Appendix V5
Review of Bemax rehabilitation capacity and record (URS 2008)

FINAL REPORT

Assessment of capability to rehabilitate areas disturbed by mining at the Bemax Resources Ltd Happy Valley mineral sands operations

Prepared for

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Executive Summary

Bemax (incorporating Cable Sands) intends to mine mineral sands at Happy Valley in the locality of Gwindinup in southwest Western Australia. This proposal includes the mining of 97.3 hectares of native vegetation. This document assesses the capability of the proponent to re-establish diverse, sustainable and resilient native vegetation based on existing vegetation types on these cleared areas.

Bemax has rehabilitated mines with native vegetation at Jangardup, Yarloop and Ludlow in southwest Western Australia. Some areas at the operating Gwindinup mine will also be rehabilitated with native vegetation. The company has an environmental team of six staff and employs a number of well-credentialed consultants to assist in the planning, implementation and monitoring of their rehabilitation. Bemax has pioneered a number of innovative rehabilitation techniques including translocating blocks of intact soil and plants.

Monitoring of areas of native rehabilitation at the Jangardup and Yarloop mines show that the rehabilitation procedures used result in an average of around 30 to more than 50 species (per 100 m^{-2}) being re-established and persisting. With the advances in rehabilitation procedures proposed for Happy Valley, such as direct return of topsoil to some areas and laser controlled topsoil stripping, there is little doubt that a diverse flora can be established at Happy Valley. This will include recalcitrant species that are difficult to establish from seed but are common in the native vegetation.

It is difficult, and probably impossible, to guarantee that young rehabilitated sites with a flora comprising many species with a life-span measured in decades or centuries will be sustainable and resilient. A critical goal of rehabilitation is to ensure that there are no foreseeable obstacles to a sustainable system developing. At Happy Valley this means ensuring that a soil profile with an available rooting depth and physical and chemical properties similar to the pre-mining profile is reconstructed. Bemax have developed comprehensive profile reconstruction procedures for the Ludlow and Gwindinup mines from research and experience in their existing native rehabilitation. If an equivalent procedure is implemented at Happy Valley, this will maximise the probability that the aim of establishing sustainable and resilient native ecosystems will be successful.

Section 1 Background

Bemax Resources Limited (incorporating Cable Sands) proposes to develop, mine and rehabilitate two deposits of titanium ore at Happy Valley North and Happy Valley South along the Whicher Scarp in the Shire of Capel. The proposal follows on from the existing Gwindinup Titanium Mineral Project down-slope of the Happy Valley deposits. The two deposits contain over 600,000 tonnes of recoverable heavy mineral concentrate that will be mined sequentially over a period of approximately four years.

Bemax purchased Cable Sands in 2004. Cable Sands is the oldest mineral sands producer in Western Australia. Since 1956, Cable Sands has mined and rehabilitated many deposits in various locations throughout the southwest. In this document I use the names Bemax and Cable Sands interchangeably. In general, I use Cable Sands when referring to documents or projects written or initiated before 2004 and Bemax for those after 2004.

This document provides an assessment of the capacity and experience of the proponent of the Happy Valley project to rehabilitate areas disturbed by mining to meet the Environmental Protection Authority's objective for rehabilitation. This objective is to minimise the environmental impacts of the mine on the regional significance of the vegetation and flora in the project area (Dixon pers. comm.). This assessment is restricted to the rehabilitation of areas of native vegetation that will be cleared during the project as the mining and rehabilitation of land currently used for agriculture does not impact on this key issue.

Section 2 Existing Environment

The Whicher Scarp is a gently sloping landform linking the Swan Coastal Plain with the Blackwood plateau. The mining proposal will disturb 210 hectares of the Whicher landform including 86 hectares of mine pit, excavated to an average of 14.5 metres. A total of 97.3 hectares of native vegetation will be cleared, of which 43.1 hectares will be within State Forest.

The ability to reconstruct or restore a piece of damaged land following disturbance relies heavily on strong ecological knowledge (Bell and Hobbs 2007). Considerable effort has been taken to characterise the flora, fauna and soils of the area (Strategen 2006). Baseline data accumulated from pre-mining analogue sites (reference or control sites) will be important in shaping the planning stage of the Happy Valley rehabilitation program as was the case at Gwindinup (Bemax 2006a).

The Whicher Scarp has a highly diverse flora (Hearn *et al.* 2003). Six botanical surveys have been carried out in the Gwindinup and Happy Valley area (Bennett Environmental Consulting 2006a). The vegetation in the area has high diversity of structure, a diverse understorey and few weeds and much remains in good to excellent condition (Strategen 2006). 286 taxa, 149 genera and 48 vascular plant families have been recorded at Happy Valley (Bennett Environmental Consulting 2006a). Species richness was 37-66 species with an average around 45 per 100 square metres (Bennett Environmental Consulting 2006a). The condition of the vegetation in quadrats above the orebody (Bennett Environmental Consulting 2006a) was rated as good to very good.

