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KINGS PARK AND BOTANIC GARDEN

SCIENCE DIRECTORATE

Restoration Research Plan

Sinosteel Midwest Corporation Limited: Koolanooka, Blue Hills and Weld Range exploration lines.

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1 Document Background

This document outlines the need for research aimed at ensuring effective restoration of vegetation communities at Sinosteel Midwest Corporation Limited (SMC) mining projects at Koolanooka, Blue Hills and Weld Range, and details a program for this research.

Ministerial statement 811 describes the restoration requirements for disturbed areas following mining at Koolanooka Hills and Blue Hills (Mungada East and West) within the shires of Morowa and Perenjori. It requires that the projects shall (a) *minimise the disturbance to, or loss of, the Threatened Ecological Community "Plant assemblages of the Koolanooka System" and the "Blue Hills vegetation complex" Priority Ecological Community,* (b) *re-establish flora and vegetation with not less than 70 percent of the known original species diversity and* (c) *develop a rehabilitation strategy to ensure that the characteristics of the constructed waste dumps optimise rehabilitation outcomes*. These are some of the highest objectives set for restoration of natural communities and, if successful, will represent leading practice in mining rehabilitation.

With the unprecedented requirements of the restoration program, and the lack of knowledge and experience in restoration of semi-arid floristic communities to this level (including TEC and PEC re-instatement), detailed research, trialling and monitoring are required to achieve successful outcomes. Approaches outlined throughout this document encompass leading research techniques and technologies developed by Kings Park to underpin rehabilitation success at the three SMC sites (Koolanooka, Blue Hills and Weld Range). Knowledge derived from research outlined within this proposal will provide a solid foundation to build rehabilitation strategies and meet mine closure requirements outlined in Section 13 of Ministerial Statement 811.

This study will be of regional significance to land managers and conservation agencies with an interest in the conservation and rehabilitation of the Midwest and Pilbara bioregions. The study will lead to long-term conservation benefits of international significance, and ultimately enable significant biodiversity conservation and rehabilitation in the post-mined landscape of the SMC operations with flow-on benefits in terms of:

1 Ecosystem function and stability.
2 Meeting best practice standards in biodiversity following mining.

3 Contributing information towards developing a scientifically robust means for establishing completion criteria for rehabilitation programs.

1.1 Restoration Requirements

The standard of rehabilitation, including species composition and community restoration, required for the project is set high within Ministerial Statement 811. The first key condition (13-3) states that “flora and vegetation are re-established with not less than 70 percent composition (not including weed species) of the known original species diversity”. To our knowledge this is the first time that this restoration target, imposed as a Ministerial condition, will be attempted by a company. Underpinning this condition is the industry benchmark established by several Western Australian mining companies, namely Rocla Quarry Products (Banksia Woodland Restoration) and Alcoa (Jarrah Forest Restoration). Kings Park has had over 15 years research experience with both companies, with scientific outcomes underpinning rehabilitation success enabling the companies to achieve more effective approvals.

The second condition (6-3) states that “The proponent shall ensure that mining and mining related activities of this proposal shall not cause the loss of or adverse impacts on any native flora, including the Threatened Ecological Community “Plant assemblages of the Koolanooka System” and the Blue Hills vegetation complex Priority Ecological Community”. As with the above condition this is the first time that such a condition has been imposed on a company, however unlike condition 13-3, there has been no precedent established to restore a plant community with this condition representing a significant scientific challenge. Failure to deliver at least a sound scientific solution/resolution could adversely impact on future approval options for the company. The added complexities of restoring a TEC and PEC therefore requires SMC to establish a new benchmark in Western Australian minesite restoration.

Establishing the new industry benchmarks as outlined in the Ministerial statement will ensure rehabilitation performance and reporting, to a level described in Condition 5-2 “the level of progress in the achievement of best practice environmental performance, including industry benchmarking, and the use of best available technology”; and 5-3 “improvements gained in environmental management which could be applied to this and other similar projects” are achieved.

To compliment these external requirements SMC have internally stipulated restoration requirements that will provide essential information for future SMC mine site restoration activities, and provide benefits/capacity building opportunities for the greater Midwest region, Western Australia and potentially facilitate future approval processes.

1.2 Restoration Aims

Subsequently, the aims of the restoration program are:

- Final rehabilitation of all disturbed areas (including post mining sites at Koolanooka and Blue hills, and exploration lines informing future restoration practices at Weld range) with vegetation communities that:
    1. are composed of original native plant species, with a minimum of 70% of initial richness
    2. represent original vegetation communities, including sub-communities of the Koolanooka TEC and Blue Hills PEC
    3. Minimize disturbance to the TEC and PEC.
- The production of a restoration practitioners manual for SMC environmental staff to assist with the implementation of scientific findings for on-ground restoration.
- To explore Midwest and State capacity building opportunities including program development with Midwest mining companies, indigenous and community engagement with SMC and Kings Park Science.

The research restoration plan will provide leading technology and practice to assist with the successful achievement of the restoration aims.

Briefly examining the three attributes of the target restored communities.

1. in order to achieve 70% species re-instatement and to ensure robust restoration targets are established, diversity at the species level must be adequately described in existing communities.

2. in order to *represent original vegetation communities*, restored vegetation must not only be comparable in diversity (as above) but also composition and structure to original communities. As these attributes are scale dependent and vary spatially and

temporally with environmental conditions it is necessary that these patterns are understood and that attributes of "original communities" and derived targets for restored- communities also incorporate this variation.

3. In addition to species diversity, to ensure that disturbance to the TEC and PEC are minimized it is important that relationships between original vegetation and landscape attributes should be recreated in restored vegetation. It is important to note that this relationship is not merely a product of topography. In terms of vegetation response, the physical, chemical and hydrological properties of substrates, including their down-profile and seasonal variation are at least as important as slope and aspect. This requirement therefore states that reconstructed topography, surface, substrate and vegetation attributes correspond – and are consistent with the original landscape-vegetation relationship.

   A concept underlying the satisfaction of these criteria is the need to ensure the long term sustainability of restored communities. Achieving this involves the restoration of ecological processes and function, dynamism and resilience, and the minimisation of threats in restored communities. Expanding these concepts: ● *Ecosystem processes* include nutrient cycling, pollination and seed dispersal and interactions among trophic levels (herbivory, predation, decomposition) and species (competition, facilitation, symbioses, etc). ● *Ecological function* includes these processes, as well as the production and maintenance of regenerative capacity of the community – such as provided by soil and canopy seedbanks, resprouting bud-banks (e.g. lignotubers), etc. –enabling recovery from disturbance (e.g. fire) or stress. ● *Dynamism* refers to the response of communities to the normal range (including extremes) of natural variation in the environment that occurs through seasonal, annual and supra-annual cycles. ● *Resilience* refers to the ability of an ecosystem to regain structural and functional attributes that have suffered harm from stress or disturbance (SER 2005). ● *Threats* to restored communities include continued mechanical disturbance, erosion / sedimentation (dust), chemical pollution (salinity), weed or pest outbreaks, excessive herbivory, altered hydrology and inappropriate fire regime.

1.3 Research Requirements

1.3.1 General Restoration Approach

The restoration of sustainable native vegetation communities using local species requires consideration of a number of key components: identifying the community's constituents and their attributes, identifying abiotic conditions necessary for the establishment and persistence of the community, techniques for recreating these abiotic conditions, techniques for successful introduction and establishment of the biotic elements of the community, and identifying and managing risks and threats to the establishment and sustainability of the community.

Optimising use of available resources including plant (topsoil, seed and plants) and soil substrate (plant growth medium and parent material) in restoration is critical. Restoration research aims to maximise restoration success with a minimal amount of intervention and thus reduce company investment. A chronological sequence of research steps develop from this aim (Figure 1) that will be expanded upon in the following sections.

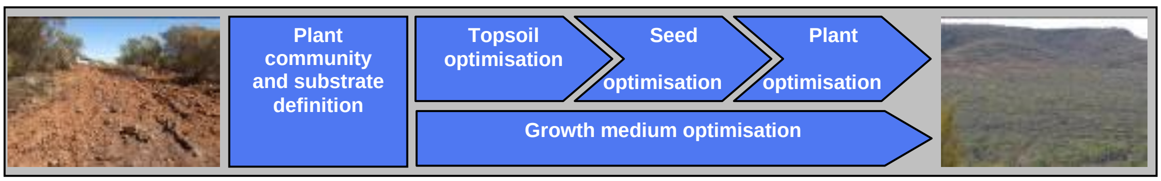


Figure 1 Chronological progression of Kings Park restoration research leading to efficient site restoration. Optimising growth medium underpins all aspects of plant research.

1.3.2 General site constraints

Specific constraints on individual restoration sites within Koolanooka, Blue Hills and Weld Range will be explored later in the document (see section 6). Information from consultant reports, SMC and Kings Park site visits (Appendix 2) have generally indicated that each site has a differing availability of restoration resources (soils, plant material) that dictates the research required. Koolanooka is in many ways a degraded site due to previous mining and pastoral activities that has lead to the low availability of natural restoration resources including plant growth medium (supports root development) and most importantly, topsoil (major source of seeds). The area proposed to be returned to natural vegetation far exceeds the availability of these resources on site and to our knowledge this is the first time in WA that a restoration project will attempt to multiply the effect of a resource to achieve sustainable restoration outcomes. For example, previous use of topsoil has relied upon a 1:1 strip:replace and for some Koolanooka sites this ratio may be as much as 1:7. Research is required to attempt to overcome the constraints of this resource deficit and avoid the otherwise likely failure to achieve restoration targets. Conversely, at Blue Hills there appears to be adequate resource availability for restoration requirements, but defined community restoration targets are lacking. The research focus at Blue Hills will be to define community structure and optimize use of all available resources. Weld Range resource availability is yet to be confirmed by a Kings Park site visit however in comparison to other sites the information contained within the PER is extensive, simplifying the strategy underpinning the research plan.

1.3.3 Delivering required research - Kings Park

The science team at the Botanic Gardens and Parks Authority (BGPA, or Kings Park) provides a single-point research and development facility capable of delivering practical research outcomes for the conservation and restoration of native plant species and ecosystems. Staff comprise 67 research scientists, graduate and honours students in the core disciplines of restoration ecology, plant population and community ecology, propagation biotechnology, seed conservation science, conservation genetics, weed biology and plant ecophysiology.

By focusing on the integration of these disciplines the research team has developed a strong track record in achieving practical outcomes in the *in situ* and *ex situ* conservation, restoration and translocation of native species and ecosystems. Key relevant Science staff include; Professor Kingsley Dixon (Director), Dr Jason Stevens (Restoration Ecophysiologist), Dr Eric Bunn (Senior Propagation Scientist), Dr Deanna Rokich (Senior Restoration Ecologist), Dr David Merritt (Seed Conservation Scientist) and Dr Ben Miller (Rare Species Ecologist).

