Environmental Review and Management Programme*. Report NoRP88A, November, 1979, prepared by Dames & Moore in association with Pipetech – MWP for State Energy Commission Western Australia.
- Tongway D. J. and Hindley, N. L. (2004). *Landscape Function Analysis: Procedures for monitoring and assessing landscapes with special reference to Minesites and Rangelands*. CSIRO Sustainable Ecosystems, Canberra, ACT.

## 11. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank DBNGP (WA) Nominees for allowing access to the property and providing information on its disturbance history, which was required in order to prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 11

### WOODLEIGH STATION

#### 1. LOCATION

In 1965, National Aeronautics and Space Administration (NASA) identified a site on the Woodleigh Station, Shark Bay, which was to be changed so significantly to be observable to astronauts with the naked eye whilst orbiting the Earth in the Gemini Titan space craft. This disturbed area lies approximately 70 km northeast of the Coburn Mineral Sand Project Area (Diagram 1).



**Diagram 1.** Location Map.

#### 2. ENVIRONMENTAL SETTING

The disturbed site is part of the Woodleigh pastoral lease, which primarily runs sheep and goats.

Woodleigh Station is part of the Shark Bay region and is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall of 219mm (source: silo patched point data set, WA Department of Agriculture). Approximately 70% of this falls between May and August. Average midday temperatures are likely to be more extreme than those at Denham due to its location away from the tempering maritime influence (Denham range 5.5 - 47°C). Dew often forms overnight. The vegetation is predominantly tall open shrubland comprising mixed *Acacia* species growing on sandplains (Sandplain land system).

The soils at the site are red sands, with slight clay accumulation at depth. The pH is 6 at the surface, tending to 6.5 at the bottom of the profile (1m).

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

Despite being located approximately 70 km north-east of the Coburn Project Area, there are a number of similarities between the disturbed sites and the proposed mining site. These similarities include:

- Both sites are located within the semi-arid Shark Bay region, and have similar vegetation and soil characteristics. However, the Woodleigh site is likely to experience slightly greater environmental extremes, such as higher temperatures and lower annual rainfall.
- The Woodleigh site has experienced the removal of topsoil and its associated seed bank, loss of vegetation biomass and thus wind protection, and likely soil compaction. Further, the Woodleigh site was, and still is, used as part of the pastoral lease and routinely grazed by sheep and goats throughout the entire rehabilitation process.

#### 4. TYPE OF DISTURBANCE

A review of aerial photography has identified 16 sites that have undergone major disturbance. Each site is square in shape and 100 acres in area. Within this square a range of patterns was produced by laying highly reflective *Coquina* shell on the surface.

The vegetation and topsoil at each site was chained and pushed into windrows, then the vegetation roots were raked to a depth of nine inches and added to the windrows, where it was burnt. The resulting charcoal was then buried to a depth of >1 ft. The area was again chained to flatten the surface, before being disc-ploughed to a depth of five inches. No vegetation litter remained within the disturbed site. The *Coquina* shell was then placed on the surface in a range of patterns to test astronaut visual acuity (Plate 1).



**Plate 1.** *Coquina* patterns on disturbed Woodleigh site.

Once the orbiting of the space craft was complete, the majority of the sites were then left in their disturbed state and subsequently abandoned with little or no rehabilitation.

## 5. REHABILITATION TECHNIQUES

Rehabilitation was attempted for only one of the 100 acre areas. This area was fenced, seeded with a range of introduced grasses and legumes, and fertilised to assess the benefits for pastoral use. However, this initiative was deemed to have failed as very few introductions persisted for more than two years. The fence was removed and the area was left to rehabilitate naturally with no further assistance. It is not known in which disturbed plot this work was conducted as it was not evident from aerial photography.

## 6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

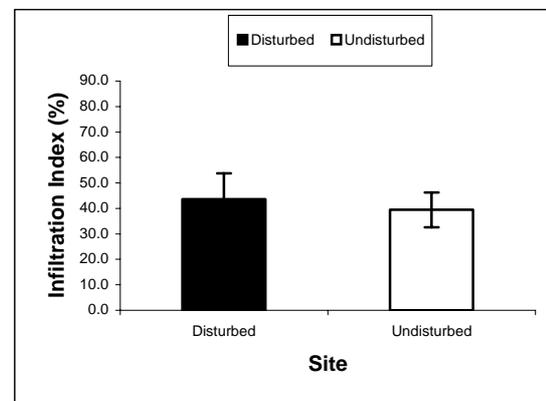
- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