Five major vegetation complexes, strongly associated with landforms and soils, were identified in the Happy Valley area (Bennett Environmental Consulting 2006a). Native vegetation from four of these complexes will be cleared for mining. These are open forest of *Eucalyptus marginata* (jarrah) and *Corymbia calophylla* (marri) on the Whicher Slopes (40.4 hectares) and Whicher Valleys (14.45 hectares), low forest of *Eucalyptus marginata* and *Corymbia calophylla* on the Cartis complex (1.59 hectares) and open forest of *Eucalyptus marginata*, *Corymbia calophylla*, *Allocasuarina fraseriana* and *Banksia grandis* on the Kingia complex (40.83 hectares) on the lateritic ridges. Twenty six percent of the Whicher Slope complex, 45.5% of the Whicher Valley complex, 70.8% of the Cartis complex and only 4.2% of the Kingia complex have been cleared since European settlement.

One plant of the Declared Rare Flora species *Daviesia elongata* subsp. *elongata,* was found in the project area. Four Priority Flora were recorded in the project area but only one, *Boronia humifusa*, was found within the area that will be cleared during mining.

The area provides quality fauna habitat and supports a range of native fauna seven species of frog, 17 reptile spp and 67 bird spp were recorded in the project area and its surrounds (review). All these vertebrate spp are widespread in the SW.

Nearly half of the area at Happy Valley assessed for the presence of dieback disease (*Phytopthora cinnamomi*) was interpreted as having *Phytopthora* (Pc) present. Unrestrained spread of Pc through the rehabilitation and into any downslope native vegetation could lead to a decrease in species richness and resilience and an increase in weeds. Procedures to manage dieback in mining areas and rehabilitation are well known and a dieback management strategy should be developed and described in the Mining and Rehabilitation Management Plan.

Section 3 Rehabilitation Challenges

The environmental significance of the Happy Valley project would probably be considered moderate when assessed using the criteria listed in Table 6 (Environmental Protection Authority 2006). The biggest impact of the Happy Valley project will be on the Whicher Valley complex where 6.5% of the currently remaining uncleared area will be cleared. While the Cartis vegetation is considered to be regionally significant as more than 70% of the pre-settlement area has been cleared (Environmental Protection Authority 2003) only 0.5% of the remaining complex will be cleared. A little more than one percent of the remaining uncleared Whicher Slope complex and 0.04% of the uncleared Kingia complex will be cleared for mining at Happy Valley.

The aim of rehabilitation at Happy Valley will be to restore as many of the pre-disturbance ecological values and functions of the site by repairing to the best extent as possible the capacity of the ecosystems to provide habitats for biota and services to people (Strategen 2006). In areas that will be cleared of native vegetation, the proponent commits to returning a self-sustaining plant community that maintains representative species composition and structure, based on existing vegetation types (Strategen 2006).

For rehabilitation at Happy Valley to be considered successful, it must be floristically diverse and contain species that resprout after fire as well as those that regenerate from seed. The established vegetation must also be resilient to disturbance particularly fire, which is a constant feature of southwest Australia. It is important to establish as wide a suite of species as possible in the initial rehabilitation effort as most native species from south west Australia, except the orchids (Grant and Koch 2003), have a limited potential to disperse through space (Grubb & Hopkins 1986). For example, Norman *et al.* (2006) found that species richness did not increase over one or two decades on rehabilitated bauxite mines in south west Australia and that unassisted recruitment of native plant species was extremely slow or nonexistent.

There are no generally accepted ways of assessing whether rehabilitation is sustainable, resilient and as productive as the pre-mining vegetation, or that ecological functions such as efficient nutrient cycles have been restored after an area has been mined. A number of different measures have been suggested for use as indicators to judge the success of rehabilitation procedures, for example, microbial biomass measurements (Sparling 1991) and ecosystem function analysis (Tongway and Hindley 2003). However, even after reviewing more than 20 years of ecosystem function research on Alcoa's rehabilitated bauxite mines in the jarrah forest of Western Australia, possibly the most intensively studied mine rehabilitation in the world, Grant *et al.* (2007) did not have enough evidence to conclude unequivocally that the rehabilitation is sustainable. It is probably unrealistic to hope that there could be a reliable way to assess definitively whether rehabilitation, with keystone species that may live for centuries, is sustainable and resilient in a similar form to the pre-mining ecosystem until many years after it is established. What is critical in rehabilitating native ecosystems is to ensure that the preconditions for a sustainable system exist. At a minimum, this requires that there is a diverse flora and a reconstructed soil profile that is stable and able to supply the nutrients and water required by the different rehabilitation types as they develop and mature.