2 Plant Community Analysis Program

2.1 Background

As project requirements include the need to return specific (original) vegetation communities, with ≥70% of their original species richness to restoration sites, it is essential that the identity and attributes of target communities are clearly understood. Ideally, communities to be restored should be identified on the basis of appropriately sampled floristic survey and vegetation mapping. Reports presenting vegetation survey and mapping data do already exist for the project area (Beard 1976, ATA environmental 2004, Meissner and Caruso 2008, Ecologia Environmental 2008) and these recognise varying numbers of unique communities. However, the sampling approach, floristic and spatial resolution, and spatial extent of these studies vary and are not focussed on identifying restoration targets. Further, the relationships between the communities they describe are not fully resolved (for site specific comments please see section 7). Ministerial requirements refer to two of these studies (ATA environmental 2004, Ecologia Environmental 2008) when identifying community targets, but from data obtained so far these are neither sufficient for identifying restoration targets nor consistent in their results.

The Koolanooka TEC is defined by a brief descriptive statement and a map outline (apparently derived from survey and mapping by ATA) and comprised of various sub communities (again defined by ATA) of which SMC will be impacting upon 4 known and up to 3 unknown original community types (section 6). Each community description in the ATA report has a species list that requires further resolution. In failing to fully resolve a species list for each community, the target species diversity (≥70%) has no benchmark with which to compare. The Blue Hills PEC, despite being linked to the Banded Iron Formation landforms, is not well defined. Given the requirements for community restoration, particularly pertaining to TEC and PEC, it is critical that this baseline data be adequately captured.

Information that is necessary for benchmarking restored communities to the level required in project plans and ministerial statement includes: a full list of species for the community, clear delineation of communities, including species whose presence / absence or variation in abundance defines each community, the appropriate spatial scale at which to assess communities, the range of variation for species richness and cover that can be expected, and the relative abundance of the most important species in each.

The species which make up plant communities each respond to variation in the environment in different ways: gradients in species composition in relation to environmental patterns may be gradual or abrupt depending on the adaptations of constituent species and the nature of variation in the environment. For this reason, the classification of vegetation communities is arbitrary at some scale; however, ecologists use a range of tools to try to objectively identify natural breaks in plant species distribution patterns which most clearly represent changes in community response to the environment. That is to say, communities are ideally recognised as different sets of species (usually with some degree of overlap) which represent significant differences in the response of species to the environment. Useful classification schemes also recognise and report the degree of difference between identified communities. Techniques for community analysis objectively define plant communities, recognise and quantify the relationships and differences between them (including identifying indicator species critical for delineating communities) and relate these differences to underlying, causative changes in the environment. Understanding these relationships and associating community definitions with them also provides a basis for recreating the environmental conditions necessary for the restoration of communities.

As species naturally vary in abundance within plant communities and most have spatially patchy distributions the definition of communities requires recognition of spatial and temporal variation. Specifically, communities vary in density (they are patchy), and in composition (not all species will be found in any one sample) over a range of spatial scales. Ecologists recognise that the number of species identified in a community increases with the dispersion of surveyed plots as well as with the total sampled area, but at a diminishing rate. A variety of techniques - based on species-area curves - exist to identify appropriate sampling area for assessing species richness. Adequate sampling for definition of vegetation communities would include replicated plots of this appropriate size in which the presence and density and/or cover of species present is assessed. The number of such plots will depend on the inherent variability of the community but must be sufficient to accurately identify the average values for species richness and vegetation cover / density, and to capture a representative amount of their variation. Finally, a useful target definition of a plant community should also include a species list that is as complete as possible for the entire area (i.e. also outside of sampled plots).

2.2 Proposed Research Program

To address the limited information pertaining to community definition and species composition, we propose a 6 month research program that will deliver the baseline data to which all restoration targets for all sites will be set. The program will deliver floristic analysis from previously assembled community information and to overlay new community information derived from activities defined below.

2.3 Scope of Research

2.3.1 Identify communities to be restored

Floristic analysis will be undertaken to classify communities utilizing all available data from consultants (Ecologia, ATA), DEC and others, together with any required supplementary survey. The focus of this analysis will be on all Blue Hills sites (currently a complicated array of small communities), several Koolanooka sites as well as confirming the data contained within the Weld Range PER (section 6). Identifying characteristic species and species whose presence/absence differentiates communities will be a key focus of these analyses. Community maps will be generated based on information collected at a scale that is appropriate to assess restoration standards.

2.3.2 Identify species composition in each community to be restored

A full species list including identification of dominant (framework) species and species that differentiate individual communities will be generated for all impacted communities. Methods used to generate the species list will include analysis of existing consultants data supplemented by vegetation survey where required, and seed bank auditing to understand species richness and composition of the latent system (see topsoil section for methodology) for sites where topsoil use is available. Target densities and frequencies of individual species will be determined for mature vegetation on a scale suitable for restoration monitoring. Key traits for individual species will also be determined including:

- Growth form (tree, shrub, annual herb)
- Ecological strategy (annual, long-lived perennial, post fire/disturbance perennial)
- Ecological amplitude (widespread, restricted to a specific community/habitat)
- Regeneration strategy (soil seedbank, canopy seedbank, dispersal dependent)
- Restoration approach (whether likely from topsoil seed-banks, collected seed, etc)
- Target range of densities (and number of individuals for the area) corresponding to reference (intact undisturbed) community.

2.3.3 Examine key attributes for each community

From the above information community distributions and extent will be determined as well as guidelines for target restoration areas. This will be underpinned by community analysis as environmental drivers. The key research question is how topographic position, slope, aspect, geology, hydrology and attributes of soils / regolith (soil chemistry, texture, physical structure as well as sub-soil features (depth to parent material), correlate with community patterns.

3 Plant Resource Program

3.1 Background

Species differ in the ease with which they can be established in restoration. This results from factors such as their abundance in the environment, seed production, viability and predation rates, dormancy mode and requirements for breaking dormancy, natural regeneration strategy (e.g. soil- or canopy-stored seedbanks) and sensitivity to the altered environment of restored substrates.

Soil seedbanks have many advantages as sources of material for restoration, they are species rich, genetically representative of original populations, and may be relatively easy to manage (if some specific requirements are met). If soil seedbanks are insufficient or unavailable for particular species or communities, then restoration from collected seed is often the next most effective approach. This works well for many species but for others can be limited by availability of good seed or lack of knowledge of mechanisms for overcoming dormancy; seed can sometimes be difficult and expensive to collect in required quantities. As a last resort, the production and planting of greenstock may be required to overcome these problems, but this can require either a large scale-propagation program, intensive and costly tissue culture or both. Unfortunately, it is likely that a number of key species will have these requirements.

Research is therefore required into the potential of soil seedbanks in restoration, noting particularly the abundance of germinable seed of each key species, total seed-bank species richness and particularly which community members are not represented or poorly represented in the soil seedbank. Research on the collection storage and application (timing, thickness, treatment) of this resource is required. For species for which soil seedbanks are not sufficient consideration of seed collection or greenstock production is required. Much is known about processes ensuring good germination of collected seed of many species, but some species remain difficult or intractable. Research will be conducted into the germination requirements of the most important of these species and how this technology is translated to on-ground restoration success.

3.2 Topsoil Research Program

3.2.1 Background

The topsoil seedbank is considered the most valuable source of propagules for restoration purposes (Bellairs and Bell 1993, Koch and Ward 1994, Rokich 1999). In addition to providing seed, topsoil also contains the appropriate fungal and bacterial symbionts required for promoting the successful establishment of many plant species (Bell *et al*. 1993). Kings Park experience with mining industry partners (Alcoa World Alumina, Rocla Quarry products and Iluka Resources) has shown that research and development into best-practice topsoil management leads to significant enhancement of native plant diversity and abundance on post-mined sites, through optimisation of conditions for seed survival and germination of topsoil-borne seed. Best-practice topsoil management can return up to 80% species diversity (of topsoil stored species) and 50% of total community diversity (Rokich pers comm.). This reduces the need for more costly plant establishment/replacement via broadcast seeding or greenstock planting and provides biodiversity reliability and security that is highly relevant to regulatory controls.

3.2.2 Proposed research program

Appropriate topsoil management requires significant research input and given the limited resource availability at Koolanooka, (section 6) is proposed to be a major focus of the SMC program. With the mining operation timelines being 5+ years across all sites it is important that sufficient time be allocated to research addressing topsoil collection, storage and return whilst allowing sufficient seasonal variation in temperature and rainfall events to ensure that management recommendations for topsoil handling reflect realistic climatic and seasonal constraints. We propose a 5 year topsoil handling program to support restoration at all three SMC sites.

3.2.3 Scope of Research

Optimising topsoil usage will be supported through a research program focussing on the stripping, storage and spreading of topsoil.

3.2.3.1 Topsoil stripping

For communities where topsoil is available (section 6) areas will be surveyed to identify potential topsoil collection zones characterized by an appropriate number of native plant species and low numbers of weed species. Surveys will be conducted by stimulating the seed bank to germinate both *in situ* (at donor field sites from SMC lease areas) and *ex situ* (SMC soil core analysis at Kings Park) by utilizing smoke technology in combination with other soil treatments (wetting/drying, chilling/heating cycles). Smoke is known to be a general environmental cue to stimulate germination of Western Australian native and weed species (technology developed by Kings Park).

Spatial variability of seedbanks across sites will guide stripping practices for topsoil. If topsoil does contain significant plant species but not in a high abundance, there is potential to investigate topsoil concentration (sieving seeds from soil) to minimize the amount of material to be stored. This technique has been previously trialed with Alcoa (successfully) and Rocla Quarry products (further refinement required).

3.2.3.2 Topsoil storage

Previous research indicates that maximum biodiversity return from topsoil comes from direct return, a process where topsoil is harvested from a donor site and immediately transferred to a recipient site. However the suitability of this technique is dependent on details of the mining operation. In the case of SMC, recipient sites are not likely to be available for direct topsoil return and therefore a period of topsoil storage is required.

Current knowledge indicates that topsoil needs to be stored and returned dry, with observations that topsoil quality quickly deteriorates when stockpiles are exposed to wetting/drying cycles in combination with changes in ambient temperatures. Given that storage will likely be required for between 1 - 4 years, the ability to successfully maintain seedbank viability needs to be demonstrated. SMC have already undertaken a ground breaking step at Koolanooka by water proofing topsoil stockpiles of two TEC subcommunities (Figure 2). Theoretically this will establish a new leading practice for topsoil handling techniques, however research is required to quantify the benefits of this practice. Seedbank viability will be assessed continually through seedbank auditing progressively from collection, through storage to final replacement. Seedbank viability will need to be correlated with environmental variables such as temperature and moisture levels within topsoil stockpiles to establish the principles behind this potentially new leading practice.