## 7. REHABILITATION ASSESSMENT

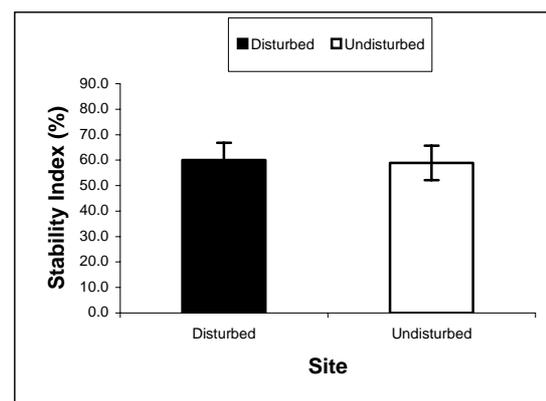
The study aimed to determine the extent of rehabilitation at the Woodleigh sites over the 40 years since disturbance. These results were compared with those from adjacent undisturbed sites.

No considerable differences were found between the three soil surface assessment indices (Diagrams

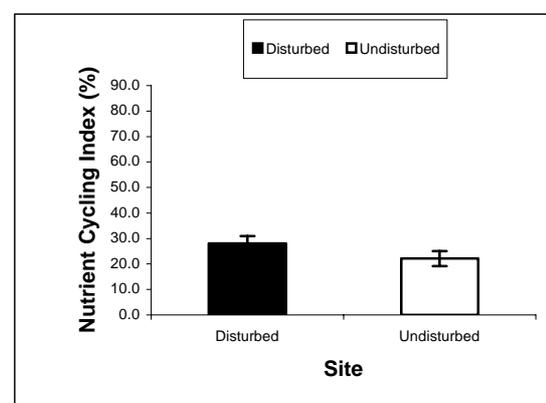
2, 3 and 4). However, in all indices the disturbed site data produced slightly higher results, suggesting that the soil may be marginally better able to withstand erosion, water infiltration occurred at a higher rate, and organic matter is incorporated back into the soil more efficiently.



**Diagram 2.** Zone Infiltration comparison for disturbed plots and undisturbed analogue sites.



**Diagram 3.** Zone Stability comparison for disturbed plots and undisturbed analogue sites.



**Diagram 4.** Zone Nutrients comparison for disturbed plots and undisturbed analogue sites.

No difference was found in the amount of vegetation covering the soil (mean %  $\pm$  SE) between disturbed (n=6; 28.8  $\pm$  7.2) and undisturbed sites (n=6; 33.8  $\pm$  9.0). In addition, the sites were not found to differ in maximum height, with the vegetation in the disturbed plots (292.5 cm  $\pm$  32.5) found to be of similar height to that in the undisturbed quadrats (275  $\pm$  10.4).

There was no difference in species diversity between the disturbed (10.3  $\pm$  1.3) and undisturbed sites (9  $\pm$  0.7). The vegetation species dominance within the sites was also similar, comprising a tall open shrubland (comparable with Coburn Project Area Community S7; Mattiske, 2004) with overstorey dominated by *Acacia sclerosperma* and *Eremophila maitlandii* over *Ptilotus obovatus* (Plates 2 & 3).



**Plate 2.** Woodleigh Station disturbed site.



**Plate 3.** Woodleigh Station undisturbed site.

Both sites contain only small litter cover (avg. 6.5%), with large open interpatches found between large *A. sclerosperma* patches. Both sites have been heavily grazed by sheep and goats prior to and

since disturbance, and according to the manager of the Woodleigh Station, the pastoral value of the area “could not be any better, taking into account that Woodleigh is going through the worst dry spell in history.”.

## 8. REHABILITATION OUTCOMES

The Woodleigh site suggests that over a rehabilitation period of 40 years, a disturbed site can return to a similar condition to that found in its pre-disturbed state. There was no discernable difference in any of the tested factors, and the areas are currently being used to their maximum pastoral potential.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was identified as applicable to the proposed Coburn Mineral Sand Mine due to the extreme disturbance events that it incurred and the subsequent lack of rehabilitation measures applied. In addition, a period of 40 years since disturbance allows for some form of prediction as to the extent of rehabilitation likely to occur at the mine rehabilitation sites over this time period.

The lessons learnt from the Woodleigh Station case study include:

- Vegetation can colonise severely disturbed areas and return to a comparable state to an analogue area in a period of less than 40 years.
- No primary colonisers were evident, suggesting that the vegetation had formed a stable community. This state is able to cope with the sustained pressure of pastoral grazing.
- The vegetation was able to return to a vegetation community comparable with analogue sites without protection from grazing pressure. However, it is unknown whether grazing protection would have changed the rate of rehabilitation.