The depth of the soil profile on rehabilitated mines must be similar to the pre-mining profile and there should be an absence of impeding layers that are not present in the pre-mining profile. The reconstructed soils should have similar physical and chemical properties to the pre-mining soils. For sand mines, the most important physical property that determines the soils ability to store and release water and nutrients is the proportion of silt and clay sized particles.

One of the features of heavy mineral sands mining that assist in rehabilitation is the minimal volume loss of soil which allows a landform to be reconstructed that closely resembles the original landform (Brooks 1996). Some potential problems that can occur when reconstructing soil profiles, such as soil toxicity and erosion, should not be a hindrance at Happy Valley. The slopes on rehabilitated areas at Happy Valley will be gentle and relatively short. Conventional erosion control procedures as used in the jarrah and marri/blackbutt (*Eucalyptus patens*) rehabilitation at Jangardup will minimise the potential for erosion. Acid-sulphate and sodic soils can be a problem in some areas in the southwest but are unlikely to cause problems at Happy Valley (Strategen 2006).

Section 4 Capacity and Experience of Proponent

Cable Sands and Bemax have rehabilitated mined areas to native vegetation at the Jangardup, Yarloop and Ludlow mines in southwest Western Australia. Mining of areas of native vegetation is also being currently undertaken at Gwindinup close to Happy Valley. Bemax has six staff dedicated to environmental issues. These staff are aided by specialist consultants from Strategen, Onshore Environmental Consulting and Bennett Environmental Consulting. The Bemax Environmental Management System procedures are certified to ISO 14001 standard (Bemax 2006a).

Evidence that the management is committed to achieve high quality rehabilitation outcomes comes from the innovation and continued improvement shown in the rehabilitation programs. Cable Sands and now Bemax have pioneered a number of rehabilitation innovations. One of the most notable is a technique of habitat transfer called translocation. Translocation is carried out using a loader with a specially modified bucket to pick up 2½ by 1½ metre blocks of topsoil and vegetation intact and then place them either directly on an area undergoing rehabilitation or onto a storage area for replacement later. The technique maximises regeneration from substrate roots, bulbs and corms as well as from seed retained on the block surface or in block vegetation. Another innovative technique has been implemented at Ludlow where a procedure has been developed to create ash beds on rehabilitated areas and to plant into them to establish a more natural looking ecosystem. Bemax have also been pioneers in developing herbicide treatments and application techniques for weed control in areas rehabilitated to native plants at Yarloop and Ludlow.

The company has also adopted best practice rehabilitation methods from the wider mining industry such as using vegetatively propagated plants. Bemax is currently planning to direct-return topsoil to around 50% of the Whicher vegetation complexes at Happy Valley (Brearley pers. comm.), a first for sand mining in the southwest as far as I know. This will require that ore is removed and stockpiled for processing later thus adding to the cost of mining.

I visited all three sites where rehabilitation has been implemented and had access to a number of reports detailing the establishment and progression of the rehabilitation at each site. Rehabilitation involved various combinations of the following procedures:

- Landform reconstruction,
- Translocating blocks of vegetation and topsoil,
- Returning subsoil and topsoil,
- Returning logs for fauna habitat,
- Ripping,
- Constructing contour banks, drainage lines and sediment basins to assist in erosion and drainage control,
- Planting seedlings (some propagated from cuttings or by division) and sowing seed,
- Fertilising planted seedlings with tablets of a native plant fertiliser,
- Fencing to exclude herbivores, and
- Weed treatments

The type of rehabilitation and a synopsis of the rehabilitation monitoring results at each site is given below.

Section 4 Capacity and Experience of Proponent

4.1 Flora Establishment

4.1.1 Jangardup

There are two adjacent areas of native rehabilitation at Jangardup referred to as the Extension and the Central Forest Block. 3.7 hectares of the Extension consisting of low scrub and heath over sedges (Cable Sands 1999) was disturbed during the mining project and was all rehabilitated in 2000. The Central Forest Block contains 39.5 hectares rehabilitated between 2000 and 2004. The jarrah and marri/blackbutt rehabilitation in this area is similar to the areas that will be rehabilitated at Happy Valley.

4.1.1.1 Jangardup Extension (Location 13471)

Included in the rehabilitation of the Extension was a revegetation trial to:

- test the performance of the block translocation method relative to the conventional topsoil replacement;
- test the effect of topsoil stockpiling periods on revegetation;
- test the comparative effect of fire on the success of block translocation and scraper stripping revegetation methods.

There were eight treatments in the revegetation trial. There were four translocation and burning treatments. The four treatments were translocation after burning, burning after translocation, burning both before and after translocation and translocation without burning. The other four treatments were a factorial combination of topsoil stockpiled for either six or twelve months after being removed from areas about to be mined that were either burnt or unburnt.