Figure 2 A TEC sub-community topsoil store. The topsoil was collected dry and immediately tarped to ensure moisture could not interact with the seedbank. This is this first example of the practice in Western Australia, and potentially represents leading practice on a global scale. Photo: Stephen Neill SMC, 2010.

3.2.3.3 Topsoil spreading

Current practice for topsoil return involves replacing topsoil in a ratio of 1:1, meaning that donor site is the same size as the recipient site. This ensures that there is maximum potential for the plant species to be restored in the same spatial arrangement (target density, diversity) as the original community. Dilutions up to 3:1 have been shown to be possible, however for some SMC sites at Koolanooka a dilution of 7:1 may be required. For example, at Koolanooka there has been 2000m^3 of topsoil collected from the two TEC sub-communities. Normally this would equate to a restoration site of ~2 ha, however the requirement to establish TEC communities at the TEC offset site and the south-fold waste dump has a requirement of ~13.5 ha. Research is required into techniques optimising the effectiveness of the topsoil resource whilst retaining a sustainable handling practice (i.e. topsoil is not degraded through the replacement technique, nor eroded or degraded following placement).

Research will utilise information previously collected from the current project including target plant densities (from plant community analysis program) and potential plant return (topsoil seed bank audits). This will provide a theoretical level (or potential dilution factor) to ensure topsoil capabilities match with community restoration goals determined by adult plant densities. Topsoil optimization treatments may include either spreading the topsoil thinner in the recipient site compared to the collection strategy or involve more strategic placement of topsoil across the landscape, leaving some areas deficient in topsoil. If topsoil is to be spread thinner across the recipient site then technologies such as soil stabilizers (e.g. mulches and chemical polymers) may need to be tested to ensure topsoil remains intact prior to the onset of opening rains. Technologies such as polymers may have additional benefits in that they hold many times their own weight in water and aid in soil moisture retention particularly in unreliable rainfall systems.

3.3 Seed Science Program

3.3.1 Background

With no topsoil resources present at some SMC restoration sites the reliance on seed-based outcomes will be substantial. A number of key areas of research are identified as important components in the development of an effective seed-based rehabilitation program, based on Kings Parks experience through research programs with the mining industry. The core principle to this program is to undertake the research and development required to ensure that seeds collected for SMC rehabilitation are used to their full potential through optimising each step in the chain of seed usage - from collection, storage, propagation and delivery to site.

Knowledge of seed germination optimisation is complex when dealing with biodiverse plant communities as found in the Midwest and Pilbara regions. Whilst in a broad sense the vegetation assemblages across the Midwest are similar, at the local scale there are differences at the species level. Species-specific information on seed use must, therefore, be tailored to site-specific needs for effective seed use in rehabilitation. Past failures in the effective use of seed (Table 1) can be linked to the need to develop site-specific, bioregional approaches to seed utilisation that address the core issues of timing of collection, quality of seed, viability of seed, dormancy release and site delivery techniques.

Table 1 Factors limiting the efficient and effective use of seeds in mine site rehabilitation.

Factors Limiting Seed Use	Impacts on Rehabilitation
Limited understanding of the phenology of seed development and maturation, and the provenance variation for these factors leading to inappropriate timing of seed collection.	Incorrect seed collection timing leading to reduced seed viability, storage life and ability to germinate.
Unresolved seed dormancy alleviation and germination techniques for many species, including those of key families Amaranthaceae, Goodeniaceae, Myoporaceae, Poaceae.	Failure of seed restoration programs attributed to inability to release dormancy.
Poor seed banking procedures that do not consider the required storage duration or designated end use of seeds.	Inadequate storage leading to significant loss of seed viability and poor germination through inappropriate temperatures, seed moisture levels and predation.
Lack of knowledge of storage requirements and germination characteristics of seed.	Low seedling establishment (< 10%) from broadcast seeds and inadequate biodiversity representation in rehabilitation
Lack of development of integrated rehabilitation methodologies to link seedling recruitment and establishment to episodic rainfall events.	Failure of seed broadcast methods in post-mining rehabilitation as seed not suitably cued to germinate and establish in remade soils at the appropriate time.

Increased efficiency of seed use in rehabilitation minimises the waste of this valuable biological resource and provides significant economic benefits. With current commercial prices for seeds of species identified in SMC leases ranging from $180 (*Acacia aneura*) to $4000 (*Dianella revoluta*) per kg (average price of $500 per kg) (Source: Tranen Revegetation Systems) and an average seed use of < 2kg/ha in SW sites (provided adequate topsoil availability) to 7 kg/ha for Pilbara sites (with limited topsoil) there is a substantial financial investment in seed sourcing for rehabilitation. Given that current seedling establishment rates resulting from direct seeding in minesite rehabilitation are typically less than 10%, more than 90% of the purchasing, processing and handling costs of native seeds are lost to inefficiencies in seed use.

3.3.2 Proposed research program

To address these limitations to seed use, we propose a research and development initiative staged over five-years that will deliver the seed management techniques necessary for protecting and restoring the biodiversity values within SMC leasehold areas in the Midwest and Pilbara. A program duration of five years is required to resolve the seed germination and storage procedures necessary to managing the seed resource and, importantly, to allow sufficient seasonal variation in temperature and rainfall events to ensure that management recommendations for seed collection and seed broadcasting activities reflect realistic climatic and seasonal constraints.

The project is based on a series of integrated research actions (Figure 3). The first stage of the project, to be completed within the first year, will examine seed quality assessments, and baseline seed germination and dormancy traits of target species that do not readily return from topsoil. This will provide a detailed inventory of the seed resource available for rehabilitation and the framework for future research targeted at optimising the use of this seed resource. The second stage of the project, over the next four years, will develop (1) dormancy alleviation techniques and germination methods for species important for restoration and identified as possessing dormant seeds; (2) appropriate methods of seed banking for both longer-term conservation (i.e. life-of-mine storage) and shorter-term storage (i.e. seeds destined for rehabilitation in the year or two following collection); (3) seed enhancement techniques to increase the effectiveness of broadcast seeding by improving site delivery techniques and seedling establishment.

3.3.3 Scope of Research

It is envisaged that SMC would utilise seed collecting contractors to undertake all seed collection. Once collected, Kings Park would undertake the following seed based research (Figure 3).

3.3.3.1 Seed quality

The main considerations when determining the quality of a seed batch are the purity of the collected material and the viability of the seeds. Many seed batches contain non-seed material such as chaff, seed decoys and floral parts. Whilst careful cleaning should reduce the proportion of non-seed material, even the best possible cleaning efforts sometimes cannot separate all foreign matter. The purity of a seed batch refers to the proportion of seed to non-seed material.

A viability test determines the proportion of seeds that are alive and, thus, have the potential to germinate. Many species have inherently low seed viability. This may vary from year to year and from site to site. Seed viability must be taken into account when assessing the germination potential of the seed batch.

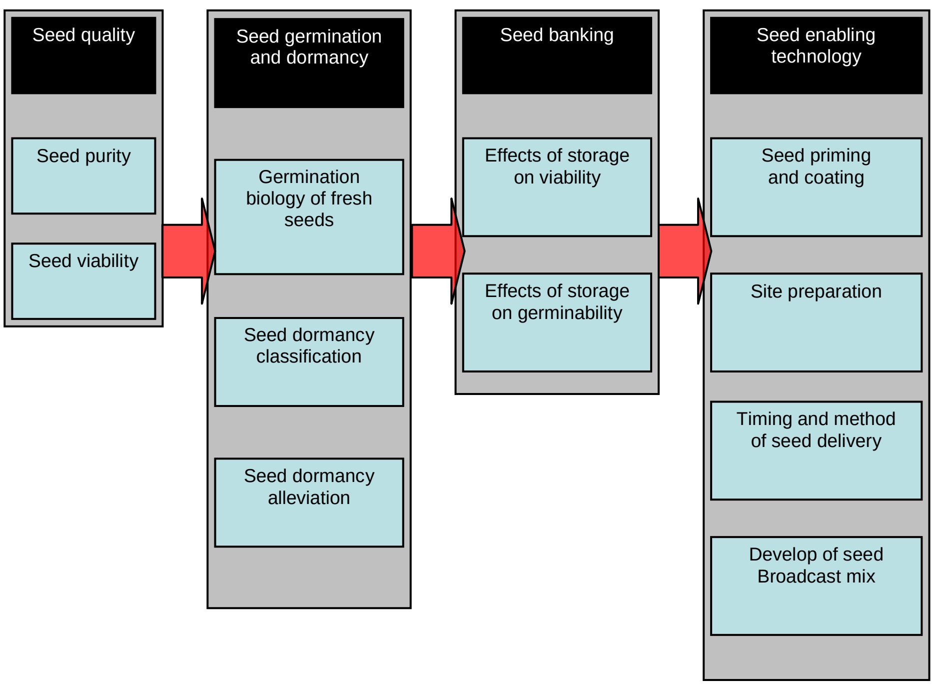


Figure 3 The systematic approach to developing seed-based conservation and rehabilitation techniques for SMC. Each research theme is staged over a five year program. Integration of each theme is necessary to achieve efficient and effective use of the seed resource.

An accurate assessment of both seed purity and viability is necessary for rehabilitation planning, providing a guide as to how much material to collect in order to deliver a known number of germinable units corresponding to target areas and densities. Combining this knowledge with the germination characteristics of each species is key to successful seed-based rehabilitation. This study will

- Assess seed purity and seed viability of target species following collection and cleaning (See Figure 4 for an example).
- Document cleaning techniques if required
- Develop a data base to store and communicate seed quality information.