## 10. REFERENCES

- Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison*. University of Western Australia.
- Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay*. Report prepared for URS Australia Pty Ltd.
- Tongway D. J. and Hindley, N. L. (2004). *Landscape Function Analysis: Procedures for monitoring and assessing landscapes with special reference to Minesites and*

*Rangelands.* CSIRO Sustainable  
Ecosystems, Canberra, ACT.

## **11. ACKNOWLEDGEMENTS**

Gunson Resources Limited and URS would like to thank the managers of the Woodleigh Station for allowing access to the property. In addition, the Department of Agriculture provided information on the history of the NASA project, which assisted in preparing this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

## CASE STUDY 12

### HAMELIN AIRSTRIP

#### 1. LOCATION

Two L shaped areas were located on aerial photography due to different contrast from the surrounding vegetation. They were identified as Royal Australian Air Force (RAAF) emergency airstrips. They are situated along the old Geraldton-Hamelin telegraph line. The site identified for this case study was the northern-most site, on Hamelin Station, and approximately five kilometres from the Coburn Mineral Sand Project Area.



Diagram 1. Hamelin airstrip site.

#### 2. ENVIRONMENTAL SETTING

The disturbed site is located within the Hamelin pastoral lease, which primarily runs sheep and goats.

The airstrip site upon Hamelin Station is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall of approximately 244 mm (B. Wake *pers comm.*). Approximately 70% of this falls between May and August. Temperatures are likely to range from 1.7 – 47.5°C, with dew occasionally forming overnight.

The Hamelin airstrip region contained a vegetation community that differed to those found within the Project Area (Mattiske, 2004), although most species identified at the studied sites were found within the Project Area. The undisturbed plant community was described as tall open shrublands with overstorey predominantly of *Acacia* and emergent *Eucalyptus* species over *Ptilotus obovatus*, *Dissocarpus paradoxus* and range of mixed annual species. This vegetation is living on sandplains (Nerren land system).

The soils at the site are brown loamy sands at the surface, merging to clayey sand at depth. The pH is 8.5 at the surface, tending to 9 at the bottom of the profile (1m).

#### 3. COMPARISON WITH THE COBURN PROJECT AREA

The Hamelin airstrip site is located approximately five kilometres east of the centre of the Project Area. The similarities between the Hamelin airstrip and the proposed mine site include:

- Both sites experience the same rainfall, wind, and temperature patterns. The Hamelin airstrip site is also located on the Nerren land system, which comprises about 5% of the Project Area.

#### 4. TYPE OF DISTURBANCE

In 1941-2, the RAAF cleared 2-3 blocks of land on the Geraldton-Hamelin telegraph line on the Hamelin and Coburn stations (J. Le Steer, *pers comm.*). These L-shaped blocks were designed to act as emergency airstrips which would receive aeroplanes and humans in the event of a raid by the Japanese on targets north of the emergency airstrip sites (J. Le Steer, *pers comm.*). It is believed that the vegetation would have been removed from the 400 m sites by bulldozer, which would also have led to soil compaction. It is unknown as to whether any further methods were used to flatten the area, or deter future vegetation growth in order to keep the airstrip clear for use.

#### 5. REHABILITATION TECHNIQUES

There is no evidence to suggest that any management programme, nor assistance, for rehabilitation was provided. Site rehabilitation post disturbance was not a requirement during that era.

#### 6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (Landscape Function Analysis, CSIRO, 2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,

- Identification of four dominant species per quadrat, including percentage foliage cover.

## 7. REHABILITATION ASSESSMENT

This study aimed to determine the extent of rehabilitation at the Hamelin airstrip site over the 63 years since disturbance (Plate 1). These results were compared with adjacent undisturbed sites (analogue; Plate 2).