Translocation was successful in establishing a diverse flora. There was a significantly greater mean species richness 15 months after rehabilitation in translocated treatments than in areas that didn't receive translocated blocks of soil and plants (42.8 species $100m^{-2}$ compared with 24.5) (Bennett Environmental Consulting 2002). The density of plants was also greater on translocated plots than on topsoiled plots 15 months after rehabilitation (5.8 m^{-2} compared with 3.7 m^{-2}). It is not possible to statistically analyse whether there was an effect of the burning treatments on the translocation blocks because the treatments weren't replicated.

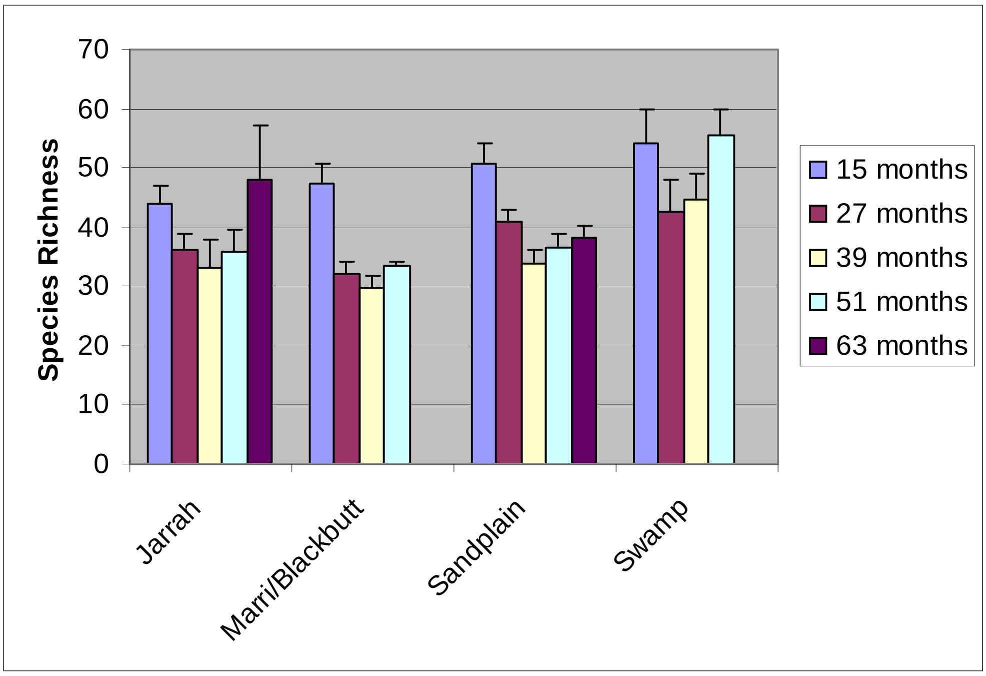
On average, there was a loss of 6.75 spp on translocated plots compared to none on topsoil plots between spring 2001 and spring 2003, although the average species richness was still nearly 50% higher on translocated plots (36 versus 24.5) (Bennett Environmental Consulting 2006b). Some of this loss of species could have been due to the edges of the translocated blocks drying out leading to plant deaths. In 2000, the translocated blocks were placed directly on the surface of the area being rehabilitated. This exposed the edges of the block to the atmosphere and encouraged the loss of moisture. This led to a change in the translocation procedure and in later rehabilitation blocks were dug into the surface soil to overcome this problem (Bennett Environmental Consulting 2006b).

Not only did the areas with translocated blocks have more species and a greater density of plants than topsoiled areas after 15 months, with time they also blended into the surrounding bushland better than areas receiving only stored topsoil (Bennett Environmental Consulting 2006b). Many native species in the southwest resprout rather than re-establish from seed after disturbance (Bell 2001). These species are often referred to as recalcitrant because many are not amenable to conventional mine restoration techniques. Species from the families Cyperaceae, Restionaceae and Xanthorrhoeaceae are typically recalcitrant and these families are dominant in the native vegetation at Jangardup (Cable Sands 2002a). Plants of the families Xanthorrhoeaceae and Cyperaceae were only found in the areas with translocated blocks (Bennett Environmental Consulting 2006b). The cover of perennial Restionaceae species was also higher on the translocation areas (Bennett Environmental Consulting 2006b).