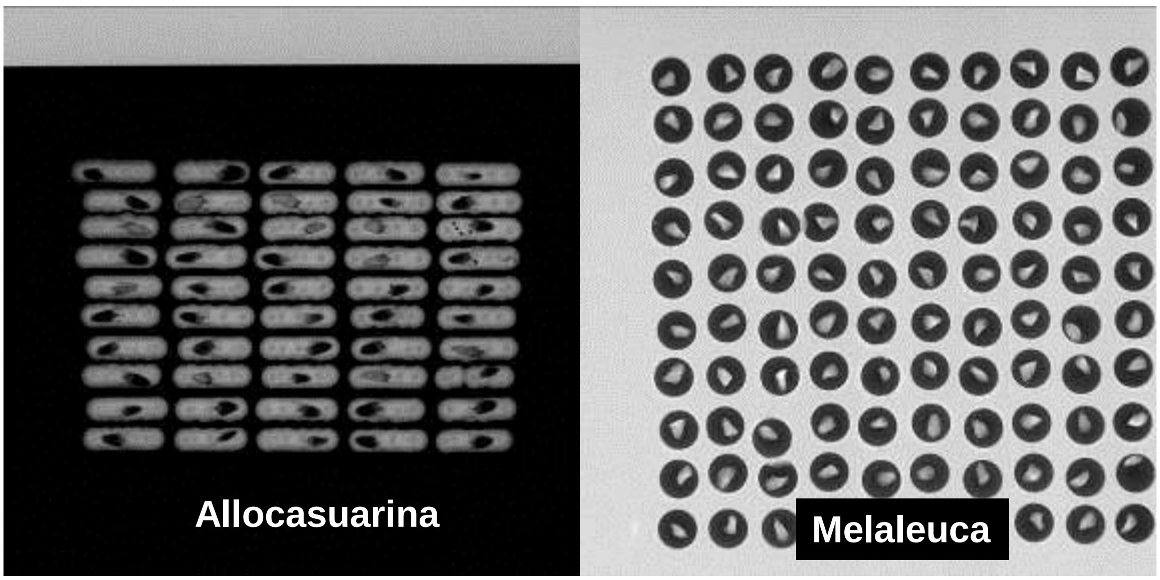


Figure 4 X-ray analysis showing seed viability of two seed lots collected from SMC's Koolanooka lease area. The Allocasuarina is ~80% filled (dark seeds) whereas the Melaleuca is completely filled.

3.3.3.2 Seed germination and dormancy

By definition, viable seed has the potential to germinate, but it does not necessarily follow that the seed is able to germinate at any given time. Viable seed can be dormant or non-dormant. Viable seeds will germinate if exposed to the appropriate conditions, but not if they are in a dormant state. Dormancy prevents germination during periods when conditions are suitable for germination, but at a time of year when seedling survival is unlikely. Instead dormant seed require some cueing process before becoming non-dormant and germinating. Seed dormancy is present in around 70% of all angiosperms and represents one of the most significant impediments to the use of seeds in rehabilitation. Many dominant plant families in the Australian flora have an abundance of species with unknown or poorly understood dormancy alleviation and germination requirements. Known problem families located within the SMC leasehold include Chenopodiaceae, Cyperaceae, Goodeniaceae, Loranthaceae and Poaceae. Some of the other families present at SMC leases have unknown dormancy/germination characteristics (See electronic files for information).

For each target species the first stage of this study will:

- Determine seed germination under a range of standard test conditions.
- Identify the presence/absence of dormancy and classify the type of dormancy.
- Identify species requiring more research to maximise germination and prioritise these by their importance for restoration
- develop research strategies for possible methods of alleviating dormancy in priority species
- Develop a data base to store and communicate seed germination information.

There are many ways in which dormancy can be imposed. Broadly, dormancy can be imposed by the structures covering the embryo (e.g. seed or fruit coat), or by a physiological "block" in the embryo. There are five main classes of dormancy, and numerous sub-classes. The type of dormancy a seed possesses can be determined even if no germination is at first achievable. Once identified, strategies and treatments most likely to result in dormancy alleviation can be applied. For species identified as possessing dormancy, in key families and dormancy classes the second phase of this study (Years 2 – 5) will:

- Adapt and apply leading practice techniques in dormancy alleviation.
- Identify optimum germination conditions once dormancy is alleviated (temperature, light, the requirement for smoke or other cues).
- Produce and document efficient and practical methods for germination.

A preliminary investigation of seed dormancy within plant families that occur at Koolanooka and Blue Hills has indicated that between 25 - 30% have deep dormancy for which there is no simple treatment. At the species level, complex dormancy and germination issues are present in 13 - 32% of the total species occuring at Koolanooka and Blue Hills respectively (See electronic files for information).

3.3.3.3 Seed banking

Seed banking is often crucial for rehabilitation success. Storing seeds represents the most efficient method of capturing a genetically representative sample of germplasm for a species and conserving it in the long-term and is the best means of ensuring no loss of species from a site. Seed banking also allows capitalisation of high-seeding years to provide a seed resource for rehabilitation activities that may coincide with poor seasons.

The conditions under which seeds are stored should be tailored to the end use of the seeds. Many seeds are used for rehabilitation purposes within a short period after collection. In such cases, storage conditions that can promote dormancy loss (e.g. warmer storage temperatures of *c*. 30 °C) can be advantageous. Other seeds may need to be stored for much longer, at least for as long as the planned mine duration. For conservation of high-value seeds, such as those from rare or threatened species, hard to collect species, threatened ecological communities, or endemic species, ensuring maximum storage life is paramount. In these cases seeds should be carefully dried and stored in freezers at -18°C.

It is crucial, also, that the storage conditions maintain the initial seed viability until the seeds are required for use. Maintaining the initial seed viability means that it is more likely that seeds retrieved from storage will produce healthy, vigorous seedlings. Seeds subjected to adverse storage conditions can age rapidly, leading to loss of vigour and pre-mature seed death. Poor storage practices will result in reduced germination and weak seedlings unable to survive once re-introduced into a habitat. Optimising the storage environment will ensure the effort put into collecting high quality seed is translated into viable, germinable and vigorous seedlings when required for rehabilitation.

The second phase of this study (Approximately years 2 – 5) will:

- Assess desiccation and freeze tolerance of seeds to classify storage behaviour and identify appropriate storage techniques.
- Determine the effects of the storage environment on seed dormancy status and the germination requirements following storage.
- Develop a database / document to store and communicate seed banking information.

3.3.3.4 Seed enabling technology and delivery to site

Post-mined rehabilitation sites generally retain the species diversity and abundance patterns that initially establish. It is therefore vital that difficult-to-germinate species, priority flora and any other species gaps identified following early establishment from the topsoil seed bank are re-introduced during the initial rehabilitation phase of post-mined sites. Broadcast seeding is widely used in industry, but a major limiting factor is poor seedling establishment. Commonly less than 10% (and often as low as 3%) of broadcast seeds germinate and result in an established plant. Failure to capitalise on broadcast seeding results in a loss of the benefits derived from correct seed collection, storage and dormancy alleviation procedures and, ultimately, an unsustainable drain on local wild seed resources. Seed enhancement is a term which describes treatments designed to increase seed germination performance and seedling establishment. Seed enhancement treatments include seed priming, coating and pelleting. Much of this technology is routinely applied in the agricultural and horticultural industries, but as yet has not been widely adopted to the native seed industry. In the third phase of this study (Years 3 – 5) research will focus on developing seed-based rehabilitation methods specific to the Midwest and Pilbara region via:

- Developing seed priming techniques that are applicable to a broad range of species and large volumes of seeds to increase the rate and uniformity of germination.
- Determining the impact of germination promoting compounds (gibberellic acid, karrikinolide) and anti-stress agents (salicylic acid, kinetin) on seedling establishment.
- Determining the effects of pre-sowing site preparation (soil ripping) and time of sowing (summer, autumn, winter) on seedling establishment.
- Develop a data base to store and communicate seed enabling information.

3.4 Greenstock Program

3.4.1 Background

For species that are difficult to germinate or do not set sufficient seed to collect for broadcasting, seedlings must be raised under nursery conditions and the species introduced to site via greenstock planting. Production of plants under nursery conditions can fall under two broad propagation strategies, traditional seed based and vegetative propagation. The first of these is relatively well established, while the second will require research for some species groups

Vegetative propagation can be achieved by combining traditional horticultural techniques with an understanding of ecological and reproductive characteristics of the species. By investigating how a species perpetuates under natural conditions, nurseries may be able to vegetatively propagate the species and produce nursery stock when there are constraints of seed propagation. The two main types of vegetative propagation are tip cuttings and tissue culture (maintaining growing plant tissues under culture conditions within a strictly controlled environment – nutrient, hormone light and temperature). Vegetative propagation is beneficial when seed propagation is difficult, large nursery stocks are required in a short time period, specific genotypes and / or disease free plants are required. The disadvantages of the system include greater production costs, a reduction in the amount of genetic diversity, and investment in propagation infrastructure. After plants are successfully produced via vegetative propagation methods they can move into traditional nursery production.

Generating plant material for restoration purposes versus gardening requires an understanding of the stresses imposed on the plants in the site to be restored. In Mediterranean-type environments, different strategies for coping with low soil water and high atmospheric evaporative demand may contribute to differences in the competitive ability and the distribution of species (Damesin et al. 1998). In Mediterranean-type environments, seedlings must survive the inherently long, hot dry summers (Roche et al. 1998) with an immature root system that has limited access to soil water (Donovan & Ehlringer 1991; Cavender-Bares & Bazzaz 2000). Irrespective of climate, transplanted tree seedlings commonly suffer water stress that can limit early growth or cause mortality (Close et al. 2005). The volume of soil occupied by a planted container-raised tree seedling is 10-fold less than that of a seedling of similar top growth that has established from seed on site.

3.4.2 Proposed research program

This research program is dependent on outcomes for the two preceding programs (i.e. plant production from seed and topsoil) and thus this research program will be targeted at the priority gap or missing species. Therefore a research timeline can not be explicitly defined at this point however the scope detailed below would need to be undertaken for each of the identified missing species. It is envisaged that this research would be undertaken in the event that standard nursery and planting practices fail to generate robust seedlings for restoration at SMC sites.

3.4.3 Scope of Research

The scope of research will involve two strategies including optimizing plant production under nursery/culture conditions and subsequent seedling treatments under field conditions to maximize outplanting success.

3.4.3.1 Optimizing plant production

For species that can be produced by nurseries and fail to establish under field conditions the research would define suitable nursery growing regimes and seedling attributes for target species to improve the quality of nursery stock and its subsequent performance after planting. In particular our research will focus on developing nursery techniques that will enhance the competitiveness of containerized seedlings in the field, reducing the need for subsequent vegetation plantings.

Techniques to be trialed would include the varying the attributes of containers in which plants are developed as well as fertilizer, irrigation and temperature conditions. Given that many of these plants naturally grow on skeletal soils (Banded Iron Formation), optimising growth under nursery condition to ensure survival and high productivity in an altered restoration site (likely to be a deeper profile) is critical.

For species that can not be produced by standard horticultural practice we would undertake a staged approach focusing initially on tip cutting technology followed by tissue culture techniques. Cutting propagation will involve research in the nursery at Kings Park whose staff are leaders in cutting propagation innovation. Cutting techniques such as manipulation of the cutting growing media and growing environment would be investigated.