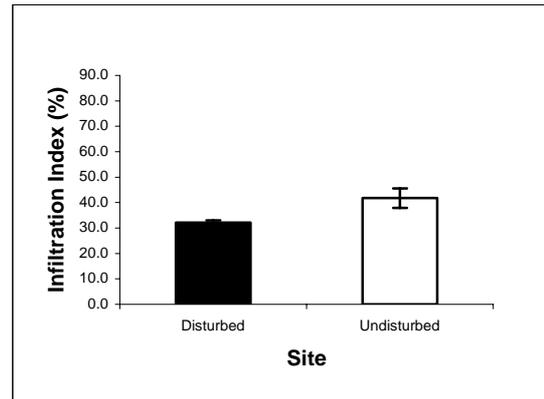


**Plate 1.** Hamelin airstrip site. Survey peg in foreground, with the disturbed airstrip area behind.



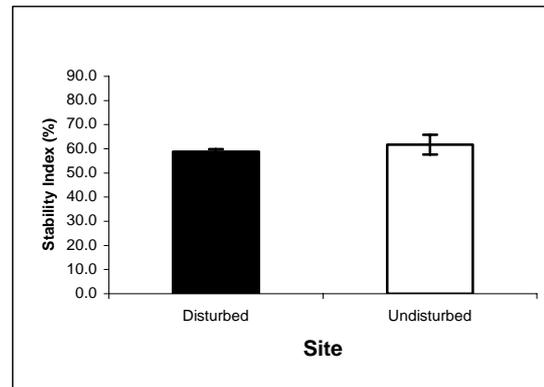
**Plate 2.** Undisturbed analogue site.

The soils in the undisturbed sites were better able to transfer rainfall into soil-water than those at the disturbed sites (Diagram 2). However, due to the sandy nature of the soils involved, little water loss through runoff is expected at either site.



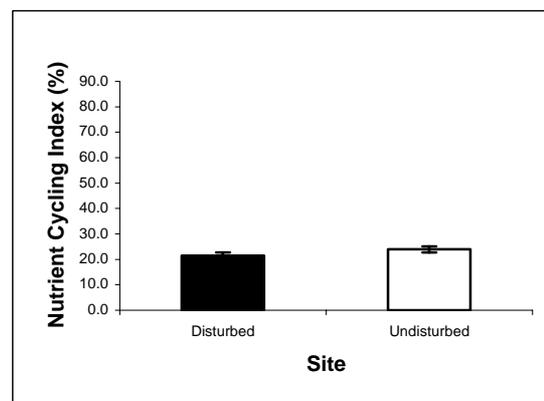
**Diagram 2.** Zone infiltration comparison for disturbed plots and undisturbed analogue sites.

A comparison of soil stability between the two sites showed no difference (Diagram 3). No erosion was observed at either site suggesting that the soils were able to withstand the environmental pressures.



**Diagram 3.** Zone Stability comparison for disturbed plots and undisturbed analogue sites.

The potential for nutrient cycling did not differ between sites (Diagram 4), indicating that both sites retain similar abilities to return organic matter and nutrients to the soil.



**Diagram 4.** Zone nutrients comparison for disturbed plots and undisturbed analogue sites.

No difference was found in the amount of vegetation covering the soil (mean %  $\pm$  SE)

between disturbed ( $n=6$ ;  $45 \pm 4.3$ ) and undisturbed sites ( $n=6$ ;  $50 \pm 3.7$ ). The vegetation on the sites differed in maximum height, with the vegetation in the disturbed quadrats ( $153.3 \text{ cm} \pm 45.6$ ) found to be shorter than that in the undisturbed quadrats ( $363.3 \text{ cm} \pm 27.9$ ).

Species diversity in disturbed sites ( $10.8 \pm 0.2$ ) was less than that in undisturbed sites ( $13.7 \pm 0.8$ ) and the dominant species differed between sites. The disturbed area had a high prevalence of deceased annual vegetation and litter, which provided an average foliage cover of 25% (Plate 2). Little cover was provided by overstorey species (3%), with *Ptilotus obovatus* providing the dominant understorey cover (4%).

The undisturbed sites were also dominated by dead vegetation and annual species litter (23%), but had a greater amount of cover provided by overstorey species such as *Acacia tetragonophylla*, *Acacia ramulosa* and *Acacia* spp. (13%). Understorey consisted primarily of mixed annuals (3%) and dead vegetation and litter (23%).

## 8. REHABILITATION OUTCOMES

Results from the Hamelin airstrip site suggest that the disturbed area may not return back to the same vegetation composition and structure as the original site. However, the site may return to comparable vegetative cover and to a stable, functioning ecosystem.

## 9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study is applicable to the proposed Coburn Mineral Sand Mine as it is located in close proximity to mining lease and is exposed to comparable environmental issues that may hamper rehabilitation efforts. The period of 63 years since disturbance also allows for the prediction of possible rehabilitation outcomes.

The lessons learnt from the Hamelin airstrip case study include:

- If not properly assisted, vegetation may not return to the original form that was evident at the site pre-disturbance.
- Although a different vegetation community to the original may exist, the soils have the capability to return to their original stability

## 10. REFERENCES

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