4.1.1.2 Forest Block

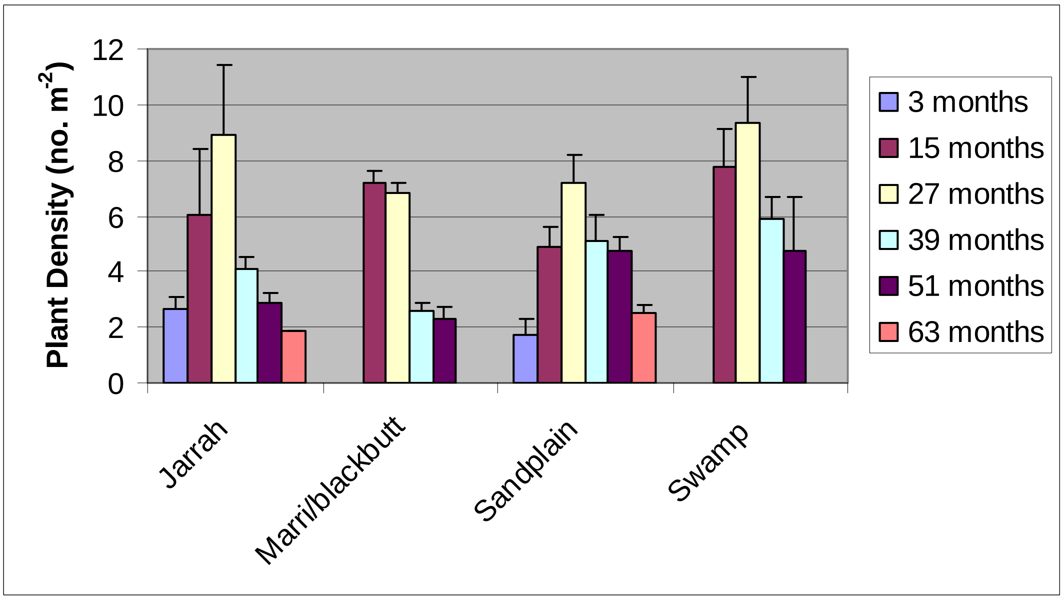
Rehabilitation in the Forest Block included areas of sandplain, swamp, jarrah forest and marri/blackbutt forest. These areas were determined according to soil type and position in the landscape. Bennett Environmental Consulting (2006b) presents monitoring data from the Jangardup rehabilitated areas for the years 2001-2005. Some of the species richness data varied in an unpredictable way. To reduce the noise in the data I averaged all the data of the same age from each rehabilitation type (Figure 4-1).

Figure 4-1 Species richness (species 100m-2) in spring one to five years after establishment on four different rehabilitation types at Jangardup. Data are from Table 3 of Bennett Environmental Consulting (2006b). Vertical bars represent the standard errors of the means (SEM).



The rehabilitation techniques were successful in establishing an average of 40 or more species on all four rehabilitation types at the 15 month assessment. After 63 months mean species richness remained at more than 30 species 100m^{-2}. Plant densities varied due to the ephemeral effect of annual species and the effect of short-lived perennial species such as the acacias (Figure 4-2).After five years, plant densities were around two plants per square metre for the jarrah, marri/blackbutt and sandplain rehabilitation and more than double this on the swamp rehabilitation.

Figure 4-2 Plant density in spring one to five years after establishment on four different rehabilitation types at Jangardup. Data are from Table 3 of Bennett Environmental Consulting (2006b). Vertical bars are the SEM.



4.1.2 Yarloop

In July 2000 Cable Sands was granted approval to mine mineral sand deposits within the Yarloop Rubbish Tip and adjacent native bushland in Reserve 31900. Mining commenced later that year, and was completed during the winter of 2002. (Cable Sands 2002b).

The reserve has a relatively diverse flora, with approximately 110-120 species recorded (Bennett Environmental Consulting 2007). The rehabilitation programme focused on the re-establishment of jarrah, marri, sheoak woodlands with a diverse understorey. Yarloop was rehabilitated in 2001, 2002 and 2003. The 2001 rehabilitation was of the old rubbish tip area which was unmined but covered with an impervious layer to prevent water infiltrating the rubbish. The 2002 and 2003 rehabilitated areas are most relevant to this report.

Weed seed in the topsoil caused problems in rehabilitated areas particularly the areas rehabilitated in 2001 and 2002. An innovative trial using a low rate of glyphosate (500mL ha^{-1}) without a wetting agent successfully controlled weed species such as *Hypochaeris glabra, Oxalis pes-caprae* and *Arctotheca calendula* without affecting the planted native seedlings (Bennett Environmental Consulting 2007).

Species richness in the rehabilitated areas (Figure 4-3) is comparable to that in bushland surrounding the mine where the mean species richness was around 43 species $100m^{-2}$ Bennett Environmental Consulting (2007). These data probably include weed species.

Figure 4-3 Mean species richness (species 100m-2) in spring one to four years after establishment on areas rehabilitated in 2002 and 2003 at Yarloop. Data are from Table 1 of Bennett Environmental Consulting (2007). Vertical bars are the SEM.