In the event that this fails to deliver an effective restoration-ready plant product, tissue culture will be investigated by: (a) *in vitro* germination of seeds and preliminary studies of multiplication of seedling culture lines; (b) shoot or nodal culture using meristematic material from selected adult plants; and (c) production of somatic embryos from seed explants or from meristems or other somatic material from adult plants of known genotypes (subject to outcomes of the genetic study). Kings Park is a nationally acknowledged leader in tissue culture technology particularly in solving propagation issues in the resources sector.

3.4.3.2 Seedling protection under field conditions

These research approaches will directly assist plants to cope with the excessive evapotranspiration demands and herbivory threats placed on newly transplanted seedlings. Although restoration should not be viewed as a gardening exercise initial treatments to assist in plant development may be required, particularly in harsh conditions. Plants derived from nursery production will be transplanted into restoration sites and exposed to a range of treatments including irrigation, shading structures (shadecloth) and herbivory and wind protection (tree guards). Treatments will be integrated with below ground substrate research outlined in the following section.

4 Soil Substrate Program

4.1 Background

The soil substrate dictates plant establishment, growth and survival and is correlated with the distribution of many plant species / communities (for example the Blue Hills PEC – is linked directly with the Banded Iron Formation). For the purposes of this proposal the soil substrate can be defined by the three categories topsoil, growing media and substrate. Topsoil, as previously mentioned is the top 10cm of the soil profile containing extensive amounts of seed, organic matter, and soil nutrient reserves. Underlying the topsoil is the growth medium where roots access water sources and nutrient pools that support juvenile and mature plant growth and survival. Supporting the entire system is the substrate, or the parent material, that amongst other things dictates sub-surface hydrology.

4.2 Proposed research program

We propose a five year research program to assess impacts of soil substrate to support plant growth leading to a restored plant community that reflects original structure. This duration will allow for sufficient seasonal variation in temperature and rainfall events to ensure that management recommendations for soil substrate activities reflect realistic climatic and seasonal constraints. To quantify substrate resource availability and determine if functional traits of restored landforms/substrates are similar to the original intact system, Kings Park would need to engage with a soil consultant, appointed by SMC.

4.3 Scope of Research

This research program aims to (a) describe soil substrate linkages to existing vegetation communities (b) characterize restoration materials to sustainably support vegetation communities and (c) trial restoration materials to optimize resource usage.

Outcomes from the plant community analysis will highlight landscapes and substrates associated with particular community types. For each community, substrate analysis would include:

- landscape level - characterizing topographic position, slope, aspect, solar radiation inputs, geology and hydrology on a broad scale.
- Surface level (topsoil and growth medium) - characterizing soil chemistry, texture, rockiness, physical structure, water holding capacity, infiltration rates. Note: previous data has previously been collected for several of these parameters (Meissner and Caruso, 2008).
- Subsurface level (substrate) – depth to soil regolith, regolith structures, hydrology

After gaining information on substrates in intact communities information would need to be ascertained for available restoration materials. The ability of these resources to match or perform similar functions to intact soils is perhaps the best means of ensuring long term community sustainability. Analysis would include:

- Quantifying restoration topsoil, growth medium and substrate resources
- Test for stability, bulk density, hydrology and water storage capacity
- Trial mixtures, amendments and profiles to attain properties matching natural communities

Moderately large scale trials of these experimental profiles are required to examine their long term stability and hydrological performance. Advice on establishing trials and models would need to be sought from a soil-science based consultant.

Trialing restoration substrate resources will enable SMC to understand direct impacts of substrate on restoration success. Research would focus on:

- varying reconstructed soils
- varying reconstructed rock sub-surfaces and profiles
- manipulating slope angle

in order to:

- minimise runoff and erosion
- enhance water infiltration and storage, minimise evaporative loss
- enhance establishment and survival of restored plant species. Restoration trials will be established in which substrate, surface, soil seedbank and seed broadcast treatments will be varied to determine optimal response in terms of seedling emergence, growth and survival. Trials to examine the role of key dominant species in enhancing or suppressing the survival and growth of other community members will also be established.

Manipulating restoration surfaces will enable SMC to understand direct impacts of surface features on restoration success. Research would focus on how treatments such as ripping, debris (see section 5.3), fertilizer, irrigation and fencing treatments :

- minimise runoff and erosion
- enhance water infiltration and storage, minimise evaporative loss
- minimise herbivory impacts and if appropriate/necessary
- enhance establishment and survival of soil crusts (see section 9.2)

Investigating plant interactions with newly formed soil profiles during their establishment phases can lead to an understanding of the sustainability of a more mature system. Studies employing plant ecophysiology to link seasonal soil water content and groundwater dynamics with plant water use (photosynthesis, transpiration), and acquisition strategies in plant species that are dominant in communities or differentiate restricted communities will be undertaken as part of this study. Plants growing in restoration sites will be compared with plants of the same age in an intact community, to assess their development and behaviour in relation to reference conditions.

5 Debris Research Program

5.1 Background

SMC's section 45 document states that SMC will "*spread vegetation debris to return organic matter to the area and to provide supplementary seeding with appropriate species*".

Plant debris may consist of a range of materials from large pieces of relatively intact vegetation (including branches and logs) to finely mulched material. Intact vegetation may provide habitat for faunal species (in the case of large Eucalyptus trunks at Blue hills), foci for nutrient cycling processes and establishment niches for seedlings. Some Western Australian mining operations utilise direct transfer of intact debris material to provide seed for restoration with varying, although largely unquantified, results. As debris is unlikely to be directly returned to recipient sites as part of the SMC operation its value as a seed resource is likely to be low.

Mulches have proved beneficial in certain restoration systems, and include the provision of plant establishment niches by offering protection from wind and water erosion, and increased soil microbial activity. Mulches can however be risks in systems with non-uniform and irregular watering (as in the semi-arid and lower rainfall zones of the Midwest and Pilbara of Western Australia) as they reduce rainfall infiltration into the soil and increase evaporation from light rainfall events. Mulches are also known to distract root development in some restoration systems (e.g. Banksia woodland), which inevitably leads to reduced seedling survival in ground water dependent systems. Finally, the type of mulch, particularly as it affects soil carbon:nitrogen ratios may influence the activity and behaviour of the soil microbial community and therefore the availability of soil nutrients. As plant performance is influenced by soil nutrient availability this inturn may drive initial plant community establishment.

Orientation of debris return has been previously trialed in desert restoration. Placing mulch in sheets (traditional) across the soil surface has demonstrated reduced soil erosion on slopes up to 31% under viticulture conditions (Bainbridge 2007). Vertical orientation of mulch may be more effective than sheet placement by: reducing water movement offsite, providing increased channels for water infiltration into soil profiles, providing windbreaks to trap seeds and dust, provide a source of below ground organic matter, reducing the volume of mulch required (Bainbridge 2007).

5.2 Proposed research program

As there has been a large amount of variation in success rates of debris return in restoration, this program will be proof-of-concept for each of the individual SMC sites. Small scale trialing is anticipated to occur within the first year of restoration at each site followed by regular seasonal assessments to be made over a five year period. Outcomes will quantify impacts (beneficial or detrimental) of debris addition for plant growth and community restoration.

5.3 Scope of Research

This research program aims to identify the effects of debris on seedling establishment. The research will focus on field application techniques of plant debris where a range of debris types from intact stems to mulched products collected from cleared vegetation will be spread onto restoration sites in various concentrations/orientations.

As is the case with other resources, there will be insufficient debris resources to ensure that restoration sites have the same amount of organic matter returned as reference intact donor sites. Determining an optimal concentration of debris to facilitate better restoration will therefore be required.

Plots in restoration sites and intact reference communities will be developed to assess the effect of above ground debris application treatments on various stages of plant establishment including seed germination, seedling emergence, growth and survival rates into subsequent years. Plots will be sown with a defined number of plant species and seasonal monitoring of plant growth and survival will be undertaken.

6 Specific Community and Site Constraints

6.1 Background

In determining the research requirements for individual sites a series of constraining factors have been identified including: those imposed by Ministerial conditions (Statement 811 and S45C – DSO Koolanooka/Blue Hills PER) and the knowledge underpinning these conditions; those imposed by the company (timelines for restoration); and those imposed by availability of natural resources (plant and soil substrate). Addressing these constraining factors through research will provide the best opportunity for SMC to establish the new benchmark in mine site restoration and achieve successful mine closure. The following sections will outline specific site requirements and restoration questions that should be addressed.

6.2 Community constraints

Adequacy of community definitions are outlined in Table 2. At the community level, five of the seven sites at Koolanooka are sufficiently defined to enable the setting of restoration targets. As outlined above, resource availability is likely to dictate the ability to sustainably restore certain communities, and is particularly true for the TEC. We proposed to treat the TEC as two communities (a ridge community for the offset site and the midslope community on the south fold waste dump). After determining the amount of area likely to be restored to each of these communities it is anticipated that a “generic local community” would be rehabilitated in remaining areas. Indeed the generic community would be established across other impacted areas at Koolanooka if resources are limited to re-establish original communities. While this generic community would be sourced from local provenance seed stocks and species (as per ministerial conditions), the species list would need to be determined – by assessing the availability of seeds, likelihood of success, and structural/functional contributions of suitable species. Currently the waste dump site west of detritals at Koolanooka has been defined as a community; however as this clearly a degraded system it is not a suitable baseline for restoration. Given its position in the landscape it is thought that the original community may resemble ATA community 25. Research to determine species distributions and substrate descriptions will assist in further informing this decision.

For the Blue Hills project area, community definition is not adequate for identification of restoration targets. The relationship between communities is not apparent from the available data and a complex array of communities is currently described across the landscape, also unclear is the association of each of these communities with the abiotic environment. Untangling these relationships – to guide identification of restoration targets, and creation of associated substrates – will require further research. For Weld Range the survey and statistical analysis to define communities appears appropriate (to be confirmed by Kings Park site visit). However, as with all sites, fine scale variation in species composition necessitates research to define the scale appropriate for assessing restoration targets.

6.3 Resource constraints

Adequacy of available resources is outlined in Table 3. Information gathered from site visits indicates that Blue Hills should not have any significant issues with resource availability or the ability to manipulate substrate to match community requirements. This is in direct contrast to Koolanooka where resources are limiting, particularly topsoil and growth medium.