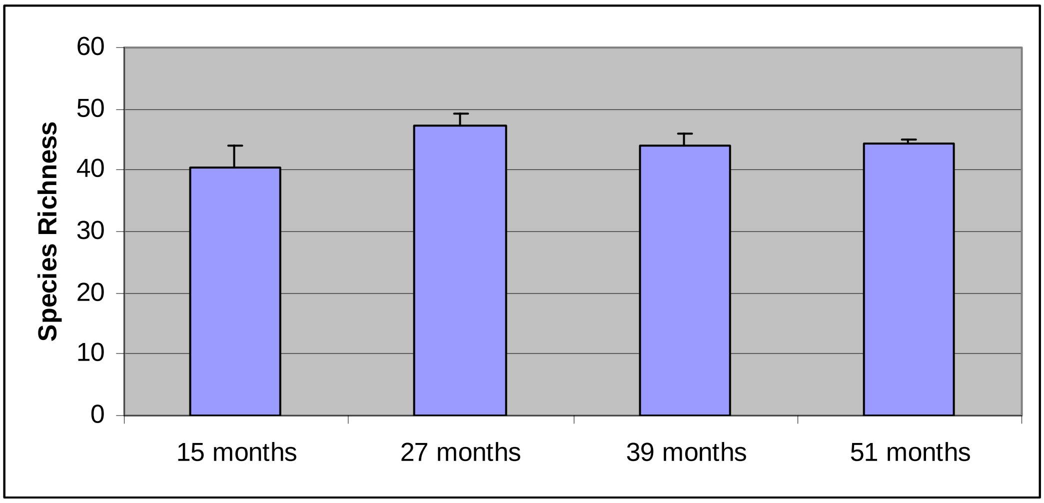
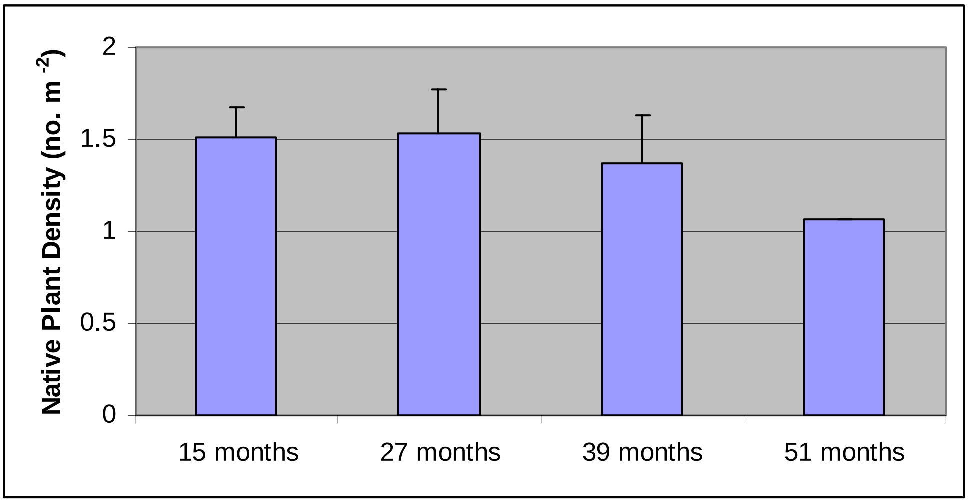


Figure 4-4 Mean native plant density in spring one to four years after establishment on areas rehabilitated in 2002 and 2003 at Yarloop. Data are from Table 1 of Bennett Environmental Consulting (2007). Vertical bars are the SEM.



Native plant densities are comparatively low on rehabilitated mines at Yarloop, particularly on the area rehabilitated in 2002. There was a problem obtaining sufficient seed for the Yarloop rehabilitation due in part to the condition set down by the state government that only seed collected from within 15 kilometres of the mine could be used.

4.1.3 Ludlow

The Ludlow mine is located within the Ludlow State Forest (LSF) west of Bunbury. The LSF has been degraded by many years of human disturbance. Soils in the area are dunes of the Yoongarillup Plain consisting of 3-6 metres of sand over limestone. The vegetation consists of a Tuart (*Eucalyptus gomphocephala*) overstorey with a peppermint (*Agonis flexulosa*) mid-canopy in some areas. *Pinus radiata* and *Pinus pinaster* were planted and persist in some areas. There is a depauperate understorey with many arum lilies that have been controlled by a herbicide spraying program since Cable Sands began managing the area.

Rehabilitation started with a 1.2 hectare trial in 2005 and should be completed by 2009. Most of the mined area is being rehabilitated to a tuart (*Eucalyptus gomphocephala*) woodland with a mixed understorey. The smaller western area is being rehabilitated with a tuart, jarrah, marri and peppermint woodland. An innovative rehabilitation plan aims to create a mosaic of Tuart clumps or Tuart/jarrah/marri clumps planted into ashbeds to produce a random non-plantation look. Ashbeds are created on the rehabilitated areas by burning clearing debris.