Table 2 Community definition taken from ATA map and proposed restoration strategy for each site within Koolanooka, Blue Hills and Weld Range

Site	Community defined (ATA)	Proposed restored community
Koolanooka		
TEC offset	1 & 3	3 + generic local community
South Fold waste dump	1	1 + generic local community
In-pit backfill	None defined	Extrapolated from ATA map as community 1 and 6 + generic local community
Waste dump (west of detritals)	15	25 – thought to be original version of the degraded community 15
Backfilling of detritals	None defined	Generic local community
Administration	25	25
Stockpile	25	25
Blue Hills		
Mungada West Pit	possible combination of up to 3 communities	Need further information from consultants
Mungada West Stockpile	possible combination of up to 6 communities	
Mungada East Pit	None defined	
Mungada East Stockpile	None defined	Need to undertake further community analysis
Plant site	1 community	

Workshop	possible combination of up to 3 communities	
Weld Range		
General site	15 mapped vegetation communities with mining to impact on at least 13.	Need further information from SMC to determine impact areas of exploration activities.

Table 3 Summary table highlighting if sufficient (✓) or insufficient (×) resources are available to meet site restoration requirement.

Community	**Topsoil (sufficient)**	**Growth medium (sufficient)**	**Substrate (ability to manipulate)**	**Seeds (collection zone defined + sufficient)**
Koolanooka				
TEC offset	×	×	×	✓
South Fold waste dump	×	×	✓	✓
In-pit backfill	×	×	✓	✓
Waste dump (west of detritals)	×	× / ✓	✓	✓
Backfilling of detritals	×	×	✓	×
Administration	×	✓	Already intact	✓
Stockpile	×	× / ✓	Already intact	✓
Blue Hills				
Mungada West Pit	✓	✓	✓	✓
Mungada West Stockpile	✓	✓	✓	✓
Mungada East Pit	✓	✓	✓	✓
Mungada East Stockpile	✓	✓	✓	✓
Plant	✓	✓	✓	✓

Workshop	✓	✓	✓	✓
Weld Range				
General site	✓	✓	✓	likely

6.4 Timeline constraints

Site availability, seasonal constraints and requirements for research outcomes (Figure 1) will influence timelines for rehabilitation. For this reason it is anticipated that SMC will need to adopt an adaptive management approach (utilizing research outcomes as they bcome available to improve rehabilitation techniques). Research outcomes from Koolanooka will inform best restoration practice for Blue Hills and exploration lines at Weld Range. The current SMC rehabilitation areas at Blue Hills and exploration lines at Weld Range offer areas to test several restoration techniques including substrate manipulation (ripping), topsoil replacement, seed broadcasting success and the impact of debris. This baseline data will assist in restoration practices once rehabilitation sites become available.

Statements in the S45C that sites will be restored within certain timeframes (for example the South fold waste dump at Koolanooka has a timeline for restoration of 12 months) may be unrealistic. The company should make every effort to commence rehabilitation within this timeframe, but be aware that further rehabilitation based on research outcomes may be necessary.

7 Midwest Capacity Building

The previous sections of this document outline a site specific approach to restoration. With extensive activity in the Midwest area by SMC and other companies (including the five constituents of the Geraldton Iron Ore Alliance – GIOA) there is great scope to develop regional initiatives. Kings Park in conjunction with a coordinator would be willing to assist in developing collaborative restoration-based programs if deemed appropriate by SMC.

SMC has already committed to partial funding of a NACC seed collection co-ordination position through GIOA. This model may also be implemented to approach some of the following activities linked with core restoration outcomes common to all Midwest mining operations.

7.1 On Site Seed Bank Development

As part of the development of an effective SMC seed-based rehabilitation program, there would be development of a detailed scoping document and advice provided for establishment of a 'Site Rehabilitation Seed Bank' for Sinosteel operations. If appropriate a common storage facility following on from the GIOA coordinated seed collection activities may be warranted. The advisory role would include:

- Development of specifications for housing seed for rehabilitation on site.
- Development of specifications relevant to optimising native seed collection, cleaning, curation and databasing.
- Advice on operation of the seed bank and annual review of seed bank performance (or as required).

7.2 Nursery production

As described in section 3.4, greenstock may be required to fulfil rehabilitation requirements in the event of failures from topsoil or seed. In this case the option is to either develop a new, or use an existing nursery facility. This decision is dependent on SMC's objectives and investment strategy. If the development of a company specific (SMC) or regionally focused (e.g. GIOA) nursery is preferred, Kings Park would assist with:

- Development of specifications for growing seedlings for rehabilitation on site.
- Development of specifications relevant to curation and databasing.

- Advice on operation of the nursery and annual review of performance (or as required).

7.3 Weed management

As part of Ministerial condition 811 (13-3), SMC are expected to rehabilitate all disturbed areas with "*weed coverage no more than that in undisturbed bushland in the area or less than 10%, whichever is the lesser*".

Invasive exotic species commonly compete with and replace native species in restored ecosystems. Even with highly efficacious weed control the possibility of reinvasion can remain high without an effective weed management plan and a robust and resilient rehabilitated system. Therefore it becomes essential for management strategies to be developed for each exotic species present, based upon biological, economic and logistical realities. Highest priority is reserved for the control of those species that pose the greatest threats. These include invasive plant species that are particularly mobile and pose an ecological threat at landscape and regional levels.

A key weed species identified at the Koolanooka mine is ruby dock (*Acetosa vesicaria)* - a serious arid zone disturbance opportunist that is now widely established on several mining leases in WA. The research plan proposes to undertake a detailed assessment of regional weed issues that could also adversely impact upon successful rehabilitation.

Kings Park has previously undertaken research into control of ruby dock weed (funded by Newcrest mining). If required, a site specific weed control program may be developed in collaboration with SMC. We would initially propose a desk-top audit program controlled by SMC, with input from Kings Park where necessary, that will deliver the baseline data necessary to make informed decisions of weed risk and control strategies. If further research is required, a program would be developed in consultation with SMC.

The initial study would be undertaken in the following phases.

- Development of a weed risk assessment at all SMC operations to identify local and regional propagule sources, natural and anthropogenic accelerated dispersal, management associated with weed outbreaks and weed ecology with respect to life cycle characteristics.

- Assessment and development of control measures including chemical and operational (soil handling, fire, vehicular transport of weed seeds) issues.
- Development of a preventative weed management and control strategy for the lease where weed impacts could affect success of the post-mined rehabilitation outcomes.
- Development of a preventative weed management and control strategy for the lease and regionally (including consultation with other surrounding minesites) where weed impacts could affect success of the post-mined rehabilitation outcomes.

7.4 Indigenous and community engagement with Kings Park Science

This restoration research plan offers the opportunity to link science with the Midwest /Pilbara community and indigenous training. Kings Park will assist in providing local community training opportunities through a series of SMC funded summer scholarships.

Under the supervision of scientists within the Biodiversity Conservation Centre at Kings Park and Botanic Garden, these scholarships will provide the opportunity for research in native plant conservation biology or restoration ecology related to SMC rehabilitation operations. Scholarships may include a **tax-free stipend of $7000 for a period of 12 weeks**, to commence each year in December for the duration of the research proposal.

7.5 The next generation of Scientists

After site visits to Koolanooka and Blue Hills sites several research areas were identified as value adding the proposed restoration plan including:

- a study on the conservation genetics and restoration of *Acacia aneura*, a species known to have various genotypes occurring across a small area (located at Blue Hills – near the southern extent of its distribution).
- A PhD program on biological soil crusts (soil surface communites of lichens, mosses, liverworts, cyanobacteria, green algae and fungi) to understand their potential for enhancing restoration outcomes (Appendix 1). Kings Park has already been approached by a potential student and we have provisionally directed them towards research at SMC sites.

It is envisaged that these projects would be supervised by Kings Park staff, with potential for significant outcomes but also minimal additional funding required from SMC. It is expected that research staff involved in the SMC restoration research plan would seek additional students to value add SMC's investment in the restoration research plan. In addition to this, Kings Park will also actively advertise SMC related projects through The University of Western Australia's 3rd year Conservation Biology and Restoration Ecology course (coordinated by Kings Park) and the 4th year UWA honours handbook.

8 Future research requirements

The above restoration research plan outlines the research required to address Ministerial conditions and site constraints that will have significant impediments for rehabilitation success. As SMC mining operations commence, and impacts and rehabilitation outcomes are better understood, there may be other requirements to ensure rehabilitation success. For example

- As part of ministerial condition 6-4 SMC need to "monitor impacts from activities undertaken in implementing the proposal, including:

  1. dust;

  2. saline water application for dust control;

  3. fire "

Kings Park has the capacity to derive research programs in these areas if impacts from mining are observed.

- Priority and Declared Rare Flora (DRF) species offer specific restoration challenges, with the entire distribution of some species linked exclusively with specific substrates (e.g. Banded Iron Formations). If SMC are deemed to have a significant or poorly defined impact on priority or DRF species, then restoration research plans would need to focus on all of the aforementioned research strategies plus considering the overall impacts on local populations (genotypes). The Kings Parks conservation genetics group (lead by Dr Siegy Krauss) has demonstrated experience in resolving genetic population issues in DRF species including *Acacia karina* (Gindalbie Metals Pty Ltd), *Darwinia masonii* (Mt Gibson Iron, Extension Hill Pty Ltd) and *Tetratheca paynterae* (Portman Iron Ore).

If required, Kings Park can assist SMC in developing a research strategy to enhance the protection of local rare and threatened species.

9 Personnel and Budgets

The research program can be initiated at any time. However, to optimise research effectiveness, a start-up that capitalises on rainfall and seeding events is desirable. The programs defined above are matched to roles described in Table 4. The vegetation community analysis program can commence once research plan is approved by SMC with spring survey necessary for comprehensive community diversity assessment. Other programs may be initiated once topsoil and seed are available. As SMC sites are to be progressively available for rehabilitation, and given that individual sites require specific research issues, the overall program is 5 years to include delivery of final reports.

A fully budgeted research plan is outlined in Table 5, covering salaries, associated on-costs and laboratory consumables. **Please note that SMC would be eligible for the 175% Research and Development Tax Concession for funds invested in research.** Given the broad scope of research required, Kings Park will provide in-kind supervisory support throughout this program as outlined in Table 5. It is anticipated that SMC would cover costs associated with on-ground research activities including site preparation, travel and accommodation.

Table 4 Role of Kings Park research staff and indicative timelines for activities to be undertaken as part of the restoration plan research.

Program	Role*	Timeframe
Plant Community Analysis	1	July 2010 - Dec 2010
Plant Resource		
Topsoil	1,2	Jan 2011 - Dec 2016
Seed	3	Nov 2010 - Dec 2015
Greenstock	4	Dec 2011 - Dec 2015
Soil Substrate Resource		
linkages to community	1	July 2010 - Dec 2010
restoration material characterisation	1	July 2010 - Dec 2016
trial restoration materials	2	Jan 2011 - Dec 2016
Debris		
Plant establishment	2	Jan 2011 - Dec 2016
Faunal and Microbiological	2	Jan 2011 - Dec 2016
Midwest Capacity Building		
Seedbank	3	Jan 2011 - Dec 2016

Nursery	4	Jan 2011 - Dec 2016
Weed Management	5	July 2010 - Sep 2010
Indigenous and community	1,2,3,4	Nov 2010 - Dec 2016
Next generation of Scientists	1,2,3,4	Jan 2011 - Dec 2016

*1 – Plant Community Ecologist (Vegetation community definition); 2 – Restoration Ecologist (Topsoil, Plant Growth Media); 3 – Seed Ecologist (Seed germination, seed storage); 4 – Plant propagation and Biotechnology; 5 – Weed Ecologist.

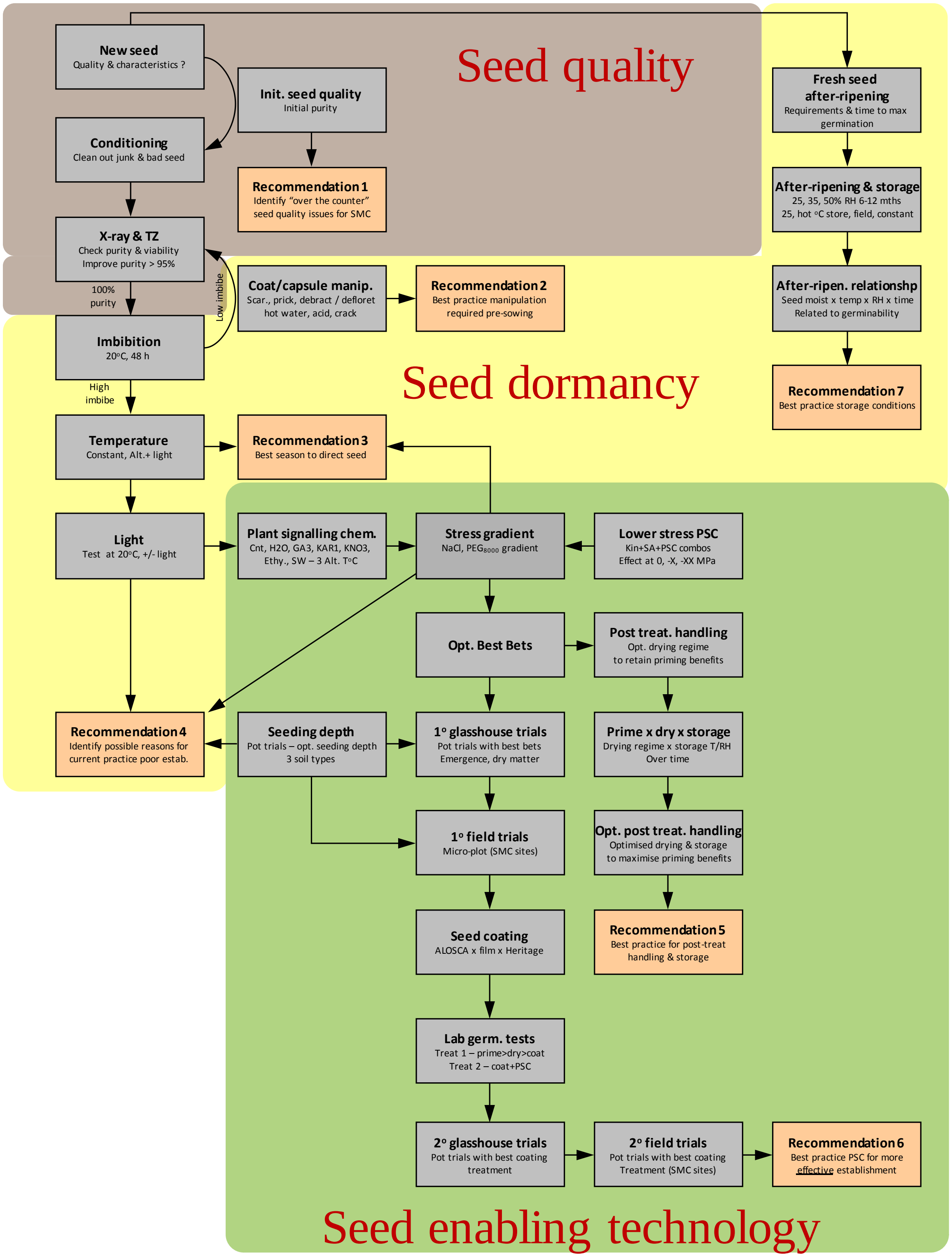
Table 5 Budget for delivery of the proposed restoration research plan. Please note that a 3 year review will allow for research outcomes to be evaluated by SMC.

Role	**Personnel**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
1+2	Research Scientist (SC LVL 2)	$95,747	$101,944	$108,565	$115,631	$119,099	$540,986
3	Research Scientist (SC LVL 2)	$95,747	$101,944	$108,565	$115,631	$119,099	$540,986
	Technical support (LVL 2)	$61,887	$65,478	$69,326	$73,435	$37,851	$307,977
	Personnel subtotal	*$253,381*	*$269,366*	*$286,456*	*$304,697*	*$276,049*	*$1,389,949*
	Operating						
1	Community analysis	$5,000	$1,500	$1,500	$1,500	$1,500	$11,000
2	Topsoil laboratory/nursery supplies	$5,000	$3,000	$3,000	$3,000	$3,000	$17,000
3	Seed research laboratory supplies	$5,000	$3,000	$3,000	$3,000	$3,000	$17,000
4	Greenstock nursery supplies			$1,000	$1,000	$1,000	$3,000
	Scholarships		$14,000	$14,000	$14,000	$14,000	$56,000
	Operating subtotal	*$15,000*	*$21,500*	*$22,500*	*$22,500*	*$22,500*	*$104,000*
	Total SMC budget:	*$268,381*	*$290,866*	*$308,956*	*$327,197*	*$298,549*	**$1,493,949**
4+5	*Kings Park in-kind support*						
Kingsley Dixon	Project Management (0.025FTE)	$4,762	$5,000	$5,250	$5,513	$5,788	$26,313
Deanna Rokich	Restoration Ecology (0.05FTE)	$6,831	$7,172	$7,531	$7,907	$8,302	$37,743
Jason Stevens	Plant Physiology (0.10FTE)	$12,338	$12,955	$13,603	$14,283	$14,997	$68,176
David Merritt	Seed Science (0.05FTE)	$6,169	$6,477	$6,801	$7,141	$7,498	$34,086
Eric Bunn	Biotechnology (0.05FTE)			$7,531	$7,907	$8,302	$23,740
	Total KP in-kind support:	*$30,100*	*$31,604*	*$40,716*	*$42,751*	*$44,887*	**$190,058**

All salaries include standard 27% on-costs plus annual wage adjustments of 3%.
*Technical support will be 1FTE in years 1-4 and 0.5FTE for year 5.

10 Research Schedule

Site	Activity	Task to be completed prior to mining activity	Task requires restoration sites to be prepared	Spring 10	Summer 10	Autumn 11	Winter 11	Spring 11	Summer 11	Autumn 12	Winter 12	Spring 12	Summer 12	Autumn 13	Winter 13	Spring 13	Summer 13	Autumn 14	Winter 14	Spring 14	Summer 15	Autumn 15	Winter 15	Spring 15
Koolanooka	Community definition	✓																						
	Seed collection	✓			All possible species				Remaining species															
	Seed quality				All species collected				All species collected															
	Seed germination/dormancy				Simple species solved					More complex species solved					Remaining species solved									
	Seed banking				All species banked with regular retrievals to ensite high quality																			
	Seed enabling technology							Simple species initial testing					Simple species refined + complex species initial testing					All species refined/optimised						
	Topsoil collection	✓				Remaining areas collected																		
	Topsoil auditing (on site trials)						Topsoil trials on site				Topsoil trials refined on site													
	Topsoil auditing (laboratory)			Auditing of topsoil stores under controlled environment conditions - quality assessment																				
	Restoration trials (established on site)		✓				Seed, plant debris initial trials				Seed, plant debris refined trials				Seed, plant debris refined trials				Seed, plant debris optimised					
	Monitoring		✓					Monitoring initial trials				Monitoring refined trials				Monitoring refined trials				Monitoring optimised trials				
Blue Hills	Community definition	✓		All communities defined																				
	Seed collection	✓			All possible species				Remaining species															
	Seed quality				All species collected				All species collected															
	Seed germination/dormancy				Simple species solved					More complex species solved					Remaining species solved									
	Seed banking				All species banked with regular retrievals to ensite high quality																			
	Seed enabling technology							Simple species initial testing					Simple species refined + complex species initial testing					All species refined/optimised						
	Topsoil collection	✓				Remaining areas collected																		
	Topsoil auditing (on site trials)						Topsoil trials on site				Topsoil trials refined on site													
	Topsoil auditing (laboratory)					Auditing of topsoil stores under controlled environment conditions - quality assessment																		
	Restoration trials (established on site)		✓				Seed, plant debris initial trials				Seed, plant debris refined trials				Seed, plant debris refined trials				Seed, plant debris optimised					
	Monitoring		✓					Monitoring initial trials				Monitoring refined trials				Monitoring refined trials				Monitoring optimised trials				
Weld Range	Community definition	✓						All communities defined																
	Seed collection	✓							All possible species				Remaining species											
	Seed quality								All species collected				All species collected											
	Seed germination/dormancy								Simple species solved					More complex species solved										
	Seed banking								All species banked with regular retrievals to ensite high quality															
	Seed enabling technology											Simple species refined + complex species initial testing					All species refined/optimised							
	Topsoil collection	✓								Remaining areas collected														
	Topsoil auditing (on site trials)										Topsoil trials on site				Topsoil trials refined on site									
	Topsoil auditing (laboratory)									Auditing of topsoil stores under controlled environment conditions - quality assessment														
	Restoration trials (established on site)		✓												Seed, plant debris refined trials				Seed, plant debris refined trials				Seed, plant debris optimised	
	Monitoring		✓													Monitoring refined trials				Monitoring optimised trials				
Reporting	Quarterly progress report				Quarterly update meetings																			
	Annual report				Annual report submitted				Annual report submitted				Annual report submitted				Annual report submitted				Annual report submitted			
	Restoration manual																						SMC restoration manual produced for	



Detail underpinning seed quality, seed germination/dormancy, seed banking storage) and seed enabling technologies as outlined in research schedule.