The only data concerning the progress of the rehabilitation at Ludlow comes from the 2005 trial area. This trial looked at soil properties in ashbeds and outside ashbeds, herbicide responses, the response of tuart seedlings to fertiliser and understorey development.

Species richness, plant density and cover were assessed in three belt transects each consisting of 20 contiguous one metre by one metre quadrats six and fifteen months after rehabilitation (Bemax 2006b). At fifteen months, mean species richness of native species was 26 (in 20 m^{-2}), plant density was 9.1 plants m^{-2} and mean cover 64%. *Trachymene coerulea* was sown at a high rate to act as a cover crop had a mean density of 3.1 plants m^{-2} after six months. There were 2300 Tuarts per hectare with an average height of 94cm at the six month monitoring (Bemax 2006b).

4.1.4 Sustainability

None of the documents I received had any data on plant growth on any of the rehabilitated areas, except the first year growth of tuarts at Ludlow. Nor were any other measures that have been proposed as indicating that ecosystem functions have been restored attempted. The rehabilitated areas are all still too young to test their resilience to fire. The rehabilitation probably needs to be around 10-15 years old before a prescribed burn can be attempted.

On my tour of the rehabilitation at the three mines I didn't see any obvious symptoms of ecosystem dysfunction. Symptoms I looked for included: widespread nutrient deficiency symptoms, groups of stunted trees, deaths of large numbers of plants of a variety of species, large areas of bare ground and soil erosion. Obviously such casual observations provide no real evidence that the areas are sustainable.

In my opinion, the most important precursor for the establishment of sustainable rehabilitation on mined areas is the reconstruction of a suitable soil profile. Bemax has used research results and experience to develop procedures that should result in reconstructed soil profiles with many of the features of the pre-mining ecosystem. Reconstructed soil profiles at Jangardup, Yarloop and Ludlow have all been studied. In addition, there has been extensive modelling of soil properties and the root distribution of tuarts in the LSF in sand mines operated and rehabilitated by other companies, and the dynamics of soil water use by tuart in unmined and proposed reconstructed soil profiles at the LSF.

A number of potential problems that could occur when rebuilding soil profiles were identified. These included the potential for compact layers that could impede root growth forming where there are sharp discontinuities between different soil materials (Oracle Soil and Land Pty Ltd 2002a). Research at Ludlow (Oracle Soil and Land Pty Ltd 2002b) showed the important role of fine material in the Ludlow soils. The soils at Ludlow only contain a small amount of fine material (defined as <63µM) but these fines have an important role in storing plant-available water in the soil. A study of the reconstructed soil profiles in areas rehabilitated to pasture at Jangardup showed that some of the coarse tailings material and most of the fine tailings layers were poorly structured, slaked upon rewetting, were prone to hardsetting and had low hydraulic conductivities (Braimbridge & Jasper 2001). They concluded that whenever fines are combined with coarser materials they must be well mixed and care must be taken to ensure that they don't become compacted.

The research generally showed that reconstructed soil profiles were similar to the pre-mining profiles. Outback Ecology (2002) concluded that the reconstruction of soil profiles in sandplain areas after mining at Jangardup appeared to have been successful in restoring a soil profile that was structurally and physically similar to the pre-mining soil profiles, especially in the upper soil layers. The sequence of organic-rich sands at the surface, grading to increasingly bleached sands at depth was closely re-created, with similar water and nutrient holding capacities. The greatest physical difference in the reconstructed and undisturbed soil profiles occurred in relation to the cemented 'coffee rock' zone found in the undisturbed soils. The integrity of this zone is unavoidably destroyed during mining. This is not a situation that will be encountered at Happy Valley where the majority the rehabilitation will be of the well-drained soils of the Whicher and Kingia complexes.

The reconstructed soils at Jangardup were also at least equivalent in chemical fertility to adjacent undisturbed soils and were less acidic (Outback Ecology 2002). While 'plant available' measures of soil nutrients used are not definitive measures and only give an indication of the ability of soils to release nutrients for uptake by plant roots, these analyses do provide some basis for confidence that reconstructed soils have adequate nutrient capital for the vegetation complexes being established on them.

This research led to protocols being developed for mixing fines with tailings sands and rebuilding soil profiles. For Gwindinup a 'clay block model' was developed to characterise the pre-mining profiles using soil data from excavated costeans referenced against mining drill hole data (Bemax 2006a). The aim is to return specific overburden types to an appropriate position in the post-mining profile. At Ludlow, the primary objective when reconstructing the landforms at Ludlow is to redistribute the fine material throughout the tailings sand and a comprehensive protocol has been developed for this procedure (Cable Sands 2006b). In addition, routine monitoring to confirm that the fines are redistributed appropriately and that there are no compaction layers that could inhibit root penetration is undertaken (Cable Sands 2006b). An equivalent protocol is being prepared for Happy Valley with soil profile data being linked with GIS data and this protocol will be described in the applicable Mining and Rehabilitation Management Plan (Brearley pers. comm.). It is important that the protocol provides details how the reconstruction process will be supervised and how it will be audited.