11 Reporting

Regular reporting is expected throughout the program. Quarterly meetings outlining research outcomes, activities and site requirements for the upcoming quarter will be delivered to SMC. Annual reviews will entail a summary of progress throughout the year including both written and oral presentations to relevant SMC staff. These annual reports will directly assist SMC in reporting against ministerial conditions. A major review point after three years is anticipated to ensure research is delivering on company expectations and will also allow the direction of research to be established for the final 2 year phase.
It is expected that Kings Park Staff will work closely with SMC environmental staff throughout the entire program. The final report will entail preparation of a restoration manual for SMC ensuring scientific outcomes are translated to leading-practice operations for SMC environmental staff.

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13 Appendix 1 - Biological Soil Crusts (PhD program)

13.1 Background

Biological soil crust communities (BSCs) are widespread across semi-arid and arid Australia where they cover most soil surfaces except in particularly sandy, moist or disturbed areas. BSCs are made up of lichens, mosses, liverworts, cyanobacteria, green algae and fungi, and while easily overlooked, these soil surface communities are believed to have a major role in influencing soil stability, nutrient cycling, and hydrological processes (sometimes promoting infiltration and water retention, sometimes inhibiting it). BSCs have also been suugested to play a role in promoting or inhibiting seed germination.

Although very little is known about the ecological functions of BSC's, their abundance in semi arid Australia and the significance of the processes they are thought to influence suggest they may be fundamental components of restoration success. Also unknown is the rate at which soil crust communities establish in post-mining restoration, what function they may have in restoration or what treatments can be used to enhance their restoration.

The Kings Park - SMC restoration research project provides an ideal context for research into the restoration of BSCs and their subsequent role in the successful restoration of plant communities. As knowledge in this field is limited, research into the practical contribution of BSCs to restoration could identify this to be critical, or non-existent, with almost equal likelihood.

13.2 Proposed research program

Supporting a 3 year PhD project in this area has the benefit of contributing to the development an almost completely new field of research, with potential for very significant impact but at very little cost to the company. A candidate student with strong interest in this area has already approached Kings Park for supervision. Their research requirements would almost completely match that of the mainstream restoration project (i.e. a restoration trial area with various treatments) so would have very little additional cost (accommodation, transport) for potentially significant return.

13.3 Scope of Research

Their research proposal is likely to include: 1) A survey of BSC composition and cover in relation to disturbance and environmental variables (solar radiation, vegetation cover, substrate, soil texture, chemistry, slope, compaction, etc) in undisturbed and old disturbed areas (fire, tracks, drill pads). 2) Experiments testing the influence of various treatments (± topsoil, ripping, mulching, stones, shade, different substrates [clay, loam, sand, gravel]...) on BSC development. 3) the role of BSCs in the development of soil function (infiltration, runoff, stability, soil temperature moderation, N-cycling, transpiration) in restoration as well as natural and disturbed sites.

14 Appendix 2 – Notes from Kings Park field trip to Blue Hills and Koolanooka.

These notes were developed from Kings Park's recent field trip to the Koolanooka and Blue Hills operations and will assist in developing the research and development plan. Given the timelines for Koolanooka it is important that some of the following procedures be conducted prior to mining.

14.1 Koolanooka site

14.1.1 Plant Communities

Communities will be defined in accordance with ATA's survey.

These communities will be defined in these notes for clarity as:

Pit communities

Ridge community 1: Mapped by ATA as community 1(yellow)

Ridge community 2: Mapped by ATA as community 3 (pink)

Waste dump communities

Flats community 1: Mapped by ATA as community 15 (grey)

Flats community 2: Mapped by ATA as community 25 (Dark blue)

Flats community 1 is where the waste dump is proposed. This area looks to be a degraded site and may be analogous to flats community 2. Michalie to confirm by looking at aerial photographs from the previous mine.

Obtaining exact species lists for each community will help define analogous sites as well as the 70% benchmark for restoration.

Vegetation clearing

Vegetation needs to be cleared to ensure topsoil reserves are not degraded or diluted. Kings Park to provide advice on previous clearing techniques (email subsequently sent to Steve).

14.1.2 Topsoil

The use of topsoil will be vital to replace species with seed in the soil seed bank. The topsoil is the top 10cm of soil profile which contains the seed bank. The next 50cm below the topsoil is the growth medium which supports seedling root development. Both of these profiles need to be stripped but must be stripped separately.

Previous research has highlighted that correct topsoil handling will give the most efficient restoration outcomes in terms of biodiversity reinstatement per unit cost. As this is the first attempt to restore a TEC it is critical that the topsoil be handled at a minimum of current best practice. As the TEC consists of various sub communities the topsoil resources need to be stripped, stored, audited and replaced separately. As discussed, the techniques outlined below may define a new benchmark in industry practice.

Four areas need to be addressed in terms of topsoil use:

14.1.2.1 Topsoil Stripping

Pit communities-

Small area that needs stripping. Steve to map and classify site on potential and ease of topsoil recovery and will be able to give a rough estimate on the cubic meters of topsoil recovered.

Conduct boutique stripping within defined areas with the use of small excavation machinery eg. bobcats and excavators. Steve to seek advice.

Strip the top 10 cm of soil with the small machinery.

Topsoil from the 2 communities need to be kept separate- Steve to flag boundary between communities to ensure operators are aware of resource zones

Larger machinery can then be used to strip the growth media (next 50cm or to bedrock whichever is shallower).

Topsoil needs to be stripped dry.

Waste Dump community

Topsoil not useful due to possible degradation no need for stripping

Strip top 50cm for growth media

May need to strip topsoil from an intact analogous community (borrow site) for restoration.

With all topsoil stripping the need to exclude areas with a potential weed liability is of great importance.

14.1.2.2 Topsoil Storing

Topsoil needs to be kept dry to prohibit germination and degradation of seeds

Cover topsoil with tarp (from wheatbins)-Steve to contact CBH

Place topsoil on a pad with drains diverting water to stop seepage of water from the bottom of topsoil stockpile.

Growth media does not need to be stored covered.

A certain amount of topsoil (yet to be determined) needs to be left uncovered to provide a comparison on best storage practice.

14.1.2.3 Topsoil Auditing

Data logging of the topsoil under the cover needs to be conducted to measure temperature and relative humidity to determine impacts on seed viability within stockpiles.

Need to audit topsoil to establish species presence/absence. This will help define the 70% species benchmark. For species that are absent, further research will be required into broadcast seeding techniques and the use of greenstock (supplementary planting).

Regular retrievals from topsoil stores to be conducted to assess viability and germinability of seeds. Regular auditing will allow dormancy research to be ahead of topsoil failures.

14.1.2.4 Topsoil Replacement

The ridge communities are to be restored on the offset area (7.2 Ha) as outlined in the Section 45 document given connectivity with surrounding TEC.

There won’t be enough topsoil to replace back 1 to 1 as the offset site is larger than the pit site so research into and management of topsoil needs to take place to optimize replacement.

Topsoil replacement time is crucial, current best practice is to replace when dry

14.1.3 Seed collection

Species that do not have seed in the soil seed bank will need to be collected from the plants.

Bradysporus species that are still holding their seed in the canopy can be collected before mining commences. Kings Park will collect, clean and store seeds from the pit area prior to vegetation removal. Target genera will include Melaleuca, Calothamnus, Allocasuarina plus others.

Other species can be collected from within ridge community one and ridge community 2 from further along the ridge outside the impact area but within the lease area at a later date.

14.1.4 Landscape forming

Landloch (or other soil/landform consultants) may provide advice on optimal landform design and growth media and how these influence soil physical and chemical parameters. This advice will then inform on possible plant performance on restoration sites and how these landforms may link with the greater TEC landscape.

14.1.5 Weed Control

Rubydock control - need to scalp affected soil (remove plants plus weed seed bank) and bury underneath waste dumps. For remaining plants there is a need to develop a weed control strategy including mapping affected areas, spot spraying, and have an ongoing monitoring program.

14.2 Blue Hills

The area at Blue hills is not to be mined for another 18 months and therefore there is not as much urgency in implementing the restoration strategy. During this time consideration of the points below should be made well in advance of mining.

The sections are divided by site into Mungada West, Mungada East and the end landuse of pit versus waste dump areas. Though the waste dump areas are considered together as the same principles apply to both they need to be dealt with separately.

14.2.1 Topsoil

The procedures of stripping, storing, auditing and replacing topsoil are the same as Koolanooka (above).

Mungada west

Most of the pit is degraded and no topsoil will be available. As there will not be sufficient topsoil in this small area an intact analogous community needs to be identified.

There is a small section of vegetation to the west of pit that will be useful for topsoil collection and its use will be critical due to the presence of species that are currently not able to be propagated (e.g. Philotheca) by any other means.

Mungada east

Larger area of topsoil available however the ease of collection and usefulness of the resource needs to be assessed.

Waste dump areas

Topsoil collected from both waste dump areas needs to be stripped, stored and returned separately (likely to retain a significant amount of the annual species seedbank from separate communities).

Research on this site needs to focus on the replacement of growth medium to support plant growth and development. This will involve using different levels of growth media over the rock waste material including a no growth media treatment (control).

14.2.2 Seed Collection

Mungada west

Seed collection from the remaining vegetation strip will need to be conducted in the next seeding season.

For species where sufficient seed is not able to be collected and is absent from the seed bank (identified from auditing topsoil) seed will need to be collected from an analogous intact community.

Mungada East

As for Mungada West seed collection however it is likely that sufficient seed can be collected from the vegetation on proposed pit area.

Waste dumps

Seed will need to be collected from these areas prior to mining for use in restoration.

The Eucalyptus will need to be propagated in the nursery and planted as green stock. This is achievable as they are in small numbers across the site.

14.2.3 Weed Control

A close watch and stringent cleaning of machinery when transferred between Koolanooka to Blue Hills needs to take place. This will minimize the transfer of Rubydock which is at Koolanooka but not Blue Hills.

Collaboration with other mining companies around the area may reduce transfer of weeds and produce a more effective weed management strategy.

14.2.4 Flora of interest

The DRF species Acacia woodmaniorum has been tagged by DEC and is part of the larger conservation genetic program currently funded by Gindalbie Metals. This program is likely to end within 2 years and project outcomes/progress may be sourced from David Coates (DEC).

Consideration needs to be given to other DRF and priority species. The research plan will highlight what needs to be undertaken to conserve and restore these species.

Acacia aneura is present at the southern end of its range and seed will need to be collected locally as large amounts of genetic differentiation occur within relatively short distances. A focus on conservation and restoration of this species will form part of student project given its wide scale implication for arid zone restoration.

14.2.5 Other notes

The Eucalyptus growing in the waste dump areas can be collected and returned to restoration sites to act as habitat. The larger braches and trunks form hollows for native fauna.

In the current rehabilitation areas on Mungada East a trial of broadcasting seed will be established (to be designed by Kings Park).