Section 5 Proposed Happy Valley Rehabilitation

Areas of native vegetation mined at Happy Valley will be rehabilitated using the methods developed at Jangardup, Yarloop and Ludlow. A number of innovations and improvements are planned for rehabilitation at Happy Valley (Brearley pers. comm.).

These improvements include:

- Direct return of some Whicher topsoils,
- Direct return of translocated blocks where possible,
- Double stripping will be carried out using laser controlled scoops to remove the top 50mm soil rather than the much less accurate scrapers traditionally used,
- Using a tractor-mounted tree spade to remove and relocate *Xanthorrhoea gracilis* and *Xanthorrhoea preissii* which are prominent features of the existing vegetation but grow extremely slowly from seed and are susceptible to herbivory in rehabilitation (Koch *et al.* 2004)
- Using a loader to transplant *Macrozamia riedlei*.
- Bemax have identified a number of species that are good candidates for vegetative propagation for Happy Valley and are working with commercial nurseries with the aim of producing sufficient numbers of plants.

If these improvements are carried out, it should extend the number and range of species that become re-established in rehabilitated areas. If this is combined with procedures that reconstruct profiles with similar soil depths and physical and chemical soil properties to the original soil profiles, then the probability that diverse, sustainable ecosystems will be re-established at Happy Valley is high. A long-term monitoring protocol should be initiated to confirm that the rehabilitation is developing along a desirable trajectory.

Section 6 Completion Criteria

Ruiz-Jaen and Aide (2005) list nine attributes that a successfully restored ecosystem should have. Unfortunately, as they point out, the costs involved are usually prohibitive and they often require long-term studies. Thus any completion criteria will need to be a compromise between what is desirable and what is practical.

Plant diversity is the most common completion criteria used for assessing rehabilitation success and is often assumed as a surrogate for all other types of organisms (Environmental Protection Authority 2006). Species richness should be the primary basis for the completion criteria relating to the biotic components of the rehabilitation at Happy Valley for the many reasons outlined on page 18 of *Guidance for Assessment of Environmental Factors* (Environmental Protection Authority 2006). Even though species richness is acknowledged as being vitally important in assessing rehabilitation success, specific species richness targets are rarely found in published completion criteria (Nichols 2006) apart from those for Alcoa's Western Australian mines (Elliott *et al.* 1996) and for Cable Sands' Jangardup mine (Bennett Environmental Consulting 2006b).

Success criteria of 30 species per 100 square metres were set for Jangardup (Bennett Environmental Consulting 2006b). This seems to be based on 60% of the approximately 50 species $100m^{-2}$ found in native bushland in the area. Sixty percent is a conservative target for contemporary rehabilitation. This figure also doesn't distinguish between species establish easily from seed and more recalcitrant species that may be common or even dominant in the pre-mining vegetation. Eighty to one hundred percent of the pre-mining species richness should be achievable at Happy Valley with the improvements in rehabilitation techniques described above. Any new target should also include the requirement that a proportion of the species (possibly around 10%) should be of recalcitrant species.

The use of 100 square metre plots as the basis for the species richness targets at Yarloop and Jangardup appears to be as arbitrary as the 80 square metre plots used by Alcoa for their species richness completion criteria (Koch 2007). Botanical assessment of rehabilitation is a highly skilled, time-consuming and expensive task. The sampling system needs to be designed so that the method chosen delivers the maximum useful information for the least effort. The sampling system used by Bemax at Yarloop and Jangardup has been criticised by the consultant employed to do the botanical monitoring work (Bennett Environmental Consulting 2005). The method also seems to be open to statistical criticism because the sampling transects are not independent and the sampling design may not adequately sample the whole rehabilitation site. I suggest a new sampling regime be developed with input from all the stakeholders, a botanist and a statistician. This group could also look at species area curves in the uncleared and rehabilitated areas to determine a scientifically sound sampling area for the baseline species richness.

It would be advantageous to have completion criteria that refer to the rehabilitation process rather than criteria that can only be measured 15 months after rehabilitation, which makes correction difficult. New criteria could specify that all areas should receive combinations of direct return of the topsoil, planting seedlings, sowing seed, directly transplanting species such as *Xanthorrhoea gracilis, Xanthorrhoea preissii* and *Macrozamia riedlei* and translocating blocks of topsoil with intact vegetation to maximise the possibility that the species richness targets are met.

Some criteria for landform reconstruction are needed. As landform data at Happy Valley will be linked to GIS data, it should be possible to come up with an agreed correlation between pre- and post-mining landforms.

Section 7 References

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Section 8 Limitations

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